INTRODUCTION

Over the last decade, honey bee populations have decreased at rates upwards of 30% per year. Preliminary data suggests that beekeepers lost 44% of their honey bee colonies between April 2015-April 2016 (Seitz et al. 2016). While commercial beekeepers have managed to adapt to these changes thus far (Regan 2013), ongoing declines may soon begin to impact production costs and threaten farmers with crop loss (Mader 2010). In the US, over 100 crops are bee-pollinated, representing two-thirds of food consumed (Allen-Wardell et al. 1998; NRC 2007). According to the *Report on the National Stakeholders Conference on Honey Bee Health* (2012), "[d]espite a remarkably intensive level of research efforts towards understanding causes of managed honeybee colony losses in the United States, overall losses continue to be high and pose a serious threat to meeting the pollination service demands for several commercial crops."

Honey bee declines have sparked new interest in wild bees as a supplement or alternative to honey bee pollination. It is well established that pollination by diverse bee species is both more efficient (due to diverse bodily adaptations, weather and floral preferences, seasonal and life cycles, etc.) and more stable (i.e., resistant to fluctuations in diverse bee populations) than by honey bees alone (Mader 2010). In the urgency to educate the public, promote wild bee conservation, and ensure stable crop pollination, pollinator-friendly programs have multiplied and been widely promoted. Research has proliferated, showing that when wild bees are diverse and abundant, they enhance the pollination efficiency of honey bees, provide services that honey bees are not adequately delivering, improve productivity of self-fertilizing crops not typically managed for pollination, can significantly increase fruit set, and can even substitute managed honey bees (Kremen 2002; Greenleaf and Kremen 2006; Winfree et al. 2008; Garibaldi et al. 2013; Blaauw and Isaacs 2015).

These services translate into economic benefit: Chaplin-Kramer et al (2011) estimated that 35-39% of the pollination services required by California crops are provided by native bees at an economic value of $0.9-2.4 billion annually. Working on the assumption that farmers are motivated by economic benefit, other research has sought to provide evidence of financial gain from technologies that work to draw and sustain wild pollinators, like hedgerows (Morandin et al. 2016). Yet, despite the research and resources available, widespread knowledge and adoption of native bee farming remains elusive.

FARMING FOR NATIVE BEES

In 2009, the UC Berkeley Urban Bee Lab launched *Farming for Native Bees* in order to address honey bee decline. In addition to developing a new technology – namely, high quality, crop-specific wild bee habitats – the project planned to conduct a standard cost-benefit analysis. The goal of this analysis was to measure the economic benefit of our unique habitat design, and contribute to the growing body of research on the economic benefits of native bee habitats overall, to incentivize farmers to adopt the technology.

The analysis faced immediate challenges: farm operations differed significantly, as well as level of farmer willingness to participate (amount of acreage, location in relation to crops, type of habitat (permanent vs. annual/seeding). The multi-year study provided sharp insight on just how dynamic these farms are – from changes in land use, to crop composition, to management

strategy (organic vs. conventional), to ownership. Several of the initial participants have since sold their land, and no access to these lands. Habitat removal/change location.

Further, participant farmers were unable to provide much of the data we had planned to collect. Those measures of "hard" economic impacts, such as crop yield information, NOIs, and balance sheets, on which we assumed farmers relied to make business decisions were not readily available, and/or did not seem to be a central factor in decision-making. In our attempts to educate farmers about native bees and their potential as crop pollinators, farmers seemed somewhat unmoved by evidence of economic benefit. None had perceived any immediate impacts of honey bee decline on their crops and, while they knew and were concerned about honey bee decline, economic benefit alone did not appear to be a primary motivation for taking on or adopting the project.

We thus began to consider some alternatives to the strict cost-benefit analysis. Several preliminary interviews were conducted with selected participant farmers with the goal of identifying data that is meaningful to farmers, as well as the best methods to collect it. Based on these initial interviews, a full-length interview was developed to garner an understanding of how the farming business is structured and how decisions are made particularly as they relate to the adoption of conservation strategies like wild bee farming. Paired with anecdotal data collected from ongoing communications and collaboration on project development and maintenance, the interviews worked to contextualize wild bee farming – both as a crop pollination and a conservation strategy – within overall operations. The goal of the following case study is to impart a vision for the eventual integration of wild bee farming into these operations, rather than simply adding another incentive to the list for encouraging adoption.

Challenges to Adoption

Farmers have a complex and varied approach to decision-making when it comes to adopting conservation practices of any kind (American Farmland Trust 2013). Few universal variables, including socio-economic factors such as education and income levels for example, consistently account for differences in decision-making (Knowler and Bradshaw 2007). Rather, decision-making seems to reflect the great variation among the farm operations themselves (how farmers approach a great variety of farm issues, their strategies/decision-making), even among similar size/crop type (California Agriculture 2016).

Within the vast diversity of small farms, what farmers do share is the complexity and broad range of issues and decisions they must face on a daily basis. In order to be successful, they must be attuned to constantly changing environmental conditions, such as rain, temperature, wind, soils, pests, disease, water supply and quality, pest and disease, pollination, while also accounting for distribution, marketing, competition, commodity prices, economies of scale, land costs, among others. Farmers are constantly working to respond to these shifting factors. Patrick Johnston clearly articulated this challenge in his interview:

> *"You're only as good as the next year you're able to continue to farm. To do that in an environment that is ever changing, whether it be because of Mother Nature, because of the market of a particular product goes down, you need to be very conservative in celebrating your successes as well as weathering through your challenges. Whether it's from heat stress or pest*

pressure or Mother Nature having a weather event, like rain, planning your planting so that you're navigating through all those obstacles and trying to ensure the best quality product you can."

This juggling act is reflected in the physical shape and composition of the farm itself, from acreage (buying and selling of properties), technologies and practices (equipment, management practices, organic vs. conventional, etc.), land use (what crops go where), to crop composition.

The dynamic nature of these operations – and shifting priorities in response to various pressures – makes long-term adoption of conservation practices particularly challenging. Existing pollinator manuals and programs acknowledge the diversity and dynamic nature of farm operations, but provide little guidance for adapting pollinator programs to these operations.

In recent years, farmers have been faced with a plethora of new challenges, including market competition from Mexico that drives down commodity prices, climate change, increased fuel and transportation costs, compliance with environmental and food safety laws, significant changes in health benefit costs, rapidly changing marketing and distribution channels, among others. Most small farmers operate at a Return of Investment significantly smaller than other industries in good years, therefore the margin for maintaining the farm business from year to year is very tight. Any gains are typically reinvested into the business, and crop insurance will not protect them from losing their businesses if a poorly pollinated crop does not yield adequate product.

Brentwood is one of the largest, most productive farming regions in the Bay Area. However, the region has experienced tremendous development pressure over the past twenty years. Brentwood is increasingly residential, with the rate of population growth in the triple digits during the 1990s and 69% from 2000 through 2005. Many of the old farms and orchards have been replaced by suburban developments since 1990. Agriculture remains important to the local economy, but has declined in relative importance as the city has become more suburban.

A number of reasons: not an immediate crisis; not enough economic benefit relative to investment (benefit is relatively small, takes too long to pay off initial investment); not taking into account other motivations farmers might have. These cost-benefit analyses cannot account for the potentially disastrous impacts of climate change and continued habitat loss.

These farmers spend a great deal of energy and resources responding to the environmental and market conditions they perceive to be important influences on their operations. Seven years of research in Brentwood suggests that farmers are keenly aware of, and adept at managing, a complex array of issues. Their solutions to these issues are not grounded simply in "hard" economic data, but rather are as layered and nuanced as the issues themselves. Quality vs. quantity – what distinguishes small farms from large, corporate farms – their niche.

Case Studies

While the sample size was too small for statistical significance, the following case studies build on the growing body of work on conservation adoption by depicting farmer interactions with the *Farming for Native Bees* project over a 7-year period. Working side by side with the farmers and

farmworkers to establish, maintain and evaluate the projects has provided significant insight on farmer decision-making, farm operations, and adoption of conservation practices.

METHODS

The Listening Sessions

In late 2014, interviews were conducted with 3 of our participant farmers to shed light on farmer knowledge, beliefs, values and needs in relation to their financial investments in crop pollination. Farmers were provided with a series of handouts to facilitate their knowledge, and a practice interview was conducted with one of the farmers to help him to prepare. All of the interviews were videotaped and transcribed in order to serve as raw material for planned educational tools and technologies.

Questions were grouped into following categories:

- *Farm operations* (depict complexity of farming operations and the diversity among these small farms. Learn about Perceptions of and Capacity to Adopt and Adapt Nb Farming/Management)
-

Partnerships

In addition to the interviews, researchers involved in the project have worked closely with farmers on every aspect of the program, from:

- identifying locations for habitat
- plant selection
- installation and maintenance (digging holes, plantings, irrigation)
- Training farmworkers

Regular communications (meetings, emails, casual conversations onsite), ongoing education (articles, posters, flip booklet, images + lots of first-hand exposure in the field, looking over habitat sites, identifying nb, etc.), and especially, negotiations of continual adaptation of project to meet dynamic operations. Regular reporting, participation in farm outreach activities. In some cases, farmers were engaged in multiple conservation practices, with which they had different relationships (e.g., Farmer Al's compost), that provided opportunities for comparisons.

The successes and challenges in developing and maintaining the projects provide extensive insight on farmer decision-making and the issue of adoption. On the one hand, offerings of new sites, integration into marketing/outreach, testimonial (Mark D. at Contra Costa F&W). On the other hand, moving habitats around, failure to water, accidental mowing, etc. Shed light on to what extent the project was adopted by each farmer, and what would be needed to support complete adoption.

Initial input from participating farmers was required to designate appropriate sites for installations. In most cases, this meant walking researchers through their farms to show the layout of the land, identify crop types and potential sites for habitats. Habitat size and composition was discussed, as well as the importance of bee pollination to specific crop types. Existing management regimes, such as pesticide use and irrigation systems, and how these might be adapted to meet the needs of bee habitat were also discussed. While these initial meetings and

conversations were informal, they set the stage for growing relationships with partner farmers. These interactions also began to shape our understanding of small farms as unique operations that are managed with widely differing strategies.

Some farmers provided support in terms of labor to install and maintain the habitats, but the researchers took on most of this work. Some farmers contributed resources, such as irrigation systems and water, and adjusted management regimes, such as weed removal (e.g., using a hoe rather than a tractor or weed-whacker near the habitats to avoid damage), to accommodate the project. The maps in Appendix II identify habitat locations.

Overall, it took much more time than expected to install bee habitat. We had imagined that farmers would contribute more at the outset in terms of resources and labor, but farmer interest, knowledge and input varied greatly and changed over time. Researchers took a larger role in initial installations to ensure plantings were done correctly and plants were watered and maintained. Both researchers and farmers experienced a steep learning curve, sharing information and techniques for installations and maintenance.

The severe ongoing drought also impacted the project: native bees are sensitive to environmental conditions, and may not emerge during especially dry years. – empirical data

DISCUSSION

1. Small farmers and farm operations are unique and change over time
2. Farmers are constantly responding to a large number of pressures, and are willing to pay experts to help them with support/projects they deem important/valuable
3. Many farmers do not perceive inadequate crop pollination as an immediate threat to their farms, which is a prime motivator for implementing new management practices
4. Financial benefit is important but often not the sole motivating factor; it is balanced with other values, which farmers prioritize differently
5. "Financial benefit" is not necessarily defined strictly by monetary compensation – quality of product emerged as a common and important motivator
6. Perceiving impact/benefit from a conservation practice ("empirical evidence") plays a powerful role in initial buy-in and adoption
7. Building relationships between farmers and supporting agencies/experts is essential

Challenges

DYNAMIC NATURE OF FARMING is among the greatest challenges.

- The great variation among farm operations (how farmers approach a great variety of farm issues, their strategies/decision-making), even among similar size/crop type (California Agriculture 2016)
- Diverse pressures (environmental, market, govt. rules/regulations) – Venn Diagrams illustrate how ALL factors are important
- Inconsistency of pressures (CalAg food safety article)

Farmers are constantly working to respond to these shifting factors. This juggling act is reflected in the physical shape and composition of the farm itself, from acreage (buying and selling of properties), technologies and practices (equipment, management practices, org. vs. conv.),

landscape use (what crops go where), to crop composition. The dynamic nature of these operations – and shifting priorities in response to various pressures – makes long-term adoption of conservation practices particularly challenging. EXAMPLES – changing land use, moving habitats.

Time constraints. Farmers mention in interviews that there is work throughout the year. New projects are often overseen by outside experts.

Due to the amount of work, factors, etc. priorities emerge as needs arise. A great challenge to farming for native bees is that the impacts of bee decline have not been uniformly felt, or are drastic enough to have become a priority need for farmers. Awareness of the issue and *potential* threats is on the rise, but most farmers (particularly smaller, diversified farms where bee-dependent crops like almonds aren't the primary crop) haven't felt the impacts first-hand. (this might be the case for many types of conservation practices – many of these have long-term benefits, perhaps don't address an immediate or apparent need).

While use of conservation practices are on the rise in California, particularly among organic farms, no one single conservation practice seems to have been widely adopted. While over 90% of farmers see conservation as their responsibility, and reported utilizing at least one conservation practice, few of the conservation practices queried had widespread use (Food Safety). This seems to suggest that no single conservation practice has gained enough traction to be seen as an integral part of the farming industry.

How to develop technologies that are flexible enough to meet the individual needs of diverse – and changing – farm operations? How to educate/incentivize farmers to encourage widespread use?

Motivations and Values

- The legacy and other values keep them in business.
- They are concerned about pollination services (CCD) and do not think there is an easy answer.
- Small farmers are close to their operations and familiar with their crops, and are open to sustainable solutions, empirical approaches, and like other problems they have faced the farmers are willing to work at and invest in solutions.
- Crop conversion (to non bee dependent crops) in event of catastrophic loss is not viable option and they will fight to keep Hb Nb dependent crops (back to motivations)
- They are all eager to learn about Hb Nb compatibility, pollination facts/surprises such as while a crop is perceived to be self pollinating (cafe) it is benefited by bee pollination, benefits of Nb, how to integrate. Can Credit Partnership of Nb farming for this interest!!
- They don't look at linear solutions and are in fact suspect of the snake oil salesman - fast solution. They are sophisticated in knowing solutions often lie in nature and require integrated conservation practices. Many of the farmers are very informed about beneficials for example and that is a model for Nb. All our farmers grasp complexity of soils for example.
- They all value product quality and believe in an investment in understanding the crops, and paying close attention to crops (such as pollination and management) is necessary to

secure a high quality product outcome. The same complexity farmers accept and embrace from the environment (climate soils H2O seasonality etc Venn) they also accept about crop species (pollination, disease, growth, fruit set, etc Venn)

- Market pressures and competition is fierce and quality product is the best tactic to deal with that.

There is such a parallel with the layers of complexity in envi factors and business decision, and they intercept in operation. **Layers of Complexity**, **solutions also layered and driven by motivation to remain in business.**

Adoption-Diffusion

Rogers Adoption-Diffusion model also provides an interesting lens for understanding how decisions are made, as well as how operations (and conservation practices) are managed over time.

CONCLUSION

10-year vision – continued trend in hb decline. Supplementary/alternative pollination services will become a more pressing need, felt more broadly by many more farmers. Farming for native bees won't just be a conservation measure, but actually a very critical need for farmers.

In order to be successful, programs ideally need to address many different factors (perceived threats, motivations/values, adoption type), and be as flexible and adaptable as the farmers themselves as operations shift in response to emerging circumstances. It has been suggested that surveys be conducted to learn more about farm operations, and farmer perceptions, needs, etc. (American Farmland Trust 2013).

ONGOING PARTNERSHIPS ARE THE SOLUTION.

- Model of investment – a shift in how government programs work with partners. Balancing government assistance with investment on the part of farmers.
- Farmers avoided govt. programs because of requirements and rigorous, time-consuming reporting. That said, monitoring (which may need to be done by an outside party) is essential to adoption – farmers want to see results!
- Long-term development of relationships with farmers (creating access to operations data and educating both parties). Led to a deeper understanding of individual farm operations/strategies for coping with complex problems.
- The types of farmers who adopt long-term are typically cautious at first. Installation/adoption needs to be progressive as farmers warm up to the concept and become more invested. This requires partnership!!

Cooperative Extension, NRCS, certified crop advisors, agribusiness are the most highly respected sources of information (American Farmland Trust) – have built a strong reputation within the farming community based on the relationships they have made with individual farmers.

Empirical evidence: Other studies have emphasized the importance of empirical evidence, and some agricultural agencies and institutions have integrated this concept into their conservation

programs, supporting projects that demonstrate successful new technologies and practices. The Natural Resource Conservation Service, for example, allocates a large portion of their funding for such projects. Pollinator-friendly projects would benefit greatly from trainings that help farmers to identify native bees and pollen-collecting methods, as well as conduct simple monitoring on their crop plants so they could see the bees at work.

Willingness to invest, either in managing the project themselves or in hiring an expert to provide ongoing support.

PRACTICES THAT ADAPT BOTH TO INDIVIDUAL OPERATIONS, AND CHANGES IN OPERATIONS OVER TIME.

While there are many motivating factors for introducing new conservation practices, the perception of immediate threat to operations is key among them. A great challenge to *Farming for Native Bees* was that the impacts of bee decline have not been uniformly felt, or are not drastic enough to have become a priority need for farmers. While there seems to be general awareness of the issue and potential threats, most farmers (particularly smaller, diversified farms where bee-dependent crops like almonds are not the primary crop) have not felt the impacts first-hand. Practices that seem primarily preventative, or that do not produce tangible results that farmers can see may be put off. In the event that bees continue to decline and crop pollination becomes an immediate crisis, more farmers may be more willing to invest their time and resources. In the meantime, education and outreach, as well as agency support will likely be required to ensure that bee decline does not reach a crisis level.

Extra = Discussion section of article I think when you cite other work. Results can show our farmers perceptions.

Further research and, perhaps even more importantly, farmer education about the economic benefits of wild bee-enhancing technologies are critical, as many farmers remain unaware of these benefits. Farmers interviewed by Pollinator Partnership in their assessment of an NRCS program in Montana (Baril 2008) stated that "creating habitat won't be economical, you just have to love it," or cited aesthetic improvement and increased wildlife as the primary benefit of installed habitat.

Solving the Problem of Time Management

Our outreach campaign has raised awareness about pollination services, the potential impacts of honey bee declines, and the role of wild bees in crop pollination. In result, farm partners have readily adopted the project, providing more acreage for demonstration habitats and resources like irrigation systems and labor for its maintenance. Yet, despite this increased interest and engagement, the greatest obstacle to implementation of our new technologies remains a simple lack of time. Many small farmers work 80+ hour weeks and, with innumerable variables to consider, are hard-pressed to introduce new management responsibilities to their daily routines.

Other pollinator programs have attempted to address this issue by offering time-efficient solutions – one-time installations of hedgerows, or seed mixes that require little management. However, compared with *Farming's* high quality, crop-specific habitats, these solutions fail to produce tangible impacts on crop pollination. Our experience with Brentwood farmers indicates that, without considerable guidance and assistance, most farmers would be unlikely to adopt wild bee habitat farming over the long term.

Our experiences in Brentwood in the past 4 years suggest that, despite farmers' (and the public's) growing concern about crop pollination – and resulting interest in wild bees – many small farmers do not have the time nor the expertise to install and manage wild bee habitat. Farmers rely on a host of specialists, from pest experts, crop consultants, and beekeepers, to marketing professionals and accountants to manage many key aspects of farm operations. In response to growing concerns about pollination services, NRCS has already established a pollinator TSP to advise and assist in the management of wild bee habitat. The project will provide NRCS with detailed, region-specific recommendations for job criteria, and will pilot test an in-depth training program with the goal of increasing these positions in California and beyond (currently, there is only one TSP on the West Coast).

Perceptions of Benefits – Drivers of Adoption CONCLUSION PERHAPS MARY

Hard economic data is not so important. "Hard" biological/crop yield evidence. Reality of the farming lifestyle – constant contact with factors that influence success, not just a concept on the page. Example of Farmer Al's soil – he believed that the success of his apricots this year was a direct result of new composting project, and is now very enthusiastic about the project. Mentioned that seeing bees on flowers would indicate to him success of bee project. Sweetness of fruit, etc.

Conclusion

Challenges to implementing *Farming for Native Bees*: takes time and careful, ongoing management, expertise. Research has found that farmers are less likely to adopt conservation practices that require more time/labor/attention. However, bee decline may soon reach the point where more drastic measures may be required. "Providing support and advice for farmers in more sustainable farming methods with reduced pesticide use is likely to have broad benefits for farmland biodiversity" (Goulson et. al. 2015) beyond an individual farm (we have found this in our research as well – surrounding land use patterns).

In anticipation of a future in which wild bees will factor prominently in agriculture, the importance of educating farmers, developing new technologies (such as installations of high quality wild bee habitats) and exploring the potential of an Advisor position to successfully implement new technologies is critical…

One of the positive features of the project is its flexibility in meeting farmer ability and interest (size and location of habitats – see Adoption of Cons Measures: "how the technology can be applied to the producer's operation" and "testing applicability at a specific site" Rogers adoption/diffusion model). Difficult to control for cost-benefit – each farm/project is different. Increasing evidence suggests that wild bees contribute important pollination services, and that these services crucial to long-term agricultural resilience. In anticipation of a future in which the services of wild bees become necessary for adequate crop pollination, it is our job as scientists and conservationists not only to develop the best technologies, but to determine the most effective means of encouraging their adoption by producers.

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