

**The Effects of Supplemental and Substitutional Bee Food on
the Common Eastern Bumblebee (*Bombus impatiens*)**

by

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A Major Paper

submitted to the Faculty of Environmental Studies

in partial fulfillment of the requirements for the degree of Master in Environmental Studies

York University, Toronto, Ontario, Canada

21/07/2018

Foreword

The work that I have undertaken has connections to main areas in my Plan of Study such dealing with current wildlife conservation and management projects. Bumblebee nutrition is a subject that is extremely important as it is directly connected to the health and survival of bumblebee species around the world. Nutrition will only become more crucial, especially as some species of bumblebee may have to be reared in captivity in order to conserve the species and be reintroduced to their native habitats in the future. This is where nutrition will come into play, as it will have a large part in the design of bumblebee conservation and management. These projects play an extremely important role in species conservation efforts and will only continue to be crucial to the long-term survival of those bumblebee species which are in decline. This is how my work determining the effects of supplemental and substitutional bee food is directly connected to my Plan of Study specifically dealing with current wildlife conservation and management. My findings could impact what is fed to bumblebees which are used in captive breeding conservation programs.

Abstract

This study was undertaken to determine the effect of supplemental and substitution bee food on the common eastern bumblebee (*Bombus impatiens*) compared to what is most commonly fed to captive bumblebees now, which is honeybee pollen. There is not an extensive amount of knowledge about the effects of supplemental or substitutional bee food and whether or not what is fed to bumblebees can have an effect on their overall success and health. Three different test groups of micro-colonies of bumblebee each with ten replicants were set up in order to test this; each were fed a different bee food: (i) 100% honeybee pollen (P), (ii) a supplemental bee food (GP) and (iii) a substitutional bee food (BP). Over the test period it was discovered that bumblebees which were fed 100% honeybee pollen consumed between 63-73% more food than those fed a supplemental or substitutional food. It was also found that there was a relationship between what is fed to bumblebees and their success, in this case the amount of eggs they laid. Those bumblebees which were fed 100% honeybee pollen (P) and those that were fed a supplemental food (GP) had comparable amounts of eggs laid; P laid 121 eggs and GP laid 112

eggs). This is despite the fact that the bees in test group GP ate 66% less food than those bees which ate 100% honeybee pollen and yet they produced a comparable amount of eggs over the course of the experiment. The amount of supplemental food eaten by GP could be compared to the amount that was eaten by those bees fed a substitutional bee food (BP) as the two test groups ate a similar amount of food. GP only ate 16% more food compared to BP. However, the amount of eggs that each of the groups laid was vastly different with bumblebees that ate a supplemental diet (GP) laying 112 eggs in total and bees fed a substitutional bee food (BP) only laying 2 eggs in total over the experimental period. These findings suggested that supplemental food may be a comparable alternative food to be fed to captive bumblebees instead of what is most commonly fed to them which is honeybee pollen.

Introduction

Bumblebees (genus *Bombus*) as a pollinator group are both ecologically and economically important in temperate regions as more than 4000 species of bees are native to North America (Singh *et al.* 2010). For example, non-*Apis* bees are used for commercial agriculture around the world and may be responsible for more than \$3 billion of produce grown in the USA (Potts *et al.* 2010). At the same time many bumblebee species and other pollinators face population decline around the world (Singh *et al.* 2010, Potts *et al.* 2010). A number of anthropogenic pressures are to blame such as: land-use intensification, climate change, the spread of alien species, diseases, and lack of food sources (Vanbergen *et al.* 2013). All of these pressures are having an impact on pollinator health, abundance, and diversity. Among those anthropogenic pressures which are having negative impacts on bumblebee species poor nutrition is thought to be a major factor causing bumblebee declines around the world (Vaudo *et al.* 2015). Nutrition is key for bumblebees as it is directly connected to survival, health, success, growth, reproduction and the size of bumblebee populations (Pelletier & McNeil, 2003 Vaudo *et al.* 2016). Nutrition is crucial in part because many bumblebee species are used in laboratory settings, especially in experiments and it is important that they are receiving the correct nutrition and care. Nutritional knowledge is also important when dealing with captive bumblebees as some species of bumblebee may need to be bred in captivity for reintroduction purposes as well as conservation.

It has also recently been found that honey bee pollen can harbour ribonucleic acid (RNA) viruses as well as micro and macro parasites which can negatively affect the health and survival of bumblebees (Graystock *et al.* 2013, Singh *et al.* 2010, Peng *et al.* 2011, Genersch *et al.* 2006).

The objectives of this study were to better understand bumblebee nutrition and discover if there was a correlation between what bumblebees were fed and the success and health of the colony, as well as if there are possible alternative food sources for captive-bred bumblebees which will provide adequate nutrition. This will be done by evaluating experimentally the effects of different bee foods on the development and success of bumblebee micro-colonies, and to determine whether micro-colonies with different types of bee food were able to be more successful than micro-colonies fed the standard bee food that is currently most popularly used in laboratory settings, honeybee pollen.

Bumblebee nutrition & why pollen is important

Like all other animals, bumblebees need the right amount and composition of resources to raise their brood and to maintain colony health (Brodschneider & Crailsheim 2010; Keller *et al.* 2005; Khoury *et al.* 2013). Proteins and carbohydrates, and to a lesser extent lipids, represent the most important macronutrients for bumblebees (Friend, 1958). Carbohydrates provide the basic energy needed for all metabolic processes, while proteins provide amino acids that are used for the animal's own protein biosynthesis (Campbell, 1997). Bumblebees obtain all of these nutrients from pollen and nectar provided by flowering species of plants (Keller *et al.* 2005).

Pollen consists of macronutrients like proteins, lipids, minerals and vitamins, and is a bumblebee's main source of protein (Keller, Flurry & Imdorf 2005; Roulston & crane 2000). An important characteristic of pollen is that its protein concentration is positively correlated with larval development and adult reproduction; particularly ovarian development and egg laying (Vaudo *et al.* 2015). If there is a shortage in pollen and therefore the protein concentration is poor larvae will not grow and adults will not reproduce (Pelletier & McNeil, 2003; Vaudo *et al.* 2015). Bumblebees are also sensitive to the quality of pollen which is highlighted in a study by Leonhardt & Blüthgen (2012) where they found that bumblebees generally collected pollen which had a significantly higher pollen protein content which in turn also contained more

essential amino acids. This ability helps some species of bumblebee selectively forage among plant species in order to hone their diet and really focus on the nutritional needs of the colony, which is something that is unique (Vaudo et al. 2015). Lipids are crucial for a variety of physiological processes in bees like: egg production, wax production, secondary energy source (Vaudo et al. 2015). Lipids also contribute to larval and adult health, development, and overwintering (Vaudo et al. 2015). Linoleic acid (omega-6), is an essential fatty acid which has been associated with higher worker production in some bee colonies (Vaudo et al. 2015). Sterols, which are only obtained from pollen, are the precursors for molting hormones, which is essential for larval development (Vaudo et al. 2015). Bumblebee colonies are quite sensitive to pollen. It has been discovered that significant decreases in pollen protein in a colony result in bees foraging more, demonstrating just how crucial pollen is to a colony (Vaudo et al. 2015).

Effects of an imbalanced diet on bumblebee health

Bumblebees have a high metabolic activity when compared to their energy stores, and as such they are prone to suffering from imbalanced diets if nutrients are provided in excess or deficient amounts (Ruedenauer et al. 2015). There have been a number of studies exploring the consequences of an imbalanced diet either in excess or deficient amounts fed to bumblebees and honeybees. Pollen is not only essential to ensure the long-term survival of a colony but is also necessary for queen vitality, brood production and development (Keller, Flurry & Imdorf 2005). Bumblebee larvae receive all the fats, minerals, proteins, and vitamins that are necessary for growth through the pollen that is collected by adult bumblebees (Vaudo et al. 2015). Pollen availability has been directly linked to the success and growth of colonies in several studies. For example, an experiment by Pelletier & McNeil (2003) dealt with the effect of food supplementation on reproductive success in bumblebee colonies in the field (Pelletier & McNeil 2003). They found that those colonies whose nectar and pollen was increased regularly throughout the season reached relatively larger sizes and had a higher reproductive success than the control (Pelletier & McNeil 2003). It was found that food supplementation increased the number of males produced and the probability of producing gynes, which are young queens (Pelletier & McNeil 2003). The results from the study propose that colonies ensure reproduction

by producing some males, and combined with opportunity and availability of food, the colony will produce gynes (Pelletier & McNeil 2003).

It has also been demonstrated that the amount of brood rearing is reduced when colonies are experiencing a lower level of pollen intake and in turn a lower protein diet (Somerville 2005). In contrast, when there is an abundance of high quality pollen it will increase the chances of the maximum amount of brood being reared and adult bees will live longer (Somerville 2005). Likewise, it was found that adult bees and larvae performed better on higher sugar concentrations (Kaftanoglu et al. 2011).

It is also true that the essential amino acids from protein are required in specific amounts in order to complete a bumblebee's normal growth and development (de Groot 1952). This was shown in a study by Tasei & Aupinel (2008) where it was found that bumblebee larvae fed with a polyfloral blend of pollen were heavier than larvae fed with monofloral pollen diets of higher protein content. This means that low pollen diversity represents a major limiting factor for bumblebee's development, and that a polyfloral diet may increase the amount and diversity of the specific proteins and amino acids which are required for bumblebee development (Alaux et al. 2010; Tasei & Aupinel 2008).

Low diversity of floral plants in the wild has been noted as one of the major causes of bee decline, and because of this one of the main actions in many bee conservation strategies recently is promoting a high diversity of resources (Biesmeijer et al., 2006; Dicks et al., 2013; Goulson et al., 2015). However, some of these conservation strategies have not taken into consideration the quality of the flowering plants which they are planting (Dicks et al., 2015; Vaudo et al., 2015). Field studies have questioned these strategies by showing that pollinator diversity is not always positively influenced by the plant diversity which is being put forward in these conservation measures (Wood et al., 2015). For example, the results by Moerman et al. (2017), who used micro-colonies of bumblebees (*Bombus terrestris*) to see if the bees could better develop on single or mixed pollen diets (Moerman et al. 2017). Through this study it was found that the chemical makeup of pollen was more important than the diversity of pollen for bumblebee development (Moerman et al. 2017). Therefore, the chemical components of pollen should be looked at in greater detail if a *Bombus* species is to be conserved as there is obviously more specific nutritional requirements than just diversity of flowering plants which help bumblebees

grow and succeed in the wild (Moerman et al. 2017). It is also important to note that different pollinator species have different nutritional requirements and more research is needed in order to find out what the nutritional requirements are for these species (Behmer, 2009; Moerman et al. 2017).

Viruses & parasites

As social insects, bumblebees live in compact, highly organized, productive colonies, and it is this social organization and the close interactions among colony members which make them highly susceptible to a variety of infectious diseases (Singh *et al.* 2013, Graystock *et al.* 2006). Today, viral pathogens and parasites are emerging as a serious threat to bumblebee health and survival (Graystock *et al.* 2013, Singh *et al.* 2010, Peng *et al.* 2011, Genersch *et al.* 2006). Another worrying emergence is that there has been the discovery of pathogen spillover from honeybees to other pollinators, like the bumblebee, and researchers have found that a number of viruses classified as honeybee viruses can infect other pollinators (Graystock *et al.* 2013, Singh *et al.* 2010, Peng *et al.* 2011, Genersch *et al.* 2006). Symptoms of the infections of these different viruses in honeybees and other pollinators range from deformed wings, discolouration, hair loss, bloated abdomens, trembling, paralysis, and brood and adult mortality (Singh *et al.* 2010). The full impact on bee behaviour and health by these different viral infections is not fully understood but could have serious consequences for the survival of the colony (Singh *et al.* 2010).

Graystock *et al.* (2013) found that pollen can be infected with a number of diseases which are infectious to bumblebees and have a significant negative effect on their health. The parasites found included three specialist parasites of bumblebees (*Apicystis bombi*, *Crithidia bombi* and *Nosema bombi*) along with two parasites (DWV and *N. ceranae*), which can infect both bumblebees and honeybees (Graystock *et al.* 2013). Pollen is an important component of bee nutrition that can enhance disease resistance (Foley *et al.* 2012), but the literature shows that it can carry parasites as well as viruses and can be hazardous to bees as well (Graystock *et al.* 2013, Singh *et al.* 2010, Peng *et al.* 2011, Genersch *et al.* 2006).

Previous research into bumblebee nutrition and disease highlights the need for more research into these topics in order to have healthier and more successful bumblebee colonies in captive settings.

Alternative food sources to feed to captive colonies of bumblebees

It is clear that pollen plays an extremely important role in the growth and size of bumblebee colonies and because of this supplements or substitutions of pollen can be used when pollen production of a colony is not sufficient, colonies experience pollen shortages, or when pollen sources have not become fully available yet (British Columbia Ministry of Agriculture 2015). A pollen supplement is a formula that also contains natural pollen while a pollen substitute is a complete replacement of pollen (British Columbia Ministry of Agriculture 2015). There are various pollen substitutes and supplemental feeding formulas commercially available and the most common ingredients include: brewer's yeast, torula dried yeast type s, soybean flour + dried brewer's yeast (British Columbia Ministry of Agriculture 2015). The success rate of supplements or substitutes of pollen is virtually unknown and the reasons for this are numerous, but probably include the lack of attractiveness of the product, the cost, limited knowledge of where, when and how much to feed each colony as well as the lack of evidence that the supplemental or substitutional food works and is beneficial to feed colonies (Somerville 2005).

My research aims to fill in the gap of knowledge about the use and effects of these supplemental and substitutional foods on micro-colonies of bumblebees. The specific questions that are guiding my research are: (i) Is there a connection between what is fed to captive bumblebees (e.g. honeybee pollen, supplemental or substitutional bee food) that has an impact on the success of the colony (e.g. number of eggs laid) (ii) Is there one bee food that is most beneficial to feed to captive colonies of bumblebees (e.g. decrease in mortality, more eggs laid) (iii) Are there problems with the food that is most commonly fed to captive bumblebee colonies (e.g. honeybee pollen) which impacts colony success (iv) Is there evidence of an association between pollen and viruses and/or parasites which are able to be transmitted to bumblebees? (v) Is there a better food source to feed captive bumblebees in the lab that will increase their success besides the most commonly fed food source (e.g. honeybee pollen)? It is an area of research that

needs to be explored further as it connects to many different aspects of survival for bumblebees and could be key for saving them in the long-term.

My research will also provide more information about the use and effects of supplemental and substitutional bee foods produced by the companies Global Patties and MannLake. Each of these brands have various claims about what their product will do when fed to colonies of bees and my micro-colony experiment will try to see if these claims are supported and if there is one type of bee food that stands out from the rest providing an adequate nutrition to bumblebees in a lab setting. Some of the claims made by the supplemental and substitutional foods used in this experiment are as follows:

Supplemental bee food - Global Patties 50% pollen:

Global Patties claims that feeding their patties to your colony will ensure colony health, maximum build-up and maximum production for the entire year, and reduce losses and dwindling the following winter (Global Patties 2018). Patties ensure a balanced diet when bees are: unable to forage due to weather, short of stored pollen, in monoculture areas where only a few pollen sources are found, too weak to forage, subject to competition from stronger hives in the yard, stressed by weather, pesticides, mites and diseases (Global Patties 2018). All pollen in their formula is carefully electron-beam irradiated by Iotron for disease prevention (Global Patties 2018). This could be an important factor when taking into consideration many bumblebee diseases and parasites have been found in honeybee pollen and could make a difference in the health of the bees which you are feeding this product. It could also give people more peace of mind that this product is safer to feed to their colonies of bees over other supplemental food.

Substitutional bee food - Bee-Pro Patties+:

Bee-Pro Patties+ claim that they are a great food source with the added bonus of Pro Health. MannLake (2018) describes Pro Health as a digestive health aide that also encourages increased consumptions of patties and medicated feeds. Bee-Pro Patties+ have many benefits

such as: balanced nutrition, not weather dependent, early brood production, and an increased bee population (MannLake 2018).

Methods

Obtaining and Maintaining the Common Eastern Bumblebee (*Bombus Impatiens*)

The study was conducted over twenty-one days from April 22nd 2018 until May 13th 2018 with thirty laboratory micro-colonies of the common eastern bumblebee (*Bombus impatiens*). Micro-colonies of bumblebees were used because they are most commonly used in food experiments and are a reliable experimental method (Moerman et al. 2017). The bumblebees used in this experiment were obtained from commercial bumblebee breeders BioBest Canada Ltd.; purchased through Plant Products (Leamington, Canada). The bumblebees were delivered in a plastic cage set in a cardboard box ready for placement. The bumblebees had already emerged by the time they were delivered to me so I was unsure of the exact ages of the bees; nor did I know the genetic details of the bumblebees.

The micro-colonies of bumblebees were then transferred from the plastic BioBest cage into 16 oz. Freshware, food-to-go packs which are BPA free. The containers measured 38.1 x 38.1 x 30.5 cm (LxWxH) and thirty to forty 11/64 inch holes were drilled into the sides and top lid of the containers for ventilation and air flow. The bottom of the micro-colony containers were covered by green bristol board. Each container housed four *Bombus impatiens* workers, standard for a micro-colony (Moerman et al. 2017).

There were three test groups in total for this study each with ten replicants. Each test group was fed 1 gram of bee food. A measurement of 1 g was chosen to be fed to the bees as I based some of my research on past work done in the field of bee food experiments such as those done by Graystock et al. 2006 and Konzmann & Lunau 2014. The first test group (P) was fed 100% honeybee pollen sources from BioBest Canada Ltd., the second group (GP) was fed a supplemental bee food sources from Global Patties and the third test group (BP) was fed a substitutional bee food called Bee Pro Patties+ sourced from MannLake. All of the test groups of bumblebees were fed a 1:1 solution of sugar which was delivered *ad libitum* using one 1.5 mL

ependorf tube which was inserted into the side of the container at a level which the foraging bumblebees were comfortably able to feed from standing on the ground.

Monitoring Bee Food Consumption

Measurements

A number of measurements were taken every day or every four days, depending on the measurement, in each of the bumblebee colonies.

The measurements that were taken every day were as follows: date, time, temperature (degrees Celsius), humidity (%), number of bees in the container, deaths, observations about the individual micro-colony's behaviour and finally comments about the test group overall.

Observations about the individual micro-colony or the test group overall included if there were observed expressions of visible disease or parasite symptoms such as: abnormal behaviour, trembling, deformed wings, discolouration, hair loss, bloated abdomens or paralysis (Singh et al. 2010).

The measurements which were taken every four days were the ones dealing with how much food was given (i.e. honeybee pollen, Global Patties bee food supplement, and Bee-Pro Patties + substitutional food) and how many eggs are laid in the four day period in each of the test group replicants. The measurements that were recorded dealing with food were as follows: weight of the food given (will always be 1 gram (g)), weight of the food after four days (g), how much food is eaten (g) after four days, and finally if sugar solution was given yes or no (Y/N). Weights of remaining food were measured using an electronic precision balance scale. The number of eggs laid after four days was also recorded. These measurements were taken as the old food was replaced with a new 1 g ball of food depending on the treatment groups assigned food type.

If there were any deaths in the micro-colony groups the dead individual was removed from the container and placed into a 1.5 mL ependorf tube; which was labelled with the micro-colony ID number as well as the date the individual died. The ependorf tube was then placed into the freezer in case later dissection was needed.

It is important to note that some of these measurements were subjective, but not arbitrary, and were less disruptive to the bumblebees, which preserved social cohesion and the health of the experimental colonies while still being an acceptable technique. This is important as I did not want to disrupt the colonies while this bee food experiment was performed as it could have impacted the results.

Statistical Analysis

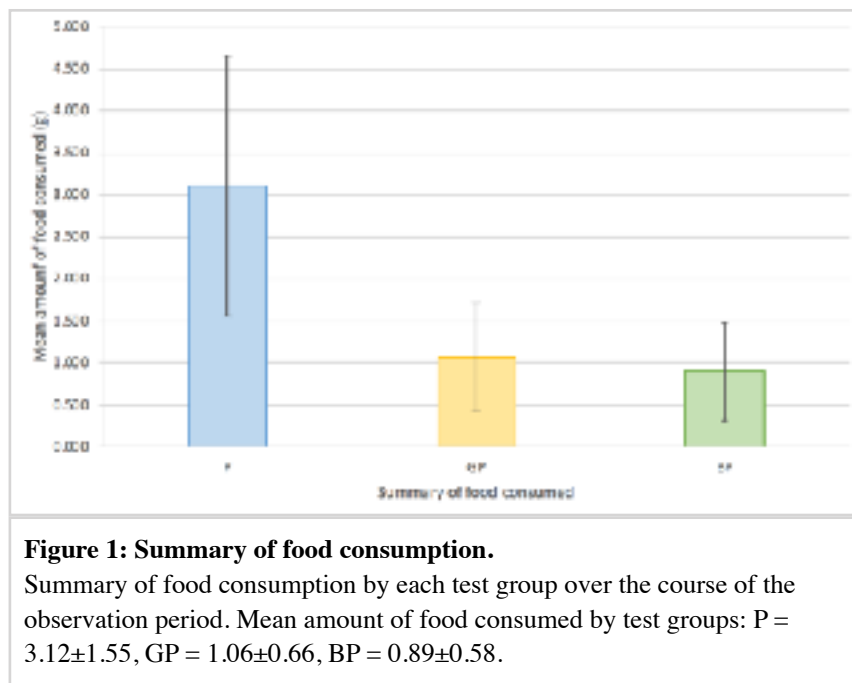
My research aims to discover if there is a connection between what is fed captive bumblebees and their overall health and success. A number of measurements and observations were taken every day in each of the micro-colonies. This was done in conjunction with a number of statistical comparisons between the amount of food consumed, the number of deaths and the amount of eggs laid. This was done in order to determine if there was statistically significant differences between the three test groups.

These measurements were analyzed using a statistical tool, the Kruskal-Wallis or H test. A Kruskal-Wallis is a rank-based nonparametric test that can be used to determine if there is a statistical significant difference between two or more groups of an independent variable on a continuous or ordinal dependent variable (Lund Research Ltd. 2018).

Results

Feeding

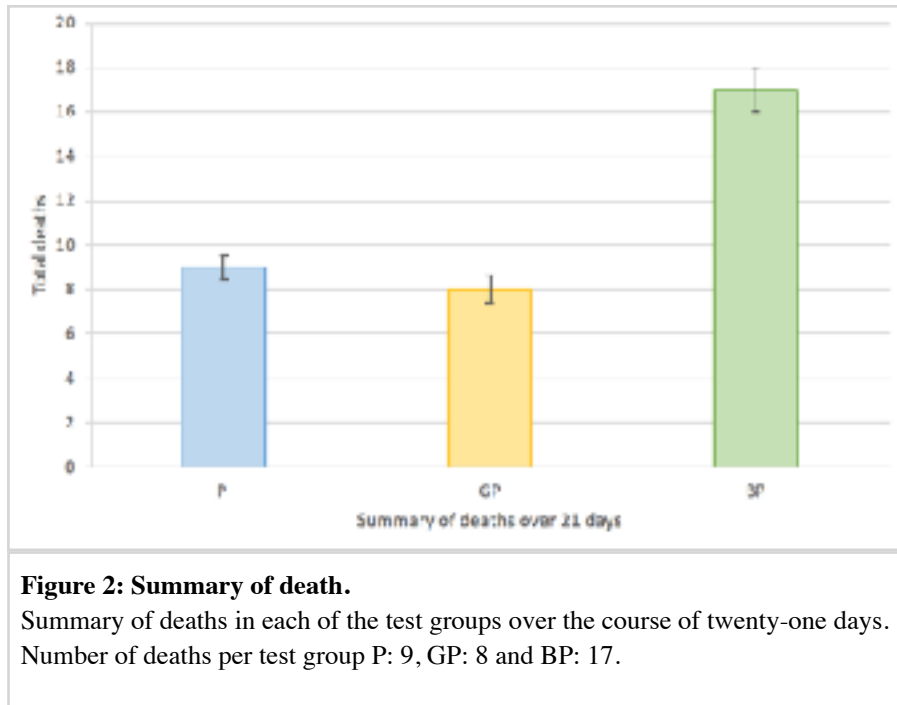
After measuring the food consumption of each test group every four days it was found that bumblebees consumed more food when fed a diet of 100% honeybee pollen (P) (18.641 grams in total), supplemental food (GP) was second (6.361 grams) and substitutional food (BP) was last (5.353 grams) (**Figure 1**).



There was a correlation found between what was fed to micro-colonies of bumblebees and how much food they consumed over the experimental period. It was shown, using a Kruskal-Wallis test, that groups P, GP and BP had statistically significant differences based on what each of the test groups were fed ($H(2) = 20.286$, $p = 0.000$), with a mean rank of 13.6 for P, 8.2 for GP and 6.7 for BP. The main finding is that bumblebees which were fed 100% honeybee pollen (P) consumed 60% more food than the other groups fed a supplemental (GP) or substitutional (BP) bee food.

Feeding and Survival

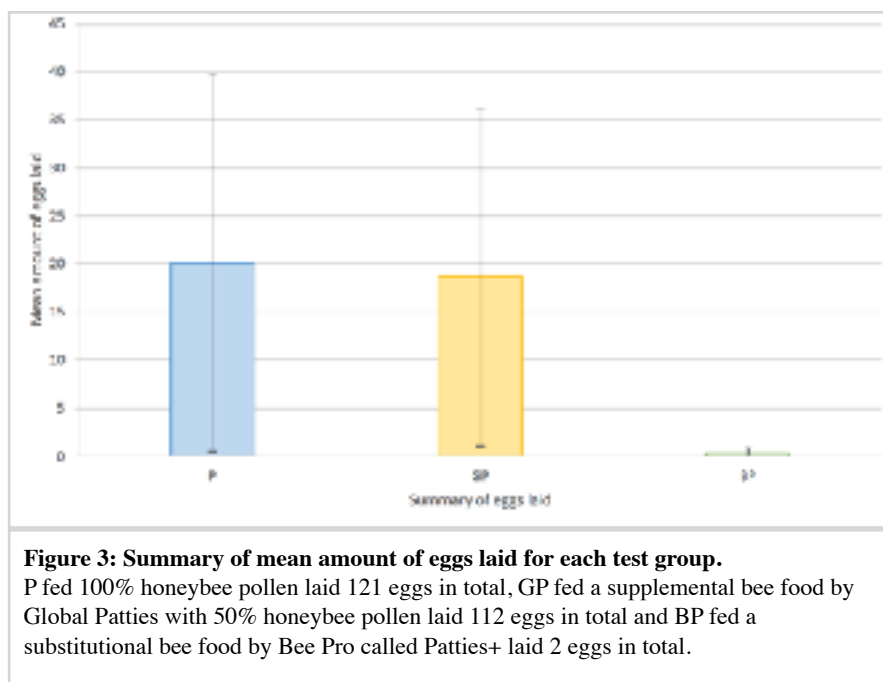
After each test group was observed over twenty-one days it was found that the most deaths occurred in those bumblebees being fed a substitutional food (BP) with 17 total deaths. Those bees fed 100% honeybee pollen (P) and those bees fed a supplemental food (GP) had very similar results death rates (**Figure 2**). None of the individuals which died during the test period in any of the test groups exhibited physical or behavioural signs of disease or parasitism before or after their deaths.



It was shown that over twenty-one days of observation that there was not a significant relationship between what type of food was fed to each test group of bumblebees and their overall survival. (Kruskal-Wallis test ($H(2) = 5.51$, $p = 0.063$), with a mean rank of 13.4 for test group P, 12.3 for GP and 20.8 for BP).

Feeding and fecundity

It was found that those bees fed 100% honeybee pollen (P) laid the most eggs over the test period (121 eggs), supplemental food (GP) laid the next largest (112 eggs) and those bees fed a substitutional food (BP) laid the least amount (2 eggs) (**Figure 3**).



There was a correlation found between what was fed to micro-colonies of bumblebees and the number of eggs laid (Kruskal-Wallis test ($H(2) = 15.36$, $p = 0.000$), with a mean rank of 21.1 for P, 18.7 for GP and 6.7 for BP).

Discussion

It is not surprising that poor nutrition is thought to be a major factor causing bumblebee declines around the world (Vaudo et al. 2015). Nutrition is key for bumblebees as it is directly connected to survival, health, success, growth, reproduction and the size of bumblebee populations (Pelletier & McNeil 2003; Vaudo et al. 2016). These are all aspects connected to nutrition that need to be taken into consideration if some species of bumblebee had to be bred and raised in captivity to ensure their survival and release back into the wild later on. This is why alternative food sources are emerging as an option to be fed to captive bumblebees.

Supplemental and substitutional bee foods have been around for a number of years but not much is known about them (British Columbia Ministry of Agriculture 2015). There have been some studies on the effects of supplemental bee food being fed to wild populations of

bumblebee, but there is not a large body of work on the subject (Pelletier & McNeil 2003). The claims that supplemental and substitutional bee food make are quite compelling and make them an attractive alternative to the most common food source fed to captive bumblebees which is honeybee pollen. Claims such as: decreased risk of disease and parasitism, increased health, reproduction and success, increased consumption of the bee food and finally a balanced diet (Global Patties 2018; MannLake 2018). These are all claims which are especially important now as bumblebee populations are facing many challenges due to what they are most commonly being fed; honeybee pollen but they are not ones that have been tested throughly to see if they hold merit (Graystock et al. 2006; Singh et al. 2013).

The research that was undertaken demonstrated some of the effects that these alternative food sources had on micro-colonies of bumblebee and builds upon the research done by Pelletier & McNeil (2003). It was found that there was a significant relationship between what was fed to captive bumblebees and the success of the colony overall, in the form of the amount of eggs laid. It was found that a supplemental food containing 50% pollen manufactured by Global Patties was the most comparable to the test group P fed 100% honeybee pollen, which is the food that is most commonly fed to captive bumblebees. Based on the results gathered a supplemental food containing 50% honeybee pollen was the most beneficial to be fed to captive micro-colonies of bumblebee as it had similar rates of success in the number of eggs laid. Another finding is that bumblebees which consumed the supplemental food ate less than those bumblebees in the group fed 100% honeybee pollen. This finding could have significant implications for conservation costs if you were able to feed less food to captive colonies of bumblebees using the supplemental bee food and still have comparable results to those that are fed 100% honeybee pollen. It could mean that the money saved on food could be used in other aspects of a conservation program that needed more attention. Based on the results of this experiment the supplemental bee food manufactured by Global Patties containing 50% honeybee pollen is a comparable alternative to what is most commonly fed to captive bumblebees which is 100% honeybee pollen.

Some of the results of this experiment were not expected when it came to looking at the connection between food consumed and death rates in the micro-colonies of bumblebee. It was found that what food was consumed and the number of deaths was not statistically significant in any of the test groups. While the correlation was not supported I believe that a more extensive study period is needed in order to determine if this is in fact the case that death and what type of

food is consumed is not related. This is because the bumblebees in test group BP fed a substitutional bee food containing no natural pollen died at a more significant rate than those bumblebees fed 100% honeybee pollen (P) or those bumblebees fed a supplemental bee food (GP). BP had seventeen deaths in total over twenty-one days which is 1.8 to 2 times the rate of death when compared to bumblebees in test groups P and GP. This supports that the substitutional bee food had a sublethal effect on those bumblebees in BP which were fed this alternative food source. While it was not a lethal effect it was still significant and a longer experimental time would help to understand why there was a sublethal effect on bumblebees who were fed a substitutional bee food.

The results gathered in this experiment contribute to the knowledge that is currently published dealing with the effects that alternative food sources have on bumblebees and will hopefully lead to a further understanding of bumblebee nutrition and the effects of alternative bee food on bumblebees.

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