SRM 4950—INDEPENDENT RESEARCH PROJECT

A Hive of Possibility

Exploring factors affecting the sustainability of apiculture in Newfoundland

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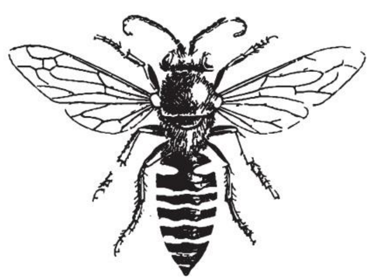

Honeybee colony losses have been documented across the world and have garnered scientific and public attention. The island of Newfoundland, NL, Canada remains one of the few places in the world still unaffected by the Varroa mite, other pests and diseases, as well as many of the externalities of industrial agriculture. Apiculture on the island therefore holds significant potential. However, many challenges also face the small industry of approximately 30 operations. This study explores some of the unique factors currently affecting the long-term sustainability of beekeeping on the island. Interviews and questionnaire responses from the beekeeping community were used here to direct an exploration of these key factors. With only about 300 hives kept in Newfoundland and only a couple commercial operations, the current industry profile stands in a precarious place. This paper explores interactions between multiple factors, their contributions to significant challenges and opportunities for apiculture in Newfoundland, as well as considerations for policy makers and managers.

1-Introduction:

Pollinator declines across the globe have not only raised scientific concern in recent years, but have also garnered widespread public and political attention as well. This is not surprising considering approximately 35% of human food sources (including 87 of the leading world food crops) are reliant on animal pollination (FAO, 2008). The global economic value of pollination is estimated to be around US$ 212 billion (vanEngelsdorp & Meixner, 2010). A few countries, including China, even legally recognize pollination as an agricultural input along with fertilizers and agrochemicals (FAO, 2008).

The western honey bee, *Apis mellifera*, is only one of more than 100,000 pollinating species (FAO, 2008). Its efficiency as a pollinator is even questionable when set against a number of other insect pollinators (Kevan, 1999). However, the honeybees' domestication, abundance, easy management and long history with humans make them perhaps the most useful and most understood insect pollinator in the world (Kevan, 1999; vanEngelsdorp & Meixner, 2010). While many non-Apis species of pollinator have remained poorly understood and documented, the honey bee has allowed for more consistent and in-depth monitoring of declining bee health and abundance (Blackburn, 2012; FAO, 2008; OPERA, 2013).

Honeybee colony losses globally are well-documented (FAO, 2008; OPERA, 2013). The estimated 40% reduction of US colonies as a result of Colony Collapse Disorder (CCD) has raised considerable concern in North America (Melhim, Weersink, Daly, & Bennet, 2010; vanEngelsdorp et al., 2009). While CCD was officially recognized in the US in 2006, the specific symptoms associated with CCD have not been diagnosed here in Canada (Melhim et al., 2010). However, the causes of CCD are thought to be multifactorial (vanEngelsdorp et al., 2009), and many of the stressors attributed to CCD are similar to those implicated in recent Canadian losses as well (AMEC, 2010; Currie, Pernal & Guzmán-Novoa, 2010; Melhim et al., 2010). Very briefly, some of these factors include diseases and pests, pesticide exposure, habitat and biodiversity reduction, weather and climate, as well as sociopolitical factors (FAO, 2008; Le Conte et al., 2012; OPERA, 2013; vanEngelsdorp & Meixner 2010).

In Canada, the 2013/2014 winter season saw 25% winter losses in honeybee colonies with Ontario loosing 58% of its hives (Kozak et al., 2014). Considering 15% losses are considered normal, many regions of the country are exceeding this threshold. Colonies in Atlantic Canada have seen about a 30% reduction over the past few years (AMEC, 2010). Overwintering losses vary considerably on a regional scale and the stressors which contribute to colony losses are also highly variable (Currie et al., 2010). Harsh weather (both in winter and during the forage season) is thought to contribute significantly to increased bee mortality along with ineffective mite treatment, the presence of *Nosema spp.* and other viruses and diseases, as well as neonicotinoid pesticides (Currie et al., 2010; ON, 2014). Potts et al. (2010) also argue that some of these factors can act synergistically. These interactions can then compound the impacts of unseasonably bad weather to the detriment of pollinator populations (see figure 1).

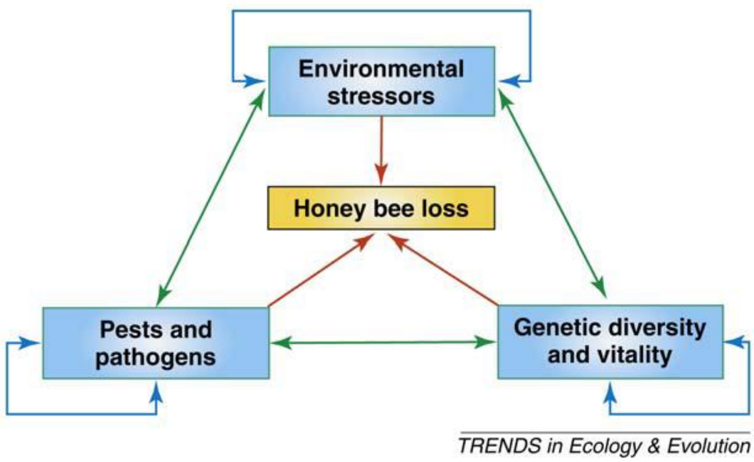

Figure 1—compounding effects and synergies within and between factors contributing to honey bee losses (Potts et al., 2010)

Given this global pollinator crisis, the island of Newfoundland off Canada's east coast currently finds itself in a very unique position. Some of the major stressors partially attributed to colony losses on the rest of the continent are thankfully absent in Newfoundland. Large-scale monoculture farming practices, intensive management and movement of hives for pollination purposes, and over-emphasis on production quantity over quality have all been attributed to the ≈30% colony reductions in Atlantic Provinces between 2007 and 2010 (AMEC, 2010). These stressors are likely of little significance in

Newfoundland at present due to a relatively low agricultural output in the province and very low productivity in the apicultural sector.

Perhaps one of the most important aspects affecting honeybee health in much of the world is the presence of invasive pests and diseases, especially the *Varroa destructor* mite and *Nosema spp*. fungus (Currie et al., 2010; Kozak et al., 2014; OPERA, 2013; vanEngelsdorp, 2009; Williams, Head, Burgher-MacLellan, Rogers, & Shutler, 2010). The Varroa mite was introduced into North America in 1987 and was first reported in Canada in 1989 (Currie et al., 2010; Shutler et al., 2014). As a consequence of this infestation, reduced hive fitness and vitality during the fragile winter months contributed to an estimated 50% increase in colony overwintering mortality (Williams et al., 2010). These parasitic mites alone are not only detrimental to honeybees, but *V. destructor* is also a vector for other diseases and viruses which can compound negative effects on a hive (Shutler et al., 2014; Williams et al., 2010). Effective treatment and treatment timing is often difficult, and reported mite resistance to treatments make suppression of this invasive parasite an elusive and expensive task (Coby, Sheppard, & Tarpy, 2012; Currie et al., 2010; Kozak et al., 2014; OPERA, 2013; Sammataro, 2012). For this reason, the production of disease- and mite-resistant strains of honeybee has gained considerable attention in recent years (AMEC, 2010; Cauia, 2010; Fries, 2012; OBA, 2015; Sammataro, 2012).

To date, Newfoundland thankfully hosts a honeybee population still unaffected by *V. destructor*, tracheal mites (*Acarpis woodi*), Israeli acute paralysis virus, Kashmir bee virus, and other significant invasive organisms (Shutler et al., 2014). The isolated island of Newfoundland has therefore been endowed with substantial possibility as a potential supplier of disease-free bees, organic hive products, as well as significant scientific research opportunities (anonym. pers. comm.; Shutler et al., 2014; Williams, 2010; Williams et al., 2010).

It may seem as though Newfoundland could stand as a bastion of healthy honeybees and offer considerable possibilities in the realms of crop pollination, apicultural research and specialty products. However, the province also faces unique and considerable challenges which could threaten the long-term sustainability of apiculture on the island. With only about 300 hives being managed across the province, beekeeping on the island remains relatively underdeveloped (Hicks, 2014). It also faces a number of challenges including high winter mortality and a precarious industry profile, possible issues of reduced genetic diversity, risk of disease/parasite infestation, and a lack of government and industry support capacity—all of which may hinder the long-term sustainability of the industry.

Along with a fledgling industry comes an underdeveloped system of monitoring and information gathering. To date, there remains no provincial database of any beekeeping operations in Newfoundland and no requirement for registration of hives (anonym. pers. comm.). Newfoundland also lacks a provincial apiarist, or any such specialized personnel in the Agrifoods Development Branch of the Department of Natural Resources (anonym. pers. comm.; NL, n.d.b). That being said, the Newfoundland and Labrador Beekeepers' Association (NLBKA) was formed at the end of 2014 and represents a significant step towards formalizing management efforts among Newfoundland beekeepers. The aims of the organization are comprehensive and have relevance not only to beekeepers in the province, but also government officials, policy-makers, researchers, and the general public (see appendix B for a list of NLBKA aims).

In light of the recent global issues facing honeybee populations around the world, it is clearly important that policies and management plans be developed in order to protect Newfoundland's unique, pest-free honeybee population as well as grow the apicultural industry sustainably. However, the current lack of information about the honeybee population in the province poses a significant problem for policy-makers. Without sufficient understanding of honeybee abundance, distribution, forage use, health, genetic characteristics and current management in Newfoundland, there are no scientific grounds on which to base policies affecting bee health and apicultural development.

This paper is meant to act as a stepping stone towards guiding strategic conversations about the sustainability of apiculture on the island. Three questions are explored in this review: 1) what are some of the key factors to consider with respect to the sustainability of apiculture in Newfoundland and how do they interact? 2) what are some major challenges and opportunities facing beekeepers on the island? and

3) what considerations may be most relevant to policy-makers and managers regarding the sustenance of pollinators, honeybee health, and the apicultural industry in Newfoundland?

2-Methodology:

This paper combines both primary and secondary research. A wide range of literature was reviewed including scientific studies on the effects of genetic diversity on honeybee colonies, genetic profiles of honeybee populations, assessments of national and global pollinator declines, studies assessing pollinator policy measures, as well as websites and documents published by government and non-governmental organizations concerning the state of provincial and national apiculture industries.

Primary information was acquired by way of a questionnaire, interviews and phone conversations. A questionnaire was compiled with the aim of providing both qualitative and quantitative information regarding the honeybee population in Newfoundland. This questionnaire (see appendix A) was sent out to all members of the Newfoundland and Labrador Beekeepers' Association. The primary aim of the questionnaire was to provide quantitative information about the current honeybee population on the island, its distribution (location of hives), and the source and genetic stock of bees across the province. In addition, the questionnaire included valuable qualitative information regarding potential challenges and opportunities facing the sustainability of individual operations and the industry as a whole in the province.

A total of seven respondents replied to the questionnaire either by e-mail or through phone conversation. This number represents about 16% of NLBKA members, approximately 23% of beekeepers in the province operating about 59% of the hives in the province. The sample represented a diversity of operations. Three were hobby, two were potential/developing businesses, and two were established commercial operations. One respondent practiced an unconventional method of beekeeping with the use of Kenyan top bar hives. Six apiaries were operated by newcomers to beekeeping in Newfoundland (started within the past 5 years), and two had practiced apiculture for over 30 years. Respondents' range of beekeeping experience based on past training and education also ranged considerably within the hobby operations.

The number of responses was inadequate for the purposes of creating a provincial profile of the honeybee population (including size, distribution, and source stock). However, the qualitative information proved useful in both identifying some of the major challenges and opportunities faced by beekeepers as well as in providing context and anecdotal evidence to contextualize some major factors.

Three of the respondents completed the questionnaire by phone which allowed for more elaboration on themes as well as more anecdotal information as compared with written e-mail responses. In addition to the questionnaire, phone conversations, in-person interviews and e-mail correspondences were also conducted with beekeepers in the province (some of whom were also respondents to the questionnaire), employees of the Agrifoods Development Branch of the Newfoundland Forestry and Agrifoods Agency and honeybee researchers outside the province. All questionnaire respondents will be identified by number (in no particular order) to adhere to privacy requirements. No interviewees gave permission to be identified by name and will be referred to anonymously.

3-Factors of Interest: opportunities and challenges within the unique Newfoundland context

The following section outlines some of the major factors currently influencing the sustainability of apiculture in Newfoundland: industry profile and the issue of scale, genetic diversity, weather conditions and overwintering, diseases and pests, agriculture, pollination and industry development, forage availability and quality, regulations/enforcement and education. While this exploration is not exhaustive, it does attempt to briefly outline key themes (many of which were identified as recurring concerns in questionnaire responses). Opportunities and challenges facing beekeepers on the island will be raised within the context of these key themes (see appendix C for diagram). It should be noted that each theme is presented in an order which provides the most logical progression of explanation and this order does not represent a hierarchy of importance in any way.

3.1-Industry Profile:

Across Canada, there has been a growing shift away from hobby beekeeping and towards larger-scale commercial operations. Despite increases of production, there has been an overall decrease in the number of beekeepers in Canada with the current tally at about 16% of 1945 numbers (Melhim et al., 2010). Of the 6,421 beekeepers who left the industry between 1993 and 2010 in Canada, 80% were hobbyists (Melhim et al., 2010). Essentially this means that honeybee colonies are becoming concentrated into more intensive operations.

Similar trends are also being seen across the western world. In Europe, it was noted that colony losses in recent years were most prominently observed in hobby operations (OPERA, 2013). This phenomenon was partly explained by hobbyists' lack of experience and resources. Since the introduction of the Varroa mite and other invasive pests, treatment is also a major cost in an already very costly hobby which can be discouraging to small-scale apiaries and entry-level beekeepers (OPERA, 2013; Roche, 2014). Effective mite treatment also requires adequate knowledge of appropriate techniques and treatment timing (Sammataro, 2012). However, despite these facts, hobbyists remain the majority of operators compared to their commercial counterparts (OPERA, 2013, Melhim et al., 2010; Neuwirth, Hambrusch, & Wendtner, 2011).

The actual number of beekeepers and honeybee colonies in Newfoundland remains somewhat elusive. The Newfoundland and Labrador Farm Guide (NL, n.d.a) states the island hosts 36 commercial apiaries. This number is deemed to be inaccurate however (anonym. pers. comm.). While Williams (2010) claims there are about 100 colonies in Newfoundland, Hicks (2014) appears to be most accurate with its estimate of 300 hives operated by between 25-30 individuals. To provide some context, this number represents about 0.05% of all the hives across Canada (Melhim et al., 2010). With neighbouring Nova Scotia hosting about 19,300 hives alone under the management of around 230 beekeepers, the scale of Newfoundland's beekeeping industry is comparatively very small (Nova Scotia Beekeepers, n.d.). Despite its size, however, apiculture should not be dismissed as merely a fanciful hobby.

Newfoundland's apicultural industry follows similar trends with the rest of the western world in terms of its profile. One operation on the island, the Newfoundland Bee Company, contains about 100 hives and is a major supplier of queens and nucleus colonies (nucs) for other operations across Newfoundland (anonym. pers. comm.). Only about 4 individuals in the province operate more than 10 hives each (anonym. pers. comm.; Hicks, 2014). Due to the scale of beekeeping in Newfoundland, this unbalance between hobby and commercial operations poses a couple key challenges related to other factors such as genetic diversity, weather conditions, and diseases/pests. In addition, the small size of most operations (including commercial ones) could make the industry much more susceptible to the challenges posed by these factors. In particular, high winter mortality in smaller operations can be much harder to rebound from.

Another important aspect of the industry profile is the ambitions and development goals of hobby and entry level beekeepers. Of the questionnaire respondents, three had hobby operations with no commercial aspirations, two had plans to grow their hobby operations into businesses and two were long-established commercial operations. No beekeeper in Newfoundland currently acquires their primary income source from beekeeping (anonym. pers. comm.). Respondent 2 manages two Kenyan top bar hives on the east coast of the Avalon Peninsula. There are about seven other people within that area who also operate a total of approximately eight such hives. It was noted that these individuals were either retired or close to retirement and had little interest in increasing the size of their operations. Respondent 7 identified the lack of young and enthusiastic beekeepers as a challenge to the long-term sustainability of beekeeping on the island. It is clear that current industry size must be evaluated in combination with existing levels of ambition and desired growth directions for future development.

While results from the questionnaire cannot be used to make numerical estimates about hobby operations on the island or their distribution, these examples are used to illustrate how operation size, operator demographics and goals are all important considerations in the development of policies and plans for industry growth and support.

3.2-Genetic Diversity:

Genetic diversity is recognized to contribute to overall fitness, evolutionary resilience and adaptability within a population (Delaney, Meixner, Schiff, & Sheppard, 2009; Lacy, 1987; Le Conte et al., 2012; Sammataro, 2012). In honeybees specifically, genetic diversity has been shown to positively influence such traits as disease resistance, homeostasis, thermoregulation and overall colony fitness (Mattila & Seeley, 2007; Sammataro, 2012; vanEngelsdorp & Meixner, 2010). For this reason, genetic diversity can be viewed as valuable “biological capital” (Büchler, 2013). The genetic diversity of Newfoundland`s honeybee population may pose a significant challenge to the sustainability of apiculture on the island. While the following section will not attempt to explore the complex field of honeybee genetics, it will outline some important facets of the genetic diversity issue in managed honeybee populations with implications for the Newfoundland context.

Genetic diversity of managed honeybee colonies in North America and Europe is already argued to be a major issue of concern, especially when honeybees are threatened by multiple stressors such as mites and diseases (Le Conte et al., 2012). Coby et al. (2012) argue that three distinct genetic “bottlenecks” occurred in North America which resulted in decreased genetic diversity of the entire North American stock. The first was a sampling bottleneck in which about 1/3 of the subspecies of *A. mellifera* were introduced to North America and these were only represented by a few tens to hundreds of queens from each subspecies. The second bottleneck involved the widespread decimation of feral honeybee colonies due to Varroa mite infestation. The third bottleneck involves the nature of selective honeybee queen breeding in the US which is concentrated to two distinct regions and produces around 1 million queens in a year from less than 600 mothers.

The need to maintain diverse honeybee stock is recognized on a national scale. For example, exceptions were made to Canada’s ban on honeybee package imports from the United States in order to allow for infusion of new genetic material into Canada’s honeybee stocks (CFIA, 2013). International trade of honeybees allows for a great deal of genetic migration between colonies. Many of Canada’s source queens also come from the major queen producing locations in the US (anonym. pers. comm.).

The export value of queen honeybees from New Zealand alone was estimated to be around $4.4 million in 2013 (Roche, 2014). This movement of bees across borders is thought to benefit the genetic diversity of populations. When examining the two major honeybee populations in the United States, Delaney et al. (2009) found no significant changes in the genetic diversity of the populations in the United States over a ten year period; influx of genetic material from Australian, Russian and Africanized stock were all thought to boost the genetic diversity of these groups. It is clear that international honeybee trade can be a significant source of genetic transfer between populations.

In order to actually consider the risks associated with low genetic diversity and population isolation, some aspects of honeybee biology must be understood. Since every colony possesses a single queen who rears all workers (females) and drones (males), every bee in a honeybee colony is related by varying degrees. For this reason, a honeybee colony is considered an "individual" within a population regardless of the number of bees residing in each colony (Cauia et al., 2010; Jaffé et al., 2009). Despite this fact, Newfoundland's honeybee population must not be seen merely as a small, disperse village of about 300 individuals. The actual scenario is more complex and involves particular honeybee traits and behaviours.

Honeybees possess a number of traits which act to maximize genetic diversity within colonies (Büchler et al., 2013). Multiple mating is one major source of genetic diversity which results in multiple sub-families within a colony. Estimates of the number of drones which may mate with a queen range as far as 40; however, between 5 and 20 is a more common approximation (Harpur, Minaei, Kent, & Zayed, 2012; Oldroyd, Rinderer, Harbo, & Buco, 1992). Drones may fly up to 15 km to drone congregation areas for mating (Jaffé et al., 2009). In Newfoundland, however, there are no feral colonies and many small apiaries exist outside a 15-20km radius from other apiaries (anonym. pers. comm.). Generally, queens will need to be replaced every 2 years on average (Büchler et al., 2013). The sperm which inseminates a queen on her mating flight serves to fertilize eggs for her entire lifespan: usually about 2 years of viability (Laidlaw & Page, 1997). It is therefore plausible that the genetic diversity of a colony in isolation may decrease significantly in a few generations (Cauia et al., 2010).

The introduction of a relatively small sample of honeybees to the island of Newfoundland and the subsequently low levels of genetic migration from outside the province could be considered a form of translocation. Thrimawithana, Ortiz-Catedral, Rodrigo, and Hauber (2013) observe that translocated groups tend to have lower genetic diversity than their larger source group. In addition, smaller populations are prone to loss of genetic diversity much faster than larger populations as a result of genetic drift (random sampling of genes which progress to the next generation) (Lacy, 1987).

It may be quite difficult to assess the actual risk of low genetic diversity in Newfoundland's honeybee population. New genetic stock has legally been brought into Newfoundland from Ontario on a regular basis (every few years), including at least two distinct lines—Russian and Buckfast. These breeding lines are additional to the Italian, Caucasian, and Carniolan lines which already exist in the province, as well as hybrids of these three. Given that frequent immigration is the most effective way to counter loss of genetic diversity (Lacy, 1987), the genetic diversity issue may appear to be significantly curbed. While some respondents and interviewees raised the issue of genetic diversity as a concern, especially in the long-term, one respondent explicitly expressed that it is not a major concern for Newfoundland's honey bees. The respondent's reason for this centered on the above-mentioned scenario of frequent, planned, genetic influx.

On the other hand, a majority of Newfoundland's apiaries are not only very small, but also rely on just a couple queen and nuc sources (commercial and semi-commercial operations) for often yearly replacement (anonym. pers. comm.). This necessity is largely due to harsh weather conditions and subsequently high winter mortality. Perhaps genetic diversity within the entire island population is a separate issue from genetic diversity within individual apiaries. If enough genetic diversity exists on the island but is not accessible to all beekeeping operations for logistical reasons, the "biological capital" cannot fully be utilized and some operations may suffer.

Due to the complexities of honeybee genetics and the multiple factors influencing genetic flow among and between colonies, it may be impossible to definitively prescribe requirements regarding "safe" levels of genetic diversity. Mattila and Seeley (2007) considered 15 patrilines (queen inseminated by a minimum of fifteen distinct drones) to be a genetically diverse colony. In the context of a managed breeding program, Cauia et al. (2010) recommends maintaining a population size at a minimum number of the selected parents of the next generation in order to avoid inbreeding. In addition, this methodology suggests the removal of any colonies with less than 85% brood viability. In Elemental Genetics and Breeding for the Honeybee, Dr. E. Guzman-Nova (qtd. in anonym. pers. comm. Feb. 15, 2015) estimates a requirement of at least 25 breeder queens for the maintenance of brood viability over 20 generations in a completely controlled/closed breeding population while a partially controlled/semi-closed populations should have at least 10-15 breeders and uncontrolled mating settings should suffice with 5 mothers. These are all different prescriptions of genetic diversity in various controlled scenarios. However, these experimental and breeding contexts are removed from the Newfoundland reality which involves many apiaries of less than 10 hives existing in isolation.

While three respondents claimed that they actively pursue some form of bee breeding in their operations, many small apiaries in Newfoundland neither perform breeding nor queen rearing (anonym. pers. comm.). This may partially result from lacking expertise or may also be an issue of time and resources to perform these involved tasks. If few apiaries actively increase their stock, ensure self-sufficiency of viable queens or breed for desired traits such as overwintering ability, a large demand pressure will persist for the very few commercial operations to replace the stock of small apiaries. The problem may be compounded by isolation from other hives and variations in environmental conditions and stressors. Essentially, some operations may experience no problems relating to genetic diversity while others (especially very small numbers of colonies in sustained breeding isolation) may face potential inbreeding depression or some consequences of external risks on inbred colonies.

Maintaining immigration of new genetic material may be the most effective method of mitigating inbreeding in small isolated populations, however subdividing the population also proves to be beneficial (Lacy, 1987). Such a management technique involves splitting a population into distinct units which cannot interbreed and using these units as supplemental genetic sources for one another in a planned scenario. Such a technique was used for the Russian honeybee breeding program in the United States. In

1997, 100 Primorsky Russian honeybees were introduced into Louisiana to initiate a disease-resistance breeding program (Rinderer et al., 2000). Since these bees had been in contact with the Varroa mite since the early 1800's, they exhibited high adaptability and decreased need for mite treatment. The breeding program was closed to genetic admixture from other honeybee strains found in the US. As a result, maintaining adequate genetic diversity and heterozygosity within the closed Russian population necessitated a scheme (Bourgeois & Rinderer, 2009). Over the first few years of the program, 362 imported queen mothers were used to produce 18 lines which were divided into 3 separate groups. The split subgroups therefore minimized genetic homogenization across the entire Russian stock and each acted as a genetic source for the other two. On a larger scale, Delaney et al. (2009) postulated that the two broader populations in the United States (Western and Southeastern) are genetically distinct and could act as genetic sources for one another. On various scales, splitting isolated subpopulations can aid in minimizing genetic homogenization in the long-term.

No genetic profile of Newfoundland's honeybee population has been conducted to date. It is therefore difficult to assess any actual long term or short term risk of inbreeding within Newfoundland's honeybee colonies. However, it is clear that some beekeeping operations stand at a disadvantage when faced with very low colony numbers, geographic isolation, high winter mortality, and the absence of a guaranteed supply of bees from within the island. As a result, cooperation among Newfoundland's beekeepers in the design of a breeding scheme or breeding program may be highly beneficial in order to ensure the sustainability of individual operations. At least three operations on the island are already practicing honeybee breeding; however, it should be noted that breeding programs can be extremely labour-, knowledge-, and resource-intensive. In the event of pathogen infestation, increased pesticide exposure, or other stressors, decreased genetic diversity could be a significant, negative compounding factor (Sammataro, 2012). Ensuring that all beekeepers have access to sufficient genetic material is vital for the overall sustainability of the industry in Newfoundland. Further research into the exact number and location of operations/potential operations, their current sources of queens/nucs, and some of the logistical challenges these operations face may be beneficial in planning the goals and design of any breeding program or scheme.

3.3-Weather Conditions and Overwintering:

Newfoundland's harsh climate is perhaps the most obvious and substantial challenge faced by beekeepers on the island. In Canada alone, long and harsh winters are considered a major challenge to beekeepers (Currie et al., 2010; Kozak et al., 2014). In particular, wet, cold spring conditions are a significant obstacle for spring build-up of colonies (Kozak et al., 2014). One springtime concern is that honeybees are often bred for fast spring build-up, so if a spring cold snap occurs and prevents bees from foraging, they may deplete their reserves and starve (Le Conte & Navajas, 2008). Considering honeybees will not forage during inclement weather conditions (Javorek, Mackenzie, & Vander Kloet, 2002), long winters with harsh spring conditions and freeze-thaw fluctuations increase the challenge for many Newfoundland beekeepers. Until the import ban on live honeybees was implemented, most beekeeping operations on the island purchased new bees every season due to high winter mortality (Hicks, 2014). Since the import ban, however, the independence and security of apiculture in Newfoundland faces considerable instability.

Five of the six respondents mentioned weather or harsh winters as a major factor affecting sustainability of apiculture (including those respondents with some of the longest experience beekeeping on the island). Three respondents also referenced the high degree of regional variability in weather patterns across the island. It is clear that weather concerns are highly localized. For example, one respondent faces the issue of high katabatic winds while another sees continual spring fluctuations around freezing as a major issue. During interviews, multiple concerns with winter protection of hives were discussed from methods of insulating largely vacant top bar hives to the issue of high snowfall completely covering hives to the construction of indoor winter hive storage as well as the use of natural and constructed wind-breaks. Many techniques exist and are being adapted to cope with local weather conditions and harsh winters. Cooperation and communication among the beekeeping community in combination with support for training workshops and effective educational material may all help beekeepers (especially inexperienced hobbyists and newcomers) to cope with the island's often severe climatic conditions.

Severe weather also interacts indirectly with the issues of genetic diversity, disease/pest risk and regulation enforcement. Two respondents mentioned unsuccessful bee orders placed at the Newfoundland Bee Company within the past few years. High overwintering mortality has been linked to high demand and low supply for honeybees on the island (anonym. pers. comm.). High yearly demand for new honeybee stock is not specific to Newfoundland; it is a widespread reality made more precarious by higher colony losses in recent years. In the US alone, yearly demand for the replacement/restocking of honeybees is estimated to be about 2.4 million colonies (Coby et al., 2012). However, Newfoundland experiences this issue on a small scale resulting in almost all provincial demand focussed on a couple major suppliers. If these operations experience a significant loss due to severe weather or any stochastic event, the entire industry could be in jeopardy.

This insecurity within the province's honeybee population not only poses a challenge to the growth of apiculture, it also increases the potential problems outlined in section 3.2 relating to decreased genetic diversity in individual, small operations. In addition, the risk of illegal bee importation may increase when demand for honeybees cannot be met. Increasing education and training measures for beekeepers on regionally-focussed management strategies, increasing awareness about the importance of the import restrictions (see sections 3.4 and 3.7) and considering genetic diversity in the strategic growth and diversification of apiculture on the island may all aid in minimizing the risks incurred by high winter mortality and harsh weather on the island.

3.4-Diseases and Pests:

Currie et al. (2010) recognize acaricide resistance and failure to control Varroa mites as one of the most important factors related to colony losses in Canada. As mentioned previously, Newfoundland stands at a considerable advantage to mainland North America as its honeybee population remains unaffected by *V. destructor*, tracheal mites (*Acarpis woodi*), Israeli acute paralysis virus, Kashmir bee virus, and significant other invasive organisms (Shutler et al., 2014). With these threats persisting in most other populations around the world (including neighbouring Nova Scotia), the risk of disease/pest infestation in Newfoundland remains relatively high. It is therefore important to consider the probable introduction of these pests/diseases onto the island as well as their implications.

The possible and probable infestation of Newfoundland's honeybee population is a prominent concern for beekeepers on the island. Three of the questionnaire respondents included introduced pests/diseases or Varroa mite infestation as major challenges facing either their individual operations or apiculture in Newfoundland as a whole. Two respondents listed illegal importation of bees as a major challenge, which implies the biosecurity issue of pest/disease importation. One respondent/interviewee considered the infestation of pests and diseases an imminent risk for which we should be prepared.

Indeed, other island honeybee populations have experienced a delayed exposure to some of these pests. Hawaii was mite free until the discovery of a Varroa-infested colony on Oahu in 2007 (State of Hawaii, n.d.). New Zealand was another isolated location which remained unaffected by Varroa mites until the pests' detection on the North Island in 2000 and the South Island in 2006 (Roche, 2014). In the words of one interviewee, infestation may "not [be] a matter of if, but when" (anonym. pers. comm.). Preparedness for mite and disease infestation is therefore paramount.

Some believe that the small number of widely dispersed hives present on the island offer an advantageous buffer to the possible spread of diseases. With no feral honeybee populations in Newfoundland and often large distances between hives, mitigating the transfer of pests and diseases may be more easily manageable than in a mainland scenario. That being said, the supply chain of bees within the province must be considered. If any one of the major suppliers of honeybees in the province were affected by disease/pest infestation, the entire island population would be in danger. Pathogen transmission via the transportation of bees, hive products, and equipment between apiaries within the province is a notable risk.

The issue of infestation is not necessarily restricted to honeybee-to-honeybee transfer. “Pathogen spillover” (transfer of infection usually between wild and managed populations) has been shown to occur between managed and wild bee populations through shared flower use (Colla, Otterstatter, Gegear, & Thomson, 2006; Fürst, McMahon, Osborne, Paxton, & Brown, 2014). It is known that bumblebees are brought to Newfoundland from the mainland for berry pollination purposes (often after they have already serviced crops in Nova Scotia) (anonym. pers. comm.). This should be considered a major risk for both native pollinators and commercial honeybee populations. Graystock et al. (2013) not only demonstrated pathogen spread from bumblebees to honeybees, but also noted that 77% of commercially produced bumblebee colonies used in the experiment carried microbial parasites despite being advertised as parasite-free. Pollinators, even when commercially produced, do not exist in isolation and their distribution cannot be truly controlled. Continued importation of non-Apis bee species puts Newfoundland’s native and managed bees at risk.

If pests such as the Varroa and tracheal mites were to infect Newfoundland’s honeybee colonies, the effects could be detrimental. The Varroa can act as a vector for significant other pests and diseases (Le Conte et al., 2012; Shutler et al, 2014; vanEngelsdorp & Meixner, 2010). The cumulative or synergistic impact of these potential inhibitions, along with already harsh climatic conditions in Newfoundland, could be severe. One of the largest costs for many beekeepers in mite-infected areas is Varroa treatment (OPERA, 2013). As previously mentioned, colony declines (often influenced by mite infestation) tend to affect hobbyists most severely. In Europe, ineffective mite control resulted in a 66% increase in colony numbers managed by remaining, larger operations (Kevan, 1999; vanEngelsdorp & Meixner, 2010). The small scale of apiculture currently in Newfoundland may make disease/pest infestation a threat from which few small operations could recover.

As it stands now, Newfoundland’s disease-/mite-free honeybee population is regarded as a significant opportunity. Beekeepers are given the advantage of not having to deal with the compounding stresses of infected colonies. Without the requirement of miticides and other chemical treatments, truly organic hive products could be sold as speciality items with proper market development (anonym. pers.

comm.; Williams et al, 2010). In addition, significant potential exists to provide disease-free, chemical-free bees for research purposes (anonym. pers. comm.; Shutler et al., 2014).

Given that Newfoundland's honeybees have not been exposed to many of the stresses on the mainland, one respondent identified the sale and use of honeybees for research purposes as a more important opportunity than commercial sale off the island. Here we encounter the issue of honeybee genetics interacting with disease resistance and therefore market potential.

Significant attention is being given to the use of genetic research and honeybee breeding in order to increase mite resistance (OPERA, 2013, Rinderer et al., 2000; University of Guelph, n.d.). Honeybee breeding has traditionally been focussed on maximizing commercially significant traits such as honey production, temperament, and colony growth (Delaney et al., 2009). Breeding for mite resistance in honeybees can involve a number of behavioural traits (Sammataro, 2012) or even targets of mite growth rate (Fries, 2012). However, breeding for resistance requires exposure to infestation pressure (Cauia, 2010; OPERA, 2013). Therefore, the sale of mite/disease-free honeybees to infested commercial operations outside the province will not be viable unless collaboration with mainland breeding programs is maintained and a focus on producing mite-resistant honeybee strains is upheld in Newfoundland. It would be wise to prioritize production goals and assess market feasibility for the potential sale of honeybees outside the province. Marketing honeybees for research purposes and to provide other breeding programs and mite-free locations may prove to be a more lucrative development direction.

The threat of mite and disease infestation in Newfoundland's honeybee population remains a significant potential challenge. However, the current lack of infestation provides opportunities which can be capitalized on given sufficient marketing and development support, collaboration between stakeholders, and diligence in the prevention and mitigation of probable infestation.

3.5-Agriculture, Pollination and Industry Development:

Plant pollination occurs through the transfer of pollen between flowers while honeybees forage for energy resources. In this way, honeybees not only collect the nectar with which honey is produced, but also perform the invaluable pollination service necessary for so many plant species and economically significant crops. Apiculture and agriculture can thus be considered complimentary industries. The inherent tie between beekeeping and agriculture is tainted, however, as unsustainable agricultural development can prove detrimental to bee health. Developing these industries with a mutual knowledge base and congruent goals may aid in improving the sustainability of both apiculture and agriculture.

The European Pollinators Support Farm Productivity (STEP project) report published in 2011 noted the most important factors associated with recent pollinator declines are linked to land use changes which occurred in the agricultural landscape after the second world war (OPERA, 2013). Increased intensity of agriculture can involve destructive practices which reduce pollinator habitat and forage availability/quality. Such practices include large-scale monoculture ecosystems, reduced hedgerows and marginal habitats, and increased use of chemical inputs such as pesticides and herbicides (Allen-Wardell et al., 1998; FAO, 2008; Le Conte et al., 2012; OPERA, 2013;). In addition, low-diversity agro-ecosystems which cannot support sufficient pollinators naturally necessitate the rental of large numbers of managed pollinators to provide this ecosystem service. As an example, some Californian colonies might travel up to 40,000 miles in one season to pollinate four different crops (vanEngelsdorp & Meixner, 2010).

Newfoundland's agricultural output is extremely low compared to its Atlantic counterparts. In 2009, Newfoundland had less than half the farms present in Prince Edward Island and only about 5% of the cropland. Farm cash receipts for Newfoundland in that year represented only 7.6% of Atlantic Canada's total (NL, 2009). Currently, fruit producers on the island make up the main demand for pollinations (anonym., pers. comm.). In particular, blueberry and cranberry crops require insect pollination for successful fruit set. There is some degree of dispute as to the efficacy of honey bees in pollinating these crops (Aras, de Oliveira & Savoie, 1996; Hicks, 2011; Javorek, Mackenzie & Vander Kloet, 2002). Non-Apis pollinators such as *Augochlora*, *Augochlorella*, *Andrena*, *Bombus*, *Halictus*, *Agapostomon*, and *Lasioglossum* have all been shown to demonstrate greater pollination efficiency compared to honeybees through sonication of flowers, or buzz pollination (Javorek, Mackenzie & Vander

2002). These species also exhibit higher degrees of tolerance for foraging during marginal weather conditions than honey bees. With that said, honeybees can be supplied in abundance and supplement low native bee numbers to successfully increase blueberry pollination (Eaton & Nams, 2012). Despite the debate about pollination effectiveness, stakeholders in Atlantic Canada established that honeybees can provide the best and most easily managed method of crop pollination (AMEC, 2010).

At present, most local honeybee pollination services in Newfoundland are provided in the Pasadena area as this is the location of the largest concentration of colonies operated by the Newfoundland Bee Company (anonym. pers. comm.). Some farmers import quads of bumblebees from Nova Scotia, often in the back of pick-up trucks (anonym. pers. comm.). *Bombus terricola* and *Bombus ternarius* are two species of bumblebees which are currently imported to Newfoundland on a seasonal basis for blueberry pollination (Hicks, 2011). One interviewee claimed he knew of berry producers who would refrain from importing bumblebees if they could be guaranteed a supply of local honeybees to serve the purpose. Three respondents included the provision of pollination services as a future goal in the development of their operations. It is clear that Newfoundland’s pollination capacity is not matched to its agricultural productivity, either in terms of pollinator numbers or the logistics of their rental, distribution or transport. That being said, mutual interest from both beekeepers and crop producers has been identified. Therefore, boosting honeybee populations on the island and coordinating communication and cooperation between fruit producers and beekeepers could aid in increasing the sustainability of these industries as well as their provincial independence.

While agriculture in Newfoundland, just like apiculture, can be considered relatively underdeveloped, it also places the province at a significant advantage. The apicultural and agricultural practices which have been linked to colony losses in other parts of the western world are not observed on the island. A relatively small portion of the province has been converted to agricultural land, and none of that land is managed on a scale comparable to large, mainland monocultures. Honey bee exposure to pesticides may therefore be comparatively small. In addition, migratory apiculture (which incurs some of the highest cost of the industry) is not practiced to any large degree in Newfoundland.

The scale of agriculture and apiculture in Newfoundland therefore affords the province an advantage in terms of pollinator health. However, the growth and development of both these sectors will necessitate careful planning in order to mitigate the impacts observed in more agriculturally intense regions. Respondent 2 identified agricultural development in the absence of pollinator knowledge and consideration as a major concern to both the sustainability of their individual operation and to apiculture in Newfoundland as a whole. Although the scale of agriculture on the island remains relatively small, its growth should be fostered along with consideration of its implications for sustainability.

One area of concern related to agricultural development is the potential increase in pesticide use which could accompany increased productivity. Honeybees are already noted for their lack of detoxification enzymes associated with moderate levels of pesticide resistance (vanEngelsdorp et al., 2009). Pesticide use and misuse have been linked to pollinator declines (AMEC, 2010; FAO, 2008; Health Canada, 2014; Hopwood et al., 2012; Le Conte et al., 2012; Melhim et al., 2010; OPERA, 2013). In particular, the group of pesticides known as neonicotinoids have become a major concern for beekeepers around the world. The European Commission restricted the use of three neonicotinoid pesticides in 2013 after they were found to cause “high acute risks” for bees (EC, 2013). These pesticides are still legally used across Canada; however, Health Canada’s Pest Management regulatory Agency has recognized the link between neonicotinoid use/misuse and declining bee health (Health Canada, 2014) and Ontario has imposed progressive restrictions (ON, n.d.). It would be wise for Newfoundland to implement pre-emptive measures in the form of pesticide regulations which reflect the most recent research on pesticide use and pollinator health.

In order to avoid destructive agricultural and apicultural practices, clear goals for pollinator health and apiculture must be integrated into agricultural land use regulations, farm best management practices, farm support programs, and other farm-related policies and management initiatives. The implications of unsustainable agricultural practices have been shown to negatively affect bee health in a myriad of ways. At this point, the relatively underdeveloped nature of both apiculture and agriculture in Newfoundland can be considered a blessing. These sectors are provided somewhat of a “blank slate” and the opportunity to develop with harmonized goals and management practices oriented towards the mutual sustainability of both industries.

3.6-Forage Availability and Quality—implications for land use and management:

As an extension of the pollination theme comes reflection on non-agricultural forage sources for honeybees. It is necessary to also recognize the impacts which other industries and sectors have on pollinator habitat and forage source. Newfoundland contains a diverse range of ecosystems and habitats and it is vitally important that consideration is given to the abundance, diversity, type and quality of forage available for honeybees in specific regions.

In response to a question regarding the largest perceived challenges to the sustainability of individual operations, respondent 5 listed the need for adequate land base and floral source as major factors. Another respondent also mentioned carrying capacity (maximum population sustainable given the available food resources) of his region as a concern. Allen-Wardell et al. (1998) note the significant gaps in knowledge and methodology which persist in determining carrying capacity estimates for pollinators and minimum plant pollination requirements. It would be advantageous to conduct studies on the floral abundance and diversity within ecoregions in Newfoundland in order to better understand target locations for potential apicultural development as well as assess the carrying capacity of different areas on the island. That being said, local knowledge (from experienced farmers and beekeepers in particular) may be valuable and should not be overlooked.

Not only is it important to assess available forage sources for pollinators, but also to create measures to protect the health, abundance and diversity of these sources. Forestry and public land development are two areas where pollinator protection measures can be very beneficial both in the preservation of Apis and non-Apis pollinator health in Newfoundland. One area of concern is the use of non-agricultural pesticides. Agricultural pesticide use was discussed in the previous section; however, pesticide use for cosmetic purposes, public land management (such as roadside spraying), and forestry management are all additional areas of concern.

Certain non-agricultural pesticide applications have been shown to be detrimental to pollinators. Control of western equine encephalitis by pesticide use targeting mosquitos in Manitoba in 1981 and 1983 resulted in $90,000 and $850,000 damage to honeybee colonies respectively (Kevan, 1999). The pesticide fenitrothion was sprayed in New Brunswick forests to control spruce budworm infestation. This pesticide application had a detrimental effect on the local ecology, including insect pollinators, which resulted in extremely low blueberry yields requiring up to seven years for some areas recover (Allen-Wardell et al., 1998; Kevan, 1999). Currently, natural ecosystems play an important role in the provision of forage for Newfoundland's honey bee population. It is therefore important that forestry practices, including pest management, are regulated with consideration of pollinator health.

Cosmetic pesticide use is also a major concern. A multitude of neonicotinoid pesticides are available for purchase for cosmetic purposes. These pesticides have been shown to be applied at concentration levels more than 16 times the levels allowed in agricultural application (Hopwood et al., 2012). Banning of all neonicotinoid pesticides would be a shrewd decision along with continual revision of pesticide and land management regulations which reflect the findings of sound scientific research.

Since honey bees and other pollinators do not adhere to property or jurisdictional boundaries in their flight range, all private and public land use changes and practices are relevant to pollinator health. In New Zealand, beekeeping is incorporated into the public planning process (Victorian State Dep't, 2013). This includes regional management plans, operational and management plans, management prescriptions, and forest zoning. Part of this process involves the designation of bee sites allocated under a licensing system. In 2012, there were 3,637 such bee sites on 7.6 million ha of forests, parks and conservation reserves in Victoria. Of course, vast differences between Newfoundland's and New Zealand's climate, ecology and floral abundance/diversity must be recognized. However, this example is meant to illustrate how apiculture development and sustainability can be incorporated within public and private management and sustainability plans and policies.

In essence, the healthy development of apiculture in Newfoundland (as well as the preservation of endemic pollinator species) will require policies and management plans to consider effects of land use changes and land management practices on honey bee health as well as forage availability and quality. The forestry sector and public land management could be important areas for the development of pollinator-friendly policies and management plans.

3.7-Regulations/Enforcement:

In this section, regulations pertaining specifically to honeybees in the province will be discussed with particular emphasis on biosecurity. In general terms, biosecurity is a set of measures intended for the protection of an animal population from transmissible infectious agents (AHBIC, n.d.). VanEngelsdorp & Meixner (2010) identify global economic liberalization and increasingly lax import regulations to contribute significantly to the global spread of invasive diseases and pests. While cross-border disease transmission occurs via legal importation of bees, illegal importation is also an important factor (AHBIC, n.d.; vanEngelsdorp & Meixner, 2010).

Unlike many other provinces, including ON, BC, AB, MB and NS, Newfoundland does not possess an explicit bee or apiary act (Canadian Honey Council, n.d.). The only specific mention of honeybees in provincial legislation exists in a section within Livestock Health Regulations under the Livestock Health Act (O.C. 96-451) (NL Reg., 2012). This regulation prohibits the importation of live honeybees onto the island without relevant certification. Unlike Prince Edward Island's Animal Health Act, however, Newfoundland's regulations do not necessitate vehicles transporting honeybees or beekeeping equipment to stop for inspection at weigh stations (PEI, 2014). In fact, Newfoundland's regulations make no mention of beekeeping equipment at all. In addition, the authority responsible for administering and enforcing honeybee regulations in Newfoundland is an accredited veterinarian. In contrast, other provinces, including PEI, have a responsible provincial apiarist.

In addition to the shortfalls of Newfoundland's regulation, the Agrifoods Branch currently has no means of monitoring and inspecting any imports—the regulation is only enforceable based on an honour system of notification in the event of suspicion (anonym. pers. comm.). As a compounding factor, Newfoundland does not require the registration of beekeepers unlike most other regions.

There are compounding influences which pose a challenge for effective control of apicultural activities in Newfoundland. These factors include: 1) absence of any form of apiary registry, 2) lack of capacity to carry out monitoring and enforcement and 3) lack of comprehensive regulation which includes consideration of other bee species and relevant products and equipment. While this section did not explore regulations pertaining to land use and agricultural practices, it is important that existing relevant regulations be reviewed and assessed for adherence to common goals and for their implications on honeybee health and the sustainability of apiculture.

3.8-Education:

The previous section outlined the significant absence of capacity to monitor and enforce regulations pertaining to apiculture and bee imports. In light of this shortfall, proper educational tools could aid in promoting pollinator-friendly practices and prompt compliance with current and future regulations. Education was raised as a significant theme by a number of respondents and interviewees. Effective education about the importance of honeybees and best management practices could be beneficial for a number of stakeholders including municipal and provincial governments, farmers and fruit producers, the general public, and active beekeepers themselves.

Beekeeping is a very knowledge-intensive activity whether it is pursued as a hobby or commercially. Two of the respondents are relatively new entrants into beekeeping and both referred to a “tough learning curve” as a significant obstacle. Respondent 5 is a more experienced beekeeper who has studied apiculture and apicultural techniques in a number of settings around the world. This respondent noted education as a major challenge facing the sustainability of apiculture in Newfoundland. He noted a proliferation of inaccurate and false information on the internet which can prompt potentially harmful management practices amongst entry level beekeepers. While internet resources on beekeeping abound, even some sound practices may not be entirely transferrable to Newfoundland’s unique ecological and climatic contexts.

This need for education within the beekeeping industry is not only present where the industry is relatively undeveloped. Nearly three quarters of the subsidies allocated for education purposes in Austria's Apiculture Programme between 2004 and 2007 were used for training. In addition, training sessions focussed on fundamental knowledge gained the highest attendance numbers (Neuwirth, Hambrusch, & Wendtner, 2011). Educating beekeepers on best management practices could not only aid in boosting the health and development of the industry, but could also prompt more diligent attention to import regulations and the use and transportation of beekeeping equipment.

Educating farmers on pollinator health and best management practices is recognized as a vital facet of any initiatives to promote pollinator health and diversity (Blackburn, 2012; FAO, 2008; Roche, 2014). Blackburn (2012) suggests the implementation of cost-sharing schemes and incentives-based policies to help farmers and crop producers incorporate pollinator-friendly practices in their operations. Considering how closely knit the apicultural and agricultural industries are, it is imperative that farmers and beekeepers have a mutual knowledge base with which to inform their respective operations.

Finally, education in the public sector will be essential in order to avoid unnecessary conflict and to ease the successful development of apiculture in the province. Two respondents identified resistance from both provincial and municipal governments as challenges facing their operations. Lack of understanding and knowledge regarding what apicultural development means, its necessary ecosystem service provision and the safety concerns related to beekeeping all typified discussions about education on pollinators (anonym. pers. comm.). Pollinator health is intrinsically linked to ecosystem health. This fact alone necessitates effective education of all stakeholders regarding pollinator health as the ecological integrity of Newfoundland is tied directly or indirectly to every citizen and industry on the island. In more specific terms, education on the importance of apicultural development, pollinator health, and best management practices can all help to harmonize the efforts of beekeepers, farmers and the general public towards viable and sustainable industries and land developments.

4-Recommendations:

Certain considerations for policy development and management strategies have been mentioned within the preceding sections. However, a number of additional reflections may be beneficial in emphasizing important points and directing more comprehensive conversations about apicultural development in Newfoundland. In particular, this section will deal briefly with the following necessities: monitoring, support programs, collaboration and communication, and ecological context.

4.1-Monitoring:

Effective and standardized monitoring is a widely recognized need from the local to international scales (AMEC, 2010; Byrne & Fitzpatrick, 2009; FAO, 2008; Kozak et al., 2014; OPERA, 2013; Meixner et al., 2010). "Bee monitoring" generally refers to surveillance systems where bee health (either generally or specifically) is observed under practical field conditions (OPERA, 2013). There are many examples of monitoring initiatives striving to increase the efficacy and efficiency of data gathering including the comprehensive German Bee Monitoring Program (vanEngelsdorp & Meixner, 2010), the ALARM project in Europe (Murray, Kuhlmann, and Potts 2009), and the US research team on CCD (Meixner et al., 2010). The European Pilot Surveillance Project initiated in 2012 was granted 70% of data collection costs covered by the European Commission (OPERA, 2013).

In order to address a number of challenges related to bee health in Newfoundland, increased effective and standardized monitoring is a necessity recognized by beekeepers, government, and academics alike (anonym. pers. comm.; Williams, 2010). Such a monitoring program will be necessary for the creation of effective, science-driven policies; however, three factors stand as significant implementation barriers: lack of capacity (both industry and governmental), lack of provincial apiarist/bee specialist, lack of provincial registry of beekeepers. These barriers will need to be creatively overcome in order to initiate an effective bee health monitoring system in Newfoundland. Harmonizing such a monitoring methodology with national and international monitoring initiatives would also be a wise decision. That being said, very basic information and a commitment to share that information can be extremely useful. The recent creation of the NLBKA is testament to such commitment.

4.2-Support Programs:

Support programs for apiarists are a vital part of growing the industry, especially given the challenges faced by industry entrants. For example, Romania possesses a vibrant and widely recognized apiculture industry with favorable conditions for bee breeding. However, the cost of production often exceeds the revenue from sales in Romania, thereby necessitating considerable government support in the form of beekeeping production diversification, scientific research, and specialist training (OPERA, 2013). No specific provincial support programs currently exist for apicultural development in Newfoundland. In fact, with funding at approximately 10% of American levels, Canada's Atlantic apiculture industry in general is facing a shortage of support (AMEC, 2010). The implementation barriers identified in relation to a monitoring program also potentially stand in the way of support program creation. That being said, a small amount of funds for start-up equipment, training, and coordination can go a long way in promoting the growth of apiculture in Newfoundland if they are allocated appropriately. In order for programs to be successful, it will be important to further assess the profile of the industry, target operations with promising development potential, and examine the key barriers currently experienced by hobby and commercial apiaries.

4.3-Collaboration and Communication:

In the words of one interviewee, it is important that we "take a lesson from the hive." The incredible ability of a honeybee colony to act in cooperation towards a common goal is valuable inspiration for maintaining the sustainability of apiculture in Newfoundland. Collaboration and communication are key assets which will ease the efficiency and efficacy of monitoring programs, support programs, and policy implementation. This includes collaboration, cooperation and communication within and between researchers/universities, beekeepers (within and outside the province), farmers/crop-producers, governments, and the public. Education about the benefits of pollinator health and best management practices for all stakeholders could help to reduce conflicts and expedite the process of policy development and implementation. Effective sharing of information and resources will ultimately aid in maximizing the benefits of management schemes, research initiatives, and support programs.

4.4-Ecological Context:

This paper has so far focussed on factors influencing apiculture in Newfoundland, however little attention has been given to a much broader group of pollinators and the ecological importance of pollinators outside of agricultural and economic terms. Canada currently has no provincial or federal legislation with explicit mention of, or attention to native pollinators (Byrne & Fitzpatrick, 2009; Tang, Wice, Thomas, & Kevan, 2007). Blackburn (2012) criticizes policies dealing with pollinators and pollinator health to be examples of "honeybee centrism," or lacking more ecologically balanced approaches. There is a clear link between biodiversity and pollination (FAO, 2008). With a predicted global loss of 20,000 flowering plant species within the next few decades, pollinator declines have been clearly linked to increased ecosystem fragility (Allen-Wardell et al., 1998). In Newfoundland, only about 50 species of native bees have been identified and there is a recognized lack of knowledge about local pollinators (Hicks, 2011). In addition, the importance of pollinator "suites" over single species has been recognized for effective pollination of many crops including blueberries (Kevan, 1999). Without delving into the highly complex issues of pollinator interactions in ecological terms, suffice to say that full consideration of ecosystem effects should be taken into account to the maximum degree possible when developing policies, management plans and research initiatives.

5-Conclusion:

The island of Newfoundland occupies a unique place in the beekeeping world. It stands as a bastion of healthy hives, unadulterated by mites and other invasive pests and buffered from many externalities of unsustainable, intensive agriculture. Given these endowments, apiculture in the province holds significant scientific and economic research potential. Market assessment and development of specialty organic hive products within and outside the province could hold great economic possibility. Apicultural and related ecological research opportunities abound. Demand for pollination services in the province already exists and will grow with agricultural development. To capitalize on these opportunities, governments, research institutions, and the apicultural and agricultural industries will have to establish common goals, communicate information and share resources.

The current profile of the apicultural industry on the island is a key element which finds itself entangled in many of the other recognized factors and associated challenges. Despite the small survey sample size used for this research, it represents 23% of beekeepers on the island operating approximately 59% of the hives. Results from the questionnaire and interviews revealed a great deal of enthusiasm and innovation within the beekeeping community. However, growth in the small commercial facet of the beekeeping industry is questionable. Therefore, the sustainability of apiculture in Newfoundland hangs ultimately on the precarious nature of the industry profile. The opportunities discussed hold great potential; however, this potential cannot be realized unless beekeepers and crop growers on the island can be guaranteed a safe and certain supply of honeybees from season to season.

It will be vitally important that growth in apiculture in Newfoundland is strategically developed with consideration of the multiple factors interacting with industry size/profile. A number of important issues were not explored in this paper but warrant further research including the potential impacts of climate change and climatic interactions with other factors as well as market potential and the feasibility of product development possibilities and out-of-province honeybee sale. Despite these limitations, valuable areas of concern have been identified. Collaboration, communication, and an understanding of the key interactions between factors influencing bee health and sustainability on the island will all aid in effective allocation of resources towards a more balanced and independent beekeeping industry. If development and diversification occur, Newfoundland could grow from a hive of possibility into a considerable hive of activity given the opportunities presented.

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Appendix A— Questionnaire sent to beekeeping member of the NLBKA:

1) When did you begin bee keeping in Newfoundland?
2) How do you consider your scale of operation—*reminder that this information will be kept confidential*:
   a. hobby
   b. business
   c. potential business
3) What was your source stock and how many colonies did you begin with?
4) What is your current population? (in colonies)
5) Where are your colonies located? (general location is adequate—eg. nearest town)
6) How often do you re-queen?
7) What is your method of re-queening (if multiple, indicate the conditions which prompt specific methods)
8) If you acquire queens/eggs/nucs (specify which) from outside your operation, please indicate the source, strain (if available), and times of introduction
9) Do you actively pursue any form of honeybee breeding within your operation?
10) Do you intend to expand your operation within the next five years? If so, what are your objectives (eg. increase honey production, increase crop pollination, queen breeding, etc.) and goals (eg. pounds of honey/season, number of colonies, percent increase in pollination rate, etc.)—*reminder that this information will be kept confidential*.
11) If a honeybee breeding program were initiated in Newfoundland, what would be your level of interest and commitment in being involved? (eg. interested in development of breeding program and willing to contribute queens or drones for breeding or offer yard for cross-breeding with other stock).
12) What do you see as the largest challenges to the long-term sustainability of your operation?
13) What do you see as the largest challenges to the long-term sustainability of the Newfoundland honeybee population as a whole?
14) What do you see as the greatest opportunity in Newfoundland for the long-term sustainability of beekeeping?
15) Additional comments/thoughts:
16) I am willing to offer additional information via phone/e-mail
   a. Yes
   b. No

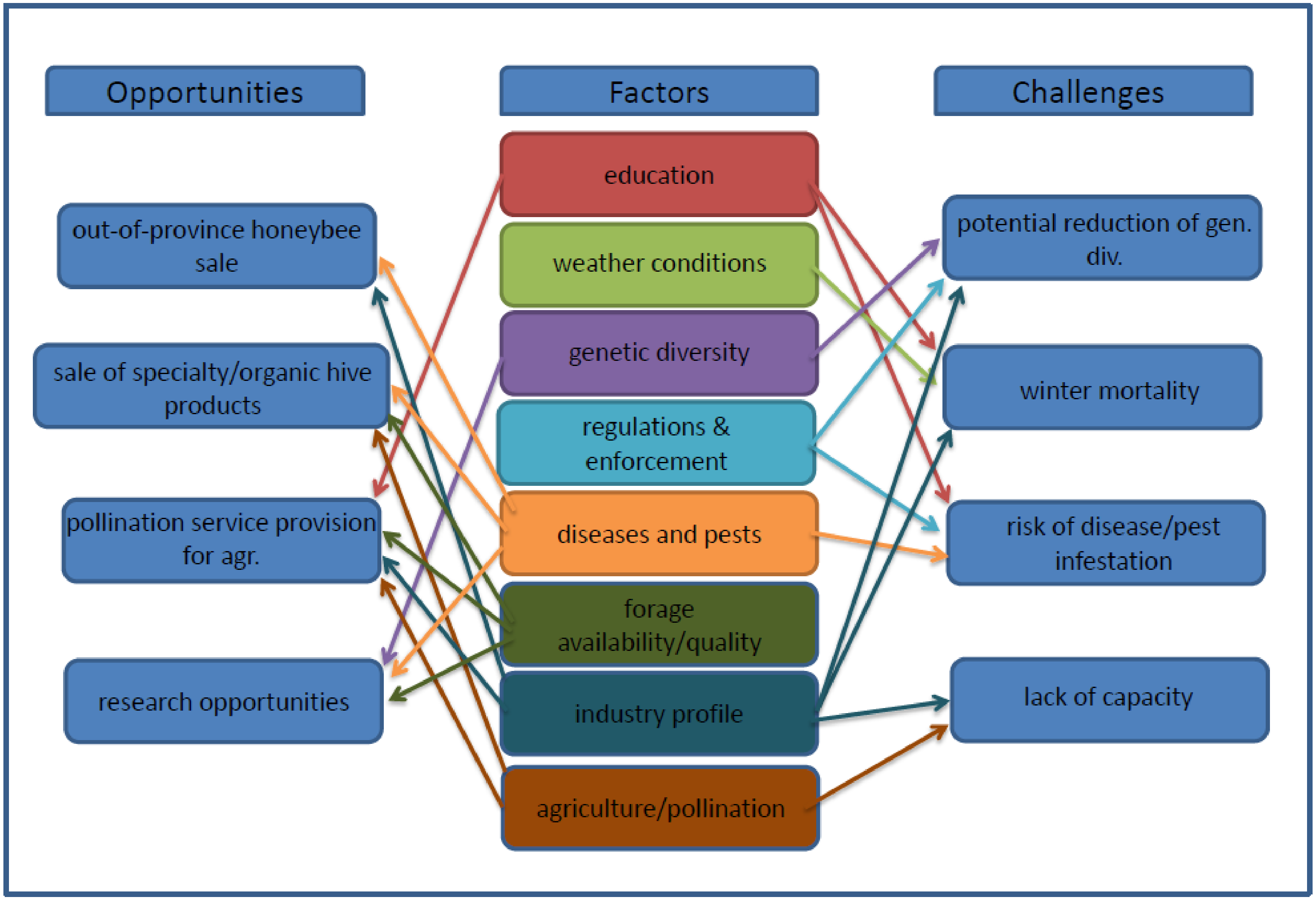
   Preferred method of contact: phone ____

   e-mail____

Appendix B—Newfoundland and Labrador Beekeepers' Association Aims:

1. Facilitate communication and cooperation among NL beekeepers and other interested persons.
2. Promote protection and preservation of NL honeybees; in particular their current status as free of diseases and pests such as *Varroa destructor*, etc.
3. Promote protection of bee ecosystems in NL including that of native/wild pollinators
4. Promote effective beekeeping practices by educating members and the general public.
5. Promote the expansion of beekeeping in NL
6. Provide a voice for NL beekeepers in communications with governments, the NL Federation of Agriculture, beekeeping associations elsewhere in Canada, etc.
7. Systematic monitoring of beekeeping productivity, honeybee health, and other information of relevance to bees and beekeeping in Newfoundland and Labrador
8. Promote scientific research that will support the activities outlined above.

Appendix C—Opportunities and challenges facing the sustainability of apiculture in Newfoundland and their interactions with influencing factors



*note—arrows indicate direct/primary interactions only