To bee, or not to bee, that is the problem: Managing wild bee decline in Canadian agriculture

by

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Abstract

The decline of bees is a phenomenon that has been observed in various regions including Europe and North America. While the decline of Canadian honeybees, a non-native species managed for commercial purposes, receives much attention, the same cannot be said for Canadian wild bees. Existing evidence indicates that large-scale agricultural practices contribute to wild bee decline through habitat degradation, pesticide usage, and removal of food sources. Pollinator-friendly agricultural practices have been identified that could mitigate the decline of wild bees. However, these practices may require additional resources that Canadian farmers cannot afford such as time, money, and available land. Hence, the choice to implement sustainable techniques requires farmers to negotiate the conflict between conservation and profit. This research examines two policy approaches that could be adopted to promote behavioural change among farmers to mitigate wild bee decline – the roles of incentives and regulations.

Keywords: Wild bees; agriculture; agri-environmental measures; regulations; policy; Canada

Hey farmer, farmer!

Put away that DDT now

Give me spots on my apples

But leave me the birds and the bees

Please!

Don't it always seem to go

That you don't know what you've got

'Til it's gone...

Joni Mitchell

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List of Acronyms

AEM	Agri-environmental Measure
BCI	Bat Conservation International
BVL	Federal Office of Consumer Protection and Food Safety
CANPOLIN	Canadian Pollination Initiative
CAPA	Canadian Association of Professional Apiculturists
CBC	Canadian Broadcasting Corporation
CSPNA	Committee on the Status of Pollinators in North America
CTV	Canadian Television
ELS	Entry Level Stewardship
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
FAO	Food and Agriculture Organization
HLS	Higher Level Stewardship
IRGC	International Risk Governance Council
NRCS	Natural Resource Conservation Service
NSERC	Natural Sciences and Engineering Research Council
OELS	Organic Entry Level Stewardship
PES	Payments for Ecosystem Services

Executive Summary

The decline of bee populations is a phenomenon that has been observed in various regions including Europe and North America. This decrease in population size has impacted both commercial and wild bee colonies and is of great concern given bees' importance in plant and crop pollination. Bee decline could result in reduced food availability, decreased agricultural productivity, and biodiversity loss (Potts et al., 2010; Goulson et al., 2008). As a keystone species, bees act as biological indicators for ecosystem health since dramatically declining populations could have cascading effects on ecosystems. The loss of their essential pollination services would result in decreased abundances of plant life and adversely affect the animals that rely upon pollinator-dependent plants.

In recent years, managed honeybee colonies in North America have been negatively affected by the spread of diseases and colony collapse disorder, resulting in diminished abundances. Although experiencing population declines themselves, wild bees, a public good that provides the essential ecosystem service of pollination, can serve as a buffer against declining honeybee populations and reduce reliance on these non-native introduced species (Winfree et al., 2007). Therefore, to protect these ecologically and economically significant insects and mitigate the adverse impacts of pollinator decline, policies must be adopted to improve the survival of wild bees.

Identified causes for the wild bee decline include increased pesticide usage, habitat loss and fragmentation, the introduction of non-native bees to ecosystems for commercial purposes, and the spread of pathogens from commercial colonies to wild bee (Winfree, 2010). These factors intersect in large-scale agricultural practices and the intensification of Canadian agriculture. Consequently, this research focuses upon the effects of large-scale agricultural practices on wild bee populations

Although the evidence indicates that bee populations are declining and highlights large-scale agriculture's contributions towards this decline, conflicting interests prevent the adoption of conservation strategies and management plans. The implementation of wild bee conservation strategies requires agricultural producers to make trade-offs

between profit and protection. Although alternative agricultural practices have been developed and identified as pollinator-friendly, their implementation may necessitate the sacrifice of profits and additional resources such as time and labour to support conservation efforts. Since agricultural producers face resource constraints already in their operations, assessing the trade-offs between the costs and benefits of pollinator-friendly practices can prevent the introduction of vital measures for sustaining wild bee populations in agricultural ecosystems.

Hence, it is evident that within Canadian agriculture, multiple interests conflict with respect to wild bee conservation whether it is commercial beekeepers, the agricultural sector, or entomologists. Mitigating wild bee decline requires negotiating the balance between conservation and profit. To address the decline of wild bee populations, I examine these conflicting interests in the Canadian context to seek a course of action for a wild bee conservation and management plan. To analyze this problem and determine policy recommendations to address this issue, the following research questions were developed: “What are the barriers that prevent Canada from effectively addressing wild bee population declines? What actions can be undertaken to overcome this policy inertia to address the decline of Canadian wild bees?”

To answer my research questions, I employed a mixed methodological approach for four reasons. First, I conducted a literature review to develop a better understanding of key drivers of wild bee decline. Second, I conducted a media scan to attempt to ascertain the general discourse surrounding wild bee decline. The media scan served as a proxy for the general public’s knowledge regarding wild bee decline since in Canada, newspapers and national media sources would serve as the main information sources for individuals’ knowledge of wild bee decline. Third, I hosted interviews with academics, government officials, and non-governmental organizations whose work touches upon wild bee decline. These interviews were conducted to provide an informed perspective of drivers behind wild bee decline, barriers to policy implementation, and potential policy options that could be adopted in the Canadian context to address the bee’s decline. Finally, from the literature and interviews, I identified cases of best practices that are explored in the jurisdictional scan.

A number of themes emerged from the research. First, a lack of research has hindered policy implementation due to the absence of long-term historical data. Second, farmers' support or lack thereof could present a challenge for policymakers in determining appropriate policies to employ to address wild bee decline in agriculture. Third, conflicting interests are difficult to negotiate when constructing equitable and effective policies. Fourth, a lack of knowledge and understanding of wild bees among policymakers and farmers presents another policy impediment. Interviewees indicated that there is a role for government and policymakers to intervene and introduce policies to address wild bee decline. There was variation among responses regarding the particular roles policymakers could take, including the provision of incentives, supporting education initiatives, and the expansion of regulations. Since wild bees and the ecosystem services they provide are considered public goods, there is no incentive to conserve their populations. This lack of an incentive signifies an area for government intervention to support wild bee populations. The examined cases from the jurisdictional scan (the United States, the United Kingdom, Germany, and Mexico) highlight two general policy approaches that decision-makers could employ to address wild bee decline in Canada. First, the utilization of voluntary economic instruments to promote pollinator-friendly practices could encourage agricultural producers to alter their farming practices. Second, regulatory interventions can also contribute to wild bee decline mitigation through pesticide application restrictions and the protection of vital habitat. The policy approaches provided by the case studies' findings can contribute to the development of policy options for addressing Canadian wild bee decline.

The overall research indicated three general policy directions that policymakers could employ to address Canadian wild bee decline in agriculture. First, policymakers could maintain the status quo. Given the lack of historical data and research for the Canadian context, policymakers could wait for existing knowledge to develop before introducing policy interventions. If wild bees continue to decline in this case, alternative pollination methods could be used to support crop production. Second, policymakers could utilize a voluntary incentive-based approach for addressing wild bee decline. Through the use of instruments such as subsidies, payments for ecosystem services, and tax credits, policymakers can encourage behavioural change and persuade agricultural producers to introduce more pollinator-friendly practices into their operations.

Third, policymakers could employ a mandatory regulatory approach. Through the use of regulations and technology standards, policymakers can target pesticide safety, habitat restorations, and commercial bee operations to support pollinator conservation.

Upon evaluating the three policy approaches, it was evident that no one clearly dominated the others for mitigating wild bee decline. Each approach contains policy instruments that may be better suited for combating a particular aspect of the factors contributing to wild bee decline. As such, it is recommended that policymakers consider a mixed policy approach combining regulations and incentives for encouraging behavioural change and supporting the implementation of pollinator-friendly practices:

- Reform current requirements for pesticide safety assessments to include the lethal and sub-lethal effects of pesticides on wild bees. Policymakers will receive a more adequate amount of information to determine the overall pesticide safety. With the accumulation of this evidence, policymakers can move to a more precautionary approach in the management and regulation of pesticide applications.
- Introduce voluntary agri-environmental measures to support the implementation of pollinator-friendly agricultural practices. These subsidies can be targeted towards regions where pollinator-dependent crops are grown to maximize the overall effectiveness and benefits of this initiative.
- Introduce a form of payment for ecosystem service subsidy or tax credit for greenhouse operators to install technologies that limit the effects of pathogen spillover. This will ensure higher compliance rates among participants.
- Consider the introduction of buffer zones to support pollinator conservation and restore habitat. This can be first established on public lands so policymakers can observe whether this method is effective in supporting wild bee populations. As knowledge develops, this effort could then be expanded to incorporate regulations for private lands.

This combination of recommended actions would be effective in preserving natural capital by reducing agriculture's ecological footprint, promoting sustainable agricultural practices, and mitigating wild bee decline. This approach can be used to address multiple aspects contributing to wild bee decline within Canadian agriculture such as pesticide usage, habitat degradation, and loss of foraging material. The implementation of both voluntary incentives and mandatory regulations creates a more holistic method for addressing conflicting interests and mitigating wild bee decline. Therefore, this research provides a preliminary plan bee for addressing wild bee decline in Canadian agriculture.

1. Introduction: The Decline of Wild Bee Populations

The decline of bee populations is a phenomenon that has been observed in various regions including Europe and North America. This decrease in population size has impacted both commercial and wild bee colonies and is of great concern given bees' importance in plant and crop pollination. Bee decline could result in reduced food availability, decreased agricultural productivity, and biodiversity loss (Potts et al., 2010; Goulson et al., 2008). As a keystone species, bees act as biological indicators for ecosystem health since dramatically declining populations could have cascading effects on ecosystems. The loss of their essential pollination services would result in decreased abundances of plant life and adversely affect the animals that rely upon pollinator-dependent plants. A popular saying among biologists suggests "One in three bites we eat, we have bees to thank for that," (Participant 1). The interconnectedness of ecosystems highlights the importance of bees and their pollination services. Thus, supporting bee conservation is vital to maintaining pollination stability and ecosystem health.

In recent years, managed honeybee colonies in North America have been negatively affected by the spread of diseases, potential colony collapse disorder, and increased overwintering losses, resulting in diminished abundances. Although experiencing population declines themselves, wild bees, a public good that provides the essential ecosystem service of pollination, can serve as a buffer against declining honeybee populations and reduce reliance on these non-native introduced species (Winfree et al., 2007). Therefore, to protect these ecologically and economically significant insects and mitigate the adverse impacts of pollinator decline, policies must be adopted to improve the survival of wild bees.

Identified causes for the wild bee decline include increased pesticide usage, habitat loss and fragmentation, the introduction of non-native bees to ecosystems for

commercial purposes, and the spread of pathogens from commercial colonies to wild bee (Winfree, 2010). These factors intersect in large-scale agricultural practices and the intensification of Canadian agriculture. Consequently, this research focuses upon the effects of large-scale agricultural practices on wild bee populations

Although the evidence indicates that bee populations are declining and highlights large-scale agriculture's contributions towards this decline, conflicting interests prevent the adoption of conservation strategies and management plans. For example, conflicts occur when managing pesticide usage for bee conservation since regulators require pesticide safety assessments only for domesticated honeybees when approving pesticides for use in Canada (Suryanarayanan & Kleinman, 2011). .Although the pesticide may present minimal risks to one species and therefore be used by farmers and beekeepers, the same chemical can be lethal for untested species (Suryanarayanan & Kleinman, 2011; Goulson et al., 2008). If the government adopts a more holistic approach to regulating pesticide usage by testing for safety with multiple bee species, the pesticide would not be approved until it was shown not to have adverse effects on the ecosystem. However, placing the burden of proof on the agrichemical producers to provide evidence of the safety of pesticide products may be met with resistance from the agricultural industry and beekeepers who use pesticides to manage crops and hives.

The implementation of wild bee conservation strategies also requires agricultural producers to make trade-offs between profit and protection. Although alternative agricultural practices have been developed and identified as pollinator-friendly, their implementation may necessitate the sacrifice of profits and additional resources such as time and labour to support conservation efforts. Since agricultural producers face resource constraints already in their operations, the trade-offs between the costs and benefits of pollinator-friendly practices can prevent the introduction of vital measures for sustaining wild bee populations in agricultural ecosystems.

In addition, the management of commercial bee colonies can adversely impact the population health of wild bees. Commercial bees from greenhouses can escape and travel around the surrounding areas. Consequently, the greenhouse commercial bees can interact with wild bee colonies, exposing wild bees to exotic pathogens and increasing likelihood of infection (Meeus et al., 2011). To address this, policies could be

targeted towards greenhouse management (Meeus et al., 2011). Lobbyist groups such as growers associations may oppose this intervention since the onus for implementation would be placed on greenhouse operators.

Hence, it is evident that within Canadian agriculture, multiple interests conflict with respect to wild bee conservation whether it is commercial beekeepers, the agricultural sector, or entomologists. Mitigating wild bee decline requires negotiating the balance between conservation and profit. To address the decline of wild bee populations, I examine these conflicting interests in the Canadian context to seek a course of action for a wild bee conservation and management plan.

This study examines the following policy problem: **"Too many conflicting interests in Canadian agriculture prevent effective mitigation of wild bee decline"**. To analyze this problem and determine policy recommendations to address this issue, the following research questions were developed: "What are the barriers that prevent Canada from effectively addressing wild bee population declines? What actions can be undertaken to overcome this policy inertia to address the decline of Canadian wild bees?"

First, before progressing further with this study, it is necessary to outline the meaning of a few key terms for this policy problem. The use of the phrase "too many conflicting interests" refers to the intersection of stakeholders' beliefs and actions that lead to negative effects on Canadian wild bees. These differing views and actions interact through the vector of wild bees. For the context of this study, "effective mitigation" is defined as the adoption of conservation strategies and management plans that will increase the probability of wild bees' survival. Effective is an improvement from the status quo where wild bees are declining. Therefore, strategies that preserve natural capital (e.g., wild bees) can be considered effective. Finally, the decline of Canadian wild bees refers to the observed decreases in bee populations throughout the country. Although the majority of the available literature focuses on the decrease of commercial bee colony losses, especially honeybees, researchers have observed decreases in sightings of wild bees and the disappearance of wild bee species (Ellwood, 2009).

This paper employs the following format. Section 2 reviews the contributing factors of wild bee decline. Section 3 discusses the methodology utilized for this research. Section 4 explores the identified barriers to policy implementation, the roles of government and policymakers in mitigating wild bee decline, key considerations for policymakers, and best practices for other jurisdictions. Section 5 establishes the criteria and measures used to analyze potential policy approaches for addressing wild bee decline. Section 6 describes general policy approaches that could be undertaken to address wild bee decline. Section 7 analyzes the policy approaches to determine which approach is most appropriate for mitigating wild bee decline. Section 8 recommends the best policy option for addressing wild bee decline at this point in time. Finally, Section 9 concludes the paper and suggests further areas for research. The next section discusses the major factors plaguing wild bee populations in Canadian agriculture.

2. Background: A Whole Hive of Issues

Pollinators, such as wild and managed bees, play a key role in Canadian agriculture through the provision of pollination, an integral ecosystem service, to support crops. Pollination leads to fertilization and successful plant reproduction. Depending upon the type of plant, this might require the assistance of an external vector such as a bee (International Risk Governance Council, 2009). The majority of fruits, vegetables, seeds, and fuel/fibre/drug crops are pollinator-dependent and require the assistance of animals such as wild bees to flourish. In addition, bees aid the meat and dairy industries through the pollination of hay crops (e.g., clover and alfalfa) upon which animals feed. Pollinator-dependent crops also tend to have a higher per unit market value than pollinator-independent crops (Committee on the Status of Pollinators in North America (CSPNA), 2006).

Media discourse surrounding bee decline indicates that there is a general awareness among Canadian media outlets regarding the role bees play in supporting biodiversity[1]. A number of the articles highlighted the importance of bees for pollinating plants and agricultural crops, with trade gardening articles emphasizing the role bees play in improving plant productivity. One noted that wild bees are particularly important for sustaining the production of certain crops (e.g., cranberries and blueberries) because managed honeybees are unable to do so (Holloway, 2011). Media coverage also reiterated the statistic that one in three bites of food consumed is due to the pollination services bees provide. Coverage also discussed the cascading effects bee decline may have on ecosystem health, triggering negative impacts to other organisms. Various articles cited estimates of the value of pollination services in Canada with one article

[1] This information was obtained in a media scan of major Canadian news outlets. Further information regarding the methods and rationale for the scan are discussed in Section 3.2.

approximating that “bees account for $1.4 billion worth of crops” (Nebenzahl, 2007, p.B3). However, the pollination value estimates never distinguished between wild and domesticated bee populations. Still, these values provide Canadian readers with an approximate value of bees to Canadian agriculture. Thus, a scan of Canadian media coverage highlights a general sense of the importance of bees in supporting ecosystems, plants, and agricultural crops.

In addition to highlighting the importance of bees and their provision of pollination services, media discourse discusses the contributions of industrialized (sometimes referred to as Western) agricultural practices towards the decline of wild and managed bees. Monoculture crops reduce the diversity of bees’ foraging material which Spears (2010) notes as worrisome due to Canadian agriculture’s movement towards producing single species of crops. Diversity in foraging material provides bees with a varied diet containing multiple forms of nutrients thereby increasing overall health (Participant 7). Adams (2010) wrote that the intensification of agriculture and its resulting chemical inputs can adversely impact bee populations with “insecticides killing bees directly, while herbicides and fertilizers are implicated as reducing food availability”. Additionally, one researcher found in unpublished laboratory tests that neonicotinoids, a class of pesticides approved for use in Canada, can impair bumblebees’ mobility and fertility at low concentrations (Higgins, 2008). Media coverage also elaborates upon modern agriculture’s effects on the natural environment and ecosystem health. Western agricultural practices were referred to as “a system that relies on chemicals and over-managed monocultures at the same time as it eschews natural systems and biodiversity” (Read, 2007, p.C7). The *Vancouver Sun* quoted SFU biologist Dr. Mark Winston, stating “It’s agriculture practices in general that are at fault… intensification of farming in the mid-20th century, when it ceased to be farming at all, and became agribusiness that exacerbated and focused the problem” (Read, 2007, p.C7). CBC News also noted:

> Agricultural production requiring pollinators has doubled in the last 50 years. Researchers say this shift was driven by economic forces, as insect-pollinated fruit and nuts are often high-value crops. This shift comes with its own environmental cost, they say, as the cultivation of high-value crops often displaces natural habitat, while honeybees themselves are often an invasive species when introduced. Such environmental costs warrant

> recognition and consideration during the development of agricultural and conservation policies (CBC News, 2009).

The industrialization of Canadian agriculture has simultaneously increased yields for farmers and risks to the environment since it has resulted in biodiversity loss and decreased ecosystem resilience (Charbonneau, 2010). Media discourse indicates that attention has been drawn to the detrimental effects of modern agricultural practices upon wild bee populations. It also suggests that there is some awareness among the Canadian public of agriculture's impacts upon bee population health although the extent of awareness is unknown at this point. In addition, scientific evidence suggests that modern agricultural practices adversely affect bee population health. The research indicates that advances in agricultural practices and agricultural intensification can negatively impact wild bee populations through its usage of pesticides, habitat loss and degradation, and the loss of vital foraging sources (Potts et al., 2010; CSPNA, 2006). Sections 2.1-2.5 synthesize current research regarding the effects of industrialized agriculture on wild bee populations.

2.1. Pesticide Usage

Through acts of foraging, feeding upon nectar, and travelling between plants, bees are vulnerable to pesticide exposure (Scott-Dupree et al., 2009). Pesticide usage in agriculture and urban landscapes can compromise wild bee population health. Bees lack detoxication genes which increases their vulnerability to pesticides (Winfree, 2010). Bees can be exposed to chemicals in three ways: through direct contact when pesticides are applied to flowering crops or nearby wildflowers, contact with contaminated plants, or through uptake of nectar contaminated with pesticides with the latter being the most common method that bees are exposed to pesticides (Goulson et al., 2008; Scott-Dupree et al., 2009). The impacts of pesticides vary depending upon the species of bee and each pesticide's lethal and sub-lethal effects.

To further complicate this matter, most toxicity tests for pesticides are conducted on honeybees only, with the results being incorrectly applied to other bee species. In Canada, the European Union, and the United States, regulators only require that toxicity risk assessments be conducted on honeybees at lethal levels. These requirements

ignore the potential effects of pesticides at sub-lethal levels on honeybees or the overall effects of a given chemical on other bee species, creating a policy gap that is harmful to wild bees (Goulson et al., 2008). For example, the pesticide imidacloprid[2] was assessed as safe for honeybees when tested for lethality (Ellwood, 2009). However, beekeepers in France observed that this pesticide harmed their honeybee colonies at sub-lethal levels. Scientific evidence reinforced this empirical observation, finding that sub-lethal amounts of imidacloprid were present in pollen and nectar and negatively affecting population health. Imidacloprid affects the honeybees' level of orientation and has led to the disappearance of honeybees from their colonies (Suryanarayanan & Kleinman, 2011; Bortolotti et al., 2003). In farming environments where neonicotinoids such as imidacloprid have been applied to fields, detrimental effects have been observed in bee populations, with researchers indicating that if negative effects are apparent with honeybees, it is likely that wild bees must also suffer from the application of neonicotinoids (Bees, 2012). However, there is some conflict regarding the harmfulness of neonicotinoid applications for wild bees. Morandin and Winston (2003) found that when applied according to the approved guidelines, imidacloprid's adverse impacts on bumblebees are not observed. In contrast, others have found that neonicotinoids negatively affect the reproductive health of bumblebees and create additional sub-lethal developmental effects (Participant 5; Scott-Dupree et al., 2009). Therefore, without formalized pesticide assessments and tests on multiple wild bee species, it is difficult to infer whether the application of certain pesticides is harmful for various wild bee species. It would also be difficult to regulate pesticide safety for all aspects of its usage, not simply its effects on human health and honeybees.

Another example of this gap in testing regulations is the toxicity assessment for spinosad, an organic biopesticide that is currently permitted for use in Canada (Morandin

[22] Imidacloprid and other forms of neonicotinoids have been approved as safe by Health Canada's Pest Managment Regulatory Agency and its application is permitted in farming operations (Health Canada, 2011). Neonicotinoids are a family of pesticides. Imidicloprid and clothiandin, the two forms of neonicotinoids discussed in the examples provided, are used as canola treatments in Canada. Canola is one of the most economically important crops in Canadian agriculture (Scott-Dupree et al., 2009)

et al., 2005; Health Canada, 2011). However, Morandin, Winston, Franklin, and Abbott (2005) found that bumblebee larvae exposed to spinosad contaminated pollen led to members of the colony experiencing reduced foraging efficiencies although this neurotoxin was previously determined to be harmless to all bee species based on the assessment conducted using honeybees. Hence, gaps in regulations for pesticide toxicity assessments make it difficult to mitigate the harm of pesticides to wild bee population health. It is important to note that agrichemical companies are now slowly beginning to consider the sub-lethal behavioural and reproductive effects of products upon wild bee species in assessing their environmental safety (Participant 9). However, without regulatory requirements, there is no legislative framework available that would force companies to provide this essential information for pesticide safety assessments.

Regulations also do not require pesticide producers to test for synergistic effects (Ellwood, 2009). An adverse synergistic effect arises when two chemicals, individually found to be harmless if used alone, interact when used together to have more toxic impacts. Agrichemical producers do not test for synergistic effects and governments do not demand these assessments in their regulations and toxicity assessments (Ellwood, 2009). Since agricultural producers may employ different chemicals in their practices, it is likely that negative synergistic effects arise that could prove harmful for wild bees.

One final issue associated with pesticide usage is the potential for chemical drift from agricultural land into adjacent natural lands (Potts et al., 2010). This phenomenon was observed in New Brunswick during the 1970s. Aerial sprays of the pesticide fenithrion were applied to agroforestry lands to manage the spread of spruce budworm among the trees. However, the sprays drifted towards adjacent commercial blueberry fields and natural lands, adversely impacting local pollinator populations and resulting in reduced crop and plant productivity (Kevan & Plowright, 1995 cited in Richards & Kevan, 2002). Therefore, one must consider the potential for pesticide drift to negatively affect native bees and the surrounding natural habitat. Not only is there a chance for pesticide intake through foraging in agricultural fields, there is also a possibility for adjacent natural habitat to become contaminated as well.

Pesticide usage highlights a conflict between agricultural producers' interests and the conservation efforts for wild bee populations. Pesticides may aid farmers in

increasing crop yield by reducing depredation on crops. However, the utilization of these chemicals can adversely affect the health of wild bees. This conflict also highlights a policy gap in Canadian regulations of pesticide usage. Without knowledge of synergistic effects of pesticides and other agricultural chemicals or the impacts of said chemicals on bee species other than domesticated honeybees, it is difficult to employ conservation efforts that are amenable to both agricultural interests and wild bee conservation. Although considerations for altering Canada's current pesticide assessments fall within federal jurisdiction and are controlled by Health Canada, provinces can direct policies for regulating the application of pesticides (Health Canada, n.d.; Basrur, 2002). As such, in addressing this driver for decline, provincial policies could target the application of pesticides in agricultural lands.

2.2. Habitat Loss, Degradation, and Fragmentation

Agricultural intensification has also contributed to the habitat loss, degradation, and fragmentation for wild bee populations. This loss has fostered decreases in available nesting sites and reduced habitat connectivity. In turn, it has been proven that this degradation of habitat due to changes in agricultural practices can contribute to agricultural intensification, wild bees' visitation rates decreased to the extent that these native pollinators were unable to completely support pollination of crops without the additional inputs of managed bee colonies (Kremen et al., 2002).

The removal of natural and semi-natural habitats within agricultural areas or in land conversion schemes can isolate wild bee populations (Garibaldi et al., 2011). Bees require a certain habitat fragment size in order to sustain their populations; the amount varying by species. With reductions in habitat connectivity, wild bees can become isolated in habitat fragments which contribute to diminishments in population size. Furthermore, Ricketts et al. (2008) found that habitat isolation has a negative relationship with wild bee population size and wild bees' visitation of crops to pollinate. As distances from natural habitat increased, the species richness and abundance of wild bees dropped. Therefore, with changing land use and the reduction in natural and semi-natural land available for wild bee species, populations may continue to diminish and produce lower levels of pollination services for crops.

In intensive agricultural settings, farmers may remove naturally occurring weeds and plants in crop fields and along marginal areas of fields since they are perceived as nuisances and pests infringing upon valuable cropland. This practice can remove nesting sites for wild bees since these weeds can provide suitable habitat for individuals (Morandin & Winston, 2006). The removal of hedgerows can also contribute to reductions in available and suitable habitat for wild bees. Certain wild bee species prefer to nest among these types of shrubbery (Carvell et al., 2007; Pywell et al., 2011). Efforts have been implemented in other jurisdictions such as England as means of reinstating habitat for wild bees and preserving the biodiversity of local ecosystems through the provision of these plants and shrubs. These will be explored in further detail in Section 4.4.1.2. Furthermore, soil tillage destroys the underground cavities in which ground-nesting bees reside. As a result, this practice also contributes to the loss of wild bee habitat in agricultural landscapes.

Kremen et al. (2002) found that organic farms near natural habitat could be completely supported by wild bee pollination. They also determined that agricultural intensification reduces species abundance and richness, thereby adversely impacting the effectiveness of pollination services. Isolation from natural habitat, reduced crop diversity, and the application of pesticides contributed to the decline in pollinator services from wild bees. Kremen et. al (2002) suggest habitat restoration and pesticide usage reduction as key measures for supporting wild bee populations. Kremen, Williams, Bugg, Fay, and Thorp (2004) noted a relationship between proportion of natural habitat and pollination services among their examined sites. Using this key finding, the authors recommended that this relationship be accounted for in land-use planning and suggested that government programming similar to the European Union's agri-environmental measures (AEMs) could aid farmers in introducing pollinator-friendly agricultural practices (Kremen et al., 2004). As a result of the above research, the United States Department of Agriculture and the NRCS allocated funding towards promoting pollinator conservation strategies in Californian agricultural operations (FAO, 2008; USDA, n.d.). Examples of the European and American AEMs are examined in Section 4.4.1.

With increasing demands for land, conservation efforts for wild bee populations are difficult. The demands of the agricultural industry coupled with urban expansion

impacts the habitat connectivity and quality wild bees require to survive. Negotiating between these various interests is an area to explore for policy development to protect pollination services and biodiversity. One reason for hope is that bees are capable of surviving in environments disturbed by humans such as agricultural lands prior to intensification. Recognition of the threshold of interference would aid in conserving wild populations.

2.3. Loss of Foraging Material

Through the introduction of monoculture crops in farm lands, the diets of wild bees can become quite limited in variety. Since the crops will bloom at the same time, this provides a narrow window of time for wild bees to forage and collect pollen. This only covers part of the life cycle of wild bees. Without a variety of plants, flowers, and crops blooming at different times of the year, there will be gaps of time where food is not available for bees to feed upon. This gap can lead to the starvation of bees due to lack of food. Similarly, a lack of variety in food sources can create a limited number of nutrients in bees' diets, similar to that of humans that feast upon only one particular type of food. To maintain healthy populations, diversity in diets is a benefit (Participants 2 & 7).

Insufficient amounts of flowered land areas can create spaces within the local environment where wild bees may be left without adequate food sources in their foraging range and could potentially starve. This can contribute to an extinction vortex since as the bees continue to decline, the amount of flowers available to feed upon will also be reduced due to a lack of pollination services. This then further increases the likelihood of bee decline since food sources will be exacerbated (Goulson et al., 2008). Hence, the positive feedback loop creates a grim setting for wild bee survival.

In addition, the removal of naturally occurring weeds and plants can incidentally decrease the amount of available foraging material for bees. These forms of vegetation serve as pollen and nectar sources for wild bees. Although they are perceived to be pests that are infringing upon crops' growing space, their growth can contribute to

increases in crop yields due to their support of wild bees and their related pollination services (Kevan, 1999; Morandin & Winston, 2006).

Hence, the promotion of monoculture crops and the conversion of land towards intensive agricultural operations can contribute to the loss of foraging material necessary to support wild bee populations. Without food to sustain life, how can one expect wild bees to sustain essential pollination services for agricultural crops?

2.4. Commercial Bee Industry's Impacts on Wild Bee Populations

Commercial beekeeping practices also degrade wild bee population health. The importation of bee colonies from other countries exposes Canadian wild bees to exotic parasites, diseases, and pathogens. This exposure could cripple not only local commercial bee colonies but wild bee colonies as well.

Beekeeper practices in managing infestations can impact the health of commercial and wild colonies. The Canadian Association of Professional Apiculturists (CAPA) (2009) notes that beekeepers lack the capacity to effectively deal with pathogens in their colonies. This is evidenced in the treatment of *Varroa destructor*, a mite that has plagued Canadian commercial honeybee colonies in recent years. Further, some beekeepers prefer to wait until the infestations of mites and parasites are so dire that they are eligible for emergency pesticide grants from the provincial governments (CAPA, 2009). Although this might be economically sensible for these particular beekeepers, these practices can harm more diligent beekeepers' colonies since bees from different colonies interact as they forage.

Wild and commercial bees interact in the natural environment while foraging among plants when commercial bees escape from greenhouses. However, wild bees are more vulnerable to these commercial bees' pathogens due to their lack of previous exposure. Through the pathogen spillover effect, infected commercial bees can spread the pathogens to wild bee populations (Meeus et al., 2011). Colla et al. (2006) observed this in wild bumblebee populations captured close to commercial greenhouses where managed bumblebee colonies were used to pollinate crops in these indoor growing

operations. The researchers found that wild bumblebees located closer to the greenhouses contained significantly higher levels of *Crithida bombi* and *Nosema bombi*[3] than those located further away, suggesting that managed bumblebees escaped from the greenhouses and infected native bees.

To address the spread of exotic pathogens in commercial and wild bee colonies, commercial imports of bee colonies are regulated at the federal level in Canada under the *Health of Animals Regulations* (Canadian Food Inspection Agency, 2011). Imports are accepted from only certain countries to reduce likelihood of infection (Ellwood, 2009). However, some producers have complained that the regulations imposed by the provinces are generally ineffective in protecting bee populations (Ellwood, 2009). One case discussed in the interviews was the decline of the western bumblebee. When Canadian bee companies brought samples of western bumblebees to European countries to learn management techniques, upon return, these travelling western bumblebees infected native western bumblebees. The populations of native western bumblebees have decline dramatically in recent years. Researchers in British Columbia have been unable to find a western bumblebee in the field for years (Participant 1). Therefore, the movement of commercial bees can significantly affect the population health of wild bees in their natural environments.

A source of conflict is thus that commercial bee interests and practices do not necessarily align with wild bee protection. Similar to the impacts of farmed fish introductions to wild fish populations, commercial bees expose wild bees to previously unknown pathogens, weakening populations and contributing to their decline. However, sanctions and regulations directed towards commercial interests may be met with resistance since commercial beekeepers will want to protect their colonies' interests and hence, their livelihoods more than the well-being of wild bee populations.

[3] *Crithidia bombi* and *Nosema bombi* are pathogens mostly found among commercial bumblebees (Colla et al., 2006).

2.5. Changing Conditions in Canada

Climate change and shifts in weather patterns can pose a threat to the survival of wild bee populations in Canada. Climate change poses a risk to all bees since food sources and thermal tolerances will be affected by changes in temperature and climate conditions (Winfree, 2010). In particular, if climate patterns change too quickly and the bees are unable to migrate or adapt to the conditions, they could face extirpation or extinction. Habitat loss and degradation will further aggravate the effects of climate change on bees (Winfree, 2010). CAPA (2009) noted that harsh weather conditions during the winter of 2008-2009 accounted for higher winter losses for commercial honeybee losses. That particular season experienced a longer period of cold weather and a cool spring. The weather conditions increased mortality rates and slowed growth rates for colonies, impacting colony productivity for the spring. Furthermore, the harsher weather conditions can increase winter loss rates since bees would not have consumed enough nectar prior to the onset of winter to last the longer than predicted season (CAPA, 2009). Although this figure pertains to the commercial bee industry in Canada, this phenomenon likely affects wild bees as well since both groups would be subjected to these shifts in weather conditions. Thus, these shifting weather conditions and potential climate change create a level of uncertainty for commercial and wild bee colonies alike.

Climate change can also alter the synchrony of the plant-pollinator interactions. With plants blooming at different times, this can create gaps in the wild bee life cycles where food sources are not available, leading to starvation and possible further declines in wild bee populations (Thomson, 2010; Participants 2 and 7). Thus, these shifting weather conditions and potential climate change create a level of uncertainty for commercial and wild bee colonies alike. Planting diverse arrays of crops that bloom at different times can help circumvent this issue since blooming floral sources would be available at different intervals throughout the life cycles.

2.6. Overall Implications of Wild Bee Decline

Pollinators have been described as bioindicators for the state of ecosystem health. Due to the mutual relationship between plants and pollinators (including agricultural crops), decreases in wild bee abundance can result in negative impacts for other organisms. This is attributed to the interconnected nature of ecosystems where various segments depend upon the health of pollinators. The cascading effects of pollinator decline indicate that the overall functions of an ecosystem, that being the necessary interactions among organisms to sustain life and functions, would be altered (Kevan, 1999). The bioindicator aspect of bees' pollination services has been observed in the past where significant pesticide usage drastically altered the composition of bee populations near New Brunswick blueberry fields which consequently affected the diversity and abundance of other organisms within that ecosystem. This event served as an impetus for regulatory change for pesticides in that jurisdiction (Kevan, 1999). As an agricultural canary in the coal mine, wild bee declines serve as a live signal that certain agriculture practices are unhealthy for supporting pollination and other integral ecosystem services. Hence, due to this keystone status, a decline in wild bee populations can indicate larger problems in the agricultural environment.

Insect pollination is responsible for the provision of 75% of crops directly consumed by humans for food (Potts et al., 2010). In this group of pollinators, bees are the main player in the provision of this ecosystem service (Winfree, 2010). Fruit crops are particularly vulnerable to pollinator decline since they are reliant upon pollination services provided by commercial and wild bees (Potts et al., 2010). Dependence on bee-pollinated crops has increased in recent years and is expected to exceed the current supply of managed honeybee pollination services but wild bees can be important for meeting future demand (Winfree, 2010). Furthermore, overwintering loss rates for managed honeybees have increased dramatically, indicating population declines in Canadian honeybee industry (CAPA, 2011). Supply of managed bees through imports can create a risky scenario in which Canada becomes dependent upon foreign pollination sources. If foreign pollinators also decline, where would that leave the national stability of pollination sources? Therefore, it is critical to preserve local wild bee populations to sustain pollination services amidst declines in the managed pollination

industry. A risk-based approach would find means to address wild bee decline in Canada. Given the issues plaguing managed bee populations such as diseases and parasites, wild bees can provide a pollination buffer and continue to support crop production in the face of commercial bee disturbances (Winfree et al., 2007). Garibaldi et al. (2011) reinforce this point, observing wild bees play an integral and irreplaceable role in crop pollination in spite of visits from commercial honeybees. They further suggest that policies should target habitat restorations in the agricultural landscape to support the protection and stability of pollination services.

Declines in wild bees will not compromise food security since essential grains such as wheat and barley are pollinator-independent and will continue to flourish. However, the availability and quality of fruits, vegetables, and hay for animals consumed as meat in Canadian diets will diminish due to their dependence on bees for pollination services. This accounts for approximately one-third of the Canadian diet, indicating that a large portion of the food Canadians consume relies upon pollination either directly or indirectly (Richards & Kevan, 2002). Hence, given their vital role in the pollination of crops and plants, conservation and protection of wild bees is important for maintaining crop stability in agricultural production.

The contributions of pollination services for Canadian agriculture are estimated to be at least $1 billion Canadian dollars. Approximately 75% of this attributed to commercial honeybees; however, the contributions of native bees has been underestimated (CANPOLIN, 2011). Most estimates tend to focus on the role of commercial honeybees rather than wild bees since their pollination services are easier to quantify (due to rental costs) and the inability to separate the contributions of wild and managed bees to pollinating crops (Potts et al., 2010; Richards & Kevan, 2002). However, in jurisdictions where wild bee populations have declined to the extent where alternative pollination methods must be employed, it has been found that production costs have increased dramatically. This is evidenced in the rise of pear prices in China where human labourers must be paid, since the increased labour is considered to be an agricultural input, to hand pollinate crops. However, this additional cost can augment the costs, thereby driving market value for crops (FAO, 2008). Hence, the replacement costs of wild bee pollination through alternative pollination methods can prove to be more costly than the ‘free’ pollination services that wild bees may provide. In addition,

pollination services are also integral for ensuring complete pollination of crops. With insufficient pollination, one can expect declines in the quality of crop products such as smaller and/or misshapen products that obtain lower market values than their sufficiently pollinated counterparts (CSPNA, 2006). With managed bee populations, particularly the domesticated honeybee colonies used for commercial purposes in North America, experiencing declines due to the spread of pathogens, stress, and colony collapse disorder (CSPNA, 2006), it will increasingly difficult to replace wild bee pollination services with that of managed honeybees. Hence, the evidence indicates that Canadians should rethink the way agricultural practices are currently conducted. As Peter Neumann, an expert from the Swiss Bee Research Centre and co-author for the United Nations Environmental Programme's *Global Pollinator Decline* report noted, "There is not an immediate pollination disaster but the writing is on the wall. We have to do something to ensure pollination for future generations" (Edmonton Journal, 2011).

Hence, the evidence indicates that industrialized agricultural practices adversely affect wild bee population health. Pesticide applications, habitat loss and degradation, the removal of foraging material, the interactions between commercial bee industry and wild bees, and changing climatic conditions all intersect and contribute to the decline of wild bees. The role of pollinators in Canadian agriculture is vital, supporting the pollination of high market value crops such as fruits, vegetables, and canola. A decline in wild bees raises questions of food availability, stability of the Canadian agricultural sector, and ecosystem health due to loss of pollination services. Since it is clear that these factors diminish wild bee populations, what is preventing the implementation of policies? The following section describes the methods used to identify key barriers to policy implementation and find examples of policies that could be applied to the Canadian context to support wild bee conservation in agriculture.

3. Methodology: Bees at Work

Policy options are directed towards all levels of government due to the abilities of each jurisdiction to target different drivers of wild bee decline. Consequently, the policies examined in the jurisdictional scan and discussed in the interviews were not limited to any specific level of government. This was a research design choice that aimed to increase the breadth of policy options examined and provide a variety of policy options that provinces could tailor to their regional specifications.

A mixed methodology approach was applied to this research for four reasons. First, I conducted a literature review to develop a better understanding of key drivers of wild bee decline. Second, I conducted a media scan to attempt to ascertain the general discourse surrounding wild bee decline. The media scan served as a proxy for the general public's knowledge regarding wild bee decline since in Canada, newspapers and national media sources (e.g., CBC News and CTV News) would serve as the main information sources for individuals' knowledge of wild bee decline. Third, I hosted interviews with academics, government officials, and non-governmental organizations whose work touches upon wild bee decline. These interviews were conducted to provide an informed perspective of drivers behind wild bee decline, barriers to policy implementation, and potential policy options that could be adopted in the Canadian context to address the bee's decline. Finally, from the literature and interviews, I identified cases of best practices that are explored in the jurisdictional scan.

3.1. Literature Review

To foster an understanding of the issues surrounding wild bee decline, I conducted a literature review. I collected scholarly articles from Simon Fraser University library databases and Google Scholar. In addition, I also read reports published by organizations such as the Organization of Economic Co-operation and Development

(OECD) and the Food and Agriculture Organization (FAO). This information supported the development of the policy problem, the driving factors behind wild bee decline, and the analysis of policy approaches.

3.2. Media Scan

Based upon the recommendations of an interview participant, I conducted a media scan to supplement my data and identify barriers to policy implementation. Newspaper articles, online media sources, and recorded interviews were consulted for data collection. I accessed these sources through Simon Fraser University. Through the library's resources, I collected articles using the Canadian Newsstand Database, a resource dedicated to major national news sources and Western Canadian newspapers, and Alternative News Sources Database, a resource dedicated to non-mainstream news sources. In addition, I searched CBC and CTV websites. I found 117 articles and eliminated reprinted documents to remove duplicates. In total, 93 articles were analyzed. I then analyzed the news coverage thematically and identified major recurring themes. These themes are discussed in further detail in Section 6.2.

3.3. Interviews

To identify the barriers to introducing policies to mitigate population decline, I interviewed professional stakeholders whose interests are connected to the management of wild bee populations. I used a snowball sampling method[4] to identify and recruit participants for the interviews. My sample included scientific researchers such as entomologists and biologists, representatives from environmental non-

4 Snowball sampling method required the identification of interview participants through a referral process. A group of potential interviewees was first identified by scanning existing literature and public websites. During the interviews, I then asked participants for additional individuals that I should interview for the research. I then contacted the recommended individuals and invited them to participate in the research project.

governmental organizations, members of organizations that represent commercial interests such as apiculture organizations, and government officials from regional and provincial levels. There was some overlap among participants regarding their professional affiliations with some connections (e.g., academics involved with non-governmental organizations). I was able to secure a total of 9 interviews.

With an invitation to participate in the interview, I sent potential participants a copy of the interview guide, a consent statement, and a description of my research. Participants were then able to review the questions prior to giving their consent and had the option to discontinue participation at any point of the research process.

I used a semi-structured format to conduct the interviews to promote flexibility in responses and encourage dialogue with the participants. I asked participants questions about their knowledge of the wild bee decline in Canada, the most important factors adversely affecting wild bee populations, their perceptions of the greatest barriers to implementing policies to manage the decline, their experiences in policymaking with regards to managing bee populations and potential policy options.

The interviews helped inform my understanding of pressures that affect policy implementation by providing information and insight that would not be easily accessible or available in existing literature. Appendix A contains a copy of the interview guide used for interviews.

3.4. Jurisdictional Scan

To identify best practices for addressing the policy problem, I conducted a jurisdictional scan. I included cases recommended by interview participants in addition to cases that I selected. To avoid selection bias, I only included cases that fulfilled the following criteria:

- Each case comes from an OECD country.
- The country has observed a decline in bee populations.
- Policies have been implemented in that jurisdiction that could be used to mitigate wild bee decline.

Although the selection criteria are admittedly general, I decided to adopt a broad approach for selection to increase diversity in potential policy solutions for addressing the bee decline. My chosen cases are the United Kingdom, the United States, Germany, and Mexico. These cases reflect different policy approaches to managing wild bee decline – incentive-based and regulatory. These cases are explored in Section 4.4.

4. Research Findings: What's The Buzz All About?

The media scan and interviews uncovered multiple themes to be considered for this issue. First, the majority of articles discussed the integral role that pollinators (wild bees and domesticated honeybees) play in sustaining ecosystems and agricultural production and the role of agriculture in pollinator decline. Second, the media scan revealed a strong media focus on domesticated honeybee decline, otherwise referred to here as honeybee centrism. This finding was reinforced in the interviews. Third, several barriers to policy implementation emerged through the media coverage and interviews. Fourth, the media scan and interviews revealed roles for government in mitigating wild bee decline and key considerations for policymaking. Fifth, articles found in the media scan highlighted potential actions that could be taken to address wild bee decline in Canadian agriculture. Sixth, the jurisdictional scan provided examples of best practices that could be adapted for the Canadian context to mitigate wild bee decline. The next section discusses the research findings in further detail.

4.1. Past and Present Barriers to Policy Implementation

When discussing past and present barriers to policy implementation for conserving wild bees, a number of themes emerged from the interviewees' responses. First, a lack of research has hindered policy implementation due to the absence of data. Second, farmers' support or lack thereof could present a challenge for policymakers in determining appropriate policies to employ to address wild bee decline in agriculture. Third, conflicting interests are difficult to negotiate when constructing equitable and effective policies. Fourth, a lack of knowledge and understanding of wild bees among policymakers and farmers presents another policy impediment. The following section elaborates upon participants' perspectives of barriers to implementing policies to mitigate wild bee decline.

4.1.1. Lack of Research

A significant number of participants suggested that a lack of research presents a hindrance to developing policy to address wild bee decline. In our discussions, Participant 1 indicated that due to a lack of research, we are unaware of the number of species of wild bees we currently have in Canada. Consequently, without this information, researchers are unsure the total loss of species that are. Baseline data would aid policy development so policymakers can assess what actions are working to improve the situation. Participant 5 supported this with his/her remarks, indicating that there are gaps existing right now in research. He/she noted that in Canada, there are no government bee biologists dedicated to serving wild pollinators, unlike our American counterparts. Honeybee biologists are hired for the federal government but there is no equivalent thus far for wild bees. Without adequate research, it is difficult to convert knowledge into effective policy. As Participant 2 notes:

> [Bee decline has] only been on the radar for maybe 10 years now, I would say... you know, really in the public eyes for the last 5 years and research is now picking up on it but there is a lag time between research and policy implementation so I think that there is a time lag going on right now... The research needs to catch up, I think, in order for policy to be formed.

Another participant suggested that this time lag can indeed present a barrier for policy implementation. Participant 4 noted that in his/her experience, this lack of baseline information regarding the historical populations and diversity of wild bees in his/her region has hindered policy development, and iterated:

> To have a policy, it needs to be targeted. So you need to be able to say what the problem is, what you are going to do about it, and what results you are hoping to achieve, and I think for something like pollinators that has so little baseline research, especially locally, it's a pretty hard sell because you don't have the data to back it up. You start tracking it and you say we did this kind of an assessment. We identified x number of species and over the last 10 years, we have been tracking and our numbers are dropping. We want to bring them back by 25 percent. We can never do anything like that around pollinators because we don't have that data. So as much as you don't want to research to death but there is a certain base minimum to have a policy that's specific... We know that pollinators are declining, it's fairly well known but in terms of our region, it's not studied. So it's hard to try and encourage action and allocate

> budget because that budget is going to come away from something else when you don't have that information.

Multiple media articles also indicate that Canadian scientists have not yet identified all species of wild bees that exist in the country. Efforts are currently underway to identify and create a database. In the interim, as pollinators continue to decline, scientists will remain unsure about whether other species have become extinct due to this lack of information.

One interviewee also commented that there is a disconnect between universities and governments. Although universities in Canada are conducting research regarding pollinator decline, there appears to be a communication barrier between the groups. Without a clear message of the current research being undertaken, it is difficult to convert science into effective policy. This highlights another potential area for policy intervention. By strengthening linkages between the institutions, the science can be made into policy.

Therefore, as the evidence suggests, the absence of research and data gaps has impeded policy development for mitigating wild bee decline. However, in recent years, the federal government has allocated funds for a research network referred to as the Canadian Pollination Initiative (CANPOLIN). This group aims to overcome these research issues and fill the data gaps existing within Canadian pollinator research to inform policymaking. As a result, current work is being undertaken to address this barrier to policy implementation. This group is discussed in further detail in Section 6.5.

4.1.2. Farmer Support

Farmers' support was another recurring theme. Multiple participants indicated that policies could be targeted towards agriculture to support pollinator conservation. Therefore, farmers' support of or opposition towards policy interventions could present challenges for policymakers. In Participant 3's local experiences, there is awareness among farmers about the important role of wild bees and pollinators in providing pollination services to crops. This encourages farmers to implement practices that support wild bee populations such as using cost-sharing structures provided by local non-governmental organizations. Participant 2 observed:

> I think from what I've seen, if government can provide cost-sharing, a lot of the farms are pretty willing to do these [conservation measures within agricultural practices]. A lot of farmers are environmentalists as well... They're very tight with time and money so I think for these things to happen, there does need to be government involvement... I think that's necessary because growers cannot be expected to shoulder, you know, the whole burden of conservation when they're running at usually pretty fine profit margins.

This highlights an important barrier to policy implementation and also a significant consideration for policymakers. In order to ensure farmers' support of potential policies, the onus should not be placed upon farmers without providing adequate assistance. Given that farmers have limited resources (e.g., time, money, and labour), policies that aim to conserve wild bees should account for these constraints in order to garner sufficient farmer collaboration. Without this consideration, this will create a significant barrier to policy implementation.

In contrast to the above, Participant 1 noted a fear among farmers of conservation policies. He/she believed that farmers "feel like conservationists are out to get them". An example was used in this discussion where if protection was provided for wild bees, if a threatened bee was found on farmlands, the farmers fear that their land would be taken away for the sake of conservation. Hence, farmers may feel unsettled with the idea of pollinator conservation policies.

With these above ideas in mind, policies must therefore be designed to garner farmer support for take up of policies while also assuaging fears of conservation. Without this necessary backing, policy implementation could be incredibly difficult for policymakers and lower the overall effectiveness of efforts.

4.1.3. Conflicting Commercial Interests

The majority of participants indicated that conflicting interests presents an extremely strong barrier for policy implementation for wild bee conservation. With divergent interests such as land development, agricultural practices, and the need to support pollinator food and habitat, balancing profits and biodiversity is a difficult task for policymakers. As Participant 8 exclaimed, society is "run by the almighty dollar". Habitat restoration has costs associated with this, whether it is foregone costs for producing

crops, the costs for planting foraging materials, or the costs for altering production methods. Consequently, decisions for conservation require an assessment of trade-offs. For instance, installing a diverse array of wildflowers and crops or leaving marginal lands free from planting presents a dilemma for farmers where they are forced to decide between profit maximization and pollinator conservation. Participant 7 discussed this dilemma, describing the choices farmers must make between making money and planting foraging material for pollinators. Participant 3 elaborated upon this in our discussions:

> The biggest barriers to policy, I guess, it's just enacting policy that actually creates habitat. That would be hard to do because how do you just create habitat when there is such a demand on the land base. For instance, in the agricultural landscape, you say "Oh, hey, farmers, why don't you go and create some habitat?" Well, how are they going to do it? Where are they going to take their land out of? They're running a business just like all of our other endeavours here. So, that can impinge real costs. Some of them, especially if they are not growing crops that require [animal] pollination, like root vegetables and cereals and other vegetables like that.

One must also account for differences among agricultural producers. Not all agricultural producers will benefit from introducing pollinator-friendly agricultural practices. Participants 3 and 4 indicated this. Participant 4 noted:

> It depends on who are affected negatively by the policies (the scope of the policies). In other situations, growers of pollination-independent crops who may be obligated to adopt costly practices without compensation and growers of seedless crops whose crop's quality can be damaged by increased incidental population provided by wild bees can exert pressures against such policies.

Consequently, one must consider the financial benefits to farmers of incorporating pollinator habitat. For producers who grow root vegetables and cereals, it is not necessarily in their interests to introduce pollinator-friendly crops such as setting aside marginal lands since they do not require the assistance of wild bees to pollinate their crops. For agricultural producers who grow fruits, vegetables, and other pollinator-dependent crops, it is in their financial interest to introduce pollinator-friendly practices.

Many of the respondents indicated that restrictions imposed upon pesticides will receive pushback from agricultural producers and/or agrichemical companies. Although this point was not touched upon by other interviewees, Participant 3 indicated that some practices perceived as pollinator-friendly could still have adverse impacts on wild bee populations. He/she specified that organic agriculture still incorporates the use of pesticides such as rotenone and techniques like diatomation. He/she noted:

> Another policy could be pesticide regulations or something like that but how do you again regulate that when you've got these growers who are running businesses and some of them are using conventional farm practices which involves the use of pesticides. Well, even organic growers use pesticides like rotenone and, you know, things like that and diatomation. Even though some of those things are organically certified as pesticides, they can still be broad spectrum insecticides that kill bees and what not. So, I mean, you can try and go out and limit the use of chemicals through policy and regulations but I think you'd get a lot of pushback from the agricultural community and that would therefore limit the effectiveness of that kind of policy for maintaining pollinators.

This view is reinforced in the literature. Spinosad, the biopesticide discussed in Section 2 is another example of organic pesticides producing harmful effects upon wild bees. Participant 2 also indicated that pesticide companies would most likely fight any regulations that would require additional testing for native bees in order to obtain certification for their products to be used in Canadian jurisdictions. Participant 5 suggested that because regulations for pesticides would be at odds with pesticide companies' interests and affect overall profits, this could create a source of pushback. Participant 7 reiterated this point in our conversations. Thus, any actions taken against pesticides will likely face opposition from producers of crops and pesticides.

In addition, policymakers must also consider the role of beekeepers in this dilemma. Since they have a vested interest in hiring out their domesticated bees for the provision of pollination services, beekeepers may dislike policy interventions that support wild bees rather than commercial hives. Participant 4 had experienced this perspective through his/her work, stating:

> In one situation, for example, beekeepers who rely on providing pollination services may perceive policies that enhance wild bees as a threat to their livelihood as increased wild bee population would

> potentially reduce the demand for their services. This concern was informally conveyed to me by a group of beekeepers who generate their income from providing pollination to blueberry bushes in NB, Canada.

Ultimately, these conflicts all point to divergent interests based on different sources of, and threats to their profits. Whether it is a beekeeper, wheat grower, fruit producer, or agrichemical company, each has a distinct interest in policies that are implemented for the sake of wild bee conservation. Policies that affect profit margins will create opposition to wild bee conservation actions.

4.1.4. Honeybee Centrism and Colony Collapse Disorder

In spite of using search terms “wild bees” and “native bees” for the media scan, much of the media coverage focused upon domesticated honeybee population decline and the prevalence of colony collapse disorder, a phenomenon recently experienced among beekeepers in the United States and potentially (although unnamed as of yet)[5] in Canada. In these articles where domesticated honeybees were the primary focus, wild bee decline was usually mentioned in passing rather than as a distinct issue. I refer to this issue as ‘honeybee centrism’ where such a strong emphasis is placed upon domesticated honeybee decline that wild bee populations are not ascribed the same level of attention. This could serve as a policy barrier where the decline of domesticated honeybees accumulates enough attention and political will that policy interventions may be focused upon this industry at the expense of wild bee policies. Particularly, since domesticated honeybees are private commodities and part of a greater, government-regulated beekeeping and pollination services industry, it would be easier for this particular group to rally the necessary support and media attention. In contrast, wild bees are not private commodities nor are they managed by a governmental body. As such, it would make sense that they would not garner the same level of media coverage as the domesticated honeybee declines appearing throughout North America.

[5] The literature consulted suggests that the Canadian apiculturists thus far has yet to comment on or refer to the experienced overwintering losses as ‘colony collapse disorder’ (CAPA, 2011).

Another example of honeybee centrism identified in the media coverage is the notion that commercial honeybee declines are frightening due to the inability of wild bees to completely support current levels of agricultural production and the required pollination service. This is exemplified in a quote from Ron Lin, a commercial beekeeper and president of Honeyland, "We can't rely on wild bees anymore because they are dying of disease. Domestic honeybees are important for pollen distribution" (Kelsey, 2007, p.13). The dialogue surrounding pollinator decline has focused primarily upon domesticated honeybees and how its decline will compromise agricultural production. However, this presupposes that honeybees are the main means of pollinating agricultural crops and maintaining the stability of pollination services. In contrast to this form of honeybee centrism, several articles highlight why a reliance on domesticated honeybees would be problematic for agricultural food production. First, an article from the *Montreal Gazette* indicates that a shift to modern Western agricultural practices has increased the need for domesticated honeybees to provide pollination services to farmers.

> Ironically, it's because pesticide use in large, single-crop farms wipes out many other sources of pollination that farmers resort to "hives for hire" and rent hives of honeybees while the plants are blooming (Nebenzahl, 2007, p.B3)

Additional articles suggest that we need a diverse abundance of pollinator species to maintain the stability of pollination services. Relying on one particular species, particularly a non-native species facing its own problems, for pollination services in Canada would be ecologically risky. Eric Mader, the director of the Pollinator Protection Campaign from the Xerces Society, stated "If we say the honeybee is all we need, that puts food security in a bad position. It's really difficult to keep honeybees alive in North America" (Moneo, 2011, p. S3). Further supporting this view, André Paquette, an entomologist from the Montreal Insectarium, noted, "Many people just put all their eggs in the same basket and there's not enough concern with what's happening to other species, other pollinators" (Nebenzahl, 2007, p.B3). The findings from this media scan indicate that Paquette is correct in asserting that more attention is placed upon domesticated honeybee decline. With the cursory mentions of wild bee population reductions in articles that are honeybee centric, it can be inferred that more focus and

media coverage highlights the decline of domesticated honeybees at the expense of wild bees.

4.1.5. Knowledge and Understanding of Wild Bees' Contributions

A significant number of participants noted that a lack of knowledge and understanding regarding the importance and role of wild bees can prevent policy implementation for their conservation. Participant 1 described his/her experiences with policymakers, noting that there is a lack of understanding and knowledge among policymakers regarding the differences between domesticated honeybees and wild bees. In one media article, Elizabeth Elle, a biologist affiliated with Simon Fraser University, wrote a letter to the editor of the *Vancouver Sun*, stating that there was misinformation regarding the role of honeybees in pollinating crops such as tomatoes. Previous coverage in the newspaper had attributed these pollination services to domesticated honeybees rather than the true providers – native bees (Elle, 2010). Perhaps as a result of this, most focus is placed upon domesticated honeybees in policymaking which is evident in current provincial government regulations. Without an understanding of the differences between domesticated honeybees and wild bees, it is difficult to garner support for implementing policies to support wild bee conservation.

In addition to a lack of understanding among policymakers, one participant noted that in his/her experience, growers are also unaware of the complexities of plant-pollinator interactions and the role wild bees may play to support the productivity of their agricultural operations. Participant 7 stated:

> [There is a] lack of education and understanding. We are doing a lot of educational efforts and it is remarkable to see how society in its urbanized system... the lack of understanding and detachment of 'Joe Blow Average' of how the environment actually operates. It would be astounding if you had been at the [*name of growing course has been removed*], that is held every year in [*location has been removed*]. Hundreds and hundreds of fruit growers come out there. It is a multi-day event... it's remarkable... Some of these people whose living is to produce crops, fruit crops, have a rudimentary understanding about the basic biology involved with pollination and what actually takes place and why it takes place. They just assume as long as you have enough fertilizer on the ground, you have pruned your bushes well, you keep diseases under control, that fruits are an automatic thing. It's not the same as growing a nail or growing hair. It's not a vegetative process that

> automatically happens... It's basically plant sex. Plants simply cannot move on their own. They need another agent to help them, an external agent in the form of an insect, to have successful sex, if you will. That enables them to reproduce successfully. That basic understanding is lacking with even people whose business it is to grow crops. It's quite remarkable. So within that context, the greatest barrier, people do not have a clear understanding of it.

However, another participant stated that in his/her experience, farmers have a general understanding of the decline and the role pollinators play in supporting their agricultural operations. Participant 3 indicated that in his/her experience, there is a general awareness of the decline. However, most of the attention is focused upon bumblebees rather than other species of wild bees. He/she noted:

> I have spoken quite a bit with a lot of farmers...about bees especially, the big one, is bumblebees the one that we can focus on. The little guys like sweat bees and miner bees, all of those solitary ones, kind of fall by the wayside in terms of awareness. But, the bumblebees, the farmers are acutely aware of them and are aware of practices that do maintain them on the landscape... so there is awareness within the farming community of these species... I can't really say whether anyone [farmers] has noticed a decline but that's not to say that someone hasn't identified it. Just overall, there is an awareness of the importance of them, especially for important crops and so, that awareness is what fuels these farmers to do some of these things and also what they have heard in the media and from literature and what not about overall, there is a decline in the pollinators in general.

With these contrasting views, it is difficult to infer the level of understanding among farmers regarding the role of larger, more well-known species such as bumblebees. However, as suggested by Participant 3, lesser-known wild bee species are most likely not receiving significant attention in conservation efforts.

Another issue with policy implementation is that it is difficult to observe the declines of pollinators since they tend to be gradual. This creates a buffer between when declines begin and when they become obvious to researchers. Consequently, it is difficult for policymakers to observe changes in abundance or population. These time lags may make it harder to garner support for conservation. Participant 7 elaborated upon this point:

> The other problem that also exists is a lack of understanding about the timeframe. If you have a pollinator, nature is full of buffers... It's not automatic. There's a buffer in the meantime. It's that gradual process that obscures us, being around for such a short time, we cannot really notice these changes very well. We have difficulty to really appreciate the declines that take place gradually, so it's that lack of understanding in all of its components. That is one of the barriers for implementing policies that will turn that around.

Consequently, the gradual nature of a long-term pollinator decline can complicate policy implementation. Similar to climate policy, the differences in timescales between policymakers and nature can make it difficult to rally sufficient momentum to enact policy changes.

Finally, a lack of comprehension of the term, "ecosystem services", and its connection to pollination and the natural services wild bees provide to plants and crops were identified as policy barriers. There is a critical lack of knowledge among policymakers regarding ecosystem services and the value these naturally occurring processes have upon human life. Participant 4 believed that it is essential that policymakers understand the key role ecosystem services play in providing 'free' services to support vital things such as crop production, water regulation, and soil fertility. With a heightened level of awareness of ecosystem services and its relation to pollination and wild bee conservation, perhaps then policy changes would occur.

4.1.6. Additional Barriers to Policy

One barrier that arose in the media scan was a debate surrounding the harmfulness of pesticide usage on bee populations in general. One article discussed a case of crop pollination in New Brunswick and the use of cosmetic pesticides. Tracy Glynn, the Campaign co-ordinator for the Conservation Council of New Brunswick pointed out that wild bees tend to be more efficient pollinators for the province's major crops than domesticated honeybee colonies. In addition, she asserted that the provincial government should assess the status of the province's wild bees, consider prohibiting the use of cosmetic pesticides, and attempt to protect habitats (Mullin, 2009). In contrast, Richard Duplain, the Vice-President of the New Brunswick Beekeepers Association argued, "I don't believe in bans. I believe in common sense, adding

moderation is the key for NBers to green their lawns without harming the environment" (Mullin, 2009, p.A2). In response to these statements and also considering the use of pesticides in agriculture, Paul Vautour, the President of the New Brunswick Beekeepers Association, noted,

> In a perfect world, it would be nice to ban pesticides and go all natural but intensive farming crops are so close together it makes it easy for pests to thrive, and you just can't live without them at all... but cosmetic pesticides, we can do without (Mullin, 2009, p.A2).

Another debate surrounding pesticides unfolded in July 2011 in the *Vancouver Sun*. Lorne Hepworth, the President of Crop Life, a trade organization that supports agrichemical industry interests, issued an opinion piece defending the use of pesticides. This was written to address concerns raised by the Canadian Cancer Society and the Canadian Association of the Physicians for the Environment who believe that pesticide usage compromises human health and advocate for its ban. Hepworth wrote:

> Health Canada has found these tools to be safe for use by individuals and so the ability to employ them should not be limited based on the unscientific, polling arguments by organizations seeking to raise more money. Decisions such as these should continue to be made on the basis of sound science, thorough research and comprehensive evaluation by the scientific professionals we all depend on to keep us safe. (Hepworth, 2011)

In response to this, David Roberts, a beekeeper from West Vancouver, retorted in a letter to the *Vancouver Sun*'s editor:

> Lorne Hepworth is a spokesman for the pesticide manufacturing industry. His article defending the use of pesticides, blithely, and I suspect deliberately, avoids a discussion of the harm that pesticides do to all the insects that we need in order to sustain life. Has Mr. Hepworth never read *The Silent Spring* by Rachel Carson? The decline in the population of the hundreds of species of wild bees is evident even to the casual observer. Pesticides do not discriminate between their victims (Roberts, 2011, p. D3).

In addition, an article from CBC News quoted Lora Morandin, a biologist and lead author of a study regarding pesticide effects on bumblebee populations, regarding the current testing standards for pesticides in Canada. She noted:

> Toxicity testing is largely restricted to direct lethal effects on adult honeybees, if it includes bees at all. Testing new pesticides on some species of wild bees will aid in developing pesticides and use recommendations that minimize impact on wild bees, leading to healthier populations of bees and potentially better crop yields (CBC News, 2005).

Participant 7 also strongly urged for strengthening the testing so that Canadian policymakers can gain a deeper understanding of the effects of pesticides. He/she indicated that complete pesticide bans without proper scientific evidence can be ineffective in addressing bee decline. He/she then highlighted cases in other jurisdictions where pesticide bans failed to mitigate bee decline.

These arguments reinforce the previously discussed existing policy gap for Canadian pesticide regulations. Without accounting for the lethality and sub-lethal effects of agrichemicals on wild bees or honeybees, legal pesticides could be improving crop yields but at the expense of the health of pollinator populations. The discourse surrounding pesticide usage highlights conflicting perspectives of its application to crops.

Additional findings that recurred to a lesser extent include a lack of political will for monitoring wild bee decline, misconceptions regarding the importance and the role of wild bees in pollinating certain crops, and a lack of knowledge of wild bee species. The lack of political support for wild bee conservation was referenced in two separate media articles. The first observed that provincial and federal governments do not consider conservation to be a top priority (West, 2006). The second remarked, "... for a country with Canada's agricultural base, there's surprisingly little sign of enthusiasm here in finding a cure" (Spears, 2010, p.A12). These two suggest that the absence of political will presents a barrier for policy implementation for wild bee conservation. Although these items imply that there is a lack of political will in Canada for mitigating wild bee decline, one could argue that the federal government's funding grant to the Canadian Pollination Initiative indicates that there is at least political interest in the issue and pollinator conservation. This initiative is discussed in further detail in Section 6.3.

Thus, conflicting perspectives regarding pesticide usage, the existing gaps in pesticide assessments, and a lack of Canadian political will for mitigating wild bee decline were smaller recurring themes within the media scan and interviews. However,

these points all serve as barriers to policy implementation and can prevent the mitigation of wild bee decline.

4.2. Roles for Government and Policymakers

All participants indicated that there is a role for government and policymakers to intervene and introduce policies to address wild bee decline. There was variation among responses regarding the particular roles policymakers could take, including the provision of incentives, supporting education initiatives, and the expansion of regulations. Since wild bees and the ecosystem services they provide are considered public goods, there is no incentive to conserve their populations. This lack of an incentive signifies an area for government intervention to support wild bee populations. As Participant 4 wrote:

> Wild bees are a public good and their pollination services are externalities. Hence, there is no market-based incentive mechanism that could signal their value and, hence, sustain their population health. In the absence of any incentive structure to signal their importance, they would most likely be threatened by human's over-exploitation of their habitats and use of the environment as a sink for their agronomic and/or urban wastes. Government intervention is usually justifiable for protecting such goods and services on the basis that the causes behind their decline are economic (driven by human activities).

Consequently, due to the characteristics of wild bee populations, a public good that requires government intervention to manage and protect this resource and attributed pollination services, there is indeed a distinct role that governments can play to manage and protect wild pollinators in Canadian agriculture. Conservation efforts to support wild bee populations create positive externalities whereby farmers cannot accrue the total benefits obtained from investing in sustainable agricultural practices. By incentivizing pollinator-friendly practices through the use of policy instruments, the governments can overcome barriers to investment and support behavioural change among farmers. Participant 4 provided examples of intervention with the caveat that the type of intervention would depend upon the activity causing decline, stakeholders involved within the scope, and the presence of property rights. His/her examples included pesticide emission taxes in instances where wild bees' natural habitat is contaminated

from nearby pesticide applications, subsidies for organic or sustainable agricultural practices, and the provision of payments on private lands that amount to foregone income incurred to support conservation efforts.

The majority of participants concurred that the government should provide incentives to encourage conservation behaviours among farmers. Participant 8 referred to these incentives as “policies that entice farmers to maintain areas”. These could be manifested in the form of AEMs present in the United Kingdom and the United States. Multiple participants turned to these jurisdictions as good examples of government intervention for addressing wild bee decline. These cases are discussed in further detail in Section 4.4.1. By providing financial assistance for farmers to take up pollinator-friendly practices, the government may then aid farmers in overcoming resource barriers that would prevent them for supporting wild bee populations in their usual agricultural operations. With these funds, farmers can restore habitat and provide adequate foraging material for wild bees with the hopes of mitigating population decline. As Participant 1 asserted, “Build it and they will come.”

Supporting education and research was also a recurring theme among respondents. Multiple respondents suggested that further research could strengthen policy efforts. One interviewee in particular advocated for the federal government to consider hiring a bee biologist to ensure that someone with expertise would be directly involved with the implementation and management of policies and programs to support wild bee conservation. Another participant suggested that governments should research the level of effectiveness for different strategies and disseminate the findings to farmers. Participant 2 supported research as a means of supporting and making informed policy decisions. Finally, Participant 7 strongly advocated for the provision of education programs and training for farmers regarding best agricultural practices and the importance of pollinators in supporting agricultural activity.

Interviewees also identified regulatory reform as another way government may intercede to support wild bee conservation. Multiple participants suggested that the governments could consider expanding current pesticide regulations to incorporate testing for the sub-lethal effects of pesticides used in agriculture. Two interviewees, Participants 2 and 8, recommended that before certifying pesticides for usage in

Canada, agrichemical companies should be required to test proposed products on wild bee species to determine the effects of the chemicals. Participant 2 indicated that perhaps not all tests are even necessarily conducted for domesticated honeybees when determining the safety of agrichemical products. Since current standards only examine for the lethal effects, there is an information gap where the policymakers are unaware of other negative sub-lethal impacts of pesticide products on bees (e.g., reduced fertility, lowered foraging ability). Three respondents indicated that more stringent testing could be incorporated in managing pesticide certifications. In particular, one participant indicated that a sample of different wild bee species could be subjected to pesticide assessment tests to ascertain the effects of a given product. The variance of reactions could provide policymakers with a better idea of whether a pesticide is harmful only to domesticated honeybees or other species as well. To a lesser extent, respondents suggested that more regulations could be implemented for the commercial bee industry, both for greenhouses and the movement/transport of bees for pollinating plants since pathogen spillover to native bee populations is detrimental.

Media articles further promoted the need for incentives in supporting wild bee conservation. One article reported upon UNEP's *Global Pollinator Decline*'s suggestion that incentives be used to encourage changes in farming practices and encourage the restoration of pollinator habitat (Doyle, 2011). The *Vancouver Sun* quoted SFU entomologist Mark Winston who recommended the following:

> Farmers need to develop ways to encourage other species of bees to flourish so they can take over some of the pollination responsibilities. Fewer chemicals and more diversity. We have to begin to realize that diversity is in our self-interest. A monocrop is not the best way to grow food. If we look at it sensibly, we'll come to see that we need to change the way we do agriculture in North America (Read, 2007, p.C7).

David Suzuki, a renowned Canadian environmentalist asserted in an opinion-editorial that payment for ecosystem services (PES) could be an appropriate mechanism for supporting wild bee populations in Canadian agriculture. He wrote:

> Declines in honeybees and other agricultural pollinators as a result of habitat loss, pesticide use, and other human activities mean that farmers are now paying to replace this critical natural service. In many areas of Canada, farmers are trucking beehives onto their farms to ensure that the

> once-free pollination services their crops depend on continue. Investing in programs to maintain, enhance, and restore ecosystem services that natural areas provide is an effective cost-savings measure and an important element of any green economy. If we were to include natural services and the environmental costs of our waste and pollution in our economic accounting, we'd have a more realistic economic system. And we'd see that the environment and economy are intertwined. Caring for one is the solution to problems facing the other (Suzuki, 2009).

The above examples indicate that perhaps voluntary incentives could be employed as a tool for changing modern agricultural practices to enhance pollinator protection.

In addition, as noted in Section 4.1.6., Morandin suggested that government tests for pesticide assessment should be expanded to test for effects on wild bee species in addition to honeybees (CBC News, 2005). Education programs have been implemented in British Columbia to promote pollinator-friendly agricultural practices. *The Globe and Mail* followed the story of Nathalie Chambers, an agricultural program assistant for The Land Conservancy who runs the Pollinator Enhancement Program. This initiative teaches farmers the value of implementing pollinator-friendly practices and provides them with the technical knowledge to introduce practices to their agricultural operations (Moneo, 2011). Education and regulations create another area for policy intervention.

Therefore, the media coverage and interviews highlight multiple policy mechanisms that could be used to address the problem of wild bee decline. Economic instruments such as AEMs, PES, changes in pesticide regulations, and education programs are examples of policy directions governments could take to support pollinator conservation in the agricultural sector.

4.3. Considerations for Policymakers

When discussing key considerations policymakers should account for when designing policies to address wild bee decline in agriculture, the responses differed among participants. The key factors for considerations discussed by interviewees were cost, budget constraints, regional considerations for policy implementation, long-term vision for policy implementation, and implementation considerations for AEMs. While these are all important considerations to be made in policy design, I focus upon two

particular recommendations, the first being the need for monitoring and evaluation and the second being specific regional differences. Participant 2 asserted that policymakers should track the progress of policies once implemented to ascertain whether they are achieving the goal of mitigating wild bee decline, stating:

> ...need to assess effectiveness with agri-environmental schemes to determine whether the program needs to be modified. It would be detrimental to conservation movement if money is invested in these schemes and it turns out that the methods could have been conducted in a better fashion. Therefore, agri-environmental schemes should be conducted in conjunction with more research or allow the sites to be studied.

The participant's statement highlights an opportunity for incorporating adaptive management in addressing wild bee decline. By conducting more research and monitoring in areas targeted by policies and programs, the data obtained can be used to inform further policy decisions for mitigating wild bee decline. This concept is explored in more detail in Section 6.2.

Participant 3 indicated that regional differences should be incorporated in the development of policy to address bee decline in agriculture. For instance, farming in a particular area might mostly consist of wind pollinated crops such as root vegetables and cereals. Consequently, farmers might not believe that it is in their financial interest to invest in pollinator-friendly practices when compared to fruit growers. Agricultural policies in areas such as this will need to directly address the needs of growers of that particular region. In areas that contain more pollinator-independent crops such as wheat, the installation of more foraging material among crop fields might require different sets of incentives since pollinator populations might not necessary improve the quality of their crops.

I integrated the above findings and the interviewees' remaining observations in the development of policies to address wild bee decline and used their comments to aid me in determining which policy would be the most effective for addressing this policy problem.

4.4. Best Practices Gathered from the Jurisdictional Scan: Other Busy Bees

This section examines best practices employed in other jurisdictions. The jurisdictional scan pinpointed potential policy options that could be utilized to mitigate wild bee decline in Canadian agriculture. As previously mentioned in Section 3.3, the selection criteria for the cases were the following:

- Each case comes from an OECD country.
- The country has observed a decline in bee populations.
- Policies have been implemented in that jurisdiction that could be used to mitigate wild bee decline.

The United States, the United Kingdom, Germany, and New Zealand fulfilled these criteria. The four cases were then classified by their common policy approach. The United States and United Kingdom represent countries that have employed economic instruments such as cost-sharing measures and AEMs to support wild bee conservation in agriculture. Germany and New Zealand are examples of countries that have used a regulatory approach towards supporting wild bee protection and conservation. The following sections elaborate upon their policies and extrapolate applications that could be utilized in developing Canadian policy responses to wild bee decline.

4.4.1. Incentive-based Approaches

4.4.1.1. United States

The *Food, Conservation, and Energy Act of 2008*, also known as the Farm Bill, enables the United States Department of Agriculture to administer a variety of voluntary, incentive-based conservation programs for agricultural lands (NRCS, 2010). The Farm Bill includes new wording that explicitly promotes pollinator conservation and habitat protection as a priority for the department. Through some of the bill's associated funding schemes, special considerations are made for proposed agricultural projects that preserve or enhance pollinator habitat (Vaughan & Skinner, 2008). Considerations for pollinators were easily incorporated into pre-existing Natural Resource Conservation Service (NRCS) programs such as the Conservation Reserve Enhancement Program,

the Conservation Reserve Program, and the Environmental Quality Incentives Program (EQIP) (Vaughan & Skinner, 2008).

In particular, the EQIP provides a significant arena for aiding farmers in adjusting their current agricultural practices to enhance the protection of the ecosystem. Whereas the abovementioned programs focus more upon land retirement strategies for environmental conservation, the EQIP is dedicated to helping farmers overcome barriers to implementing more sustainable agricultural practices. This program helps participants introduce new management practices by sharing the introduction costs with farmers or by providing one hundred percent coverage of foregone income if the proposal involves crop rotations where farmers do not plant crops in a given area for a season (Vaughan & Skinner, 2008). This aids farmers in overcoming financial barriers to implementing beneficial agricultural practices that conserve pollination services. Contract lengths vary from one to ten years and applications can be made to either NRCS state or local offices (Vaughan & Skinner, 2008). In addition, when funding proposals for the EQIP are assessed, states can use their discretion in awarding projects that specifically address pollinator needs with more points for the evaluation, thereby increasing their rankings and chances of winning funds. States that have incorporated this in their administration of the EQIP include Montana, South Dakota, and California (Vaughan & Skinner, 2008).

Since contract terms vary in length and the Farm Bill's new provisions for pollination services were introduced only three years ago, it is likely premature to measure the overall effects of the EQIP on pollinator conservation. To the best of his/her knowledge, Participant 2 believed that no evaluations of the program had been conducted at the time the interview was held. However, the program provides an example of a federal voluntary program that can be implemented at the state level. This program also provides a means of overcoming financial barriers to implementing pollinator-friendly agricultural practices.

4.4.1.2. United Kingdom

Under the European Union's *Common Agricultural Policy*, member states administer AEMs to support farmers in introducing agricultural practices that promote wildlife conservation and biodiversity. Member states may use their discretion in managing AEMs in ways that are appropriate and useful for their local context (Carvell et

al., 2007, European Commission, 2008). A number of interview participants indicated that the United Kingdom provides an example of best practices in the European context. England's AEMs are explored in further detail below.

In England, Natural England administers agri-environmental schemes (Natural England, n.d.). This group is tasked with advising the government using evidence-based material on the best ways to preserve the natural environment (Natural England, n.d.). Natural England engages land managers, scientists, researchers, and agricultural producers in its programming (Natural England n.d.). In addition to its consulting and research work, Natural England manages the funding schemes, providing application materials and educational information to potential farming applicants and land managers regarding the funding schemes available for their usage. The three schemes that have been identified as beneficial to supporting pollinator populations are the Entry Level Stewardship (ELS), the Organic Entry Level Stewardship (OELS), and the High Level Stewardship (HLS).

Currently, almost sixty percent of agricultural land in England is covered under the ELS scheme. The ELS is a program open to all farmers with agreements lasting for the duration of five years. Similar to the United States, ELS promotes a list of priority agricultural practices that receive a certain number of points per hectare (Natural England, n.d.). A number of practices have been identified as particularly beneficial to pollinator populations such as:

- the introduction of pollen and nectar flower mixtures
- the maintenance of hedgerows
- the planting of buffer strips
- the reduction of fertilizer inputs

(Bumblebee Conservation Trust, n.d; Natural England, n.d.).

Farmers are free to choose which practices they would like to introduce to their pre-existing operations. Farmers' applications are then assessed using a points system where points per hectare are given across the entire farm. If a farmer meets the points target, satisfies the agreement's conditions, and agrees to implement the chosen practices, he or she will receive the associated funds (Natural England, n.d.). This

approach provides agricultural producers with flexibility in implementing the scheme's practices while accommodating their production operations. If farmers must reach the target of 30 points per hectare, they are awarded approximately 30 British Pounds per hectare covered by the agreement (Natural England, n.d.).

OELS is similar to the ELS, however it is open to farmers whose lands are either certified as organic or in transition to organic by the appropriate government bodies. Farmers receive 60 British Pounds per hectare annually in exchange for delivering 60 points per hectare of agricultural options (Natural England, n.d.). In addition, this scheme provides producers with additional funds to support their operations' transition towards organic agricultural practices. This funding support equals approximately 175 British Pounds per hectare per year for the initial two years of the agreement (Natural England, n.d.).

HLS is a more targeted program that is delivered in identified priority areas. The priority areas are targeted due to the projected benefits conservation strategies will have on wildlife, biodiversity, and ecosystem health. This particular scheme is more complex for farmers to manage. Consequently, Natural England provides farmers with the necessary technical support and an advisor from program consultants. HLS agreements are set for a longer period of time when compared to their ELS and OELS counterparts. In order to qualify for an HLS agreement, land must already be registered for ELS or OELS (Natural England, n.d.).

Carvell et al. (2007) studied some of the management options available under ELS. Their research found that pollen and nectar seed mixtures incorporated in the priority checklists that are awarded direct payments could have beneficial effects on bumblebee populations. Consequently, participation in ELS and the use of the pollen and nectar seed mixtures could support wild bee populations. Pywell et al. (2011) also studied the effectiveness of pollen and nectar seed mixtures in support bumblebee and butterfly populations. They found that the existing guidelines for the AEMs for this management option will remain effective for approximately 3-4 years and suggest that guidelines be updated to incorporate this finding. They also recommend that perhaps after this period, to maintain the level of effectiveness, farmland incorporating foraging

material should be rotated. These studies provide scientific evidence that habitat restorations could be effective in supporting wild bee populations and mitigating decline.

Hence, this program provides an example of a program that targets pollinator conservation. As the academic research indicates, the options offered in England's AEMs do provide farmers with low-cost opportunities to support pollinator conservation. The programs also provide farmers with flexibility in terms of the amount of time and resources they would invest in conservation efforts and changing agricultural practices. By having multiple options, farmers can choose which option is best suited to their needs, resources, or attitudes.

4.4.2. Regulatory Approaches

4.4.2.1. Germany

In May 2008, several cases of bee kills were observed in multiple areas in southern Germany. It was estimated that approximately 11,000 colonies were affected in this phenomenon. The Federal Office of Consumer Protection and Food Safety and the Ministry for Food and Rural Areas investigated these incidents in conjunction with local authorities, beekeepers, and the Julius Kuhn Institute (BVL, 2008). The investigation concluded that clothianidin, a neonicotinoid pesticide produced by Bayer Crop Science, had caused this incidence of bee mortality. Consequently, the German government adopted a precautionary approach and temporarily suspended the application of this pesticide to maize and rapeseed crops until further investigation could yield more information regarding this chemical (EPA, 2010).

Eventually, the German government lifted this ban. Its investigation found that "sticker" products[6] were not used properly in the application of the clothianidin. The maize seeds, which had been treated with clothianidin, were sown using strong seeding machines. Without the "sticker" product, the machines' abrasions to the seeds scrape the pesticides off the particular product and enter into the flowers which poisoned the

6 A sticker product is a binding agent that adheres the pesticide to the seed.

bees as they foraged among the crops (BVL, 2008). In addition to the improper usage of stickers in seed treatments, higher concentrations of clothianidin had been sprayed for that particular application due to detected pests among maize crops. The investigation led to stronger regulations regarding sticker usage in pesticide applications although clothianidin is still approved for use in Germany (BVL, 2009).

Although honeybees were the impetus for the German ban, it is likely that wild bee populations were also impacted by the application of clothianidin. The bee kills were mostly noted among beekeepers who then alerted the appropriate German authorities to the higher incidence of bee mortality (BVL, 2008).

This case provides an example of governments willing to adopt a precautionary regulatory approach in managing the usage of pesticides within their jurisdictions. Although the toxic chemical is still approved for general use at this point in time, albeit with more stringent regulations, the precautionary principle is an idea to be entertained in the Canadian context for testing potentially pollinator unfriendly chemicals until further results suggest that restrictions, bans, and stronger regulations are necessary to protect honeybee and wild bee populations.

4.4.2.2. Mexico

Mexico is one of the most biodiverse countries in the world with a vast array of plant, faunal, and marine species residing within its territories (Valdez et al., 2006). However, it has not escaped the effects of global pollinator decline with decreased abundances of bees. In addition, Mexico has seen diminished populations of another significant pollinator- bats. Bats provide pollination services to key Mexican crops such as agave, the plant from which the alcohol tequila is derived. This plant is important for the local and national economies (Eardley et al., 2006). Thus, bat conservation protection is integral for supporting pollination services and promoting stability among Mexican agricultural commodities.

However, in spite of the important role bats play in Mexican ecosystems through pollination and seed dispersal, their populations were facing rapid declines until the early 2000s. Due to fears of bats and attempts to control populations, farmers and ranchers destroy vital bat habitat. To combat habitat destruction, the Institute of Ecology at the

National Autonomous University and Bat Conservation International (BCI), a non-governmental organization dedicated to the protection and conservation of bats formed the Programme for Conservation of Migratory Bats in 1994. (Eardley et al., 2006; Walker, 2001). This partnership developed a rigorous education campaign to convey the value of protecting local bat populations and their role in pollinating crops. In addition, the program worked in conjunction with the Mexican government to protect habitats around migratory corridors. The program instituted a key regulatory change that aided in the protection of bats. As per their recommendations, the Mexican federal government amended its federal wildlife law to make all caves and crevices (key habitat areas for bats) "de facto protected areas" (Walker, 2001; BCI, 2001). In addition, management plans were developed for identified critical habitat (BCI, 2001). Since the program started, bat populations in Mexico increased from 100,000 individuals to 1.5 million individuals from 1995-2001.

Although this example does not explicitly deal with the conservation of wild bees, this case provides an example of regulatory intervention for the sake of pollinator conservation. By invoking legislative change to provide protection for key areas of bat habitat, the federal Mexican government explicitly supported pollinator conservation through this key move. The example of legislative change could thus be applied to a Canadian context. Perhaps through legislative amendments or designation of protected areas, the Canadian federal or provincial governments could then support wild bee conservation using a regulatory approach. The protection of natural habitat is vital.

4.5. Summary of Key Findings from Data Analysis

Overall, the data analysis points to six major barriers to policy implementation for mitigating wild bee decline. First, a lack of research prevents policymaking because data gaps stifle the momentum needed to garner support for policy interventions. Second, farmer support for proposed policies can affect the success of interventions. Third, conflicting interests impede policy implementation because it is difficult to strike a compromise between personal gains and the public good of pollinator conservation. Investments in conservation practices require foregone profits. Without compensation or incentives, it is difficult to negotiate this trade-off. Fourth, more attention is given to the

decline of managed honeybee populations. With the focus upon this particular species, it is difficult to rally support for native bee conservation simply due to lack of coverage and inattention. This is manifested in current policies and legislation which mostly target managed bees. This is discussed further in Section 5.5. Fifth, a lack of knowledge regarding the importance of wild bees' role in nature can prevent policy implementation. Without an understanding of the connection of wild bees to the provision of key ecosystem services, policymakers will not be able to develop effective policy to mitigate wild bee declines and provide natural buffers to protect against diminishing managed bee populations. Finally, conflicting perspectives regarding pesticide regulations creates an additional barrier to policy interventions.

Incentives were consistently discussed in the media, interviews, and cases in the jurisdictional scan. In addition, regulatory measures such as pesticide regulations and protecting habitat arose as potential ideas for policy interventions to support wild bee conservation. Furthermore, governments could promote educational campaigns and strategies to overcome some of the policy barriers (e.g., increased understanding can also lead to farmer support for measures). By promoting the role of wild bees in sustaining ecosystems and agriculture and teaching valuable sustainable agricultural practices, governments can increase knowledge capacity for mitigating wild bee decline.

Two main policy design considerations that arose were the need for monitoring to ensure effective achievement of policy goals and the differences among farming operations that should be accounted for when trying to promote behavioural change among farmers to promote pollinator conservation.

The above cases from the jurisdictional scan highlight two general policy approaches that decision-makers could employ to address wild bee decline in Canada. First, the utilization of voluntary economic instruments to promote pollinator-friendly practices could encourage agricultural producers to alter their farming practices as evidenced by EQIP, ELS, OELS, and HLS. Second, regulatory interventions can also help mitigate wild bee decline. The willingness of German authorities to adopt a precautionary approach in addressing the adverse impacts of pesticide usage demonstrates that it might be useful for governments to adopt this approach to ensure that harmful substances are used with caution. While the temporary German ban does

not necessarily point to outright detoxification nor did it result in an outright ban, it provides a foundation for further policy discussions surrounding pesticide regulations for the sake of wild bee conservation. Additionally, the protection of vital habitat highlights another key area for government intervention. The preservation of identified habitat areas along with legislative change could contribute to sustaining wild bee populations. The policy approaches provided by the case studies' findings can contribute to the development of policy options for addressing Canadian wild bee decline.

These findings inform the development of policy goals and objectives. The objectives contribute to the formulation of criteria and measures used to assess the viability and effectiveness of proposed policy options. Finally, these findings also feed into the development of policy options. The policy options are discussed in further detail in Sections 6.5 and 6.6. First, the following section outlines the goals and objectives for policy interventions to mitigate wild bee decline.

5. Criteria and Measures: The Nectar and Pollen

The overall goal for any policy adopted to mitigate wild bee decline is the preservation of natural capital given that the value of wild bees cannot truly be replaced with human-made capital. With this goal in mind, policy options should achieve the following objectives: 1) reduce Canadian agriculture's ecological footprint with respect to impacts on wild bee populations, 2) mitigate wild bee decline in Canada, 3) promote sustainable practices for pollinator conservation, 4) ensure stakeholders' needs are addressed in an equitable manner, and 5) instil the values of adaptive management in wild bee decline mitigation. These goals and objectives were developed based upon the research findings.

The first two objectives speak to the negative effects of agriculture on wild bee populations and aim to reduce said impacts to preserve wild pollinator populations. Reductions in agriculture's ecological footprint should contribute to wild bee decline mitigation. The third objective speaks to the need for behavioural change in farming practices to mitigate wild bee decline. By increasing technical capacity, policymakers can promote sustainable agricultural practices and encourage behavioural change, resulting in stronger conservation efforts. The fourth objective addresses the need for farmer support of policies to mitigate wild bee decline. Optimal policies should support conservation without placing farmers at an economic disadvantage. Farmer support of policies can encourage participation, thereby contributing to bee decline mitigation. The fifth objective incorporates adaptive management, a flexible framework used for increasing capacity for managing resources when science is uncertain. The International Pollinator Initiative incorporated this framework within its objectives (Williams, 2003). Adaptive management is continually promoted as a means of managing ecosystem services, (Kremen et al., 2007). These objectives contribute to the development of evaluation criteria, used to assess the trade-offs of the identified policy options. The following sections describe the chosen criteria for analyzing the policy approaches.

5.1. Effectiveness

Effectiveness explores the ability of a proposed policy approach to preserve wild bee populations and mitigate their decline in agricultural environments. I assess whether the proposed policy can encourage uptake among farmers that promote habitat restorations and reductions in pesticide applications. The criterion is assessed based on whether the proposed policy approach fulfills the first three policy objectives[7]. Policies that satisfy all three policy objectives are deemed more effective in reducing the detrimental effects of agriculture on wild bee populations, promoting uptake among farmers, and increasing participation among farmers. Evidence for this criterion comes from my review of the literature, jurisdictional scan, and interviews. If an approach satisfies all three policy objectives, it is assessed as highly effective. Fulfillment of two policy objectives results in an assessment of moderately effective. Approaches that fulfill only one policy objective have a low level of effectiveness. Effectiveness is also weighted by a factor of three in the evaluation because it incorporates three policy objectives.

5.2. Administrative Ease

Administrative ease refers to the ease with which a policy can be implemented without encountering institutional inertia. Policy options that encounter more institutional barriers and are more complex to implement will have a lower assessment of administrative ease. Examples of barriers and complexity include whether major legislative change is required to introduce a given policy option overlapping jurisdiction (e.g., municipal and provincial governments, or federal and provincial governments, or interagency jurisdictions such as health and agriculture) or the establishment of an

[7] The fourth and fifth policy objectives contributed to the formulation of the horizontal equity, increased capacity, and the flexibility criteria. They are not assessed in the effectiveness criterion to avoid double counting.

overseeing body to implement the policy. The assessment for this criterion comes from my review of the literature and jurisdictional scan.

5.3. Stakeholder Acceptability

Stakeholder acceptability assesses whether the proposed policy option will be well-received by the identified stakeholders. For the scope of this analysis, identified stakeholders include farmers, greenhouse growers, political leaders, involved ministries, agrichemical producers, and beekeepers. The general public is not included in this analysis due to a lack of information regarding their perceptions of wild bee decline and opinions regarding the proposed policy approaches. The perceptions of conventional farmers, organic farmers, and greenhouse growers are examined separately within this criterion since their chosen agricultural practices would be affected differently depending upon which policy option the provincial government chooses to implement. Since agrichemical representatives' reactions were cited in interview discussions and noted in the media scan, their perceptions are also considered in the analysis of stakeholder acceptability. Policies that are not likely to be supported by the identified stakeholder groups will receive a lower score for stakeholder acceptability. The assessment for this criterion is informed by information obtained from the interviews, media scan, and literature.

5.4. Horizontal Equity

Horizontal equity explores whether all farmers will be equally affected by the implementation of the proposed policy approach. This criterion examines policy impacts upon farmers of different operational types. For instance, the introduction of stronger pesticide regulations may place a higher burden upon conventional farmers to alter their production methods when compared to organic farmers. Variations among size in farming operations also influence how farmers experience the effects of policy implementation. An analysis of these effects inform policymakers of the trade-offs to different stakeholder groups in the introduction of policies to support wild bee

conservation in agriculture. This criterion is assessed using information obtained from the literature and media scan.

5.5. Low Cost

Cost examines the amount of resources required to implement the proposed policy approach to mitigate wild bee decline. This includes the time and funds needed to administer the policy, design structural adjustments, and enforce the policy. For instance, the design and introduction of a new overseeing body to implement a policy would require more funds and resources than voluntary programs. If the proposed policy approach is more resource intensive, it will receive a lower ranking for cost which is interpreted as a negative trade-off. It is acknowledged that this method for assessing cost creates a risk for double counting due to potential overlap with administrative ease.

5.6. Increased Capacity

Increased capacity examines whether the proposed policy will contribute to increasing the knowledge base of policy practitioners in addressing wild bee decline in agriculture. This excludes the effects of the educational programs that should be incorporated into either policy approach when implemented. Capacity looks at whether the proposed policy will enhance the institutional capabilities for mitigating wild bee decline. This criterion was adopted from the *Pollinators and Pollination: Resource Book for Policy and Practice*. It defines capacity building as "building human knowledge, skills, and institutional capabilities" (Eardley et. al, 2006, p.29). Proposed policy approach that has a higher chance of increased practitioners' capacity receive a positive, higher ranking.

5.7. Flexibility

Policy options are also assessed based upon their ability to espouse the values of adaptive management. Adaptive management is a technique utilized to manage

natural resources and ecosystems in times of growing uncertainty and lack of substantial data (Gregory et al., 2006). It enables policymakers to test management methods to ascertain optimal treatments for addressing environmental issues in the face of data gaps. Adaptive management is lauded for the flexibility it provides resource managers in addressing environmental issues such as wildlife conservation due to its ability to test different treatments to ascertain the most effective intervention (McFadden et al., 2011). Adaptive management has also been promoted as a guiding principle in the International Pollinator Initiative and a framework for conserving ecosystem services provided by mobile organisms (Williams, 2003; Kremen et al., 2007). Given the acknowledged research gaps in wild bee decline, it would be prudent to promote policy approaches that provide the necessary flexibility to address wild bee decline with incomplete information. Therefore, ideal policies introduced to address wild bee decline should be flexible to provide policymakers and resource managers with the required manoeuvrability to alter policy approaches as new information and science develop. A policy that is more flexible in that policy practitioners can alter a given policy easily once new information about how to improve wild bee survival is obtained. A flexible policy provides more room for adaptive management than one that is rigid. Policy approaches with a higher level of flexibility are more desirable since they can be tailored with ease when dealing with resources under scientific uncertainty. Assessment for this criterion is informed by the information obtained from the literature and interviews

With the context for analysis now established through the development of criteria and measures, the next section discusses the identified policy approaches.

6. Policy Options: Foraging Among the Flowers

Policy options considered for introduction and implementation must account for the barriers highlighted in the analysis of interviews and media articles. First, interviewees indicated that there are still data gaps for Canadian wild bee decline and its related effects on agriculture. Policies will need to reflect this lack of data and be tailored in a way to account for the accumulation of new information as further research is conducted.

Second, policies must support conventional farmers in initiating behavioural changes in their agricultural practices to mitigate wild bee decline. As noted in the interviews, wild bees are a public good. Since wild bees' pollination services are non-rivalrous and non-excludable, farmers have no incentive to invest their resources in conservation efforts. Without government intervention, there is no way for farmers to fully capture the benefits from wild bee conservation since their adjacent neighbours could act as free-riders and capitalize upon their private investments in sustaining local wild bee populations without forgoing income themselves. Pollinator-friendly practices require farmers to invest in planting foraging material (some of which are not marketable crops to be sold), setting aside marginal lands rather than planting crops, or transitioning towards organic agriculture[8]. The first two require land that could be utilized for crops to be sold on markets. Since Canadian farmers already operate within narrow profit margins, implementation of beneficial practices could be difficult due to budget restraints and the inability to capture the full benefits of conservation. Therefore, wild bee conservation efforts could be perceived as balancing trade-offs between profit and sustainability. Without mechanisms to support farmers in implementing beneficial

[8] Please refer to Appendix B for examples of pollinator-friendly agricultural best practices.

agricultural changes, commercial profits may receive more consideration than conservation efforts. Since trade-offs can heavily influence farmers' decision-making for agricultural operations, policy options should address the conflicting commercial interests that farmers may face in adopting pollinator-friendly agricultural practices. The goal of this research is to find ways to encourage uptake of the above highlighted sustainable agricultural practices that will conserve wild bee populations while enabling policymakers to learn more about Canada's regional requirements for habitat restorations.

Finally, policies should overcome the lack of knowledge and understanding among farmers, policymakers, and the general public regarding the vital role wild bees play in pollinating crops as well as maintaining biologically diverse ecosystems. This will most likely involve overcoming the honeybee centrism present in current provincial legislation and manifested in media coverage of Canadian pollinator decline.

To address wild bee decline, the governments could strengthen legislation and enforcement. Examples include pesticide regulations or altering existing legislation to entrench wild bee conservation into laws such as provincial laws (Tang et al., 2007). Another direction would be the provision of economic incentives to encourage farmers to adopt bee-friendly agricultural practices. Education campaigns can aid in addressing knowledge gaps within the population at large, farmers, and among policymakers. However, in order to develop a holistic approach to wild bee decline mitigation, policy approaches that target the identified contributing factors (loss of foraging material, habitat loss/degradation, and pesticide usage) must be developed. Policies cannot simply focus on habitat restoration or pesticide regulations since they will only solve parts of the underlying issue of agriculture's impacts on wild bee populations. Consequently, rather than highlighting and assessing individual policy options, this paper examines and evaluates three policy approaches – maintaining the status quo, the use of incentives, and the regulatory approach. The following describes a series of actions that could be undertaken with each given policy direction.

6.1. Why Education?

Regardless of which policy approach is ultimately recommended to address wild bee decline in Canadian agroecosystems, education will play a key role in mitigating this decline and supporting pollinator conservation. Education is a key tool used to overcome information barriers by informing farmers of the importance of pollinators to agriculture and natural ecosystems and teaching policymakers about the importance of ecosystem services and the role wild bees play in supporting pollination services. Education reduces information gaps, creating momentum for change and encouraging behavioural changes among farmers. Thus, it is advised that education be incorporated within any proposed policy approach. Consequently, it will not be evaluated with the identified policy options.

Interview participants stressed the importance of educating not only the general public regarding the importance of wild pollinators and their decline but also emphasized the need to educate farmers and key policymakers. A lack of knowledge and understanding among policymakers can create institutional inertia in adopting policies that encourage behavioural changes that mitigate wild bee decline in agriculture. Policymakers must comprehend the differences in factors affecting wild bees versus managed bee species (e.g., domesticated honeybee). Without this comprehension, policies may continue to be directed towards managed bee populations and detract much needed focus and energy from wild bee conservation. Timely consideration of wild bee conservation requires an understanding of the importance of wild bees' pollination services, particularly with respect to their contributions to Canadian agriculture. Thus, it is integral that education programs be directed towards policymakers to enhance their working knowledge of wild bee decline to ensure that adequate policies will be designed and implemented to address the wild bee conservation efforts in agriculture.

In addition, education programs should also be directed towards the Canadian farming community to enhance awareness and knowledge capacity for wild bee conservation in agricultural production. As identified by three interview participants, a lack of knowledge among farmers regarding potential pollinator-friendly practices and an incomprehension of the importance wild bees play in pollinating crops can prevent

farmers from altering their current production practices to promote wild bee conservation. Similar to what has been done in the implementation of AEMs in the United States and United Kingdom, tools such as information pamphlets, workshops, and online resources should be made available to increase farmers' knowledge of sustainable agricultural practices and their capacity to implement them. By offering technical capacity and providing farmers with the know-how to adopt pollinator-friendly practices, farmers can introduce new techniques to their agricultural operations to enhance wild bee conservation, without necessarily reducing their crop yields and incomes.

To promote adoption of behavioural changes, educational programs could incorporate an intergenerational theme. As one participant noted in the interviews, farmers tend to place much value in maintaining their farmlands to bequest as an inheritance to their children and subsequent generations. By framing education with discourse surrounding the bequest value of wild bees and the pollination services they contribute to the farmland, this could encourage farmers to alter behaviours and implement more sustainable agricultural practices. Additionally, educational programming directed towards farmers should take place during the planting off-season to maximize participation rates and uptake.

Therefore, regardless of which approach is adopted, it is essential that education be incorporated within policy approaches. Educational strategies targeted towards farmers will foster a deeper understanding regarding the connections of wild bees to supporting ecosystems as well as agriculture. Farmer education will also furnish growers with the necessary technical knowledge to implement pollinator-friendly agricultural practices.

6.2. Adaptive Management as a Guiding Principle

To address the uncertainty surrounding wild bee population health, adaptive management could be employed as policymaking tool. Adaptive management is an iterative, systematic, goal-oriented process used in times of uncertainty where policy treatments are implemented and monitored to see if they achieve the outlined

management objectives. Policymakers can extrapolate newfound information from the monitoring to refine the management strategy (Allen et al. 2011; McFadden et al., 2011). Sources of uncertainty include previously unobserved variations in the environment which in this case would be pollinator decline. (Allen et al. 2011). By accepting uncertainty and experimenting with alternative policy options, adaptive management seeks to overcome difficulties in directing natural resource management with incomplete knowledge when adaptation and action are required.

The ultimate goal of adaptive management is to increase the knowledge base. The value of adaptive management lies in knowledge accumulation and the resulting reduction of uncertainty (McFadden et al., 2011). Adaptive management places a strong emphasis upon learning and refining strategies based on the learning obtained from this method. The cyclical nature of this tool reduces uncertainty through knowledge accumulation (Allen et al. 2011). However, it must be noted adaptive management can never completely overcome uncertainty since some form of uncertainty always exists in science and the natural environment (Tyre & Michaels, 2011).

Although this management approach might appear to be a haphazard 'trial-and-error', it is not a random experimental process (Keith et al. 2011). Rather, adaptive management requires a clear structure for the process with a statement of management goals (e.g., managing Canada's pollinators to promote economic, environmental, and social sustainability), the identification of objectives for policies, the presentation of hypotheses regarding the causes of a phenomenon, and data collection to monitor and evaluate the effects of implemented policy treatments. Adaptive management incorporates consultation with stakeholder groups to clarify management objectives and to build consensus in the objectives and selection of policy options (Tompkins & Adger 2004). The monitoring of options is followed by iteration where managers, upon examining the data will further tailor the policy to improve achievement of management objectives (Allen et al. 2011). These actions all contribute to the amelioration of natural resource management strategies.

Adaptive management is promoted as a guiding principle in the International Pollinator Initiative's Plan of Action (Williams 2003). As well, when developing a policy management framework for ecosystem services provided by mobile organisms, Kremen

et al. (2007) assert that it is important to distinguish between temporary improvements to population health and long-term restoration. In this context, they believe that continual research can support this development of knowledge capacity. Adaptive management as a policy framework could support this endeavour. Adaptive management should direct management of pollination services to ensure flexibility in altering management tactics to account for new research and policy developments. The present understanding of plant-pollinator relationships, pollination dependencies, and the ecological requirements of wild bees is still quite limited that implementing rigid policies may prove to be ineffective (Participant 2; International Risk Council, 2011).. Since adaptive management offers a systematic method for developing policy in times of limited knowledge, it should be incorporated in policies for mitigating wild bee decline. As the interviewees noted, there is still limited information for the Canadian context with respect to wild bee population health and how policies will support conservation efforts. Hence, ideal policies for wild bee decline mitigation should operate under an adaptive management framework, providing policymakers with the necessary flexibility to tailor policies to suit unknown conditions and alter policies as new information is obtained.

6.3. Canadian Status Quo

Policymakers could choose to continue their current stance and not actively address wild bee decline. The lack of baseline data and research may lead policymakers to delay policy interventions to mitigate wild bee decline. Furthermore, a lack of knowledge regarding the differences between managed and wild bees might lead policymakers to rely on managed bees to supplement pollination services in Canadian agriculture until existing knowledge base of wild bees and the state of managed bees in Canadian agriculture changes. Therefore, policymakers may decide to maintain the status quo until further notice. The following describes some of the characteristics of the Canadian status quo.

Without policies to promote sustainable agricultural practices and behavioural changes among farmers, industrialized agriculture can continue to remove valuable food resources, necessary habitat, and utilize pesticides, compromising the survival of wild bees and their pollination services. With the resulting declines in wild bee populations,

agricultural crops may require alternative means of pollination that could be more costly than modifying current farming practices that threaten wild bees. As previously mentioned, overwintering losses for managed bee populations has increased in recent years (CAPA, 2011). Continued managed bee population decline could increase pollination costs since the resulting limited supply of managed honeybees could lead to increased rental costs (Kremen & Ostfeld, 2005). Furthermore, alternative pollination methods such as mechanical pollination and hand pollination are quite labour-intensive and more costly than the free pollination services of wild bees (FAO, 2008). Maintaining the status quo could lead to a reliance on replacement methods for pollination and require investments of money into supporting pollination services in agricultural production.

To address research gaps, the Natural Science and Engineering Research Council (NSERC) awarded funding to the Canadian Pollination Initiative (CANPOLIN) in 2008 for a five year period (2009-2013). The main objective of this nationwide multidisciplinary network is to conduct pollination research from a Canadian perspective. This network consists of wide array of researchers, including economists, entomologists, biologists, and apiculturists, who assess various themes of pollination. The network's key themes for research include policy and economics, taxonomy of bees, plants, and ecosystems. By examining these different themes, it aims to provide a holistic picture of the state of pollination services in Canada, to inform policy decisions regarding conservation for both wild and managed pollinators, and to increase knowledge capacity for addressing pollinator decline (Kevan et al., 2010). Since the federal government has already invested key funding in this network initiative, it has demonstrated that this theme is a priority. Approximately $5 million was awarded in the grant (Participant 9). However, due to this funding grant, although research and knowledge of Canadian wild bee decline is limited, it would be unrealistic to explore further funding grants for extensive research. The deliverables from this research group will be available in the near future. Furthermore, due to NSERC's investment of funds into research regarding managed and wild pollinators, research will not be explored as a key policy option. Rather it will be integrated into the monitoring of the effects of the proposed policy interventions when developing policy options.

Currently, legislation and regulations directed towards bees are managed at the provincial level. In an analysis of Canadian provincial legislation targeted towards bees, Tang et al. (2007) determined that almost all laws specifically focused upon the honeybees, defining the term “bee” as *Apis mellifera*, the scientific name for the honeybee species most used by beekeepers globally. The only exception to this finding is Manitoba where the definition of bee was expanded to include the alfalfa leafcutter bee. These legislative gaps highlight a lack of capacity in Canadian legislation to conserve wild bees. With legal focus placed upon one particular species, this signifies a lack of legal support for wild bee conservation, particularly for non-honeybee species.

Similar to the instruments examined in the jurisdictional scan, some economic incentives are available for pollinator conservation in Canada; however neither the federal nor the provincial governments administer these initiatives (Participant 1). For instance, the Delta Farm and Wildlife Trust administers AEMs, a form of PES, for local farmers to introduce pollinator-friendly practices to their agricultural operations. These payments equal approximately $300 per acre of farmland. This payment is to compensate farmers from foregone revenue from implementing these beneficial practices in lieu of maximizing profit (Delta Farm and Wildlife Trust, 2011). However, interviewees noted that neither the provincial nor federal governments provide similar programs (Participants 1, 2, 3, 7, 8, & 9). These programs highlight opportunities for government intervention and the promotion of conservation efforts.

The above highlights the current Canadian context for wild bee management. As the interviewees indicated, government involvement is quite limited in addressing this issue. Other than provision of funding through research and collaboration within CANPOLIN, programs have not been implemented by the provinces or federal government to address wild bee decline in Canadian agriculture. Maintaining the status quo could lead to increased reliance on non-native pollinators or alternative pollination methods to support agricultural production. This stance could be maintained until a deeper understanding is formed of wild bees in Canada.

6.4. Voluntary Incentive-based Approach

Multiple interview participants emphasized the use of incentives and voluntary economic instruments for fostering behavioural change among farmers. This approach can promote farmers' flexibility in their production choices to maximize personal profits and simultaneously support biodiversity conservation and wild bee population health. Respondents continually reiterated the need for incentives to support farmers in shifting agricultural practices towards more pollinator-friendly and sustainable methods. In this medium, governments can play a role in incentivizing wild bee conservation through the introduction of instruments such as PES, AEM, or subsidies where participation would be voluntary. Overall, the voluntary incentive-based approach can take two forms: completely voluntary mechanisms (e.g., subsidies, tax credits, PES) or mandatory instruments with incentives to reduce adverse impacts on wild bees (e.g., taxes on pesticide usage). However, this might create an adversarial aspect that is counter to the supportive aspect that arose in the interviews. Multiple policy tools are available that policymakers can consider and utilize to tailor regionally-specific strategies for mitigating wild bee decline in agricultural areas.

Subsidies can be employed to promote the conservation of wild bee populations. Payments for ecosystem services (PES) are a policy instrument to promote biodiversity conservation. PES is a completely voluntary economic instrument where a service buyer such as a government body, private company, or non-governmental organization can purchase a well-defined ecosystem service from a service provider that can be supported through specific land-use practices (Wunder, 2005). The rationale for PES is that private actions can produce externalities and adversely affect the public interest. Actions taken to eliminate the externality can create a private burden although the public benefits from these actions (Engel et al., 2008). In the case of wild bee decline in Canadian agriculture, farmers' conservation efforts are privately financed but the public captures the most of the benefit for these actions. Consequently, there is little incentive for farmers to introduce pollinator-friendly practices without a clear private benefit. Hence, PES could be used to overcome this barrier while promoting public and private interest. In the case of wild bees, beneficiaries could then purchase pollination services from agricultural landowners through PES to implement sustainable farming practices.

This would support wild bee health, resulting in sustained provision of pollination services for not only the farmlands under the PES agreement but for the adjacent lands. Wild bees in Canadian agriculture provide 'free' pollination services as an input into agricultural production. Pollination is already a marketable good due to the commodification of managed bees' pollination services. Treating wild bees as a service that can be 'purchased' by protecting their habitat affords them an analogous treatment to managed bees. The question is whether the relative cost of the protecting wild bees is greater or less than the cost of increasing the purchase of managed bees, assuming equivalent productivity. The potential for increased crop productivity and its related profitability can persuade farmers to invest in supporting pollination services. These connections reflect a marketability that is essential for designing PES systems (Kroeger & Casey, 2007).

Governments can provide financial incentives to farmers through subsidies, cost-sharing structures, or AEMs that enable agricultural producers to introduce pollinator-friendly agriculture practices to their farming operations. The United States and United Kingdom, examples of PES examined in Section 4.4.1, employed different systems for administering PES. In addition to these two cases, smaller scale efforts from non-governmental organizations have introduced similar programs (e.g., Delta Farm and Wildlife Trust's initiative). These instruments incentivize pollinator-friendly practices since the positive externalities accrued from farmers' behavioural change are not captured in the implementation costs of pollinator-friendly practices. Hence, PES helps farmers capture the full benefits of pollinator conservation by furnishing farmers with necessary funding support and knowledge capacity to introduce pollinator-friendly practices.

One method for introducing PES into wild bee conservation strategies is to expand current provincial programming that supports organic agriculture with a specific pollinator conservation focus. Some provinces have direct payment measures and cost-sharing structures that provide farmers with financial assistance to transition their agricultural production processes towards organic methods. This is also similar to the OELS scheme available in the United Kingdom. Organic agriculture methods reduce pesticide inputs, improve crop diversity, and reduce tillage which incidentally and simultaneously supports wild bee population health. Hence, programs of this nature can

support the introduction of pollinator-friendly practices such as transitioning towards organic production.

Another method could be the design of regionally specific biodiversity-focused AEMs. These could be generalized schemes where farmers can choose management practices that suit their agricultural operations, similar to the ELS in the United Kingdom. Farmers would be flexible in choosing specific agricultural practices that suits their needs for profitability and the regional environment. For instance, in areas that might support more pollinator-independent crops like wheat and other cereals, it will be harder to incentivize uptake of pollinator-friendly agricultural practices since farmers are not reliant upon pollinator populations such as wild bees to support their growing operations. For growers of pollinator-independent crops, it might not be worth their while to alter their production methods, forgo income from marginal lands and invest in additional foraging material to support wild bees whose services they do not need. Incidentally, provincial governments will need to consider this caveat in the design of AEMs and PES systems, by accounting for regional differences. This was a significant point raised by Participant 3 in our interview discussion. In contrast, governments could target AEMs toward identified priority ecosystems and regions. Similar to the HLS, specialized restorations could be introduced in priority areas such as regions where pollinator-dependent crops are grown. This could ensure funds are efficiently allocated towards regions that would benefit most from PES and wild bee conservation practices. Rather than focus upon general restorations, the programs would focus upon areas where the benefits would be greatest for conservation.

Commodification of pollinator-friendly products creates another area for an incentive-based approach. Kevan and Thomas (in press 2012) explore this option as a means of supporting pollinator conservation. By marketing products produced in pollinator-friendly agricultural environments as “Bee-Friendly” or another pollinator-positive moniker, this can create a market niche and incentive for farmers to develop products using sustainable, pollinator-friendly agricultural practices. Similar to that of organic produce, certified products would be grown in agricultural settings that fulfill a specific set of production conditions that support pollinator conservation. However, it must be noted that consumer demand for pollinator-friendly products is necessary in order for this particular policy route to be effective (Kevan & Thomas, in press 2012).

With education programs to increase public awareness of pollinator decline and the importance of wild bees, consumer demand can begin to increase such that it becomes profitable for farmers to convert their practices to meet consumers' desires for pollinator-friendly products.

Voluntary non-refundable tax credits for pollinator-friendly behaviours can also be used for pollinator conservation. One interviewee recommended this tool as an option for encouraging behavioural change among farmers. To encourage farmers to set aside marginal lands or restore habitat, a non-refundable tax credit could be awarded for square footage amount. A similar tax credit could also be introduced to greenhouse growing operations. To prevent commercial bee escapes into the wild, provincial governments could offer a form of tax-incentive to encourage greenhouse operators to properly block ventilation systems. Proper blockages such as screens over vents could create a barrier and prevent commercial bees from leaving the indoor areas and spilling pathogens by interacting with their native bee counterparts. An intervention of this nature could mitigate pathogen spillover in wild bee populations and avoid infection.

Another final method for incorporating an incentive-based approach in wild bee decline mitigation strategies is the introduction of a tax. For instance, a tax on pesticides that harm wild bee populations could be applied to pesticide usage to encourage farmers to use fewer pesticides to manage their crops. Taxes of this nature have been implemented in jurisdictions such as Denmark, Italy, and Sweden (FAO, 2010). This tax would be an example of a mandatory measure with an incentive to reduce overall pesticide usage. A farmer can choose to continue to apply pesticides or reduce inputs and consequently pay lower amounts of tax. Hence, this tax would be voluntary in terms of reductions but nonetheless, provide an incentive to introduce more pollinator-friendly practices. This tax, admittedly, would be difficult to introduce in Canada due to stakeholder acceptability and potential impact on crop yields, and would only address a fraction of the issues associated with agriculture's impacts on wild bee populations. However, taxing inputs could strongly encourage reductions in pesticide usage, reducing the likelihood of bee poisonings. This instrument would be to be implemented habitat restoration measures in order to create a holistic approach for mitigating wild bee decline.

Hence, there are multiple methods to be considered in introducing an incentive-based approach for mitigating wild bee decline. PES, AEM, certification of pollinator-friendly products, and tax credits could encourage behavioural change among growers to support pollinator conservation. The following section elaborates upon methods to be considered for a regulatory approach.

6.5. Mandatory Regulatory Approach

In contrast to a voluntary incentive-based approach, policymakers could consider employing a mandatory regulatory approach to induce behavioural changes in agricultural practices to support wild bee conservation. A regulatory approach can target all farmers. It will also reduce uncertainty in farmer take-up since participation would be mandatory. Consequently, this approach will have more measurable results. In addition, regulatory approach would be easier to enforce rather than incentives. The following provides some examples of regulatory methods that support wild bee conservation in agriculture.

First, provincial governments could consider creating buffer zones of protected areas surrounding agricultural areas. This could be done with public lands, through the purchase of private lands, or the creation of buffer zones regulations similar to those used for riparian zone conservation[9]. The creation of protected areas surrounding farmlands could support wild bee conservation through the use of regulations, similar to the case of bat conservation in Mexico observed in 4.4.2.2. However, depending upon the expanse of farmlands, these buffer zones might vary in terms of effectiveness since bees tend to have smaller geographic ranges. For instance, in agricultural settings

[9] Riparian zone buffer regulations have been implemented in jurisdictions such as British Columbia to protect valuable habitat along the margins of waterways and wetlands. These buffers are meant to prevent human activities from adversely affecting wildlife and their habitat (British Columbia Ministry of Agriculture, 2011). This idea could be applied to wild bee conservation by mandating pollination buffers that provide natural habitat and foraging material to support wild bee populations in agricultural areas.

where natural habitat was located within 750 metres of crops, wild bee abundance increased (Morandin & Winston, 2006). Therefore, in intensive agricultural settings, these buffer zones might only benefit farmlands closest to the preserved natural habitat.

Another method to be considered is reducing the amount of roadside maintenance for roadways in rural areas. Participant 9 discussed this as an option in our discussions and indicated that certain areas in Ontario have started to reduce landscaping along roads to preserve biodiversity. Rather than maintain manicured roadsides by mowing grassy areas and applying pesticides, governments could reduce the amount of landscaping conducted on these lands to promote habitat restoration and to allow native plants to grow freely. This could provide invaluable sources of foraging material and nesting spaces for wild bees in areas closer to agricultural lands. This would also be a low-cost option for governments to consider since they would reduce the costs used to manage roadside landscapes.

For the regulation of commercial bees, two regulatory interventions could be introduced. First, limitations on movement of commercial bees into and within Canada could be strengthened. Participant 4 recommended this as an option, suggesting that governments should strongly reconsider existing regulations for managing transport and movement since even moving species from eastern to western Canada to pollinate crops can lead to the spread of exotic pathogens to native bee species. Furthermore, the importation of exotic bee species to support pollination services could prove to be detrimental to local bee populations as well through the introduction of exotic pathogens. Second, technology standards can be introduced in greenhouse growing operations to prevent the escapes of commercial bees into the wild. By mandating the use of specific technologies (e.g., barriers to vents to block bees from escaping), greenhouses would hold the burden of reducing pathogen spillover into adjacent wild bee populations.

As previously indicated, the federal government could alter the current process for conducting pesticide safety assessments. As the interviewees suggested, the current standards only require that agrichemical companies test for lethal effects on managed honeybees when registering products with Health Canada. The federal government could expand requirements to include lethal and sub-lethal effects testing for both managed and wild bee species. Since Canada has hundreds of wild bee

species, it would extremely difficult to conduct pesticide safety tests on all existing species. As one participant noted, agrichemical companies could conduct tests of a sample of different wild bee species to gain a deeper understanding of a given pesticide's effect of bee species. If the pesticide has negative effects on multiple species, it could be inferred that perhaps the pesticide should not be approved for usage in Canada. These requirements create a more holistic and precautionary approach to regulating pesticides. With more stringent testing on multiple bee species, there would be a higher burden of proof placed upon agrichemical companies to ensure that their products will not adversely affect Canadian pollinators. The results of sub-lethal and lethal tests on wild bees can better inform policymakers by providing a complete picture of pesticide safety before approving its usage. It is hoped that expanding the requirements for tests will prevent the approval of pesticides that have negative sub-lethal effects on wild bee species.

Additionally, policymakers can reduce pesticide usage in a given area using regulations. At the provincial level, for example, pesticide use can be addressed through changes to zoning by-laws. Toronto and Edmonton have banned the use of cosmetic pesticides for municipal lawns. Regional governments and provincial governments could consider zoning by-laws that would manage pesticide applications in the agricultural context to protect wild bee populations. This could include lowering the amount of pesticides allowed to be sprayed, creating more stringent regulations for application requirements, or introduce pesticide bans in agricultural zones. For instance, provincial governments could consider applying the precautionary principle, similar to that of Germany and temporarily ban the use of certain types of pesticides (e.g., neonicotinoids such as imidacloprid or clothianidin) until stronger, more holistic assessments are conducted upon wild bee species in addition to domesticated honeybees. Suryanarayanan & Kleinman (2011) recommended that this approach be utilized for pesticide management and wild bee protection. These policy routes would have to be tailored to the regional needs within the province, incorporating for example the pollination needs for agriculture, status of wild bee populations, and other economic and ecological factors.

Canadian provinces could consider altering the existing legislations to promote the protection of wild bees. As noted previously, the majority of existing provincial bee

laws define bee as strictly the honeybee (Tang et al., 2007). This narrow scope limits the legislative support for wild bee conservation. An expansion of this legislation can provide legal and binding protection for wild bee populations along with managed honeybee colonies. One interviewee suggested that amendments be made to the *Species At Risk Act* so that species protection under this legislation would apply to lands outside of federal jurisdiction. He/she perceived the current wording as a limitation to protecting species that have faced drastic declines in recent years (e.g., the western bumblebee). This could be considered as another approach; however, negotiations for amending this particular piece of legislation could be extremely difficult given the division of powers between the provincial and federal governments. Expanding the scope of the legislation to incorporate lands outside of federal jurisdiction could be met with gross pushback from provincial governments.

Under a regulatory approach, land-use planning could also limit further land conversions. For instance, provincial governments could consider introducing programs such as British Columbia's Agricultural Land Trust where agricultural land is protected from urban and commercial developments. Within the Agricultural Land Trust, the board aids in the protection and promotion of agricultural production (Government of British Columbia, 2011). Land trusts could be introduced in other provincial jurisdictions while including stipulations that limit agricultural intensification and promote extensification along with pollinator-friendly practices. In addition, land-use planning can promote habitat connectivity and the planting of foraging material to support wild bee populations. By either mandating that certain percentages of a farm should be dedicated to either set-asides or planting foraging material, policymakers can use land-use regulations to restore habitat rather than rely on voluntary incentives or economic instruments. Furthermore, land-use planning provides more certainty with the amount of habitat restoration occurring. Additionally, land managers or policymakers can use mandates like this to connect habitats through the use of land corridors. This will prevent further isolation of wild bee populations while supplying them with necessary food and habitat resources.

It is acknowledged that implementing a regulatory approach for habitat restoration and limiting pesticide usage will be difficult. Since agricultural lands are mostly private, regulatory policy interventions may face opposition since farmers will be

forced to alter agricultural practices without financial support for transitioning towards pollinator-friendly practices. The costs of adhering to regulations might create a financial barrier for farmers.

Hence, I have identified three general policy approaches that policymakers could pursue in addressing wild bee decline. First, one could maintain the status quo. Second, one could employ a voluntary incentive-based approach to encourage behavioural change and promote sustainable agricultural practices to mitigate wild bee decline. Third, one could implement a mandatory regulatory approach to establish behavioural change and support wild bee conservation. The second and third approaches should include educational components to increase knowledge and understanding and also promote an adaptive management framework since it is considered to be a useful tool for managing wild bee populations in times of scientific uncertainty and promoted as an ideal approach for bee conservation. The next section analyzes these proposed approaches using established criteria to determine which approach would be optimal for mitigating Canadian wild bee decline.

7. Analysis of Policy Options: Catching More Bees with Honey or Vinegar

Although I presented various examples of actions that could be undertaken within a given approach, I analyzed the three policy approaches at a higher level to avoid selection and evaluation biases. Since multiple factors contribute to wild bee decline, the selection of specific policy options could have eliminated elements that adversely impact wild bee populations and reduced the potential effectiveness of the intervention. Therefore, I evaluated the approaches at a higher level to ascertain which policy approach would generally be more optimal in mitigating wild bee decline. Each approach has its strengths and weaknesses for addressing specific drivers of wild bee decline. Table 2 contains a summary of the multi-attribute trade-off analysis for the three identified policy approaches to mitigating wild bee decline in Canadian agriculture.

Table 1. Synthesis of Qualitative Assessments for Policy Evaluation

	Status Quo	Incentive-Based Approach	Regulatory Approach
Effectiveness	Fails to reduce agriculture's ecological footprint Does not mitigate wild bee decline Does not promote sustainable land-use in agriculture	Reduces agriculture's ecological footprint Mitigates wild bee decline Promotes sustainable land-use in agriculture Issue of adverse selection and free-ridership	Reduces agriculture's ecological footprint Mitigates wild bee decline Promotes sustainable land-use in agriculture by addressing some parts of the issue Issues with compliance
Administrative Ease	Easy because it does not require further action	Requires the development of an overseeing body to implement incentives	Requires the development of new legislation or legislative amendments May require the creation of new pesticide assessment standards Enforcement structures

Stakeholder Acceptability	Maintaining the status quo would be accepted by most parties involved except for farmers who grow pollinator-dependent crops and	Generally acceptable among stakeholders due to the personal flexibility it provides One caveat is government acceptability	Agrichemical companies and greenhouse growers could disagree with policy interventions chosen Land use initiatives could lead farmers to reject initiative due to drops in property value
Horizontal Equity	Not equitable due to disparities in experiencing wild bee decline among pollinator-dependent farmers and pollinator-independent farmers	Equitable	Moderately equitable
Low Cost	Does not need additional investments of time, resources, or funds	Requires extensive labour, time, resources, and funds to design, develop, and implement policy interventions	Requires extensive labour, time, resources, and funds to design, develop, and implement policy interventions
Increased Capacity	CANPOLIN findings will augment existing knowledge	Can build upon CANPOLIN's findings through the use of adaptive management (the use of control and treatment sites)	Can build upon CANPOLIN's findings since it tends to prescribe actions across the board
Flexibility	Highly flexible since decision-makers can alter their approach in the future as scientific knowledge deepens	Highly flexible since requirements for cost-sharing agreements can easily adapt to fit scientific developments	Highly flexible since regulations can easily adapt to fit scientific developments

7.1. Effectiveness

To examine effectiveness, one must consider whether the policy approach reduces Canadian agriculture's ecological footprint, mitigates wild bee decline in Canada, and promotes sustainable land-use for pollinator conservation. The status quo, incentive-based approach, and regulatory approach vary in their levels of effectiveness in preserving natural capital.

Currently, the status quo is failing to reduce Canadian agriculture's ecological footprint. The current gaps in pesticide safety assessments fail to account for the lethal and sub-lethal effects of approved pesticides on wild bee populations. In addition, commercial greenhouses are not regulated to prevent the escapes of commercial bees into the wild. Current large-scale farming practices utilize unsustainable, pollinator-unfriendly practices such as monoculture crops, tillage of soils, and removal of natural vegetation. These practices remove habitat and foraging material. The current context does not provide farmers with sufficient knowledge, capacity, or incentives to alter current farming practices. Consequently, the status quo does not promote sustainable use of agricultural lands to promote pollinator conservation. Finally, since wild bee species are continuing to decline or disappear, it is assessed that the status quo is failing to mitigate wild bee decline. Therefore, since the status quo does not satisfy the three policy objectives, it is considered to have a low level of effectiveness.

In contrast, a voluntary incentive-based approach has the potential to reduce Canadian agriculture's ecological footprint. Although it is difficult to predict the participation rates and uptake for the incentives in Canada, in other jurisdictions where incentive tools have been employed such as AEMs, participation has been high. Natural England (n.d.) estimates that approximately 60% of the country's farmland is now covered under the ELS agreement programs. In addition, smaller scale Canadian AEM initiatives have received high levels of participation. One interview participant noted that the Delta Farm and Wildlife Trust currently has a waiting list for farmers to enter an AEM agreement with the organization to support wildlife conservation. Furthermore, it has been noted that incentive-based initiatives like AEMs have higher levels of compliance among participants and are generally better received among farmers when compared to mandatory regulatory interventions since participation is voluntary (European Commission, 2005). Furthermore, as observed in the UK case study, the ELS's agricultural practices have been proven to support wild bee populations and promote pollinator conservation which means incentive-based approaches can also contribute to the mitigation of wild bee decline (Carvell et al., 2007; Pywell et al., 2011). With the combination of educational programs to communicate the importance of pollinator conservation strategies and teach pollinator-friendly farming techniques, this option has

great potential for reducing the ecological footprint of Canadian agriculture on wild bee populations, promoting sustainable-land use techniques, and mitigating wild bee decline.

However, in spite of education, there is a distinct possibility that due to financial and resource constraints, farmers might not choose to implement more sustainable techniques due to the voluntary nature of incentives such as PES and AEM. One caveat for this approach is that incentive-based approaches could suffer from adverse selection where policies such as PES and AEM may capture farmers who would likely have altered their agricultural practices without the financial incentives. A similar phenomenon has been observed with subsidy programs provided for individuals seeking upgrades for energy efficient appliances (Jaccard, 2010). Free-ridership may also occur in which non-participating farmers attempt to capitalize upon the efforts of the policy's first movers. For instance, if a farmer chooses to enter into an AEM agreement and invests resources into restoring habitat on her land, her neighbouring farmer could choose to not participate in the initiative but still benefit from the neighbouring farmer's efforts since the increased wild bee abundance can translate into higher levels of pollination services in the local area. Due to this approach's inability to completely capture the positive externalities associated with pollinator conservation, this policy does not completely fulfil the first objective of reducing agriculture's ecological footprint. Hence, since the incentive-based approach does not entirely fulfill the three objectives, it is assessed as being moderately effective.

A regulatory approach can also reduce agriculture's ecological footprint. The creation of buffer zones can aid in habitat creation and restoration. Pesticide application restrictions can be introduced to limit the amount of chemical inputs sprayed. Pesticide regulations would have a high participation rate since all farmers are supposed to comply, although complete compliance among farmers cannot be guaranteed. In addition, mandatory regulatory interventions can mitigate wild bee decline. For instance, stronger regulations on greenhouse operations can prevent managed bee escapes. Mandating technological standards (e.g., barriers on vents) can help reduce the effects of pathogen spillover on wild bee decline. Finally, a regulatory approach can promote sustainable land-use and promote behavioural change due to its mandatory participation. The creation of buffer zones can protect vital habitat and foraging sources for wild bees, supporting their population health. If implemented, pesticide restrictions

can also promote more sustainable land-use practices since it could reduce the usage of harmful agrichemicals. Thus, the potential policy instruments under a regulatory approach have the ability to fulfill the three effectiveness objectives.

However, although participation is mandatory with a regulatory approach, this does not guarantee complete compliance among all affected parties such as farmers and agrichemical companies. Since interventions under this approach are not voluntary, individuals may fail to comply either due to lack of resources for implementation or general disregard for the regulations. As such, without complete participation, this could limit the overall effectiveness of instruments under a mandatory regulatory approach.

Therefore, even though a regulatory approach can satisfy all three effectiveness objectives, the regulatory approach is considered to be moderately effective due to issues with compliance.

7.2. Administrative Ease

The status quo is assessed as having high administrative ease since policymakers would not likely encounter institutional barriers in maintaining the current situation.

An incentive-based approach to addressing wild bee decline in agriculture was assessed as having low administrative ease. Since governments at both the federal and provincial levels are facing fiscal constraints and strategic reviews of ministry budgets, it might be more difficult to obtain the necessary funding to implement this policy approach to mitigate wild bee decline. Provincial governments might be able to justify funding allocations due to the declines in managed honeybee colonies in the commercial pollination sector. Efforts to restore habitats and reduce pesticide usage for wild bee populations may provide policymakers with an alternative approach to addressing the issues in the commercial bee industry. By targeting native bee species in policy, policymakers can attempt to enhance the stability of pollination sources by relying on local bee populations rather than increasing reliance upon introduced species such as the European honeybee. In addition, to administer incentives such as PES or AEM, overseeing administrative bodies would need to be developed for program

implementation, thereby increasing the administrative complexity of this approach. Consequently, this approach is assessed as having low levels of administrative ease.

A regulatory approach would also not be simple to implement. The expansion of pesticide safety assessments necessitates regulatory reform. Furthermore, the designation of protected areas is a lengthy, resource-intensive process that requires consultation among relevant stakeholders, scientific experts, and available funds to implement. Protected areas require people to act as land managers to ensure the protected area runs smoothly. The creation of land trusts would also need the purchases of lands to establish the trust, the design and implementation of zoning regulations to restrict the land-use, and the instalment of a management board to ensure that the land trust's farming values are upheld to support pollinator conservation. The above regulatory approaches to mitigating wild bee decline are complex in that they require negotiations and reformations of existing legislation, coordination between multiple parties, and/or the establishment of overseeing committees. Hence, a regulatory approach for mitigating wild bee decline is assessed as having a low level of administrative ease.

7.3. Stakeholder Acceptability

Maintaining the status quo would most likely be amenable to farmers at this current time. Without the introduction of education programs, farmers may remain unaware of the importance of wild bees in supporting pollinator-dependent crops. As a result, they might not be willing to alter their production methods to pollinator-friendly practices without educational programming to establish a foundation for why such actions should be implemented. However, as declines continue, if pollination services diminish and alter crop quality and quantity, the acceptability of the status quo will also diminish. Decreases in wild bee populations and the resulting need to hire commercial bees will increase production costs for farmers. In addition, the difficulties facing Canadian managed bees will likely increase rental costs further. Hence, the status quo would be moderately acceptable to farmers as of now but could decrease in the future.

The status quo would not force production changes among agrichemical companies due to the existing legislative gaps identified in previous sections regarding pesticide safety assessments. Political leaders would also find the status quo appealing since public awareness is not sufficient enough to place high pressure upon leaders to enact policy interventions to mitigate wild bee decline. This can be attributed to honeybee centrism in media coverage since most coverage tends to focus on the plight of managed bees rather than that of wild bees. Involved ministries such as the Ministry of Agriculture would most likely support the status quo since the existing legislation clearly defines the species of interest for bee legislation. Expansion to include wild bee protection would be difficult since this would require expanding a definition for multiple species. In addition, not all wild bee species in Canada have been identified which can pose a problem in terms of ministries attempting to support pollinator conservation for unknown species.

Beekeepers would remain ambivalent towards the status quo. While policies to support wild bee populations might detract attention away from their commercially managed bees, the status quo is likely insufficient for their purposes since they are suffering higher than average overwintering losses and would likely want to see policies directed towards their bees instead of wild bees. Furthermore, interventions to support wild bee populations might detract business away from their commercial colonies. Finally, conservation groups would dislike the status quo since it does not directly address pollinator decline in the immediate-term. Therefore, due to the above assessments, it is believed that the status quo is considered to be moderately acceptable.

A voluntary incentive-based approach using tools such as PES and AEM for addressing wild bee decline would be highly acceptable among stakeholders. The provision of incentives for encouraging behavioural changes in agricultural practices was a recurring theme in the interview process, stating that economic instruments would aid farmers in overcoming barriers to implementing sustainable agricultural practices. The incentive-based approach promotes personal flexibility among growers to implement practices that match their personal needs for profit, allows them to develop their own plan for behavioural change, and supports behavioural change through financial support. If provincial governments introduce mandatory forms of encouragement such as taxes

for pesticide applications, it is predicted that agrichemical companies may pushback against policies of this nature since that will reduce their profits. Farmers who employ conventional farming methods would also find this application unacceptable since rather than providing financial support to foster behavioural change, it would be perceived as a negative pressure and a 'stick' rather than a carrot. However, this depends upon whether a province chooses to introduce taxes for pesticides. If focus is placed solely upon PES and AEM, incentive-based approaches would be considered highly acceptable to farmers. Greenhouse growers would also react favourably to incentive-based approaches employed to prevent commercial bee escapes into the wild since the introduction of subsidies to block ventilation systems would provide financial support or a form of a carrot to encourage their changes. As a result of positive feedback from the other identified stakeholders, political leaders might accept the incentive-based approach although it would be vital to convey the message of initiatives such as PES in order to garner that support. Government ministries might remain ambivalent towards the introduction of incentives. If institutions such as PES or AEM are introduced, this will require significant overhaul to establish overseeing bodies. The changes in management could be perceived as undesirable. However, the trade-off is that incentives have higher compliance rates as previously discussed, leading to less enforcement work for government ministries. Due to the above analysis, it is believed that an incentive-based approach would receive high levels of stakeholder acceptance.

Some instruments used in a mandatory regulatory approach to mitigating wild bee decline may be considered unacceptable to some involved stakeholders. It is predicted that decision-makers would face stakeholder inertia in attempting to introduce more stringent pesticide regulations. Decision-makers should expect backlash from agrichemical companies and conventional farmers who rely on pesticides to protect their crops. This was a recurring theme among interview participants and in the media scan. Participants noted that pesticide regulations face much inertia in implementation due to the pushback of agrichemical companies and farmer support for the products. It is expected that lobbying will most likely occur, impeding implementation of this particular policy. One participant remarked that land-use planning could face negative feedback from farmers due to its potential effects on property value. For instance, the introduction of buffer zones or protected areas surrounding agricultural lands since re-sale value may

drop. However, as noted by Participant 9, Canada tends to adopt regulatory approaches for addressing environmental issues, noting “market-based incentives are not the Canadian way”. Given this particular insight, provincial and federal governments may be more amenable to implementing a regulatory approach for mitigating wild bee decline. Ultimately, parties like to have choices and flexibility in their production choices. Consequently, although governments may prefer the regulatory approach since it is the Canadian way and easier to administer in terms of having clear responsibilities and enforcement, other parties involved may dislike the regulatory style. Therefore, this approach is deemed to have moderate levels of stakeholder acceptability.

7.4. Horizontal Equity

The status quo creates issues in terms of which farmers experience the effects of wild bee decline more. Growers of pollinator-independent crops will likely not be as concerned with population decreases when compared to farmers reliant upon pollinators to support their crops’ quantity and quality. However, the practices of both farmers can affect wild bee species and population abundance within the same area. Therefore, the status quo is assessed as not equitable among farmers.

Organic farmers could potentially be disappointed since they might not have had access to policy resources such as PES or AEM to aid in the transition of their agricultural operations. However, since organic farmers could still tap into voluntary incentives to support more pollinator-friendly practices, this would still provide equitable outcomes among farming groups. They could all equally access the programs. Furthermore, organic farmers would have to make fewer alterations to their production methods since the majority of their practices are pollinator-friendly. Therefore, this reduces the burden of behavioural change for organic farmers, neutralizing the lack of financial resources to transition towards organic agriculture in the past to support wild bee populations. This approach also allows farmers of pollinator-dependent and independent crops to choose to participate in initiatives. For farms of varying sizes, the incentive-based approach could be equitable since it provides support to all farms in encouraging behavioural change. Larger farms might have to set aside more land or feel a heavier burden to enact behavioural change. However, this could be counteracted

with the allotment of an appropriate and proportional incentive to alter production methods when compared to smaller counterparts. Consequently, an incentive-based approach was ranked as equitable among farmers.

The introduction of standards and regulations without the use of voluntary incentives will likely have a stronger impact on conventional farmers when compared to organic farmers. Out of necessity, organic farmers rely upon pollinators to pollinate their crops and reduce their pesticide inputs whereas conventional farming more lends itself to practices such as monocrops, soil tillage, and pesticide applications that are detrimental to wild bees. Therefore, if performance or technological standards are implemented with new land-use regulations, conventional farmers who rely on industrialized or large-scale agricultural techniques will likely have more changes to make in their day-to-day operations when compared to organic farmers but without the production choice flexibility and financial support that a voluntary incentive-based approach would offer them. In contrast, organic farmers would not have as many difficult choices to make in adhering to newly implemented standards. Differences in crop pollination requirements also create a platform for inequality. The implementation of regulations to support wild bees implies that pollination is essential to all agricultural crops which is not the case. Pollinator-independent crops such as wheat, barley, and rye do not require the pollination services of wild bees. Therefore, the implementation of standards among all farmers is unfair to growers of pollinator-independent crops since they would be required to forgo income to support conservation efforts when they do not benefit financially from the investment. Participant 2 touched upon this in the interviews. However, if pesticide regulations are designed to account for regional differences in crop production, policymakers can overcome the inequalities faced by pollinator-independent crop producers when wild bee conservation policies are introduced. Finally, smaller family-owned farms might encounter more difficulties in implementing standards due to limited resources and budget constraints when compared larger scale farms. However, it must be noted that in the face of performance and technological standards, all farmers would have to comply which could be perceived as a form of equity. Therefore, a regulatory approach is assessed as being moderately inequitable.

7.5. Low Cost

The status quo is assessed as having a low cost since it does not require the expenditure of further resources to implement (e.g., time, labour, money). Resources have already been allocated for CANPOLIN's research, enforcement of current pesticide regulations, and conducting current pesticide safety assessments. The status quo does not require additional resources for policy interventions. Hence, this option receives a high, positive ranking.

In terms of cost, incentives will require a higher level of resources. This is because in order to fund programs such as PES or AEM, the provincial governments must generate the necessary revenue to run the programming. In addition, previous reports have indicated that developing voluntary incentive-based instruments requires the development of new implementation structures to administer the funding and initiate cross-compliance mechanisms. This was suggested in an evaluation of AEM in Europe (European Commission, 2005). The development of implementation structures would necessitate time and resources to construct appropriate mechanisms. Consequently, the cost was assessed as high and received a negative ranking since the program would need to raise funds to operate this initiative. To maximize the cost-effectiveness of policy interventions and reduce costs, policymakers could consider introducing incentives in regions that could benefit most from pollinator conservation (e.g., areas where the dominant crops are pollinator-dependent).

In terms of cost, a regulatory approach is deemed to have high costs as well. The amount of time and resources required to design, develop, and introduce mandatory regulatory instruments and then monitor and enforce compliance would be high. Without having a specific application, it is difficult to predict whether the mandatory regulations would cost more than providing PES, hence both measures are rated as high cost. Similar to the incentive-based approach, to reduce costs and maximize cost-effectiveness, policymakers could also consider targeting specific measures towards regions that would experience the highest gains from pollinator conservation (e.g., introducing buffer zones in areas where the dominant crops are pollinator-dependent).

7.6. Increased Capacity

Due to investments in CANPOLIN's research, the status quo would have a moderately increased capacity already to address wild bee decline. Although at the moment, knowledge of wild bee decline is still limited, at the conclusion of this network's research period in 2013, more deliverables and studies will be released which would increase current human knowledge and technical capacity to address wild bee decline. However, the funding is assigned to examine both managed and wild bee species and to identify strategies for mitigating pollinator decline in general. It is not specifically focused upon wild bee species. Still, the investments and related research contribute towards reducing uncertainty attributed to wild bee decline. Furthermore, CANPOLIN does not clearly state whether they will be undertaking any adaptive management studies to continually track the progress of potential interventions, which limits the ability to further increase current knowledge capacity for managing wild bee decline. Consequently, the status quo is assessed as moderately increasing capacity since it accounts for the future contributions of CANPOLIN to existing Canadian knowledge of wild bee decline.

An incentive-based approach will further increase capacity for addressing wild bee decline and build upon the status quo. Through the provision of initiatives such as PES and AEM, policymakers can learn the revealed preferences of farmers. The payments farmers accept to support the conservation of wild bees' pollination services can demonstrate an approximate monetary value for this ecosystem service. In addition, due to the voluntary nature of programs such as PES and AEM, this naturally creates control and variables sites through which adaptive management experimentation with policy intervention treatments can be tested to determine their overall effectiveness. This is because not all farmers will participate in the voluntary initiatives. Those who do not participate create control areas whereas those who do create treatment sites. By having control and treatment sites, policymakers and land managers will be able to observe differences among the treatments to obtain valuable information regarding the most effective tools. Therefore, the incentive-based approach is assessed as having a high ability for increasing working knowledge and capacity for mitigating wild bee decline.

A regulatory approach can further increase capacity for addressing wild bee decline when compared to the status quo. The introduction of more holistic and stringent pesticide safety assessments can provide policymakers with newfound information to support the precautionary approach in regulating pesticide approvals. This knowledge can build upon existing data, providing policymakers with a clearer understanding of sub-lethal and lethal effects of pesticides on wild bees. With this information, policymakers can then make better informed decisions regarding pesticide usage restrictions or bans.

The creation of buffer zones and protected areas can also support knowledge development since policymakers can observe whether these initiatives can help restore local wild bee populations. However, without the separation of control and treatment sites, it would be difficult to separate confounding factors in assessing the effectiveness of these interventions in mitigating wild bee decline. However, a regulatory approach can still build upon existing knowledge provided by the results of CANPOLIN's research. Consequently, it is also assessed as having a high ability for increasing capacity for mitigating wild bee decline.

7.7. Flexibility

The status quo is considered to be highly flexible since it still provides policymakers with sufficient ability in the future to adapt their current policy approach to support pollinator conservation as science develops and the knowledge base increases. It does not increase regulatory restrictions or limit policy mobility at the current time.

Incentive-based approaches are assessed as high in terms of promoting flexibility in policies, supporting the tenets of adaptive management. Although PES agreements and AEM will require contractual agreements and guidelines to which farmers must adhere, they can be updated to cater to the development of new research, pending the findings obtained from monitoring and evaluation and the release of new studies. Consequently, voluntary incentives can be tailored as the science develops. This would be a strength of the voluntary incentive-based approach because it can be dynamic, moving with the research in a fluid manner. Thus, a voluntary incentive-based

approach to mitigating wild bee decline is highly flexible and easily fits into the framework of adaptive management.

A mandatory regulatory approach can also be updated to suit the development of new information. For instance, as research accumulates regarding pesticide safety, policymakers could then use the evidence to consider implementing more stringent pesticide application restrictions. In addition, if the creation of buffer zones is found to be effective, the guiding regulations could be expanded to include other areas where pollinator conservation might be beneficial. Hence, this approach can also provide policymakers with the necessary and flexibility and fluidity to adapt wild bee management as new research is developed and released. Therefore, this criterion is ranked as highly flexible.

7.8. Evaluation Results

To consolidate the criteria assessments and facilitate comparisons of trade-offs between policies, I created a table that converts the qualitative descriptions into numerical rankings. High, positive rankings received 3 points. Moderate rankings were awarded 2 points. Low, negative rankings received 1 point. To weight effectiveness, the ranking for each option was multiplied by a factor of 3. I then calculated the sum of each approach's criteria scores to determine which approach should be recommended. The calculations aid in the identification of a recommended approach. Table 3 provides these calculations.

Table 2. Summary of Policy Evaluation and Calculations

	Status Quo	Incentive-Based Approach	Regulatory Approach
Effectiveness	Low 3 × (1 point) = 3 points	Moderate 3 × (2 points) = 6 points	Moderate 3 × (2 points) = 6 points
Administrative Ease	High 3 points	Low 1 point	Low 1 point
Stakeholder Acceptability	High 3 points	High 3 points	Moderate 2 points
Horizontal Equity	Low 1 point	High 3 points	Moderate 2 points
Low Cost	High 3 points	Low 1 point	Low 1 point
Increased Capacity	Moderate 2 points	High 3 points	High 3 points
Flexibility	High 3 points	High 3 points	High 3 points
TOTAL	**18 points**	**20 points**	**18 points**

When observing the above numerical reductions, it appears that an incentive-based approach receives the highest score of the assessed approaches. However, it is not a clear winner since only two points separate the voluntary incentive-based approach from the status quo and mandatory regulatory approach. However, the status quo does fail in terms of its overall effectiveness when compared to the other approaches. Since it does not fulfill the overall objectives of reducing agriculture's ecological footprint, mitigating wild bee decline, and promoting sustainable land-use, it is removed from the overall recommendations. Without interventions, one can expect to see wild bee decline to continue within Canadian agriculture. As such, the other two approaches present methods for addressing the issue of wild bee decline and work towards the overall goal of preserving Canada's natural capital.

Excluding the status quo, instruments proposed within each approach have the ability to achieve great gains in mitigating wild bee decline in Canadian agriculture. It is not abundantly clear from the analysis that one specific approach will address all concerns surrounding wild bee decline. For this reason, recommended next steps for

addressing the stability of wild bee pollination services should incorporate aspects from each. The next section elaborates upon suggested next steps for mitigating wild bee decline.

8. Recommendation: Plan Bee

Based upon the above analysis, a combination of instruments from the voluntary incentive-based and mandatory regulatory should be introduced to mitigate wild bee decline in Canadian agriculture. It is suggested that, in addition to educational programming, policymakers implement the following actions:

- Reform current requirements for pesticide safety assessments to include the lethal and sub-lethal effects of pesticides on wild bees. Policymakers will receive a more adequate amount of information to determine the overall pesticide safety. With the accumulation of this evidence, policymakers can move to a more precautionary in the management and regulation of pesticide applications.
- Introduce voluntary agri-environmental measures to support the implementation of pollinator-friendly agricultural practices. These subsidies can be targeted towards regions where pollinator-dependent crops are grown to maximize the overall effectiveness and benefits of this initiative.
- Introduce a form of payment for ecosystem services subsidy or tax credit for greenhouse operators to install technologies that limit the effects of pathogen spillover. This will ensure higher compliance rates among participants.
- Consider the introduction of buffer zones to support pollinator conservation and restore habitat. This can be first established on public lands so policymakers can observe whether this method is effective in supporting wild bee populations. As knowledge develops, this effort could then be expanded to incorporate regulations for private lands.

The recommended policy directions have the ability to address the identified drivers for wild bee decline – pesticide usage, habitat degradation, loss of foraging material, and the effects of commercial bees. Furthermore, these recommendations can aid policymakers in addressing the conflicting interests that prevent effective mitigation of wild bee decline. The provision of voluntary incentives can help agricultural producers overcome resource barriers to introduce pollinator-friendly practices. Incentives enable agricultural producers to negotiate the trade-offs between conservation and profit, thereby overcoming the barrier of conflicting interests in agricultural production. Furthermore, due to their voluntary nature, they tend to have higher compliance rates.

The introduction of more stringent pesticide assessments places a stronger burden of proof on agrichemical companies to ensure their products are safer for ecosystem health. These regulatory demands will create an incentive for companies to protect their commercial interests by creating more benign products. With better comprehension of product effects, policymakers can wisely and properly regulate applications. It is highly unlikely that permanent pesticide bans will be palatable or implemented in Canada. Therefore, this suggested action ensures that the best available science is used for managing agrichemical usage. Incentives for greenhouses can also reduce the pathogen spillover effect. Since it would be extremely difficult for governments to monitor and enforce technology standards in the various greenhouse facilities across Canada, the use of voluntary incentives such as subsidies or tax credits can facilitate the introduction of necessary technologies to prevent commercial bee escapes. Finally, the creation of buffer zones provides important protection for wild bees through habitat restorations, limitations to pesticide usage, and the growth of foraging material. This can support habitat restorations that may not voluntarily occur on private lands through the protection of first public lands and then considerations for private lands.

To promote cost-effectiveness since this policy area is still in its preliminary stages of research and development, these actions can be targeted towards regions where the observed benefits will be the greatest (e.g., areas with predominantly pollinator-dependent crops). As knowledge and understanding deepens, policymakers can consider expanding programs in the future to other areas in Canada that may benefit further from wild bee conservation.

Therefore, given the findings of the research, it is evident that a mixed approach is most effective in preserving natural capital due to its ability to reduce agriculture's ecological footprint, promote sustainable agricultural practices, and mitigating wild bee decline. This approach can be used to address multiple aspects contributing to wild bee decline within Canadian agriculture such as pesticide usage, habitat degradation, and loss of foraging material. The implementation of both voluntary incentives and mandatory regulations creates a more holistic method for addressing conflicting interests and mitigating wild bee decline.

9. Conclusion: The Bee All but not the End All

This research provides an analysis of general policy approaches to addressing wild bee decline in Canadian agriculture. It contributes the literature by identifying barriers to implementation, examining media discourse surrounding the issue, and analyzing approaches for mitigating wild bee decline in Canadian agriculture. A mixed approach using combinations of voluntary incentives and regulation is offered to address wild bee decline, negotiate conflicting interests, and encourage behavioural change among farmers.

Limitations to the study include a western focus with the examined media scan articles. Furthermore, a higher level of non-governmental organization would have enriched the interview process. However, when recruiting interviewees, it was found that most non-governmental organizations felt uncomfortable speaking to the issues surrounding wild bee decline. Perhaps as existing knowledge is strengthened, more organizations will become involved with pollinator conservation and could lend their perspectives to the issue. Further research should also attempt to incorporate a First Nations perspective of wild bee decline. Due to the sampling methods utilized in the methodology, no potential First Nations participants were identified for the study. A survey of farmers' perspectives would also be useful in revealing preferences for policy approaches since this will provide valuable insight regarding their potential uptake of policy interventions. Based upon the recommendations of Kremen et al. (2007), a full account cost-benefit analysis along with a risk management assessment should be conducted to assess the full economic benefits and costs,

Next steps should examine specific implementation strategies for each individual province to suit regional considerations. In addition, the findings of CANPOLIN's research should be incorporated into the development of provincial pollinator conservation plans. This research provides a 'plan bee' for wild bee conservation but it is not the 'bee' all and end all.

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Appendices

Appendix A.

Semi-Structured Interview Guide

1. What is your position and role in your organization?
2. What is your experience with the wild bee decline in Canada?
3. In your opinion, what are the most important factors affecting wild bee population health in Canada?
4. In your experience, what are the greatest barriers to implementing policy to manage wild bee population decline in Canada?
5. What kind of pressures do policymakers face in introducing potential policies to address wild bee decline?
6. In your opinion, what kind of role has differing stakeholder interests played in policy discussions?
7. If possible, can you speak to your experiences in policymaking with regards to wild bee management in Canada?
8. Do you see a role for government intervention for addressing the wild bee decline? If so, what actions can the government undertake to address declining wild bee populations?
9. What are some of the key considerations that policymakers would need to consider before introducing measures to address bee decline?
10. To the best of your knowledge, are there examples of successful government intervention in managing wild bee declines in other jurisdictions?
11. Through my research, it appears that there are four general policy directions the government could take to address this issue. Since governments have limited resources, options might need to be prioritized since it is not always possible to implement all potential measures. Which of the four directions would be the most important and why?
    - economic instruments – taxes/agri-environmental schemes
    - legislative reforms – redefining the meaning of bee in laws, pesticide regulations
    - land use planning – incorporating nesting habitat in urban parks
    - education – awareness campaigns
12. Which of the four directions would you consider to be the least important and why?
13. What are some of the trade-offs for these proposed policy directions?
14. Do you have any suggestions for participants that I should contact?
15. Are there any final comments you would like me to record before we conclude?

Appendix B.

Agricultural Best Practices

To support pollinator conservation and increase the diversity and abundance of wild bee populations, a shift away from agricultural intensification could contribute towards achieving the policy objectives of preserving natural capital and ecosystem services. The following describes some examples of agricultural best practices that policies could support to promote wild bee conservation in the agricultural sector.

CSPNA (2006) outline some examples of agricultural land management practices that promote healthier populations of wild bees. Table 3 listed below provides an adapted summary of suggested agricultural practices that will improve floral resources, restore or create nesting sites, and target harmful pesticide usage.

Table 3. Summary of Agricultural Best Practices That Support Wild Bee Populations

FLORAL RESOURCES
Growing multiple types of crops instead of crop monocultures to provide a variety of floral foraging sources. It is beneficial to include flowers that do not bloom simultaneously to provide continuous flow of foraging material and to attract a multitude of different pollinators.
Let weeds grow along the margins of crop fields to enhance the diversity of foraging sources for wild bees. This does not increase costs for farmers.
Planting insectary strips within fields, along field margins, and within buffer strips. This practice supplies wild bees with pollen and nectar sources and attracts wild bees to crop fields (Altieri and Nicholls, 2004; Carvell et al., 2004; Pywell et al., 2005)
Use cover crops in set-aside fields and allow them to bloom before plowing.
Incorporate mixtures of wildflowers in fallow fields, let weeds grow so that meadows can be produced. This practice can support wild bee populations while making use of fields currently not in use for crop planting.
Plant native shrubbery and plants to create hedgerows. This furnishes wild bees with more nesting areas and habitat. It also provides additional pollen and nectar sources. The hedgerows are also beneficial for crops by mitigating erosion and providing windbreaks.
Conduct habitat restoration for fragmented areas in set-aside lands. A focus could be placed upon marginal lands where it is difficult for farmers to cultivate crops. This could increase the amount of available nesting sites for wild bees.

NESTING
Converting irrigation systems to either drip or spray methods. This will protect ground-nesting bees from flooding. Changing the timing of irrigation can also protect bees. Night-time irrigation should not interfere with the foraging habits of wild bees.
Altering tilling methods to reduce the disturbance to wild bees' nesting sites. Employ techniques such as Shallower tilling and no-till farming. These are considered to be more pollinator-friendly and increases population densities of wild bee species.
Leaving bare patches of ground in hedgerows for ground nests, leaving behind dead wood on farmlands, and drilling holes into dead wood. This creates additional nesting sites for wild bees.
PESTICIDE USAGE
Utilize pesticides with less harmful, active ingredients or in safer forms (e.g., granular pesticides instead of dust pesticides).
Pay more heed to the timing of pesticide applications and the form. Avoid applications during crop blooms or during the day when wild bees could be foraging. Also avoid aerial sprays since this increases likelihood of intoxication.
Consider transitioning some or all farming fields towards organic agricultural production (Vaughan et al., 2004)

Adapted from CSPNA (2006) p. 178-183

When incorporating these agricultural practices into farming operations, CSPNA (2006) stress in their literature review that other considerations should be incorporated in implementation plans. First, native plants should be promoted for habitat restorations and foraging material in lieu of introduced and foreign species. They are considered to be preferable treatments for supporting wild bee populations through their maintenance of biodiversity in local ecosystems. Floral sources should also bloom at different times of the year to prevent food shortages for wild bee populations. Finally, the preservation of existing habitats should technically take precedence over habitat restoration in order to preserve their current ecosystem functions which may never return completely even with the implementation of habitat restoration methods.

Therefore, there are multiple methods farmers could employ in their agricultural operations to support wild bee conservation and mitigate their decline. Further research may be required to fully understand the effects of these practices in the Canadian context and to determine which native plants and resources will be best suited for

mitigating wild bee decline through habitat restoration, amelioration of diet sources, and reductions of pesticide impacts. However, the key issue is developing ways to encourage farmers to introduce these methods in their agricultural operations. This requires navigating the conflict between limited resources (e.g., time, labour, funds to introduce these sustainable practices) and foregone income from introducing these measures. It is ultimately a decision between perceived profits and conservation.