Honey Bee Colony Strength in the California Almond Pollination Market

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Honey bee colony strength is an important factor in almond pollination decisions due to increased pollination efficiency of larger colonies. Growers use contract provisions to secure a minimum level of colony strength, thus making strength an influential component of the overall colony supply and demand which has not been considered in previous economic analyses.

In recent years, high per-colony almond pollination fees have focused almond growers on the specifics of their pollination contracts. A primary component of almond pollination contracts, along with the price per hive and number of hives contracted, has become the strength of honey bee colonies. The industry measures colony strength by counting the number of active frames of bees, where an active frame meets one of two criteria: bees cover at least 75% of both sides of a standard frame of comb within the hive, or at least four bees per square inch of comb.

Colony strength is an important consideration for almond growers in their pollination decisions because honey bee colonies exhibit increasing returns to scale in pollination. Sheesley and Poduska found that a colony with eight active frames (an 8-frame colony) will collect on average 2.5 times more pollen than one with four (a 4-frame colony). A 12-frame hive collects on average nearly 60% more pollen than three 4-frame hives. (Technically speaking, a “hive” is the physical structure that contains a “colony” of honey bees, although the two words are interchangeable.)

In light of larger colonies’ increased efficiency in pollination, Sheesley and Poduska suggested developing a multiple tier pricing system for almond pollination that would incentivize beekeepers to provide colonies of high strength. We learned from a survey at the 2015 Almond Conference that such incentive contracts have become a common practice. In 2015, more than 20% of the respondents used pollination contracts that included incentives for high colony strength.

We asked growers about specific colony strength stipulations in their pollination agreements. Over 45% of growers used a colony strength specification of an 8-frame average. This large share suggests the existence of a standard colony strength for almond pollination. However, colony strength specifications deviated above and below this standard, and many growers reported no frame count stipulation at all.

Despite the importance of colony strength in almond pollination contracts, colony strength has not been acknowledged as an economic decision tool, distorting economic interpretations for many reasons. Surveys often collect pollination fee data without considering colony strength; therefore, previous economic analyses of pollination markets utilized averages of pollination fees across all colony strengths. These average fees misrepresent the distribution of almond pollination fees by overstating fees for low colony strength while understating fees for high colony strength.

Colony strength influences pollination fees in a given almond pollination season due to the strong correlation between colony strength and the overall number of colonies available for almond pollination. Beekeepers make pollination contract decisions before observing realizations of winter mortality rates and colony strength for almond pollination. Consequently, they may not receive sufficient compensation for their efforts in years when overall industry colony strength is poor.

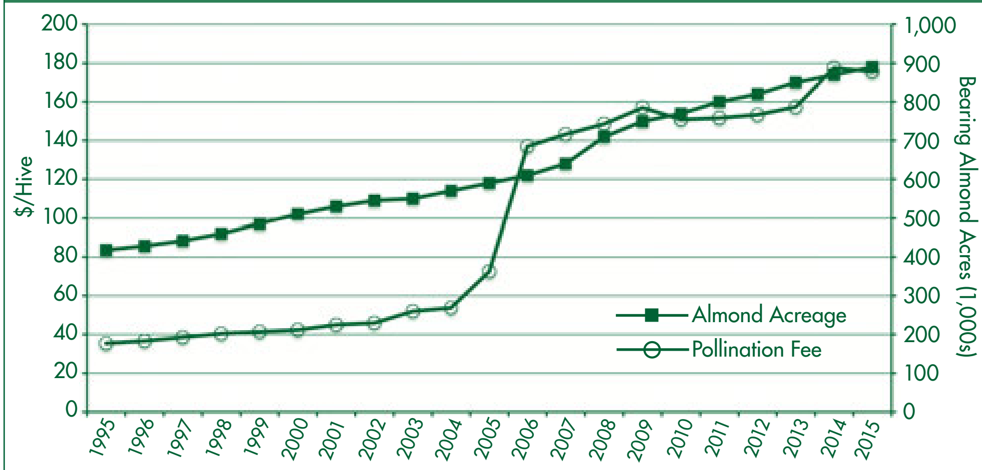
Relatively fixed hive densities despite pollination fee fluctuations have perplexed many economists. Rucker, Thurman, and Burgett (2012) provided two possible explanations for this phenomenon: pollination costs represent only a small share of total production costs and the lack of knowledge of marginal yield benefits from pollination. However, we demonstrate that a factor not previously considered by economists easily explains why hive densities may not fluctuate: the substitutability of colony strength and hives/acre in pollination efficacy.

We define pollination efficacy as the number of almond blooms pollinated per acre, so pollination efficacy is the input of interest to almond growers, not hives per se. The pollination efficacy of the rule-of-thumb two hives/acre density differs considerably for average colony strengths of 4-frames and 8-frames. In the absence of information regarding colony strength, hive densities convey little information regarding pollination efficacy preferences. As a primary choice variable for almond growers and beekeepers in pollination contracts, colony strength is an important component of the economics of managed pollination services.

Almond Pollination Fees

Over the last decade, per-hive almond pollination fees have increased (Figure 1 on page 6). Fees jumped substantially between 2005 and 2006 and increased steadily before and after those years. A combination of supply and demand issues can explain the upward trend in fees. Beekeepers’ costs of supplying hives for almond pollination have increased due to Colony Collapse Disorder (CCD) and other health inhibitors (e.g., varroa mites), which reduce the

Figure 1. Per-Hive Almond Pollination Fees and Bearing Almond Acreage, 1995–2015



Source: California State Beekeepers Association Pollination Fee Surveys; USDA NASS; Almond Board of California 2015 Almond Almanac

number of viable hives and the strength of surviving ones. Higher overwintering losses for beekeepers have led to a costly and uncertain supply of colonies.

Meanwhile, almond acreage has expanded steadily over the last decade (Figure 1). Bearing almond acreage in 2016 required approximately two million colonies for pollination—76% of the honey-producing colonies in the United States during 2015.

Honey Bee Colony Strength as an Input Choice

In a perfect world, an almond grower would pay a price per honey bee and employ honey bees until the price per bee equals the value of employing an additional bee in terms of the bee's contribution to the almond orchard's yield. However, this method is impossible for many reasons, not least because no individual bee can be tracked and the bee does not necessarily forage on the almond orchard in which its colony is placed.

Fortunately, due to the clustering nature of honey bees in a hive, industry participants use a less costly standard of measurement to estimate the efficiency of a colony in pollinating a particular orchard: counting the number of active frames within a hive. This efficiency measure allows growers to substitute between average colony strength and the total number of colonies in a particular orchard.

Colony Strength for Almond Pollination: Inspections and Contract Provisions

Almond growers and beekeepers typically make pollination arrangements months before beekeepers observe overwintering losses and colony strength. In response to the associated risks, almond pollination contracts have played an increasingly important role in the procurement of hives for almond pollination, and third-party colony strength inspections routinely occur in many almond pollination transactions. Inspections are typically associated with contract provisions: to verify the almond grower received the strength she paid for or to calculate monetary bonuses/penalties to allocate to the beekeeper based on his delivered colony strength.

Either the almond grower or the beekeeper can initiate an inspection by a private third-party operation or, in major almond-producing counties, the County Agricultural Commissioner's office for a fee. The party requesting the inspection typically pays for the inspection.

Colony strength inspections for almond pollination occur after hive placement in the orchard. The inspections cover a random sample of 10–25% of hives to arrive at an average frame count for the hives supplied by the beekeeper. Examination of only a sample of hives occurs because it takes time (and therefore money) to inspect honey bee hives for colony strength. The responsible party must pay the inspector(s) anywhere from $20–100/hour and may also pay for the inspection certificate for each orchard/beekeeper (an additional $30–40 per requested certificate). On average, almond growers at one inspection operation paid an additional $1.50–$2.00 per inspected hive.

Regardless of who pays for the inspection itself, an inspection can be costly to the beekeeper due to the possibility of colony loss. Inspectors must carefully replace hive equipment while inspecting a colony so that its queen remains unharmed. Killing a colony's queen results in the loss of the colony, inhibiting or even eliminating its pollination services for the remainder of almond bloom. All parties involved find it desirable to disturb as few of the hives as possible.

Table 1. Sample Almond Pollination Incentive-Based Contract

Almond Pollination Pricing Schedule		
Benchmark Colony Strength: 8-Frame Average	Bonus/Frame Above Benchmark (Max Bonus=$20)	Penalty/Frame Below Benchmark
$175	$10	$15
Beekeeper Per-Hive Payments		
Beekeeper	Average Frame Count	Price/Hive
Beekeeper #1	9.5 Frames	(1.5x10)+175=$190
Beekeeper #2	7 Frames	$160
Beekeeper #3	11.5 Frames	$195

Inspections may be used for verification in both fixed-compensation and incentive-based contracts. Fixed-compensation contracts between the grower and beekeeper provide a fixed pollination fee for all contracted colonies. This contract embeds a specified minimum average frame count that the beekeeper must meet. A grower may request a third-party inspection to verify the minimum average frame count is met, but this does not always happen.

Incentive-based contracts provide a base pollination fee for colonies of a benchmark colony strength in terms of frames per hive. If the actual average frame count found in the inspection exceeds the benchmark, the beekeeper receives a bonus per colony for the number of frames above the benchmark (frequently a maximum bonus will exist). If the colonies fall below the benchmark strength, the beekeeper receives a penalty per colony for the number of frames below the benchmark strength. Table 1 presents an example of an incentive-based contract with resulting per-hive pollination fees for three beekeepers with different frame counts.

A minimum frame count may also be specified in the contract. The beekeeper receives no pollination fees for any colonies failing to meet the minimum frame count. The minimum frame count stipulation in a contract presents an incentive for less variable colony strength. With this provision in a contract, a grower penalizes the beekeeper for providing extremely low strength colonies even if the beekeeper's average frame count exceeds the specified average frame count in the contract.

Colonies for almond pollination can also be procured with no colony strength specifications or as "field run" colonies, and as such would not typically be subject to colony strength inspections. By specifying colonies as "field run," beekeepers are not required to thoroughly inspect and merge small colonies prior to placement in almond orchards to achieve more uniform colony strength for pollination. On average, field run colonies will have acceptable colony strength (6-8 frames although this is not likely specified in the agreement), but colony strength may vary significantly across hives.

Table 2. 2015 Almond Pollination Fees by Colony Strength Contract Type

2015 Almond Pollination Fee/Hive Summary			
Colony Strength Contract Stipulation	Average	Min	Max
None	$165.22	$140.00	$180.00
Average of 8 Frames or Less	$169.66	$135.00	$215.00
Average of More Than 8 Frames	$179.36	$150.00	$200.00

Pollination Prices by Colony Strength

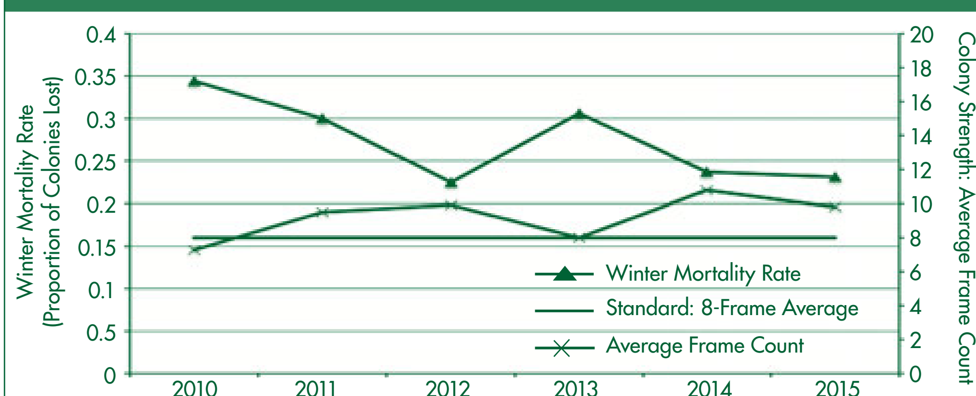
Previous work on the economics of managed pollination services relies on average per-hive pollination fees from various surveys. This use of an average price assumes homogeneous colony strength when in reality industry use of multiple colony strength specifications means that fees represent colonies contracted at different strengths.

Table 2 displays average pollination fees per hive by different colony strength stipulations reported by growers in our survey for the 2015 pollination season. The mean pollination fee per hive for contracts specifying high colony strength significantly differs from the means of both the contracts specifying low and no colony strength. Growers paid on average a 5.7% premium for colonies above the standard colony strength.

The most frequently reported pollination fee in 2015 was $180 and provides an illustrative benchmark when comparing the pollination fees across colony strength categories. Nearly 60% of growers with high colony strength contract provisions reported pollination fees above $180, while only 13% of growers with low colony strength contracts reported fees above $180. None of the growers with no colony strength stipulations disclosed pollination fees greater than $180. The relationship of grower-reported fees to the benchmark price for 2015 supports the notion of fee differences across the three categories of colony strength.

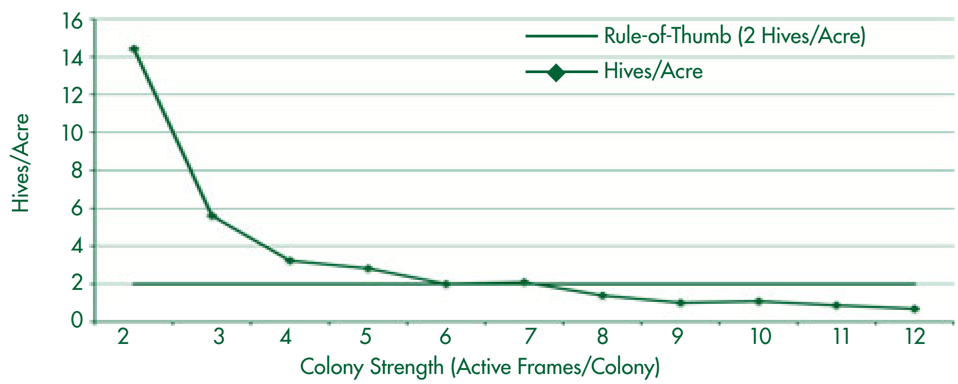
Almond pollination fees thus differ based on the average frame count stipulated in the contract. Additional issues likely complicate reported fees when not accounting for colony strength. Figure 2 displays the average frame counts across all hives inspected during almond bloom by The Pollination Connection, a third-party colony strength inspection operation, and the average winter mortality rates each year from thousands

Figure 2. Almond Pollination Colony Strength and Winter Mortality Rates, 2010–2015



Source: The Pollination Connection; Bee Informed Partnership Winter Loss Surveys

Figure 3. Honey Bee Hives/Acre and Colony Strength Pairs that Pollinate the Equivalent of Two Hives/Acre with Six Active Frames



Source: Sheesley and Poduska (1970)

of beekeepers across the U.S. reported by the Bee Informed Partnership. Average winter mortality rates indicate the number of colonies available for almond pollination because California almond pollination occurs toward the end of winter across most of the country.

Figure 2 shows that the average frame count across the sample of colonies in each almond pollination season correlates inversely with the U.S. winter mortality rate. Thus, fewer colonies available for almond pollination corresponds with beekeepers likely experiencing higher costs of meeting colony strength requirements. This creates the potential for extreme price fluctuations for colonies contracted close to almond pollination after winter mortality rates and colony strength have materialized. The low number of high strength colonies may force a grower to pay a high price even for colonies that fall below the industry standard strength.

The relationship between colony strength and winter mortality rates potentially strains beekeepers financially in many ways, especially those whose contracts specify high colony strength. Beekeeper revenues may decrease due to the decreased number of colonies from high winter mortality rates, while the costs of supplying high strength colonies may increase. Additionally, if a beekeeper is not able to meet the contracted colony strength, the almond grower may impose a monetary penalty on the beekeeper. Therefore, ignoring colony strength in any given almond pollination season omits an important element of supply.

As discussed previously, colony strength plays a role in the almond grower's decision concerning the number of hives to stock per acre. Figure 3 plots the colony strength-hive density combinations that pollinate the equivalent of two 6-frame hives per acre using Sheesley and Poduska's pollen count analysis. A clear non-linear relationship exists between the number of hives per acre and colony strength. Less than one 12-frame hive per acre will pollinate the equivalent of two 6-frame hives. Consequently, growers can substitute hive density and colony strength to find their optimal level of pollination efficacy per acre. As with reported average pollination fees, reported hive densities lack information when colony strength is not considered.

Conclusion

Disregarding colony strength ignores a major component of the supply of honey bee colonies for almond pollination. The high correlation of colony strength during almond pollination with winter mortality rates may disproportionately impact the supplies of the different colony strength grades available for almond pollination. For example, high winter mortality rates lead to a lower supply of colonies overall for almond pollination, but the ratio of high to low strength colonies available may also be smaller relative to low winter mortality years. The disproportionate supply changes complicate economic analysis because reported pollination fees per hive are affected by colony strength. This effect could be intensified if growers view multiple low strength colonies as an imperfect substitute for a single high strength colony.

Additionally, in expected rainy years for almond bloom, such as California's 2016 El Niño winter, almond growers may increase colony strength specifications while holding hives/acre constant to insure against fewer honey bee flight hours during bloom. This creates an uneven demand shift across different colony strengths, therefore convoluting reported pollination fees when ignoring colony strength. It would be beneficial to collect colony strength information alongside pollination fee and hive density variables to obtain a more accurate picture of the economics of pollination markets.

Goodrich, Brittney and Rachael E. Goodhue. "Honey Bee Colony Strength in the California Almond Pollination Market." *ARE Update* 19(4) (2016): 5-8. University of California Giannini Foundation of Agricultural Economics.

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For additional information, the authors recommend:

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