Barriers and Strategies to Integrating Native Bee Habitats in Bay Area Farms

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ABSTRACT

Pollination is essential to ecosystems, economies, and food security. As honey bees are often the most important pollinator for many crops, their precipitous decline should be a major cause for concern. However, native bees are a reliable and more sustainable alternative to honey bees because they are more readily available, cheaper to manage, and less labor intensive. Native bee populations require a consistent and diverse supply of plants for sustenance as well as sufficient undeveloped land for burrowing. Crop farmers can provide a crucial role increasing native bee habitats as their cyclical crop growth process attracts pollinators. While there are research studies and resources dedicated to informing farmers about implementing native bee habitats, current worldwide agriculture trends indicate deterioration of agro-ecosystems and habitats, which means less naturally occurring services such as native bee pollination. In this research, I conducted a series of interviews and surveys with Bay Area farmers and farmer advisors to analyze barriers in implementing native bee habitats and strategies to overcome these barriers. This research identified that the two most effective strategies in implementing native bee habitats are the opportunity for one-on-one technical assistance and the interaction with a network of farmers with already-operational native bee habitats.

KEYWORDS

native bee populations, wild bee practices, pollinator habitats, sustainable pollination, farmer partnerships, collaborative research

INTRODUCTION

Bees are considered the best and most efficient pollinators in a majority of crops worldwide (Delaplane et al. 2000). They are publicized and researched more than other pollinators such as wasps, flies, butterflies and moths, beetles, bats, birds, and any other animal that has the capability of transferring pollen with their body. Bees heavily rely on nectar and pollen for survival, which motivates them to travel greater distances and visit more flowers compared to other pollinators that have other sources of nutrients and sustenance (Delaplane et al. 2000). They also have physical characteristics that have been adapted to different plants morphologies, allowing them to visit more plants and collect a wider variety of pollen than other pollinators (Delaplane et al. 2000). All organisms –-including humans— have adapted to make use of benefits such as "nourishment and shelter" from flowering plants that bees are responsible for pollinating (Frankie et al. 2014). Studies have shown that without bees there would be a substantial decrease in bee-supported food crops, which are a major source of both income and sustenance (Delaplane et al. 2000). It has been estimated that one-third of the human diet can be directly or indirectly linked to bee pollination (Delaplane et al. 2000). Therefore, crops pollinated by bees comprise an important component of a well-balanced and varied human diet (Kremen et al. 2002).

Recent research has demonstrated that, in comparison to honey bees, native bees are the most sustainable and beneficial option for farmers because they contribute to increased crop pollination, yields, and profits (Vaughan et al. 2015). Native bees are also more widespread and naturally available, more cheap to manage, and less labor intensive (Vaughan et al. 2015). However, native bee habitats are severely impacted when land is developed for urban, industrial, or agricultural purposes, leaving the bees with no nesting or feeding areas, which drastically drives down their population size (Moisset 2011). Farmers can assist in increasing the numbers of native bees while simultaneously benefitting their own crops by installing plants that provide these nesting and feeding areas for beneficial insects (Kremen et al. 2002).

However, with all the information regarding the benefits of native bees and the most effective steps for increasing their habitats, not much action has been taken by farmers to preserve or install native bee pollinator habitats on their farms. Farmers in commercial agriculture still depend primarily on managed honeybees, even though scientists have found that native bees are the more sustainable and cost-effective option for current agriculture practices and long-term

benefits (Holl et al. 2013). This could be due to a variety of factors: the lack of reputable sources of information, lack of knowledge on native bees and their benefits, lack of marketing and popularity among their social networks, lack of policy and incentives, lack of structural resources such as labor and money, or lack of perceived necessity to incorporate native bee habitats.

LITERATURE REVIEW

Theoretical Framework

The way that I will be approaching this study is by trying understanding how to apply the scientific research to real-life problems and their on-the-ground efforts (Keeler et al. 2017). I want to form "authentic partnerships with individuals and communities [so they] can also expand the frontiers of traditional disciplines, leading to new insights. At the same time, reframing environmental problems in terms of their impact on people will broaden the uptake of research, attract new partners, and increase media coverage" (Keeler et al. 2017). If we truly want to move toward sustainability and resiliency in our society, researchers need to be collaborating with their partners. Instead of purely analyzing, "academia must link our work with stakeholders in ways that elicit significant action. This is especially important, since guiding the planet for the future will likely require some fundamental changes — not just in human economic and governance systems, but also in societal values" (Barnosky et al. 2016). I communicated with farmers and farm advisors to understand their current knowledge, their concerns, and what they would need from researchers in order to install native bee habitats.

Site Description

In 2014, the total crop value in the United States dependent on bee pollination was more than $24 billion a year (Office of the Press Secretary 2014). Therefore, a drastic decline of bee populations will threaten both the U.S. agricultural and economic systems. From 2008 to 2013, wild bee abundances decreased around 23% in the United States (Koh et al. 2016). With these trends, more than 700 North American bee species are headed toward extinction (Worland 2017). As seen in Figure 1, 139 counties are at supply risks due to decreasing wild bee abundances and

increasing crop pollination demands (Koh et al. 2016). As seen in Figure 2, from 2016 to 2017, around 33% of honey bee colonies were lost in the United States between 2016 and 2017, which despite being lower than previous years is still above 30% loss, an indicator of poor honey bee health (University of Maryland 2017).

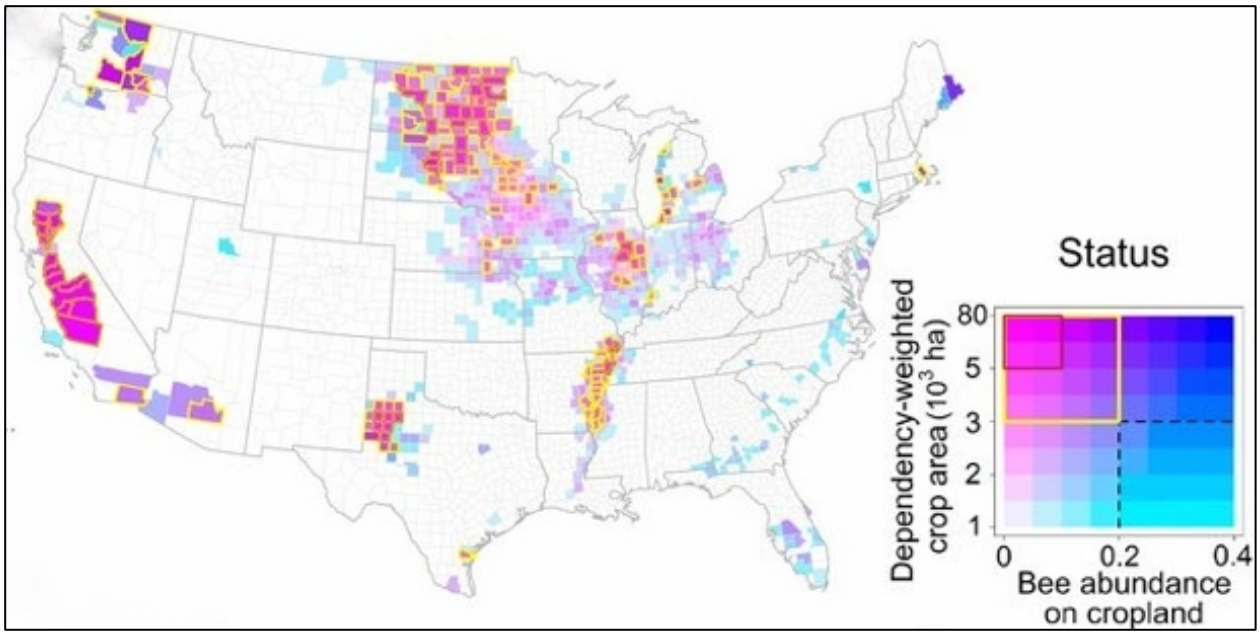


Figure 1. U.S. map of agricultural risk. This is a map of the United States highlighting 139 counties in 2016 facing agricultural risks due to decreasing wild bee abundance and increasing crop pollination demand (Koh et al. 2016).

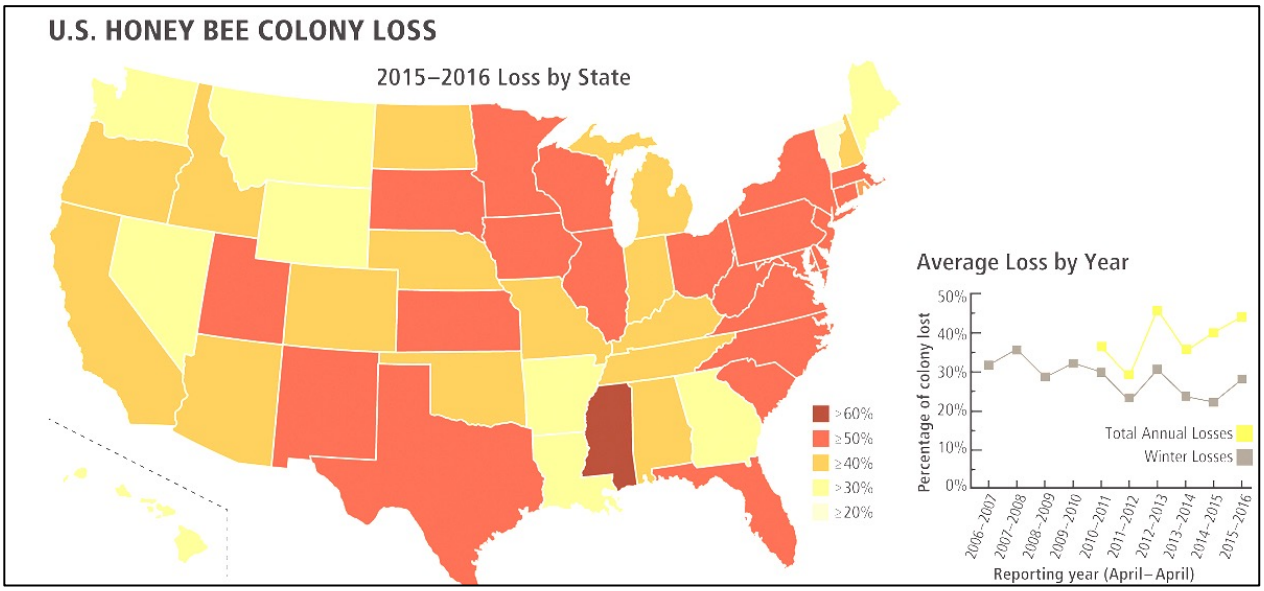


Figure 2. U.S. map of honey bee colony loss. This is a map and accompanying graph indicating the loss of honey bee colonies in the United States from 2006 until 2017 (University of Maryland 2017).

In comparison to other North American states, California will be impacted most given that it is the most important area concerning agriculture (Kremen et al. 2002). California produces half of the country's supply of fruits, nuts, and vegetables, which are valued at $16.45 billion (Kremen et al. 2002). Of California's 20 most economically important crops, which account for 74% of gross farm income, 10 are somewhat or entirely dependent on insect pollination (Rich 2005). California is also known internationally for its large plant diversity containing a wide range of plants endemic to the area (Kremen et al. 2002). Therefore, pollinators play a large role therefore in maintaining California's agricultural output and diverse ecosystems (Kremen et al. 2002). Currently in North America there are over 4,000 species of bees naturally occurring with California housing over 1,500 of those species (Kremen et al. 2002). However, as "agricultural production has expanded and intensified in areas of California, native habitat has declined and can no longer support a sizeable native bee community" (Kremen et al. 2002).

This study will specifically examine the barriers for native bee habitats in California's Bay Area. The counties that I included, as seen in Figure 3, are Marin, Sonoma, Napa, Solano, Contra Costa, Alameda, Santa Clara, San Mateo, and San Francisco counties. The Bay Area produces agricultural products that are valued at $1.8 billion a year (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). While the Bay Area agricultural sector remains large and valuable, there has been a decline of valuable agricultural land in previous years traced to development (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). The Bay Area is also home to at least 200 species of native bees (Arneson 2000).While most farm operations are "small farmers selling niche products locally though farmer's markets, community-supported agriculture (CSAs), and local grocers", Bay Area farms represent a variety of acreages, operation scales, and markets (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011).

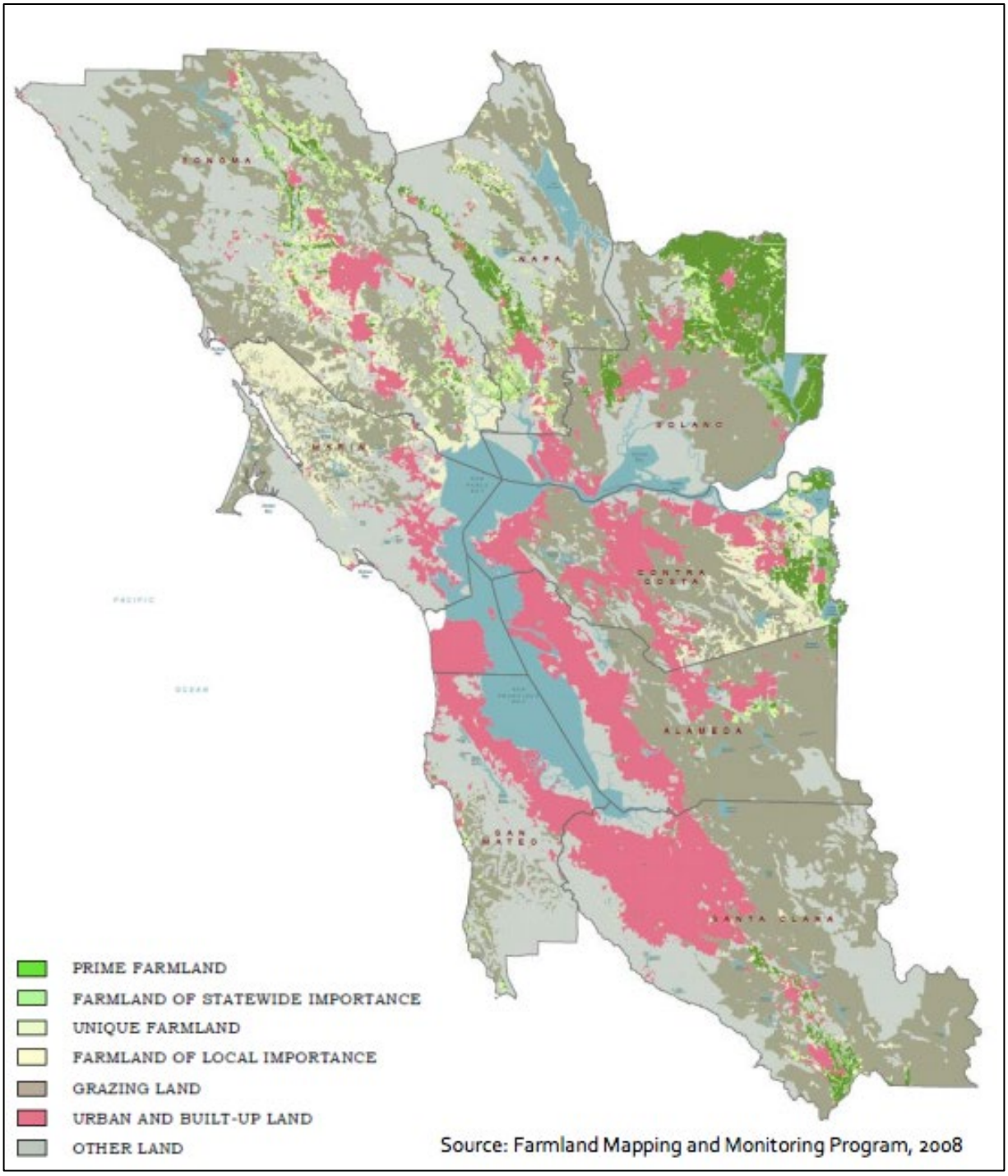


Figure 3. Map of Bay Area Farm Lands. Map of the Bay Area in 2008 indicating prime farmland, statewide important farmland, unique farmland, locally important farmland, grazing land, urban and built up land, and other land. (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011)

Bay Area counties vary slightly from each other in terms of agricultural production, as seen below in Figure 4. Alameda County used to have rich land dedicated to agriculture but due to urban development, there is now very little farm land left (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). Contra Costa County is one of the Bay's most "iconic" agricultural spaces (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). It is divided between the rich Brentwood farming regions in the east and the packed urban places in the west (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). Marin County dedicates 40% of its land to farms and ranches (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). The average size of a farm here is large in comparison to its counterparts (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). Napa County is well known as America's top wine-making region with almost all of its agricultural landscape set aside for grape production (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). San Mateo County is the Bay Area's fourth highest county in terms of agricultural production, even though it has very little land dedicated to agricultural production (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). Santa Clara County is not only the fastest-growing country but also the largest and most productive agricultural region in the Bay Area (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). Solano County is the third most profitable agricultural county in the Bay Area, after Sonoma and Napa County, with over $290 million (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). It also has very high crop diversity, growing over 80 different crops (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). Sonoma County has land predominantly dedicated to ranging, earning its name as a "dairy belt"(American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011). However, wine grapes are also grown here (American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education 2011).

Table 1. Bay Area Counties 2012 Agricultural Census Data. This table outlines key agricultural facts about each of the Bay Area Counties (USDA 2012).

County	# of Farms	Farm Land (in acres)	Average Farm Size (in acres)	Most Valuable Commodities	Most Common Crop	Farmer Demographics
Alameda	452	177,798	393	Fruits, tree nuts, berries	Grapes	Male, White, 59.9 years old
Contra Costa	602	127,670	212	Fruits, tree nuts, berries	Forage-land use (hay, haylage, grass silage, greenchop)	Male, White, 61.6 years old
Marin	323	170,876	529	Milk from cows	Forage-land use (hay, haylage, grass silage, greenchop)	Male, White, 60 years old
Napa Valley	1,685	253,370	150	Fruits, tree nuts, berries	Grapes	Male, White, 61.5 years old
San Mateo	334	48,160	144	nursery, greenhouse, floriculture, and sod	Forage-land use (hay, haylage, grass silage, greenchop)	Male, White, 58.6 years old
Santa Clara	1,003	229,927	229	nursery, greenhouse, floriculture, and sod	Harvested vegetables	Male, White, 62 years old
Solano	860	407,101	473	Fruits, tree nuts, berries	Forage-land use (hay, haylage, grass silage, greenchop)	Male, White, 60.8 years old
Sonoma	3,579	589,771	165	Fruits, tree nuts, berries	Grapes	Male, White, 60.1 years old

Crops and Pollination

There are three types of crops: those that require pollination by bugs, those that can be hand-pollination, and those that don't need pollination (Jones 2014). Plants that require pollination are cucumbers, melons, watermelons, berries, and tree fruits (Jones 2014). Those that can be hand-pollinated are winter and summer squashes, tomatoes, eggplants, sweet and hot peppers (Jones 2014). Crops that don't need pollination are all leafy greens, brassicas (which includes broccoli, cauliflower, cabbage, and kohlrabi), vegetables with roots below ground (such as carrots, parsnips, salsify, potatoes, sweet potatoes, and horseradish), vegetables with roots at ground level (such as beets, turnips, and rutabagas), legumes (which includes beans and beans), corn, herbs, celery, onions and leeks (Jones 2014).

The largest crop pollination in the country and the largest managed pollination event anywhere is actually that of California's almonds with around 1.7 million honey bee colonies being imported to pollinate them (Philpott 2015, American Bee Journal 2017). Due to California growing a majority of the world's almonds, 80% to be exact, it requires a lot of pollinators, which usually comes in the form of honey bees (Philpott 2015).

Honey Bees

The European Honey Bees, also known as *Apis mellifera*, is the most commonly known and managed bee in the world and it is because it is considered the most effective pollinator by saving pollinators time and money (vanEngelsdorp and Meixner 2010). They tend to visit the same types of flowers on a single trip, thereby pollinating more plants with higher quality, making them more efficient than other bees that visit flowers at random (Huang 2012). They are both extremely social and highly structured, meaning they construct their own hives, live in large numbers, and every bee, whether a queen, worker, or drone, has a responsibility to carry out a task (Partap 1999). Considering it is very rare for bees to be social and live in colonies, humans find them more efficient at allocating time and effort to pollinate (Huang 2012). Also since they do live in these hives and do not make individual nests in the soil like 75% of bees usually do, it is easier to transport the hives in movable-frame wooden hives to different farms to effectively pollinate the plants nearby (Partap 1999). Additionally, these bees are highly adaptable to many types of environments because they can survive several years on food reserves, and in cold weather can form a cluster to stay warm (Partap 1999).

While global stocks of honey bees have increased, there has been a sharp decline specifically in Europe and the Americas due to the much-publicized colony collapse disorder and the stress of diseases, parasites, pesticides, queen loss, climate change, and other socioeconomic factors (vanEngelsdorp and Meixner 2010). Main factors are diseases, such as American Foul Brood disease, parasites specifically Varroa Mites, and pesticides specifically neonicotinoids, that cause physical and mental damage to bees. This is because these factors can cause everything from birth defects, digestion damage, and paralysis to disorientation and behavioral changes (vanEngelsdorp and Meixner 2010). Other variables such as unexplained colony collapse disorder in managed honey bee hives, less available area for honey bee foraging, increased periods of rain

and cold weather, reduced gene pools due to beekeepers breeding from the same queens, and unexpected queen loss have also caused honey bee colonies to decline (vanEngelsdorp and Meixner 2010). During the winter, there are significant, troubling honey bee colony losses due to queen loss, starvation, Varroa mites, and severe winter temperatures in that order (vanEngelsdorp and Meixner 2010). Especially in California, the drought has caused especially high losses. Not to mention there are other socio-economic factors such as new regulations in exporting and importing honey bee colonies and increased costs in renting colonies (vanEngelsdorp and Meixner 2010).

As much as there are losses, this might not always be seen in the records because beekeepers keep increasing their bee colony size in order to compensate for the losses they expect (vanEngelsdorp and Meixner 2010). They do this by taking a honey bee colony that is on the verge of decline and splitting up the bees into two managed colonies, which is cheaper than buying a whole new colony (vanEngelsdorp and Meixner 2010). This also means it is easier to deal with honey bee losses than it is to deal with native bee losses (vanEngelsdorp and Meixner 2010).

If farmers continue to use the declining populations of honey bees as a main source of pollination, the consequences could be detrimental to communities around the world (Palmer 2015). Therefore, it is imperative that we understand exactly what is stopping farmers from supplementing honey bee pollination with that of native bee's pollination.

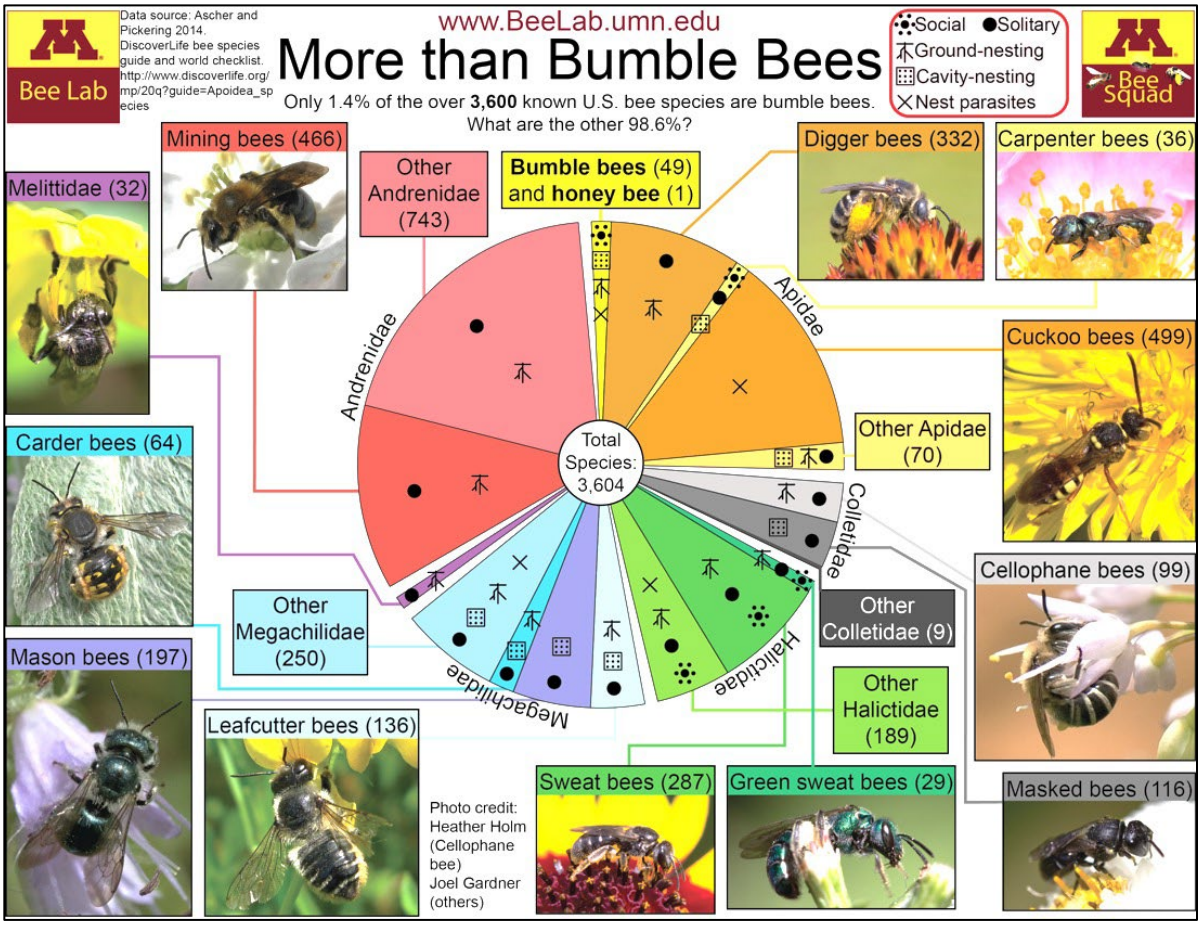
Native Bees

In North America, there are more than 4,000 native bee species (Vaughan et al. 2015). Native bee species are bees that are indigenous to the areas in which they are located, which could be any bee besides the commonly known honey bee species. As seen in Figure 5, 98.6% of bees in the United States are not honey bees (the most popular bee species) or bumble bees (the most popular native bee species) (CFANS 2015).

Native bees range in size, color, behaviors, and nesting and foraging habits (Moisset 2011). However, most native bees are actually solitary, except for bumble bees and many species of sweat bees, which mean that a female makes her own nests and dies soon after it's complete as opposed to sharing the responsibility of foraging and raising broods (Vaughan et al. 2015). Also around less than 1% of native bees live in hives, around 70% live in the ground, and around 30% live in

wood and other small cavities (Vaughan and Black 2008). This means that a large percentage of native bees need undisturbed areas under the ground in order to build their nesting sites.

Figure 4. Different species of bees in the U.S. This pie chart shows the different species of bees in North America. While bumble bees are the most popular native bee species, only 1.4% of species are bumble bees (CFANS 2015).



Many native bee species are actually more effective than honey bees at pollinating plants due to various factors (Vaughan et al. 2015). One factor, is that many native bees are more active than honey bees in weather conditions that are cooler and wetter (Vaughan et al. 2015). Another reason is that the foraging habits of native bees are a lot more diverse and therefore suitable for the some of the plants that they are visiting in terms of their attractiveness and feasibility to some bees (Vaughan et al. 2015). Some native bees also are more efficient at carrying pollen: some utilize their dense hair patches to transport pollen which prevents it from getting wet from the nectar and becoming less viable and some utilize their abdomen to transport pollen which makes it easier for transferability among plants (Vaughan et al. 2015).

A diversity of bees have been found to be necessary in providing stable crop pollination (Kremen et al. 2002). This is because when there are such diverse plants through geographic areas and during various times, there needs to be an assorted presence of bees in order to provide pollination services (Kremen et al. 2002). Also a presence of diverse bee species is beneficial if one bee species population happens to get naturally affected by certain parasites or diseases (Vaughan et al. 2015). The benefit of native bee habitat can be seen in studies that have taken place: In the Central Valley, if within 1.2 km of a field is more than 30% natural habitat, then watermelon farmers can achieve full pollination (Mader 2008). In Canada, if canola farmers have at least 30% natural habitat on their land then they can make more money than if they planted their land (Mader 2008). In New Jersey and Pennsylvania, 90% of watermelon farmers had native bees provide all their pollination (Mader 2008).

Potential Barriers Farmers Face

There are several potential barriers that farmers may face in installing or preserving native bee habitats on their farms for increased pollination. I am attempting to identify if these barriers can be attributed to lack of sources of information, lack of knowledge on the bee problems, lack of popularity in utilizing native bees, lack of policies and incentives, lack of perceived inability to install native bee habitats, or lack of necessity.

One potential barrier is a general lack of reputable sources of information that farmers read since farmers do "depend on sources other than the Cooperative Extension Service and other educational agencies to provide them with information" (Lawson and Dail 1996). Considering that agriculture is one of the most vulnerable sectors when talking about climate change effects, if farmers don't trust scientific sources on risk perceptions, then they are less likely to act on them (H 2016). On a positive note however, learning new ways to be sustainable in agriculture happens through a process where there is initial conflict between scientists and farmers and subsequent realignment and reevaluation of knowledge and views (Eshuis and Stuiver 2005).

Another potential barrier could be a lack of knowledge on the honey bee crisis and native bees in general. Farmers can either be unaware about the drastic loss of honey bees or about the benefits of native bees. This could be because some farmers consider "pollination services as an

unsolicited free service or as a public good" (Munyuli 2011). This means they see it is as something that they either have or don't and there is no way to change that.

There could be a lack of popularity in utilizing native bees for pollination since "the adoption attitude of neighbors is often an important determinant of whether a farmer chooses to adopt a new technology" (Case 1992). If a new idea is not marketed enough, then there is a chance that few farmers will use that idea because if they haven't seen or heard about their neighbors using it then they will probably wonder "if it's so good why aren't my neighbors using it" and therefore will probably not implement it.

Lack of policies and incentives for farmers can be another barrier in shifting their practices since "designing and implementing policies to reduce agriculture's environmental costs is difficult" (Tanentzap et al. 2015). Related policies in place offer some incentives and assistance for implementation. The 2014 Farm Bill already offers a large range of conservation programs for agricultural lands through the use of incentives and prioritization of pollinator needs. (USDA 2008). Some of the major programs aimed at agricultural lands and farmers are the Conservation Reserve Enhancement Program (CREP), Conservation Reserve Program (CRP), Conservation Stewardship Program (CSP), and Environmental Quality Incentives Program (EQIP). They offer a combination of incentive payments, up to 75% cost-share, and repaying foregone income for installing pollinator habitats. A helpful action for increasing efficient pollinator conservation would be expanding on Farm Bill Programs already in place. Some policies that would help would be enacting pollinator-friendly pesticide policies, conserving and enhancing pollinator habitats policies, developing incentives and payments for ecosystem services from pollinators, ensuring participation and empowerment of diverse stakeholders such as from rural and indigenous people, supporting collaborative research, and training policies (Rose et al. 2015, USDA 2016). Not to mention farmers seem more receptive to adapting to climate change than to outright capping and limiting certain actions in relation to climate change (Rose et al. 2015, USDA 2008, Arbuckle et al. 2015a, Gaines-Day and Gratton 2017)

A farmer may also have perceived inability to install native bees, due to the "perceived time and financial commitments required" such as labor, money, and other resources (Gaines-Day and Gratton 2017). Costs are a major factor in making any big decisions. Farmers hesitate to put in pollinator habitats because the upfront costs of buying the pollinator friendly plants and taking land out of production seem daunting. According to the Xerces Society, the typical estimated costs

of establishing and irrigating a hedgerow are $338.06 (Cruz et al 2016). However, it is important to realize that when looking at the cost benefit analysis of implementing native bee habitats, the benefits can offset the initial costs after 10 years (Vaughan et al. 2015). There are a few technical and financial sources of assistance for farmers when considering putting in pollinator habitats (Vaughan et al. 2015). There are national government programs, conservation programs, and non-profit land trusts that can help with this as well (Vaughan et al. 2015).

Lastly, a lack of implementation of native bee habitats could be due to a perceived lack of necessity to do so because "effectively adapting to and mitigating climate change requires both an understanding of the causes and impacts of climate change and a willingness to change behaviors" (Arbuckle et al. 2015, Niles and Mueller 2016).

RESEARCH QUESTION

If we want native bee populations to increase we need to make sure that these habitats not only have a consistent and diverse supply of plants for sustenance, but also have enough undeveloped land to burrow in. However, while there are research studies about and resources dedicated to informing farmers about alternative pollinator solutions, they are not implementing native bee habitats. I will therefore be conducting interviews and surveys to farmers and farm advisors in the Bay Area to understand barriers and strategies to implementing native bee habitats.

METHODS

Study Population

I sent the questionnaire to farmers in the Bay Area region, since it is the nearest region. The places I included in the Bay Area region for the purposes of this project are Marin, Sonoma, Napa, Solano, Contra Costa, Alameda, Santa Clara, San Mateo, and San Francisco counties, all pictured in Figure 6. I have no other restrictions on my population set and simply wanted to get feedback from as many farmers as possible. I also contacted and interviewed University of California Cooperative Extension advisors and other researchers in the field to learn more about their insights as to the barriers farmers face when implementing native bee habitats. I also asked the farmer advisors to send out these emails to the farmers they work with in their counties.

Questionnaire

My questionnaire is a total of 40 short response questions and should take approximately 20-30 minutes. I attempted to make the questions as broad as possible while also providing direction and as least bias as possible as to not influence this answers in this questionnaire. I sent out the survey on Qualtrics. However, I did send it out as a Word document at the beginning.

My objective in conducting this questionnaire is to learn about the practices of and obstacles faced by farmers, specifically in relation to installing native bee habitats with the purpose of supplementing honey bee pollination with native bee pollination. I want to know if there is a lack of reliable sources on native bee habitats, a lack of communication on the scientist's part and therefore a lack of knowledge on the farmer's part, a lack of marketing and popularity of this method of pollination, a lack of policy and incentives in place, or a lack of money and resources to install and maintain the habitats. I also want to know what questions they have about installing native bee habitats and what resources they would need to make this happen.

I started my questionnaire with general logistical questions that will help me get a better sense of the layout of the farm (size, crops, employees, rented/owned land, organic/conventional practices, years of farming) and the farmer (priorities, information sources). Then in the next section I ask about their honey bee knowledge and reliance on the farm to understand more about their interactions with honey bees. In the section after that, I ask questions about native bees and this is where the majority of my questions are located. Here, I ask questions to guage their knowledge, reliance, perceived popularity, and concerns about native bees and the resources, information, or other measures they need to be able install native bees, if they haven't already. This information will be most helpful for analyzing the obstacles the farmers face in installing native bee habitat. Lastly, I asked demographic questions about the farmers such as their age, ethnicity, and education, which could be contributing variables.

Interviews

I conducted interviews with technical experts in the field. I contacted Amber Scilligo, who is a post-doctoral researcher in the University of California, Berkeley Kremen Lab and Joshua

Arnold, who is a graduate student in the University of California, Berkeley Altieri Lab. Amber Scilligo put me in contact with Jo Ann Baumgartner and Rachael Long, both of who I interviewed.

I interviewed am Gordon Frankie who is the Project Investigator of the University of California, Berkeley Urban Bee Lab, in which I am an undergraduate researcher in. I also interviewed Rob Bennaton who is a County Director of Alameda and Contra Costa counties and a Bay Area Urban Agricultural Advisor.

I decided to conduct follow-up interviews with farmers who responded to my survey. Only three farmers responded to my request. They were from Alemany Farm, Ashby Community Garden, and Rodger Ranch.

Data Analysis

This collected data allowed for an analysis of the barriers and strategies that farmers face in implementing native bee habitats. I also want to see if there are any common factors and themes that predict whether farmers use native bee pollination. My thesis project then can be best described as interpretive and qualitative. This is because I care more about their answers than any statistical significance or numerical analysis.

RESULTS

Demographic and Characteristics of Farmer Responses

I received 32 responses out of over 250 distributed surveys, which represents a response rate of approximately 12.75%. I sent the survey to 251 farmers and 14 farmer advisors and there have been further redistributions as well. At one point through redistribution some respondents thought that this survey was meant for bee keepers and therefore I have another five people who responded that were honey bee keepers, which I will consider and talk about separately from farmer responses throughout the results. It is also important to mention that the first three responses from Frog Hollow Farms, Buttercup Farms, and Acta Non Verba Youth Urban Farm Project were through a Word document and had fewer questions than the survey sent out through Qualtrics.

Farmer respondents represented a wide range of geographic locations, as seen in Table 2. Surveys were sent to the nine counties in the Bay Area Region including Marin, Sonoma, Napa, Solano, Contra Costa, Alameda, Santa Clara, San Mateo, and San Francisco County. However, only farmers from the Marin, Sonoma, Contra Costa, Alameda, Santa Clara, San Mateo, and San Francisco counties responded. The most farmers were from Alameda and this could be because Rob Bennaton the UCCE Advisor from Alameda and Contra Costa Counties was extremely helpful in sending out my survey to farmers. However, the county with the highest percentage of farmers is San Francisco because they only had six farms and out of those six farms, two responded. Farmers from Napa and Solano counties did not respond. There were also four farms for which I don't have records of their exact location and one farm that responded outside the area of study.

Table 2. **Bay Area Farm Response Rate.** This table represents how many farms are in each county as of 2012, how many farms in each county responded to my survey, and what the response rate from each county was for my survey.

County	**# of Farms (as of 2012)**	**# of Farms Responding**	**% Responses from Each Counties**
Marin	323	3	9.38 %
Sonoma	3,579	4	12.5 %
Napa	1,685	0	0.0 %
Solano	860	1	3.1 %
Contra Costa	602	4	12.5 %
Alameda	452	9	28.1 %
Santa Clara	1,003	1	3.1 %
San Mateo	334	2	6.25 %
SF	6	2	6.25 %
N/A	0	6	18.75 %
TOTAL	**8,844**	**32**	**100%**

The most common demographic of the farmers I interviewed are located in Table 3 below. The most common age range of the farmers who responded to the survey were split between seven respondents answering 40-49 years old and another seven respondents answering 50-59 years old. Five respondents stated that their age range was 20-29 years old and five respondents stated that their age range was 70-79 years old. There were also two respondents who stated their age as 30-39 and six responded their age as 60-69. This resembles very closely a bell curve of age ranges

through the response rate. The most common ethnicity origin of the farmers who responded to the survey was white with 23 out of 32 farmers selecting this option. Three identified as being Hispanic or Latino, one responded Asian/Pacific Islander, and five responded other.

The most common highest level of education of the farmers who responded to the survey was a college education with 25 out of 32 farmers selecting this option. The most common response was a Bachelor's Degree (including Bachelor of Arts, Bachelor of Science, and Bachelor of Fine Arts) however, there were two who have JDs and ten who specified that they have their masters. It is really interesting to see as well a wide range of education interests with one farmer identifying as a registered nurse, one identifying as a pastor, one studied construction engineering, and one even studied art history. While the respondents have been farming over a wide range of years, all of them have been farming 15 years or less, or 30 years or more. The most common response was having farmed for ten years with four respondents selecting this. This was one of the questions that I had not specified for the first three respondents.

Table 3. Most common farmer demographics. This table represents the most common responses from farmers in my survey for each of these demographic questions.

Demographic Identification	Most Common Response
Age Range	40-49 years old, 50-59 years old
Ethnicity	White
Highest Level of Education	Bachelor's Degree

There were also a diverse range of farm operations with the most common ones listed in Table 4. Most farmers owned all of their land (15) and the rest either rented their land (7) or other (10), with responses describing "other" as a mix of both renting and owning or as some form of public or federal land. The most common property size was 2 acres or less. The majority of respondents reported using organic practices (20 respondents). Three of the farmers reported being conventional and eight reported being other 'low environmental impact', which means they are either not certified organic or use other biological or sustainable practices. The most common items respondents reported having grown were vegetable and fruits, however, a lot of respondents didn't specify which ones exactly. This could probably be due to the constant variation in crops being grown from season to season. The most common number of full-time employees the respondents had were zero and the average number of part-time employees the average respondent

had were also zero. However, some did clarify that while they did not have a lot of employees, they relied a lot on volunteers.

Respondents reported using a wide range of source of information to influence and guide their management and practices on their farm with the most common one being the UC Santa Cruz Center for Agroecology and Sustainable Food Systems. However, there were very diverse answers ranging from local experts in certain tasks, colleagues, the internet, varied research and books, their own experiences, and the most common was university and extension specialists. The most common difficult decisions farmers reported having made on farms were under the theme of production decisions with 25 farmers having chosen that option. A lot of farmers specified having to make difficult production decisions surrounding the topic of irrigation. This might have been because this was one of two suggested examples of a problem under production decisions. Then marketing and business decisions fell close behind with 22 farmers having selected it (with some common responses being "social media" and "finding new markets"), food safety decisions following with 16 selections (with sanitation being the most repeated problem), and legal decisions last with 10 selections (with ongoing land negotiations being the common answer), and decisions that didn't fit into these categories had 5 selections (with not enough labor or resources being the most repeated responses). There were a handful of farmers that in multiple categories had actually specified that it is hard to balance education and community as opposed to output and income. Just to clarify, farmers could have chosen multiple choices for the theme areas of difficult decisions. While the question was the same for the first three respondents, the specific categories were only added after the survey was put on Qualtrics.

Table 4. Most common farm logistics. This table represents the most common responses from farmers in my survey for each of these logistical farm questions.

Farm Logistics	Most Common Response
Years of Farming	10 years
Property	Owned Land
Land Size	2 acres or less
Practices	Organic Farming
Crops Grown	Fruits and Vegetables
Number of Full-Time Employees	0
Number of Part-Time Employees	0 (but many relied on volunteers)
Information Sources	UC Santa Cruz Center for Agroecology and Sustainable Food Systems
Difficult Decisions	Production Decisions (specifically regarding irrigation)

Current Bee Management Practices

This section will be reviewing honey bee and native bee management practices among both farmers. In Table 5 below, I have listed the percentage of farmers who reported having honey bee colonies and the percentage of farmers who reported having native bee habitats. In the survey, there were also some unexpected responses from honey bee keepers that will also be reviewed in this section.

Table 5. Percent of farmers using bees. This table represents the overall amount of farmers responding to my survey who used honey bee pollination and native bee pollination on their farm.

Farmer Bee Practices	Percentage
Using honey bee pollination	65.6%
Using native bee pollination	81.32%

Farmer Honey Bee Management

Out of the 32 respondents who responded to the survey, the majority (21) reported using honey bee pollination on their farm as seen in Figure 5. Most of the farmers who responded had two to three colonies. Out of that group of respondents who used honey bee pollination on their farm, the majority (80.95%) owned their colonies with three (19.05%) reporting that they use honey bee pollination but don't have honey bee colonies on their farm and one (4.76%) reporting that they rent their colonies. Seven respondents reported not using honey bee pollination on their farm and four respondents reported not being sure about if they used honey bee pollination on their farms. Six respondents answered that they have had honey bee losses higher than normal, nine reported that they have not had losses higher than normal, and three responded that they were not sure. Out of those who reported having losses, all of them owned honey bee colonies, and they were losing on average 44.8 % of their honey bee colony hives. Out of those who reported not having losses, they are mostly concerned they will in the future with 5 responding yes, 1 responding no, and 3 responding unsure if they use honey bee pollination.

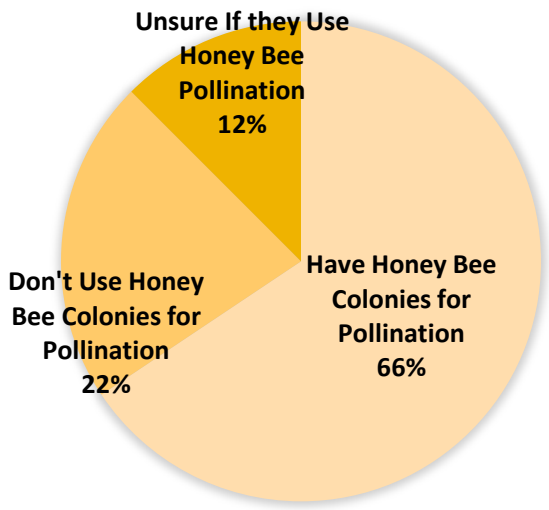


Figure 5. Farmers using honey bee colonies for pollination.

Respondents were very aware of the diverse problems that honey bees in the U.S faced. For the most part they reported habitat factors as the main problems that they think honey bees in the US face with 27 people selecting that option. Some of the most common responses were pesticides, mono-cropping, and habitat diminishing for the bees. Other comments are "newbie beekeepers who don't monitor/feed colonies and they rob my apiary," "We can provide habitat but cannot prevent contaminants from neighboring operations," "In semi-urban locations in particular there needs to be more bee colonies for queens to properly mate, and in non-urban locations there is less area for hives to pollinate and live." "Many farms spray chemicals that make them inhospitable to healthy hives. In order to promote healthy hives their surrounding habitat must also be rich in biodiversity," and "Suburban spaces have become very unfriendly for Bees. "Brown is the new green" is the call for homeowners to take the easier but ecologically injurious path to water conservation. Bees (domesticated and wild) would benefit from plantings of native plants that can used for excellent drought-tolerant landscapes. A higher use of water in the suburbs is to dedicate small spaces to grow food organically."

However, in this question they were able to choose more than one answer and the second most common answer was biological factors with 22 respondents selecting that option. The most common responses were pesticides, pests, and diseases. One response from Pie Ranch was very well put and stated that "I think the commercialization and commodification of bees in monoculture challenges the health of hives because of the need to alter bees natural rhythms and

timing, the feeding of sugar/high fructose corn syrup, and the lack of exposure to natural elementals that imbue bees with antifungal and antibacterial strength." Another very well put answer was from Fertile Groundworks which stated that "Pesticides such as neonicotinoids are both killing and weakening honey bee and wild bee hives and colonies. The pesticide pressure/stress is insidious and unrelenting. Since we do our farming/gardening in suburban space, we are surrounded by homeowners who spray pesticides that harm both honey bees and wild bees and wasps. It's hard to drive around town without seeing one or more Orkin or other brand "pest" exterminator either spraying or driving to their next destination. These poisons make the bees more vulnerable to other stressors such as Varroa mite, other parasites and pathogens." Other comments are that "Monsanto's chemicals are everywhere" and "Glyphosate is likely the single biggest threat to honey bees."

The third most common factor that farmers responded they thought affected honey bees were economic factors with 19 of farmers responding that this was a problem. The most common answers were high costs and the trucking of honey bees over distances with Rodgers Ranch Urban Farm stating that "many people treat bees as machines rather than living creatures. Transporting bees in trucks is a major industry and that may cause bee health problems by introducing unknown pathogens into bees simply because of the business greed." However, the most surprising answers in this category were that one person mentioned vandalism and another person mentioned theft, which I didn't even realize were problems occurring with honey bee colonies at the moment. Other comments are "lack of market opportunities ala. co high one day fees, locked out of farmers markets due to small production level," "Prices are up for pollination, and for honey products. Down side, people get greedy and mismanage the bees for greater profits, and actually hurt the overall bee health," and "increase in corporate farms and loss of small organic farms, lack of profitability in farming, and government policy geared towards corporate interests..."

A total of nine people responded that there are other types of problems, with some being "weird swarming patterns that leaves hives really weak either before winter or near the end of winter", "non-local selling and shipping of bees", "high levels of CO2, low protein in pollen", "Homeowners frequently tell us they want a hive as a personal honey machine. We tell them not to do this, but most non-farmers simply want personal honey. They don't give a damn about farms or bee health", and "As our areas gets an increase housing density, we are seeing an increase in 'gardeners' and other landscape professionals. These people do not think about the effect they have

when making decisions about plants, sprays, or designs of outdoor spaces." Other comments are "impact of foreign imports." An interesting comment is that Green Grrrl Gardens cited Monsanto as a problem for honey bees in each category of biological, economic, and habitat factors.

Table 6. Respondents answer honey bee problems. This table represents the various problems I listed in my survey that honey bees might face, the percentage of farmers who thought they were a problem, and the most common examples they gave of those problems.

Problems Honey Bees are Facing	Frequency Mentioned	Most Common Responses
Habitat Factors	84.4%	pesticides, mono-cropping, and decreasing habitat space
Biological Factors	68.8%	pesticides, pests, and diseases
Economic Factors	59.4%	high costs of and large trucking distances of honey bee colonies

Farmer Native Bee Management

Twenty-one respondents reported having native bee habitats, four reported having no native bee habitats, and seven stated that they weren't sure but after further explanation five stated that had native plant habitats. This data is represented below in Figure 5. The most common response was that farmers had areas where they would leave the ground undisturbed and areas where they would allow for wild flowers and plants to grow. One farmer also specifically has mason bee hives and plants for their farm. The different native bee habitats, as well as the frequency they were mentioned among farmers are listed below in Table 7. Overall there was a very high awareness about pollinator habitats and having them. Twenty-six farmers responded that they indeed had cover crops and twenty-one of those farmers responded that those crops attracted pollinators. This question was only added after the survey was put in Qualtrics format and therefore only means 30 farmers responded to it. The most common characteristic these farmers shared was that the majority of them also rely on honey bee pollination on their farm, which could imply their necessity for pollination and their knowledge about the wide range of ways to achieve plentiful pollination. Respondents, for the most part, did believe that native bees were helping to pollinate their crops with 21 farmers having responding yes, 10 responding not sure, and 1 responding no.

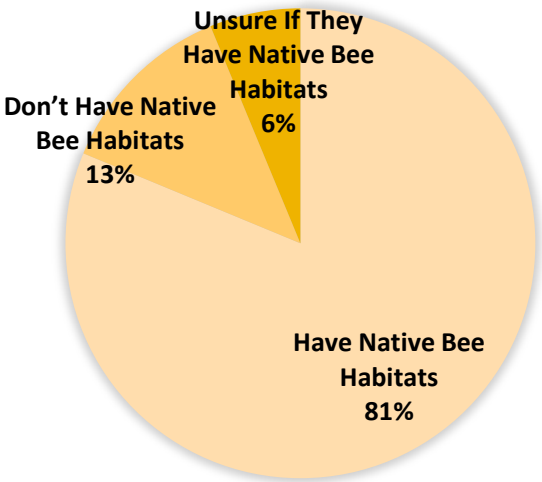


Figure 6. Farmers who have native bee habitats.

Table 7. Reported types of native bee habitat. This table represents the different types of native bee habitats farmers reported having on their farms, the frequency in which they were mentioned throughout the survey (most farmers reported having more than one), and the varied terms farmers used to describe the habitats.

Reported Types of Habitat	Frequency Mentioned	Varied Terms
Wild Flowers/Grasses	10	"native", "weeds", "clovers", "passion flower vines", "flowering plants, "shrubs"
Undisturbed Ground	8	"open ground", "bare ground", "fallow unmanaged wild spaces", "bare dirt patches", "bare soil"
Planted Flowers	7	"perennial plants", "small native garden area", nectar producing plants", "pollinator flower gardens", "designated green zones", "bee/butterfly friendly garden"
Trees	6	"coastal live-oak", "eucalyptus", "fruit trees", "flowering trees", "forests"
Cover Crops	3	"vegetable crops gone to flower"
Wood Piles	3	"decaying logs", "woodstacks"
Hedgerows	3	
Vegetables Area	2	"urban vegetable farm", "organic garden"
Water Access	2	"riparian"

Out of the 32 farmers who responded to the survey, most respondents reported seeing native bees foraging on their crops frequently (14), a good amount reported seeing native bees foraging on their crops occasionally (12), and a few reported rarely seeing native bees foraging on

their crops (6). Twenty-two farmers reported being able to recognize native bees. The native bees that farmers were able to recognize the most were bumble bees, carpenter bees, and sweat bees. This is because these are the most common bee species in the world besides the honey bee species (Pestwiki 2016). The ones that reported being able to recognize native bees and could not name a few made comments that they were at least able to recognize native bees from honey bees.

Out of the four who reported not having native bee habitats, they did not have concerns for not doing so with one stating that they "We've tried unsuccessfully", and another stating that they "would love to do that!" but that "Since we have a small staff and rely on volunteers, [they would need] plenty of information about upkeep, maintenance requirements." Not unsurprisingly the former stated that they would not consider installing native bee habitats and the latter stated that they would consider it. Out of the same group of farmers who reported not having native bee habitats, the other two farmers responded that the information they would need would be "Means of attracting native bees, construction details for habitat" in order to do so and another farmer stated that they would need to know "Where is the best place to install it? Would it affect the Honey Bees?" Both of these farmers later stated that they would consider installing native bee habitats. This is surprising because there are plenty of informational sources on how to create and maintain native bee habitats, however, it seems that there needs to be more than just pamphlets to help farmers.

Most of the farmers, 17 to be exact, who responded did know others who had developed native bee habitats, while 15 did not know anybody. Interestingly enough while this is not a huge sample size, the people who did respond about having known others who developed native bee habitat all had some form of wild plants growing (intentionally or unintentionally) for native bees, with only one person not sure if they had any type of habitat. However, this relationship doesn't follow the inverse as only 13 out of the 26 farmers with native bee habitats know someone who has native bee habitat. Therefore, there is a strong correlation of having native bee habitat based on if a farmer knows someone with native bee habitat, but there just because a farmer has native bee habitat does not correlate that they are more likely to know other farmers with native bee habitats.

The sources and of information that farmers reported using for information on native bees, the frequency in which they were mentioned, and the various examples that farmers gave for each category are listed below in Table 8. The most repeated sources of information that respondents

would go to for information on native bees are the University of California Division of Agriculture and Natural Resources and all of its branches such as the Cooperative Extension, Master Gardener Program, UC Davis and its Apiculture Extension, UC Berkeley, and the Master Beekeeper Program. This is followed in frequency by the internet and different forms of literature. The next most reported sources of information are various beekeeper associations, the UC Berkeley Urban Bee Lab, differing organizations (including non-profit, for-profit, and national), and specific people. The most common sources of information that respondents would *not* go to for information on native bees are quite varied and range from the internet to commercial/conventional farming sources to pest exterminator businesses, with some surprising answers being the USDA, Nature Centers, "my neighbors," the American Bee Journal, and even a sarcastic answer of The Bible.

Table 8. This table represents the different sources of information that farmers reported using for information on native bees, the frequency in which they were mentioned throughout the survey (most farmers reported having more than one), and the various specific examples the farmers named.

Reported Sources of Information	Frequency Mentioned	Examples
UC Division of Agriculture and Natural Resources (ANR)	9	Cooperative Extension (2), Master Gardener Program (1), UC Davis (3), UC Berkeley (1), Master Beekeeper Program (1)
Internet	8	Wikipedia, "Google With Scrutiny"
Literature	6	Wiley of Berkeley, California Insects, Jerry Powell Guide to the Common Bees of California, USDA Bee Basics, American Bee Journal, "charts and books"
Beekeepers Association	5	Alameda Beekeepers Association, San Francisco Beekeepers Association, Mount Diablo Beekeepers Association, "local native beekeeping groups"
UC Berkeley Urban Bee Lab	5	
Organizations	5	California Native Plant Society, Nature in the City SF, SF Bee Cause, National Center for Appropriate Technology, Marin Bee
Specific Person	5	Les Crowder, Gordon Frankie, "bee mentor", volunteer beekeeper, native pollinator talks
Xerces Society	4	
Magazine	2	Bay Nature, Mother Earth News,
Specific Place	2	UCSC Farm, Biofuel Oasis (Berkeley)

Some of them left additional comments at the end and these were that "We need to protect our bees of all kinds. A key to this is changing our bee laws," and "There are numerous chemical hazards to honey bees but glyphosate is the greatest due to its strong mineral chelation ability and its potent antibiotic capabilities."

Honey Beekeepers Bee Management

The common demographics of the beekeepers are listed below in Table 9. Out of the six beekeepers that responded to my survey, three were from Alameda County and three were from Santa Clara County. All identified with a white ethnicity. The most common age range was 70-79 years old with two people responding this and the one respondent being 20-29 years old, one being 30-39 years old, another one 40-49, and another one 50-59 years old. The most common level of education attained was college level with four beekeepers selecting that option, two even achieved their masters, one beekeeper is getting their high school education (since they are 17 years old), and another beekeeper responded with having attended trade school.

Table 9. **Most common beekeeper demographics.** This table represents the most common responses from honey beekeepers in my survey for each of these demographic questions.

Demographic Identification	Most Common Response
Age Range	70-79 years old
Ethnicity	White
Highest Level of Education	College Level

They all just managed honey bees and honey bee wax. The most common beekeeping logistics are listed below in Table 10. They all have relatively small areas that they worked within. The largest is 10 acres, three were on small lot or backyard areas, and one was 0.06 of an acre and another was 4 acres. Three owned their land and the other three used their own land and used small spaces elsewhere by bartering or keeping on family and friend land. Two of the beekeepers that own their own land considered themselves organic, while the other four considered themselves other low environmental impact. They also all own their own bee hives. One really surprising statement that was made, which I did not know about was from the beekeeper on 10 acres of land that stated "Organic honey is a misnomer, since we cannot track where the bees collect nectar

from." They all had zero full-time employees and half had zero part-time and the other half had one part-time worker. They didn't report having to make any recent production or legal decisions. Four, however, responded having had to make recent difficult marketing and business decisions in terms of expanding their business and outreaching about their products.

Three reported their key information sources that they use to influence and guide their management and practices on farm as being other beekeepers. Another beekeeper listed literary sources such as the American Bee Journal and Bee Culture Magazine, and another one had a really sophisticated answer of "I'm a multi-potentialite and gather influence for management of my bees and land from very diverse sources of constant evolution of study. Biology, anthropology, simple observation, mechanics, physics, chemistry, other farmers, gardeners and bee keepers." Their experience in this ranges from 5 years to their whole lives, one even stating 50 years.

In terms of biological factors, five beekeepers chose this as a problem for their honey bees, with the most common answers being varroa mites, pesticides and parasites. Only two people mentioned economic factors being a problem with one responding that "mass expectation of low cost food cause pressure of return on investment for farmers to customer costs and corners in their practice farming plants and the way in which mass apiaries are managed." In terms of habitat factors, five beekeepers responded that this was a problem with the most common answer being monoculture. One person mentioned in detail that "Due to global climate changes results in change of weather patterns which then leads to change in when swarms swarm. Rain is coming after flowers bloom knocking all the pollen off leaving little food to forage," which was something that I did not know about after extensive research of honey bee loss in the country right now and something I thought would actually benefit pollination due to helping flowering plants flourish.

Table 10. Most common beekeeper logistics. This table represents the most common responses from honey beekeepers in my survey for each of these logistical farm questions.

Farm Logistics	Most Common Response
Property	Owned Some Land
Land Size	Small Lot or Backyard Areas
Practices	Low Environmental Impact
Number of Full-Time Employees	0
Number of Part-Time Employees	0, 1
Information Sources	Other Beekeepers
Difficult Decisions	Marketing and Business Decisions (regarding expanding and outreaching)

In terms of native bees, three responded that they do see native bees frequently on their crops and that they are helping to pollinate their crops, and three responded that they see native bees frequently but they are not sure if they are helping pollinate their crops. This is interesting as at the beginning they responded that they only had honey bees on their plots but I assume that since the honey bees need to be foraging plants for honey, those same plants are also available to the native bees present. Four responded that they had native bee habitat and two responded that they were not sure if they did, however, one did state that their tree has a cavity which native bees are using for habitat. A comment that one of them stated in the additional comments section was that "bees are living beings that know how to take care of themselves if left alone it's our heavy hand in their life that is detrimental to their survival," which was interesting to me because they are a beekeeper. Even though this is not a sizable sample it is amazing that most of them knew about native bees and had habitat for them, even though they only manage honey bees. And something else that really was interesting was that even though they manage honey bees for profits they are very aware about the problems that honey bee face and prefer not to treat them as commodities.

Overall Bee Management Follow-Up Interviews

I conducted three phone interviews with three farmers who had responded to the Qualtrics Survey. From this I found two different approaches to the way native bee habitats have been created on farms. One way was that some members of the farm were very interested in creating native bee habitats and decided to create or set land aside for non-use. Another way was that after some members of the farm were interested in native bees due to presentations or curiosity they reached out to an organization to help such as the Urban Bee Lab to specifically help create and install these sites. In all these cases, the farmers did not use pesticides or herbicides and knew how dangerous they were if they wanted to maintain their honey bee and native bee pollination.

Technical Perspectives

While the farmers who responded to my survey were aware about the problems facing honey bee populations and the benefits of native bees, the technical experts I interviewed stated

that the farmers they were in contact with were not aware about all of this. This helped me get a broader perspective on the field of bee management in the Bay Area. I interviewed Jo Ann Baumgartner when I was just getting the project initiated, and she has been instrumental in getting native bee hedgerows installed in the Central Coast. While this did give me more insight into reasons farmers are not implementing native bee habitats, she specifically worked out of the Central Coast region and therefore I realized this information might not be directly applicable to Bay Area farmers. She I also interviewed Rachael Long who is a UC Cooperative Extension advisor from Yolo County, who has conducted a similar survey in her county. It is also important to note that since Yolo County is on the outskirts of the Bay Area counties, her experiences might have been more applicable to my area of study. I interviewed Rob Bennaton who is a County Director of Alameda and Contra Costa counties and a Bay Area Urban Agricultural Advisor. I interviewed Dr. Gordon Frankie who is a Project Investigator in the University of California-Berkeley Urban Bee Lab which works one-on-one with farms in the Brentwood Region and recently in the Southern California Region to implement native bee habitats "to demonstrate how native bees can play a part in the food crop pollination process."

Potential Barriers

Each of the technical experts I interviewed had variations in what they saw as reasons for farmers not installing native bee habitat on their farms, some of which were repeated.

By far, the most repeated barrier seemed to be a lack of technical knowledge. Dr. Frankie stated that he doesn't think that farmers don't want native bee habitats on their farms but rather that "they just don't know how to get it and what to do with it once it arrives." He further states that it's not a lack of knowledge on native bees but really a "lack of how we can use this knowledge to fit into our farming operations." Baumgartner shared similar sentiments when she states that farmers "don't know what plants [to use], they don't know where to get the plants." In Long's survey, she found that farmer's "didn't know how to install" native bee habitats.

One of the potential barriers for farmers not implementing native bee habitats is food safety. According to Jo Ann Baumgartner is that "California farmers depending on where they are selling have a food safety issue" because of a "perceived misconception that habitat can be problematic because it can support organisms with salmonella and E-coli." Rachael Long shared

this sentiment stating that that "diseases, insects, and pest problems worry them." While these worries did not come up in my survey, I think this is important to keep in mind that these are potential factors. However, it is important to note that both of these UC Cooperative Extension Advisor are not from the Bay Area and therefore these could be uncommon barriers in the Bay Area because of regional differences.

Another reason that farmers may not be installing native bee habitats is that they lack the time and attention to focus on it, rather than the lack of money or resources. Jo Ann stated that creating native bee habitats means "putting in extra crops, taking more ground out of production, and costing more time, material, and attention," which is why farmers that do know about the benefits of native bee habitats don't install them. Rachael Long stated that farmers "don't have room" and that "funding is not so much an issue." Rob Bennaton's main point was that what concerns farmers is the "actual interest in taking the time to do it and spending their time. For any farmer, time is money and time is a very valuable resource so it's about that." He went on to state that if farmer "value it and they want to do it, they will do it but not everybody values it." He didn't believe that there was a "lack of resources needed to implement them." However, Dr. Gordon Frankie does state that "if farms are a moderate size, and they have a dozen people working with them, they have resources. If they have a farm that depends on the owner and maybe one or two full-time or part-time laborers they are not the kind of people you expect to make much. Their profit margin is already really small. I mean, as it is, the average profit margin is 4-5%."

A third common barrier might be the lack of incentives. Rob Bennaton stated there are not a lot of incentives that are financial, there's mostly incentives that are ecological." But even the ecological incentives might not be as enticing. Dr. Frankie states they see the [honey bee] decreases, they don't worry about it too much because you just buy a few more bees. It's when you really begin to lose bees that's when you catch the farmer's attention." It's also hard because according to Dr. Frankie, "we are telling them what we think is going on but we don't have a definitive. People ask me do they think this is going to increase my production? Am I going to get more fruit? Well, I don't know." Dr. Frankie further states that if they still "have access to honey bees, probably they'd have to see some hard numbers indicating that there is a relationship between the increased number of bees and their orchards or farmlands and productivity of the crop… they'd have to see that."

Another reason interviewees mentioned might be limiting farmers from installing native bee habitats is a lack of farmers around them installing them. Baumgartner states that installing native bee habitats is essentially a "leap of faith until they rely on it and do it" because in they are thinking "if it works so well why isn't everyone doing it." Rob Bennaton also believes that not enough farmers around them installing native bee habitats plays a factor in all of this.

A very good point that Rachel Long made was that at the end of the day farmer capabilities and knowledge vary because some farmers "have crops dependent on pollination, some farmers know pollination is important, [and some farmers know] the crisis of honey bees and native bees."

Effective Strategies

During the interviews, I also asked what they thought would be the most effective strategies moving forward to get native bee habitats installed on farms.

One of the most mentioned strategies for implementation was increased communication. Dr. Frankie states that it "comes down to how much talking the farmers are doing with other people" and he doesn't assume it's much. As Baumgartner put it one of the best forms of outreach would be through "word-of-mouth." Rachael Long suggested "putting habitats on farms that showcase what they are doing is a great way for getting data out there on how to put habitat ... [and] encourage more information sharing and getting the word out there" because "people love to go out on other people's farms and see what neighbors are doing." She stated that this is better than "trying to hand them information." Another way of getting information sharing happening is by using the preferred source of information by farmers which Rob Bennaton states "younger farmers are more likely to use email, older farmers are more likely to prefer hard paper, you know envelops snail-mail."

Another commonly mentioned strategy was increased collaboration between farmers and researchers. Dr. Gordon Frankie states that "first of all its to find out what farmers would like to know from your form of research." Then Jo Ann Baumgartner states farmers "need one-on-one" attention. She further states that farmers need someone to help them put in pollinator habitats as they barely can do this without any help to which Dr. Frankie furthers this stating that he doesn't "know a single farmer who has done it on his own yet."

Policy was another common topic in approaching success of installing native bee habitats. Jo Ann Baumgartner mentioned government as being a key part of success in installing native bee habitat. If there were financial incentives, Rob Bennaton believes that this could increase the participation of farmers. If there were more policy, specifically if there were increased "responsibility to researchers and extension people…in establishing policy" according to Dr. Frankie then there would be better outcomes. Dr. Frankie further states that "you can set up any type of policy [and] they all sound good until a new pest arrives and then they start spraying things again. Maybe, they didn't want to but the thing of the matter is they have to protect their crop." Therefore, if there are increased policies they need to be more holistically looked at by government.

DISCUSSION

After surveying farmers and interviewing various stakeholders and farmers, I identified various barriers and effective strategies to implementing native bee habitats. While they may not be definitive for every farmer in the Bay Area, these trends from my sample study may be helpful in further guiding implementation of native bee habitats on farms. Even though most farmers had native bee habitats, the responses I received from those who did not and from technical experts, indicated that the barrier may be hindering farmers the most is lack of technical knowledge. Since most farmers had native bee habitats, the most effective strategies I identified from them and from technical experts was that one-on-one collaboration in creating native bee habitats was needed as well as increased communication between farmers who have habitats and those who don't. While there were limitations in my study, overall this is a qualitative study, which makes the responses valid in their own right. Moving forward there should be more collaboration between farmers and researchers, more information sharing between farmers, and more awareness of policy incentives. It is also important that when moving forward with installing native bee habitats on farms or any other sustainable options, researchers form partnerships with farmers as opposed to hierarchical relationships if there is to be success.

The way I approached my study and wanted to research this topic was to really just engage with and understand the positionality of farmers on the subject of bees. An article by Keeler resonated with me that said "individuals and communities are largely side-lined in environmental research, too often seen as passive recipients of knowledge or as objects of study rather than as

true research partners" (Keeler et al. 2017). Therefore, I wanted to approach my research not by analyzing and imposing recommendations on farmers but rather by asking them what concerns them and what they needed in order to move forward with installing native bee habitats.

Potential Barrier: Lack of Technical Knowledge

Since most farmers who responded to the survey already had native bee habitats, this section focuses on the barriers mentioned among those who didn't have habitats and on the interview responses from technical experts.

The most commonly referred to barrier was a lack of technical knowledge on creating and maintaining native bee habitats. Some of the responses from farmers who did not have native bee habitats were that they needed to know "construction details for habitat," "best place to install it," and "upkeep and maintenance." The stakeholders I interviewed also shared similar sentiments about these barriers. Rachael Long stated that farmers "didn't know how to install" native bee habitats. Gordon Frankie stated that farmers "just don't know how to get it and what to do with it once it arrives." He further states that it is not a lack of knowledge on native bees but really a "lack of how we can use this knowledge to fit into our farming operations." And Jo Ann Baumgartner stated that "they don't know what plants [to use], they don't know where to get the plants." While these may seem like obvious key points in creating and maintaining native bee habitats on farms, this came as a surprise (a key reason I did not put this as a potential barrier) because there seemed to be a plethora of online resources on this topic. However, the prominent lack of technical knowledge indicates a strong need for heightened communication.

However, while lack of technical knowledge was the most commonly reported barrier in my research, it is important to note that the other barriers in terms of lack of knowledge on native bee benefits and honey bee crises, lack of good sources of information, lack of money and resources, lack of policy and incentives, and lack of necessity, may also be barriers.

Effective Strategy: One-On-One Collaboration and Assistance

One of the common traits among farmers who have successfully installed native bee habitats is that they have had one-on-one collaboration with researchers. In the follow up

interviews with some of the farmers and through some written survey responses, it became apparent that farms had either reached out to organizations or had members highly interested in native pollinators, which is why they installed habitats in the first place. Dr. Gordon Frankie states that "find out about their willingness to adopt a new strategy… You need to know something about what they would need from you upfront instead of dropping on top of them and that's really important." Therefore, from the beginning there needs to be partnerships in which researchers understand farmers' concerns and needs and are able to address those concerns and needs in a collaborative manner.

Previous research on attracting native bees for apple pollination states that "encouraging growers to explicitly integrate wild bees into their pollination strategy requires extension programs that inform growers of wild pollinator efficiencies and provide guidance in implementing pollinator-friendly management practices" (Park 2014). As Jo Ann Baumgartner puts it farmers "need one-on-one" attention. In order to increase the willingness of farmer adoption of conservation programs there needs to be "more intensive outreach efforts, such as one-on-one land-owner visits and localized workshops and tours" (Lemke et al. 2010). As an extension officer from a research study about farmer participation in native vegetation management stated "What the farmer wants is that one-on-one thing. And he wants you to go on his place, and show him how it's going to work, how it's going to benefit him and how it's going to benefit his farm operation" (Mendham et al. 2007). This means that the relationship between farmers and researchers can't just start strong it needs to continue strong in order to have success. Jo Ann states that farmers need someone to help them put in pollinator habitats as they barely are able to do this without any help to which Dr. Frankie furthers this stating that he doesn't "know a single farmer who has done it on his own yet."

In addition, there needs to be constant communication and follow-up in order to maintain a farmer's conviction and dedication. The relationship between extension officers and farmers is "vitally important in raising landholder awareness of the practice and maintaining long-term commitment to ongoing management (Mendham et al. 2007)." Therefore, when going through this process a theme of success is constant, direct, positive, and effective interactions and engagement between researchers and farmers (Mendham et al. 2007).

Recommendation: There should be more workshops, tours, and events with speakers in order to congregate and encourage collaboration between researchers and farmers. There needs to

be more one-on-one interactions with outreach specialists and farmers, which can be done by hiring more cooperative extension advisors so that they don't oversee so many farmers at the same time and can have more quality relationships with the farmers they do work with.

Effective Strategy: Communication and Influence within Social Networks

Another trend I identified is that approximately 75% of farmers who knew someone with native bee habitats had it themselves. This means that if farmers knew someone with native bee habitats they were more likely to have it themselves. However, if they do have habitats, this does not assume that they know someone with native bee habitats. This is a relatively high correlation, indicating the important influence a farmer's network as well as how exposed they are to something has on their management.

There needs to be increased communication in farmer's social networks in general. Dr. Frankie stated that it "comes down to how much talking the farmers are doing with other people" and he doesn't think it's much. Rachel Long also shared a similar sentiment that we need to "encourage more information sharing and getting the word out there." Currently, farmers are thinking "if its works so well why isn't everyone doing it?" as Baumgartner put it, which is probably very influential in how farmers decide or not decide to do activities on their farm. But if more farmers are hearing about the benefits of native bees and implementing native bee habitats, then more farmers will hear about it and also be influenced to try it. Previous research indicates that "the adoption attitude of neighbors is often an important determinant of whether a farmer chooses to adopt a new technology" (Case 1992). Therefore, it is important for farmers to constantly be communicating with each other because as Erin Deihm, a prominent figure in helping get Berkeley listed as a Bee City, states it is "more powerful to hear the pitch from someone who has done it."

Rachael Long suggested "putting habitats on farms that showcase what they are doing is a great way for getting data out there on how to put habitat ... [and] encourage more information sharing and getting the word out there" because "people love to go out on other people's farms and see what neighbors are doing." She stated that this is better than "trying to hand them information." This sentiment is shared by previous research of pollinator conservation in Wisconsin Cranberry growers, in which they recommend that "demonstration sites can be an

effective tool for conservation science in order to demonstrate the effectiveness and feasibility of implementing conservation management in a real-world setting" (Gaines-Day and Gratton 2017). This same study stated that there could also be a peer-mentoring program to connect farmers who currently have native bee habitat with farmers who are interested in installing native bee habitats, since around 64% of farmers in their study received their information from neighbors and friends (Gaines-Day and Gratton 2017).

Recommendation: There should be more demonstration sites where farmers can go to look at successful native bee habitats within their local communities. Communities should also set up programs where farmers who want to install native bee habitats can be put in contact with those who already have native bee habitats to guide them through the process.

Limitations

There were some limitations, however, consisting of the low participation rate, the inherent responder bias, and the specific scope of study. I received a total of 32 farmer responses from the entire Bay Area, and while each response was substantial in its own right, I by no means have a complete view about the various, complex barriers each farmer faces when installing native bee habitat. Another limitation is that the farmers who responded to my "Honey and Native Bee Management Survey" had an inherent bias in that they were most likely already invested in, knowledgeable on, or cared about bees. The scope of this study consisted of the Bay Area, however, the Bay Area is unique and niche in its culture which means the results could potentially differ from nationwide or even statewide results.

Broader Implications

In general, this can be applied to any collaboration between the agriculture sector and researchers. In the article by Keeler, she mentions that "Authentic partnership with individuals and communities can also expand the frontiers of traditional disciplines, leading to new insights" (Keeler et al. 2017). Therefore, the process of researchers discovering sustainable solutions, recommending them to farmers, and expecting them to follow through, should be discontinued.

Instead researchers should be in constant communication and collaboration with farmers through the research and implementation process.

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REFERENCES

American Bee Journal. 2017, February 1. U.S. Honey Crops and Markets – February 2017.

American Farmland Trust Greenbelt Alliance Sustainable Agriculture Education. 2011. Bay Area Agriculture Today: Sustaining Our Agricultural Bounty.

Arbuckle, J. G., L. W. Morton, and J. Hobbs. 2015a. Understanding Farmer Perspectives on Climate Change Adaptation and Mitigation: The Roles of Trust in Sources of Climate Information, Climate Change Beliefs, and Perceived Risk. Environment and Behavior 47:205–234.

Arbuckle, J. G., L. W. Morton, and J. Hobbs. 2015b. Understanding Farmer Perspectives on Climate Change Adaptation and Mitigation: The Roles of Trust in Sources of Climate Information, Climate Change Beliefs, and Perceived Risk. Environment and Behavior 47:205–234.

Arneson, L. (2000). Record of Native Bees Found in the Greater San Francisco Bay Area Region. http://www.yerbabuenanursery.com/BayAreaBeeList_study.php.

Barnosky, A. D., P. R. Ehrlich, and E. A. Hadly. 2016. Avoiding collapse: Grand challenges for science and society to solve by 2050. Elem Sci Anth 4.

Case, A. 1992. Neighborhood influence and technological change. Regional Science and Urban Economics 22:491–508.

CFANS. 2015, January 27. Bee Diversity. Text. https://www.beelab.umn.edu/bees/bee-diversity.

Delaplane, K. S., D. R. Mayer, and D. F. Mayer. 2000. Crop Pollination by Bees. CABI.

Eshuis, J., and M. Stuiver. 2005. Learning in context through conflict and alignment: Farmers and scientists in search of sustainable agriculture. Agriculture and Human Values 22:137–148.

Frankie, G. W., R. W. Thorp, R. E. Coville, and B. Ertter. 2014. California Bees & Blooms: A Guide for Gardeners and Naturalists. Heyday.

Gaines-Day, H. R., and C. Gratton. 2017a. Understanding Barriers to Participation in Cost-Share Programs For Pollinator Conservation by Wisconsin (USA) Cranberry Growers. Insects 8.

Gaines-Day, H. R., and C. Gratton. 2017b. Understanding Barriers to Participation in Cost-Share Programs For Pollinator Conservation by Wisconsin (USA) Cranberry Growers. Insects 8.

H, Y. 2016. A Review on Relationship between Climate Change and Agriculture. Journal of Earth Science & Climatic Change 7:1–8.

Holl, J. S., for N. G. N. P. May 10, and 2013. 2013, May 10. The Plight of the Honeybee. https://news.nationalgeographic.com/news/2013/13/130510-honeybee-bee-science-european-union-pesticides-colony-collapse-epa-science/.

Huang, Z. 2012. Pollinators. http://www.cyberbee.net/column/pollinator/beepoll.shtml.

Jones. 2014, January 21. Vegetable Crops That Do Not Need Pollinators - HorticultureHorticulture. http://www.hortmag.com/plants/fruits-veggies/vegetable-crops-that-do-not-need-pollinators.

Kay, J.K., Sardinas, H, Jordan, S.F., Lee-Mader, E, Hopwood, J. 2016. Estimated Costs to Establish Pollinator Hedgerows. Xerces Society.

Keeler, B. L., R. Chaplin-Kramer, A. D. Guerry, P. F. E. Addison, C. Bettigole, I. C. Burke, B. Gentry, L. Chambliss, C. Young, A. J. Travis, C. T. Darimont, D. R. Gordon, J. Hellmann, P. Kareiva, S. Monfort, L. Olander, T. Profeta, H. P. Possingham, C.

Slotterback, E. Sterling, T. Ticktin, and B. Vira. 2017. Society Is Ready for a New Kind of Science—Is Academia? BioScience 67:591–592.

Koh, I., E. V. Lonsdorf, N. M. Williams, C. Brittain, R. Isaacs, J. Gibbs, and T. H. Ricketts. 2016a. Modeling the status, trends, and impacts of wild bee abundance in the United States. Proceedings of the National Academy of Sciences 113:140–145.

Kremen, C., R. L. Bugg, N. Nicola, S. A. Smith, R. W. Thorp, and N. M. Williams. 2002a. NATIVE BEES, NATIVE PLANTS, AND CROP POLLINATION IN CALIFORNIA. Fremontia 30.

Kremen, C., N. M. Williams, and R. W. Thorp. 2002b. Crop pollination from native bees at risk from agricultural intensification. Proceedings of the National Academy of Sciences 99:16812–16816.

Lawson, W., and H. Dail. 1996. Sources of Information for Farmers.

Lemke, A. M., T. T. Lindenbaum, W. L. Perry, M. E. Herbert, T. H. Tear, and J. R. Herkert. 2010. Effects of outreach on the awareness and adoption of conservation practices by farmers in two agricultural watersheds of the Mackinaw River, Illinois. Journal of Soil and Water Conservation 65:304–315.

Mader, E. 2008. Farming for Bees: Conservation of Native Pollinators. *University of Missouri Extension.*

Mendham, E., J. Millar, and A. Curtis. 2007a. Landholder participation in native vegetation management in irrigation areas. Ecological Management & Restoration 8:42–48.

Moisset, B. 2011. Bee Basics: An Introduction to Our Native Bees. USDA, Forest Service.

Munyuli, T. 2011. Agricultural Sciences Farmers ' perceptions of pollinators ' importance in coffee production in Uganda.

Niles, M. T., and N. D. Mueller. 2016. Farmer perceptions of climate change: Associations with observed temperature and precipitation trends, irrigation, and climate beliefs. Global Environmental Change 39:133–142.

Office of the Press Secretary. 2014, June 20. Fact Sheet: The Economic Challenge Posed by Declining Pollinator Populations. https://obamawhitehouse.archives.gov/the-press-office/2014/06/20/fact-sheet-economic-challenge-posed-declining-pollinator-populations.

Palmer, B. 2015, May 18. Would a World Without Bees Be a World Without Us? https://www.nrdc.org/onearth/would-world-without-bees-be-world-without-us.

Park, M. 2014. Importance, Drivers And Conservation Of Wild Bees For Apple Pollination.

Partap, U. 1999. Pollination Management of Mountain Crops through Beekeeping- Chapter 4: Hives Bees As Crop Pollinators. International Centre for Integrated Mountain Development.

Pestwiki. 2016, December 15. Pestwiki.

Philpott, T. 2015, May 25. If you like almonds, the bee die-off could be very, very bad news.

Rich, D. 2005, May 21. Abuzz about bees / California's native bees can lessen farmers' dependence on the European honey bee - SFGate. https://www.sfgate.com/green/article/Abuzz-about-bees-California-s-native-bees-can-2632860.php.

Rose, T., C. Kremen, A. Thrupp, B. Gemmill-Herren, B. Graub, and N. Azzu. (n.d.). Mainstreaming of Biodiversity and Ecosystem Services With A Focus On Pollination:66.

Rose, T., C. Kremen, and L. A. Thrupp. 2015. Policies to Protect Pollinators: Actions Needed to Avert a Global Crisis in Agriculture:6.

Tanentzap, A., A. Lamb, S. Walker, and A. Farmer. 2015, September 9. Resolving Conflicts between Agriculture and the Natural Environment. http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1002242.

University of Maryland. 2017, May 25. US beekeepers lost 33 percent of bees in 2016-17. https://phys.org/news/2017-05-survey-honeybee-losses-horrible-bad.html.

USDA. 2008. Using Farm Bill Programs for Pollinator Conservation:16.

USDA. 2012. Census of Agriculture - 2012 Census Publications - State and County Profiles - California. https://www.agcensus.usda.gov/Publications/2012/Online_Resources/County_Profiles/California/.

USDA. 2016. Pollinators. page. https://www.fsa.usda.gov/programs-and-services/economic-and-policy-analysis/natural-resources-analysis/pollinators/index.

vanEngelsdorp, D., and M. D. Meixner. 2010a. A historical review of managed honey bee populations in Europe and the United States and the factors that may affect them. Journal of Invertebrate Pathology 103:S80–S95.

Vaughan, M., and S. H. Black. 2008. HOW TO PROTECT AND ENHANCE HABITAT FOR NATIVE BEES:12.

Vaughan, M., J. Hopwood, E. Lee-Mader, M. Shepherd, C. Kremen, A. Stine, and S. Hoffman Black. 2015. Farming for Bees: Guidelines for Providing Native Bee Habitat on Farms. The Xerces Society for Invertebrate Conservation.

Worland, J. 2017, March 2. More than 700 North American Bee Species Face Extinction. http://time.com/4688417/north-american-bee-population-extinction/.