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Honeybees on the move: Pollination services and honey production

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Selected Paper prepared for presentation at
the 2018 Agricultural & Applied Economics Association
Annual Meeting, Washington, D.C., August 5-7

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Introduction

About one-third of the world's food crops depend, at varying degrees, on pollinators—including managed honeybees (*Apis mellifera*) and more than 3,500 species of native bees (USDA-NRCS, 2016). Some crops, such as almonds and melons, require pollination to produce nuts or fruit; other crops, such as tomatoes, apples, blueberries, cherries, and canola, use pollination to boost yields. Farmers growing crops that depend on pollination can rely on local pollinators or pay beekeepers to provide honeybees. Over the past decade, the pollination services market has grown, such that beekeepers now receive a larger share of their income from providing pollination services than from producing honey (Ferrier 2018). Beekeepers truck their honeybees around the country to meet the pollination demand from farmers whose crops flower at different times during the year, while also securing time for the bees to rest in areas rich in forage, such as the Northern Great Plains.

Despite the importance of honeybees to fruit, vegetable, nut, and seed production, limited nationwide data exists on the share of migratory and resident honeybee colonies, the routes these colonies take, and the distances colonies are transported throughout the year. This information is critical to understand how travel affects pollination services, honey production, and colony loss. In recent years, demand for fruits and nuts that require pollination and for honey have grown (USDA-ERS 2017 and USDA-ERS 2018), while at the same time colony loss rates remain high. In addition, because honeybees are moved, crop production that requires pollinators in one state (e.g. almond in California) is dependent on forage in another (e.g. grasslands in North Dakota). As demand for pollination services grows, so will the links between these regions. This information also has implications for federal policy. For example, USDA's Conservation Reserve Program (CRP), which is concentrated in regions where beekeepers place their honeybee colonies,

incentivizes farmers to take land out of agricultural production and plant species that improve environmental quality. The House Agriculture Committee 2018 Farm Bill markup (HR2) would increase the CRP enrollment cap from 24 to 29 million acres.[1] In addition, the UDSA's Farm Service Agency, through The Emergency Assistance for Livestock, Honey Bees, and Farm-raised Fish (ELAP) program, helps eligible beekeepers recover from colony loss. In the first year after eliminating the $20 million cap on indemnities, payments have reached $37 million of which over 80% are claims for honeybee losses.

While there is much anecdotal evidence on the pollination routes taken by beekeepers, to date there has been no quantitative analysis of honeybee colony movements. Bond et al. (2014) provided a qualitative analysis of pollination routes determined mainly through conversations with beekeepers and USDA's Natural Resources Conservation Service. A recent survey of beekeepers by USDA's National Agricultural Statistics Service (USDA-NASS 2017a) allows us to track the movements of the number of colonies by quarter and state.

Results show that each winter (January – March), up to 55% percent of honeybee colonies are in California from as far as the Northeast or Southeast. These beekeepers come to California mainly to pollinate almonds (95% of pollination service revenue in Arizona, California and Hawaii). In the summer, 33% percent of colonies can be found in the Northern Great Plains, a flowering landscape rich in forage for honeybees. Our results also show that beekeepers seek out grasslands (e.g., CRP land) and other summer flowering crops (e.g., canola) as a source of forage for their honeybee colonies. Therefore, CRP land in the Northern Great Plains, where many beekeepers

[1] Based on the latest signup period (49th, December 1, 2005 to February 26, 2016), there appears to be excess demand from farmers for the Conservation Reserve Program. FSA received offers to enroll about 1.86 million acres but only accepted about 407,000 acres.

bring their colonies in the summer, contributes to the production of pollinated fruits, vegetables, nuts, and seeds throughout the United States.

Background

Honeybees are social insects that live together as a colony, consisting of a single queen bee along with tens of thousands of female worker bees and hundreds of male drones. Alongside honeybees, pollination is provided by wild pollinators, including butterflies, moths, birds, bats, and over 3,500 species of native bees. As opposed to wild pollinators, honeybees can be managed by a beekeeper, who provides the hive box, manages honey collection, treats for diseases and mites, and controls colony size through splitting and requeening. Historically, pollination of agricultural crops was provided by wild pollinators and managed honeybees in the vicinity. With the decline in populations of wild pollinators and lack of access to year-round forage for honeybees in areas with intense agricultural production, a market for transported honeybees has emerged.

The movement of colonies around the country is driven primarily by two reasons: the provision of pollination services in different parts of the country (1) and the search for forage to produce honey and ensure overwinter survival of colonies (2). Farmers that plant crops that require or benefit from pollination (e.g., almonds) pay beekeepers to pollinate their crops. After pollination, the beekeepers must move their colonies to the next crop that needs pollination (e.g., apples, cherries) or move their colonies to landscapes that provide forage. This second reason, the demand for good forage to produce honey, drives beekeepers to move their colonies after crop pollination season to areas of the country where honey can be produced and the colonies can grow and be split before the next pollination season.

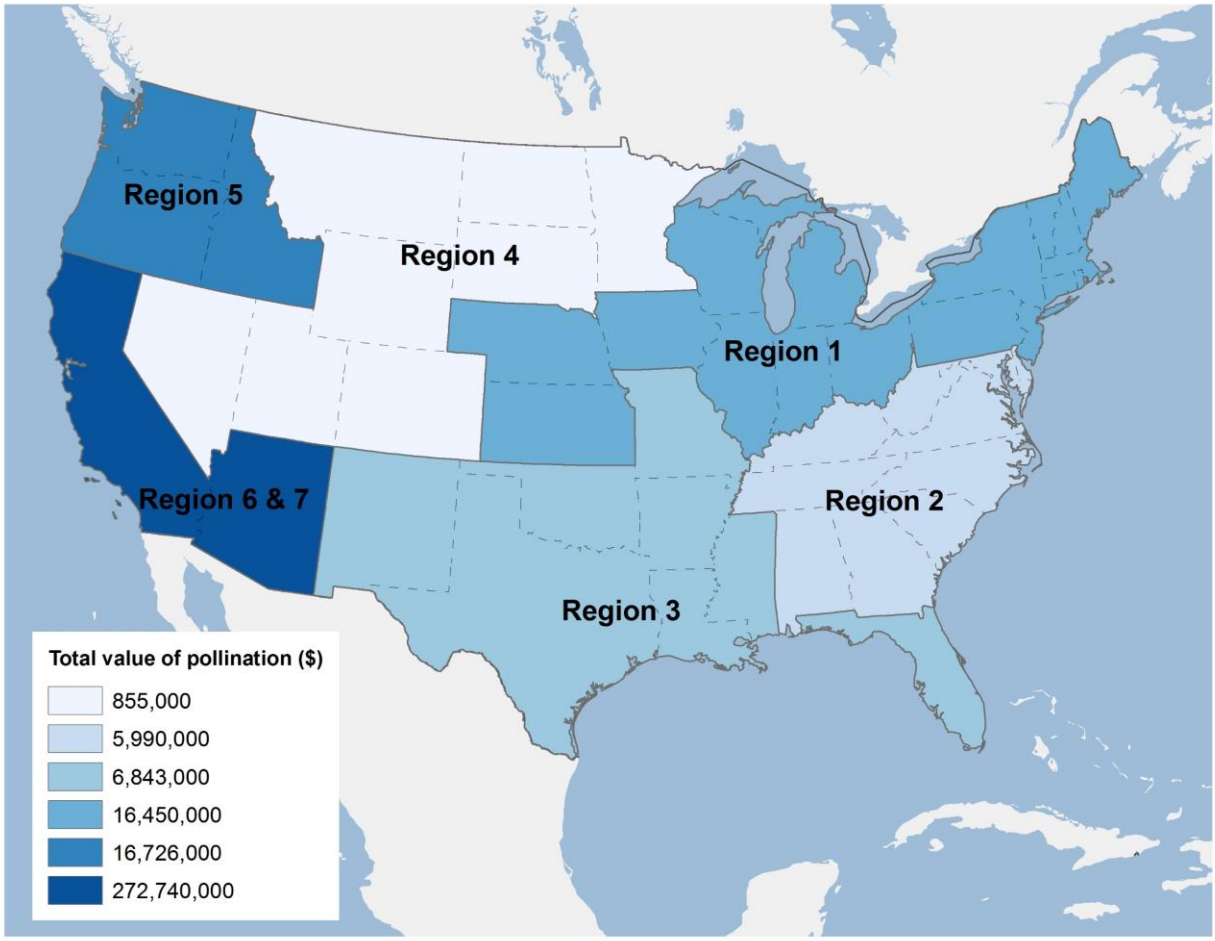
Pollination Services Market

In 2017, U.S. farmers paid $320 million for pollination services (Figure 1, USDA-NASS 2017b). Producers of almonds alone accounted for 80 percent of that amount—over $253 million – while producers of apples and blueberries paid almost $10 million each. Pollination services have emerged as the most lucrative aspect of beekeeping. The largest share of the revenue earned by beekeepers in 2017 came from pollination services (USDA-NASS 2018).

Beekeepers truck their honeybees around the country to meet the pollination demand from farmers whose crops flower at different times during the year. Pollination season starts in February of each year, when 57 percent of all honeybee colonies come to California to pollinate almonds. In 2017, almond bearing acres reached one million acres. This is an increase of 56 percent in the last 10 years. The value of almond production is now over $5 billion dollars, making it the 7th most valuable crop in the U.S. The bearing acreage is projected to continue to rise, as there are approximately 330,000 non-bearing acres that will mature into almond production in the next 3-4 years. As these non-bearing acres begin to bear almond flowers more honeybees will be needed for pollination. From the almond fields, beekeepers move their colonies to pollinate other crops, produce honey, or rest the bees in areas with good forage and low risk of pesticide exposure.

Tree Fruits, such as apples and cherries, are grown across large parts of the U.S. with production concentrated in the Pacific Northwest and the Northeast. Berries (i.e., blueberries, cranberries, and raspberries) are concentrated in the Northeast, while melons (i.e., cantaloupe, honeydew and watermelon) are grown mainly in the South and in California. Demand for pollination services for these crops draws honeybee colonies to these regions each spring.

Figure 1: Value of Paid Pollination Services by Region



Source: USDA, Economic Research Service analysis of USDA, National Agricultural Statistics Service (NASS) Cost of Pollination Survey (USDA-NASS 2017b).

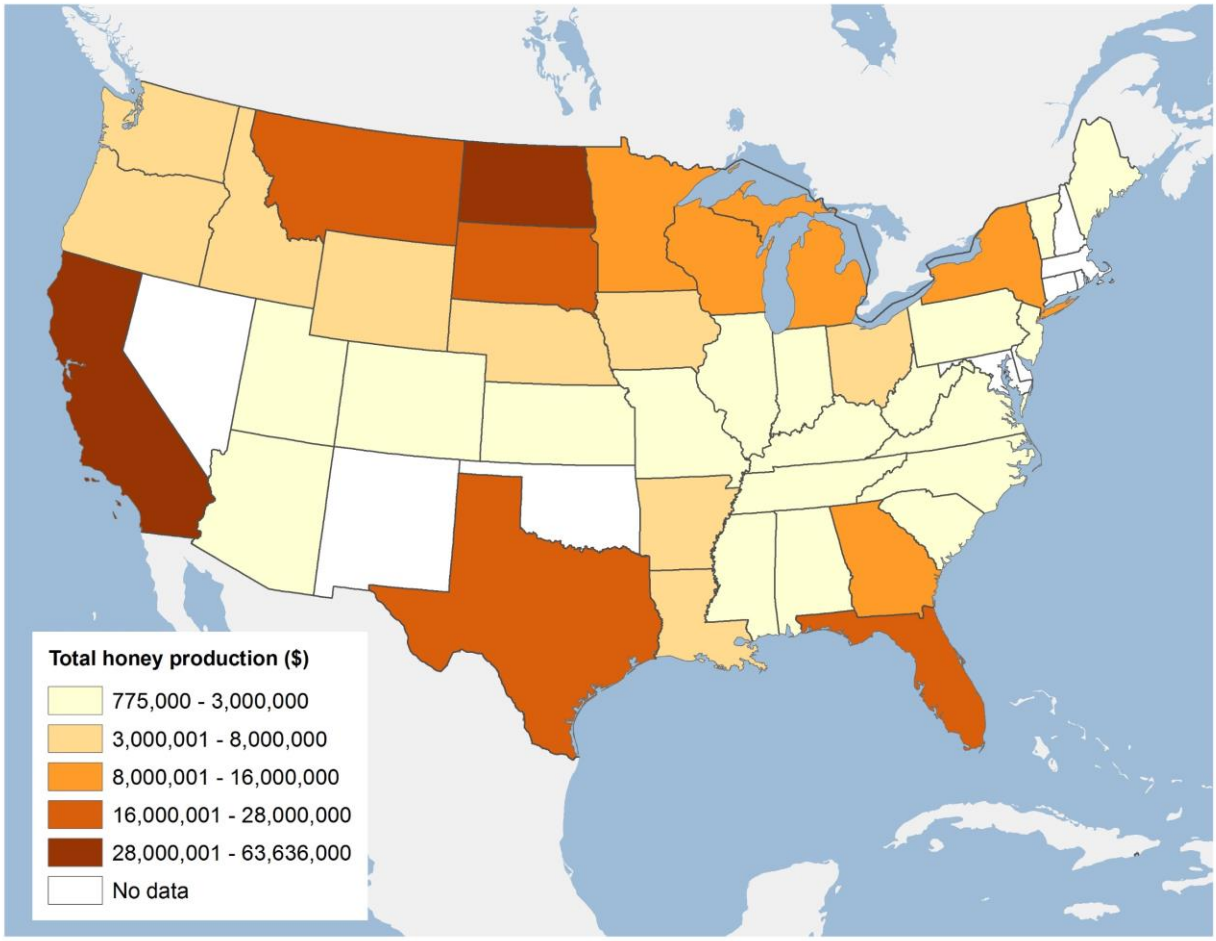
Honey Production and Forage Resources

In addition to providing pollination services, honeybees produce honey and beeswax, among other products. Honeybees collect nectar and pollen from flowering plants and produce and store honey in the hives. When honey stores in the hive are high, this honey can be pulled and sold. Honey production and other products (including queens and beeswax) provided respectively $318 million and $163 million in revenue to beekeepers in 2017 (USDA-NASS 2018).

Honey production and pollination services are activities that do not always go hand-in-hand. The honey produced from bees foraging on almonds is bitter and not sought by consumers. Beekeepers must decide how much honey to pull from a colony to not jeopardize colony survival. At least some honey or supplementary feed in the form of sugar water are left in the hive for the honeybees, as honeybees feed on these stores during the winter months when forage resources are low. Pulling too much honey can result in the loss of the colony or a weaker colony. Lower strength colonies (less than eight-frames) will bring in lower pollination service fees during the February almond bloom as more and more pollination contracts have a strength requirement and/or have per-frame bonuses (Goodrich 2018).

Honey production is highest in states with good forage resources. North Dakota leads the nation in honey production (Figure 2): in terms of value, almost 20 percent of U.S. honey in 2017 was produced in North Dakota. North Dakota and other states in the Northern Great Plains, including South Dakota, Montana and Minnesota feature a combination of a short growing season, ample precipitation, and cooler temperatures that results in a burst of flowering plants over the summer that beekeepers seek out for their colonies.

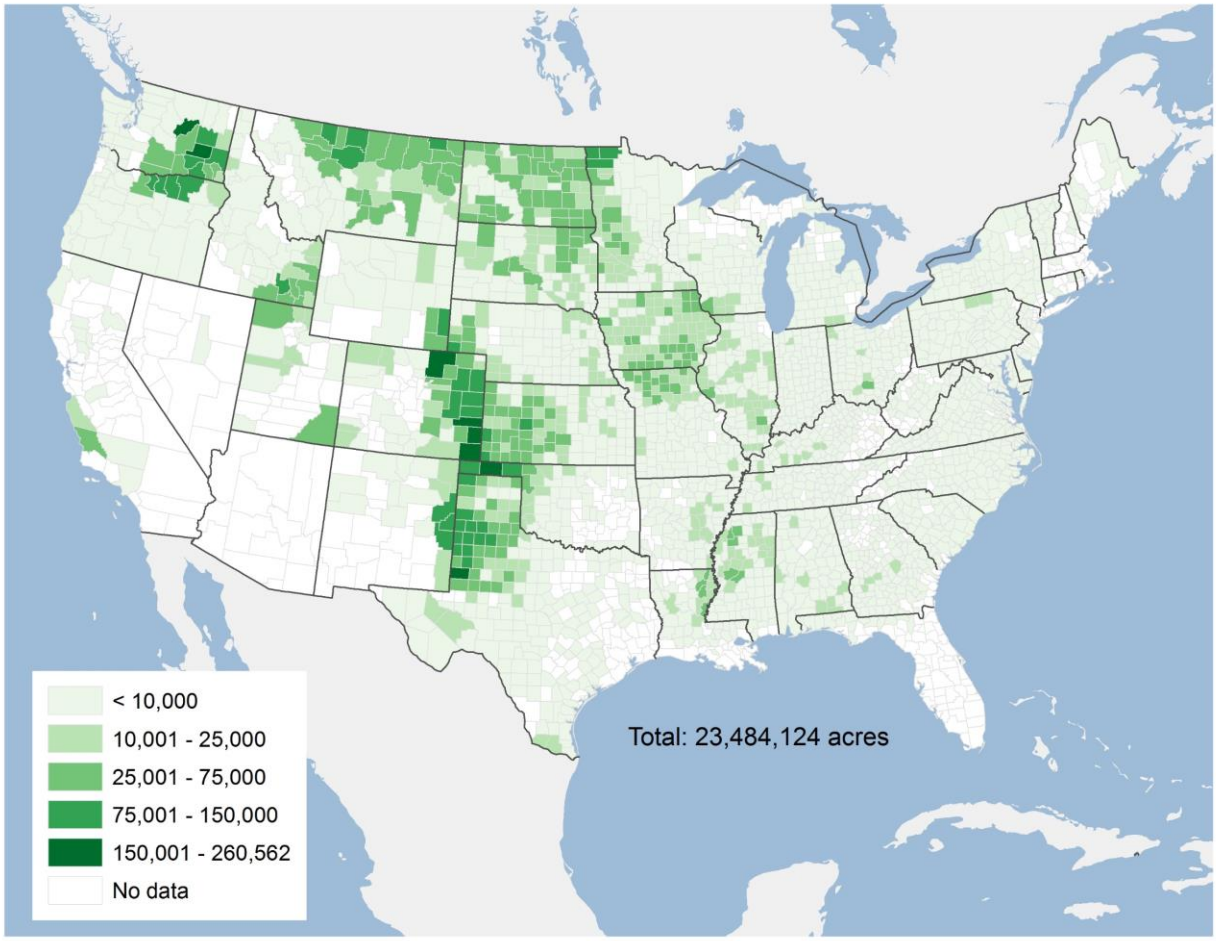
Figure 2: Value of Honey Production by State, 2017



Source: USDA, National Agricultural Statistics Service (NASS), Honey Report (USDA-NASS 2018)

The Northern Great Plains is also an area where acreage enrolled in the Conservation Reserve Program (CRP) is concentrated (about 22 percent, Figure 3). Beekeepers seek out grasslands, such as CRP land, as a place with quality forage and a low risk of pesticide exposure. In experiments in North Dakota, colonies in areas of uncultivated forage land, which includes pasture, USDA conservation program fields, fallow land, grassland, hay land, and roadside ditches, had higher rates of colony survival and honey production than colonies in areas with agricultural production (Smart et al. 2016). Between Spring and Summer the number of honeybee colonies in the Northern Great Plains more than quadruples (Table 1).

Figure 3 – Enrolled acres in the Conservation Reserve Program, January 2017



Source: USDA, Farm Service Agency (USDA-FSA 2017)

Table 1 – Honeybee colony stocks and honey production by state

	Honeybee colonies (thousands)			
State	Summer (July 1, 2016)	Fall (October 1, 2016)	Winter (January 1, 2017)	Spring (April 1, 2017)
California	740	770	**1,150**	1,140
North Dakota	**510**	385	50	112
Florida	200	255	**260**	245
South Dakota	**178**	146	21	34
Montana	**147**	124	19	46
Minnesota	**132**	113	27	34
Texas	129	136	270	**345**
Michigan	**108**	101	29	55

Oregon	**107**	98	71	84
Georgia	102	96	123	**125**
Idaho	79	**121**	95	61
Wisconsin	**71**	59	17	18
Washington	57	65	68	**89**
New York	**56**	48	32	25
Louisiana	51	48	44	**56**
Iowa	50	**54**	10	13
Nebraska	**45**	37	8	9
Colorado	**33**	30	10	17
Arkansas	**32**	28	18	17
Wyoming	**32**	25	7	15
Other	322	293	289	348
Total	**3,181**	3,032	2,616	2,886

Note: Honeybee colony stocks are presented in bold in the season with the most colonies.
Source: USDA, National Agricultural Statistics Service (NASS), Honey Bee Colonies Report (USDA-NASS 2017a)

Data and Methods

In 2016, the National Agricultural Statistics Service (NASS) began surveying beekeepers with 5 or more colonies regarding colony health, in order to build the body of knowledge on honeybees in the U.S. (USDA-NASS 2017a). NASS' Colony Loss Survey of beekeepers collects honeybee colony data every quarter, starting in the third quarter and ending in the second quarter of the following year. As part of the survey, the beekeepers indicate, in which state their colonies were in that quarter. Combining data from multiple quarters, this allows us to track the movements of colonies by quarter and state.

The NASS Honey Bee Colony survey does not track particular groups of colonies throughout the year. Instead, the beekeeper responds to the survey on a quarterly basis and indicates where groups of colonies are located. For beekeepers that had a single group of colonies in a quarter, we know where these honeybee colonies came from and where they went. However, if there are colonies in different states within a quarter, we only know where these honeybee colonies came from if in

the prior quarter that beekeeper only had colonies in a single state (or where they went if the beekeeper in the next quarter only had colonies in a single state). For example, if a beekeeper has colonies in California, Montana, and Washington and moves them to North Dakota and South Dakota the following quarter, we do not know which particular colonies were moved from California to North Dakota. We proceed by assuming proportionality in colony movements. Using the example above we assume that the colonies in California, Montana, and Washington move to both North Dakota and South Dakota. Most (97-98 percent) of the beekeepers and colonies in our sample do not move colonies from multiple states to multiple states from quarter to quarter. For these beekeepers and colonies we know exactly which states they came from and which states they go to. We summarized these movements by regions (described in Table 2). Regions were chosen to be representative of the pollinated crops, forage, and colonies in these regions.

In 2016, NASS also started collecting data from crop farmers that pay for pollination services from honeybees (e.g. almonds, apples; USDA-NASS 2017b). This dataset sheds light on the location of demand for pollination services. The survey reports prices paid, acres, and total value of pollination services by region and crop.

Honeybee Colony Movement

The movement of honeybee colonies around the U.S. is dominated by two main events: movement into California for almond pollination in February and movement into the Northern Great Plains for access to quality forage in the summer. Table 2 shows the share of resident colonies in each region on the first of January and the first of July. Here we define resident colonies as those that were in a region both on that date and 6 months earlier. At the beginning of 2017, only about one-third of the colonies in California were also in California on July 1, 2016. These 374,000 resident colonies remained in California for the second half of 2016. These colonies are used to pollinate

alfalfa (July), melons (August), sunflowers (August) and squash (September). Resident California colonies may also be producing honey during this time. According to the honey report, honey was pulled from 310,000 colonies in California in 2016.

Table 2: Share of resident colonies in a region on January 1 and July 1

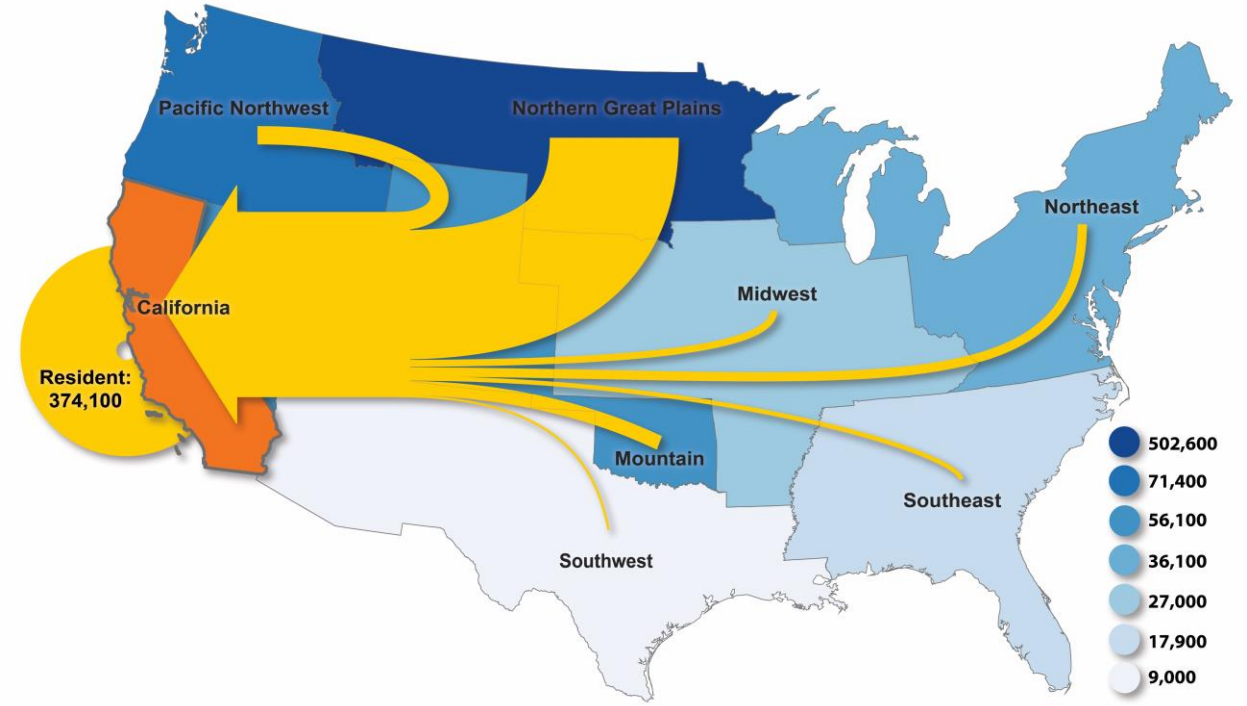
	Colonies on January 1, 2017 (From July 1, 2016)		Colonies on July 1, 2016 (From January 1, 2016)	
Region	Share of total	Number	Share of total	Number
California	34%	374,100	92%	526,800
Mountain (CO, NV, OK, UT)	40%	17,700	15%	11,200
Southwest (AZ, LA, NM, TX)	54%	189,900	92%	197,100
Southeast (AL, FL, GA, MS, NC, SC, TN)	67%	305,200	90%	316,900
Pacific Northwest (ID, OR, WA)	73%	172,300	63%	153,800
Northern Great Plains (MN, MT, ND, SD)	92%	114,100	15%	131,200
Midwest (A, IL, IN, IA, KS, KY, MO, NE)	92%	41,700	55%	51,900
Northeast (CT, DE, DC, ME, MD, MA, MI, NH, NJ, NY, OH, PA, RI, VT, VA, WV, WI)	96%	148,500	45%	153,500
All Regions	54%	1,363,500	56%	1,542,500

Source: USDA, Economic Research Service analysis using USDA, National Agricultural Statistics Service, Colony Loss Survey (USDA-NASS 2017a).

Figure 4 shows the movement into California from July 1, 2016 to January 1, 2017. By far, the largest share of colonies that move into California by January come from the Northern Great Plains. Two adjacent regions, the Pacific Northwest and Mountain regions, are also important sources of colonies for California. Over 50,000 colonies come from as far away as the East Coast. Figure 5 shows the movement out of California from January 1, 2016 to July 1, 2016. Again, the majority of colonies (411,000) moving out of California are destined for the Northern Great Plains, and another 114,000 and 59,000 colonies head to the neighboring Pacific Northwest and Mountain

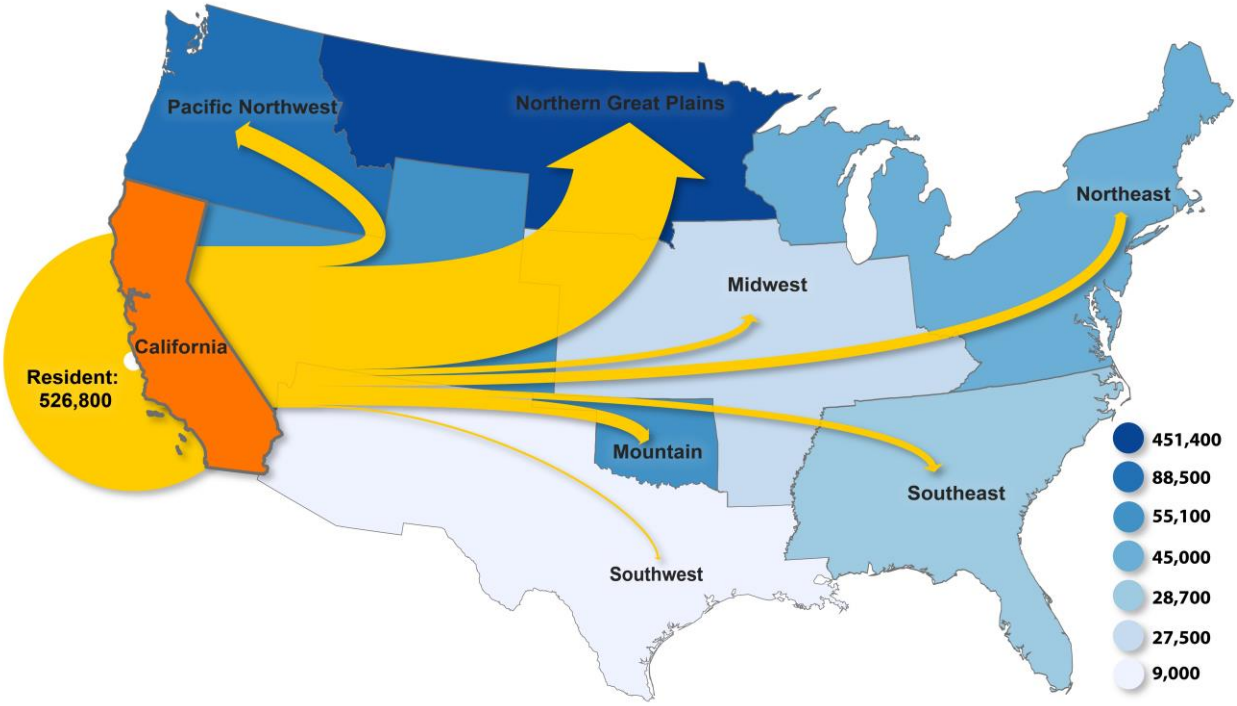
regions, respectively. Over 100,000 colonies head to the Northeast and Southeast regions on the East Coast.

Figure 4 – Honeybee colony movements into California from July 1, 2016 to January 1, 2017.



Source: USDA, Economic Research Service analysis using USDA, National Agricultural Statistics Service, Colony Loss Survey (USDA-NASS 2017a).

Figure 5 – Honeybee colony movements out of California from January 1, 2016 to July 1, 2016.

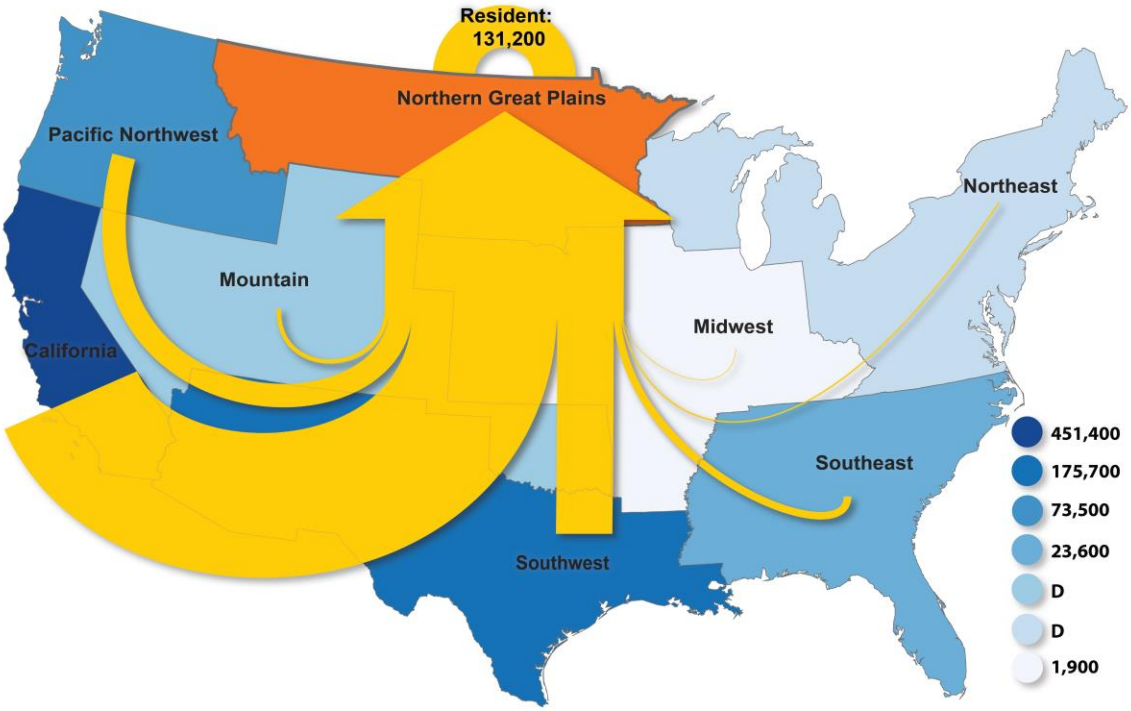


Source: USDA, Economic Research Service analysis using USDA, National Agricultural Statistics Service, Colony Loss Survey (USDA-NASS 2017a).

The Northern Great Plains are one of the main destinations for honeybee colonies in the summer, and Figures 6 and 7 show colony movements into and out of this area for the summer of 2016. Aside from the 411,000 colonies from California, another 203,000 colonies come from Texas and other states in the Southwest. The fact that colonies are moved to the Northern Great Plains in the summer despite the relative lack of demand for paid pollination services (the region including the Northern Great Plains accounts for less than 1 percent of total paid pollination services in 2017), indicates that beekeepers bring the colonies mainly in search of forage resources rather than paid pollination work. The search for areas with low risk of pesticide exposure may be another factor. Anecdotal evidence through conversations with beekeepers suggests that beekeepers move their

honeybees out of California following almond pollination, in order to avoid exposure to pesticides applied to other crops in the area.[2]

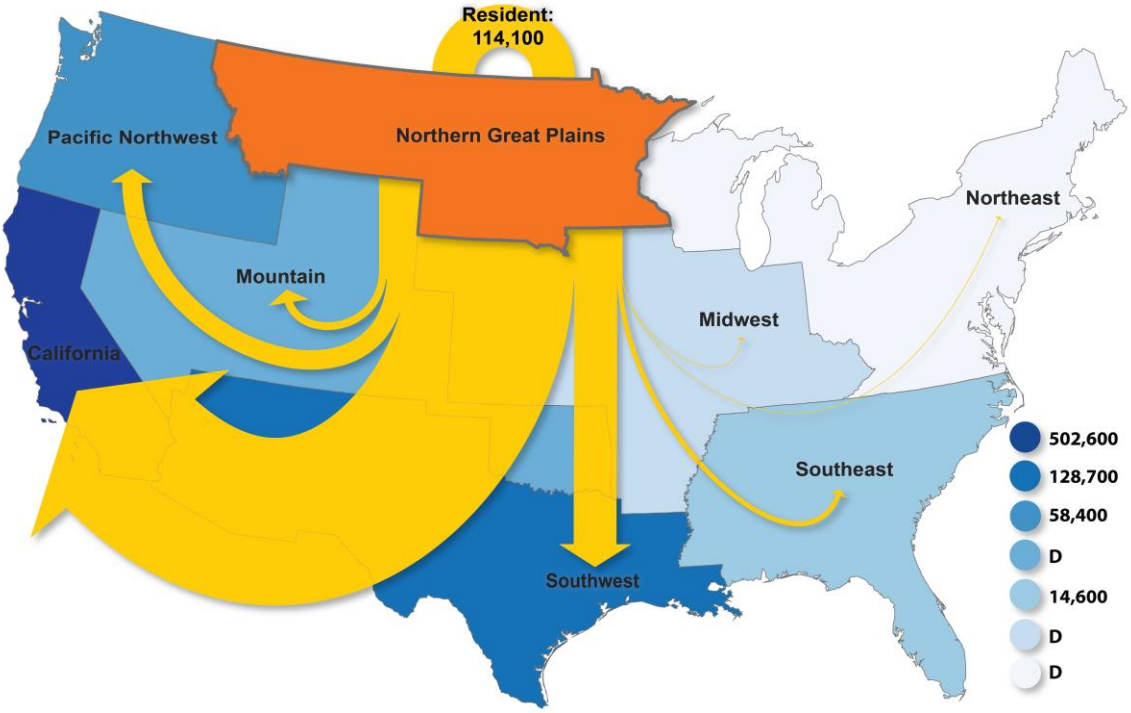
Figure 6 – Honeybee colony movements into the Northern Great Plains from January 1, 2016 to July 1, 2016



Source: USDA, Economic Research Service analysis using USDA, National Agricultural Statistics Service, Colony Loss Survey (USDA-NASS 2017a).

[2] Personal communication, Gene Brandi, American Beekeeping Federation, in March 2018.

Figure 7 – Honeybee colony movements out of the Northern Great Plains from July 1, 2016 to January 1, 2017



Source: USDA, Economic Research Service analysis using USDA, National Agricultural Statistics Service, Colony Loss Survey (USDA-NASS 2017a).

Currently, South Dakota, Montana, Wyoming, Arkansas, and New Mexico provide for exclusion zones or buffer areas around registered apiary sites, in order to protect the forage resources available to established apiaries, while the Nebraska legislature is considering instituting such a regulation (Leonard 2017). When honeybee colonies are crowded together, competition for forage resources can result in a decline of honey production and colony health (Abbott 2018). The 3-mile exclusion zones in South Dakota and Montana, along with the 2-mile exclusion zone in Wyoming, have put pressure on forage resources in North Dakota, which only requires beekeepers to register their site with the state and ask permission from the landowners.

Due to the cold during the winter months, most of the honeybees are moved out of the Northern Great Plains after the summer and into warmer states in the South, while some are able to overwinter in the North in heated warehouses, including heated potato cellars in Idaho (Jabr 2013).

However, not all colonies travel along these major routes into and out of California in the winter and into and out of the Northern Great Plains in the summer. Just over half of all colonies do not leave their region between July and January of the following year. Of the colonies that do move between regions between July and January, 37% move into regions other than California. About 130,000 colonies were transported from the Northeast into the Southeast for the winter and back again for the summer. Another 9,000 colonies that summered in the Northeast in 2016 spent the following winter in the Southwest. Finally, about 9,000 colonies were moved between the Midwest and Southwest in the summer and winter.

Distance Traveled

Transportation for pollination services is a stressor to honeybee health, as it involves long-distance travel, displacement and feeding on one type of pollen. During travel, honeybees are unable to access foraging resources and are instead fed sugar water. During the summer, overheating while in transit can become a problem, if the hive boxes and the array of boxes on the flat-bed truck does not allow for proper ventilation. Beekeepers can also arrange water hoses on the top of the truck to provide for cooling if forced to stop for lengthy periods of time (Wyns 2018).

Three recent studies document the biophysical effects of transportation for pollination services on honeybee health. Honeybees experiencing transportation have trouble fully developing their food glands, which might affect their ability to nurse the next generation of worker bees (Ahn et al. 2012). Zhu et al. (2014) found an increase in the abundance and prevalence of the fungal pathogen,

Nosema ceranae, in honeybees that were transported for pollination in contrast to colonies that were not moved. Finally, in a set of field experiments, Simone-Finstrom et al. (2016) detected a significant decrease in the lifespan as well as higher oxidative stress levels in migratory adult bees relative to stationary bees.

To help inform research on the impact of travel on honeybee health and colony loss, in this section we estimate the average distance traveled by colonies between quarters as well as over the course of a year.

Using distances between state centroids, we can estimate the total distance colonies were moved throughout the year. This analysis relies on the more detailed state-to-state movement data rather than the region-to-region movement data discussed elsewhere in the report, since disclosure of sensitive information is less of an issue.[3] Table 3 shows the average distance traveled by a colony for various pairs of quarters from April 1, 2016 to April 1, 2017 - the latest set of quarterly data available from NASS. The first column shows the average distance for the subset of colonies that were moved between the pairs of quarters, while the second column shows the average for all colonies, including those that remained in the same state.

The quarterly nature of the data does not allow us to calculate distance traveled within quarters or even within states. Instead, we can calculate the average distance between the states colonies were located in at the start of two quarters. Colonies that were moved were not necessarily moved in each quarter. The 1,018 mile total of the average distance between states for each pair of quarters in a year in the "All" column captures colonies that were moved between one pair of quarters but were resident colonies between another pair of quarters. However, it also contains colonies that

[3] The underlying state-to-state movement data is not discernable from the national averages of distance traveled that are presented here.

were never moved at all. The true average distance traveled by colonies *that were moved* is likely higher than this. Given that the distance between the West and East Coast of the contiguous U.S. is 2,800 miles, honeybee colonies may be considered some of the most well-traveled livestock in the U.S.

Table 3 – Estimated average distance traveled by colonies from April 1, 2016 to April 1, 2017

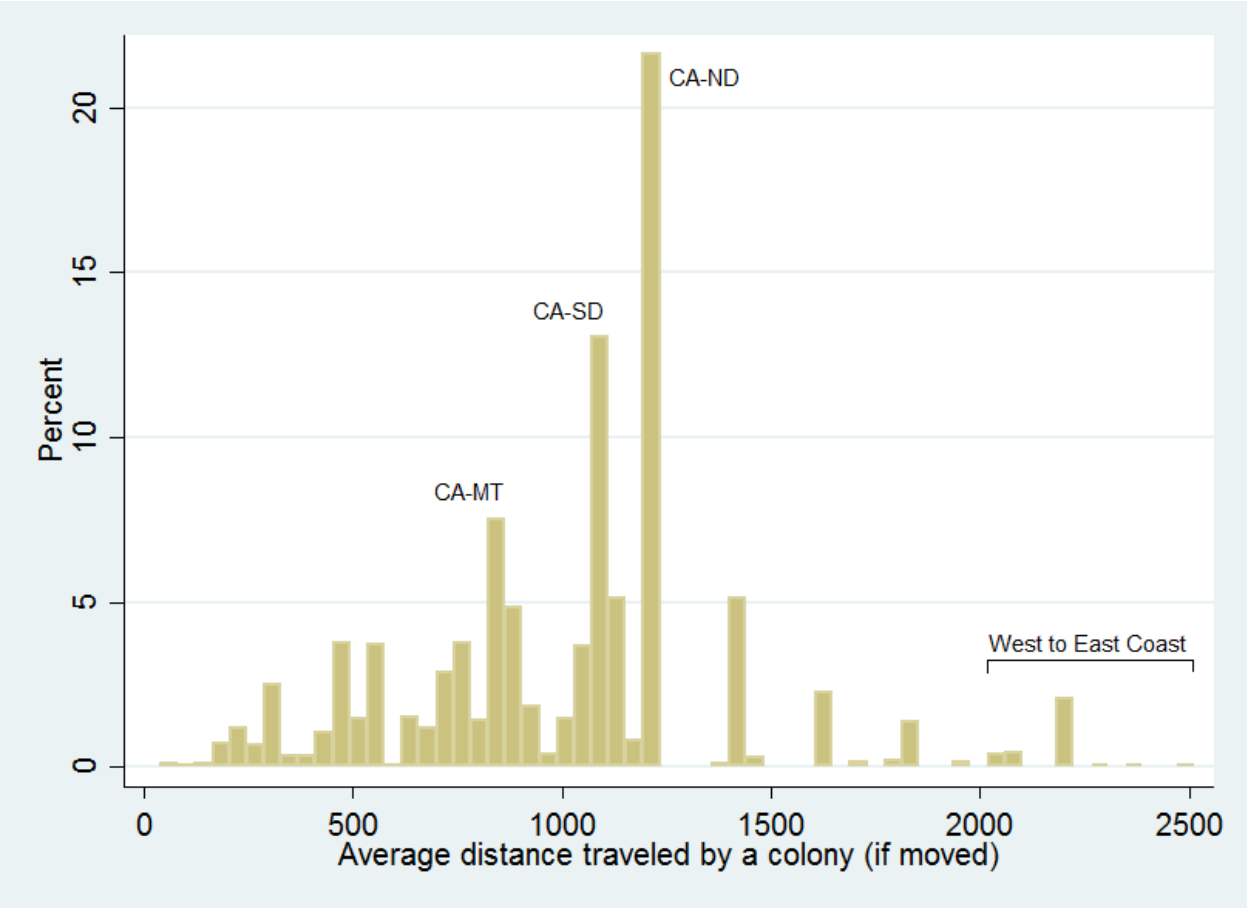
	Average distance between the states the colony was located on the first day of the quarter (miles)	
	If moved	All
1 Apr 2016 – 1 Jul 2016	983	371
1 Jul 2016 – 1 Oct 2016	816	121
1 Oct 2016 – 1 Jan 2017	1,009	318
1 Jan 2017 – 1 Apr 2017	989	207
Full year	-	1,018

Source: USDA, Economic Research Service analysis using USDA, National Agricultural Statistics Service, Colony Loss Survey (USDA-NASS 2017a).

The concentration of almond pollination in California and its location at the edge of the contiguous U.S. is one explanation of the long distances colonies are moved throughout the year. The average distance traveled by colonies coming from various states in October 1, 2017 that were moved into California by January 1, 2017 was 1,100 miles – a 20 hour drive at 55 miles per hour.

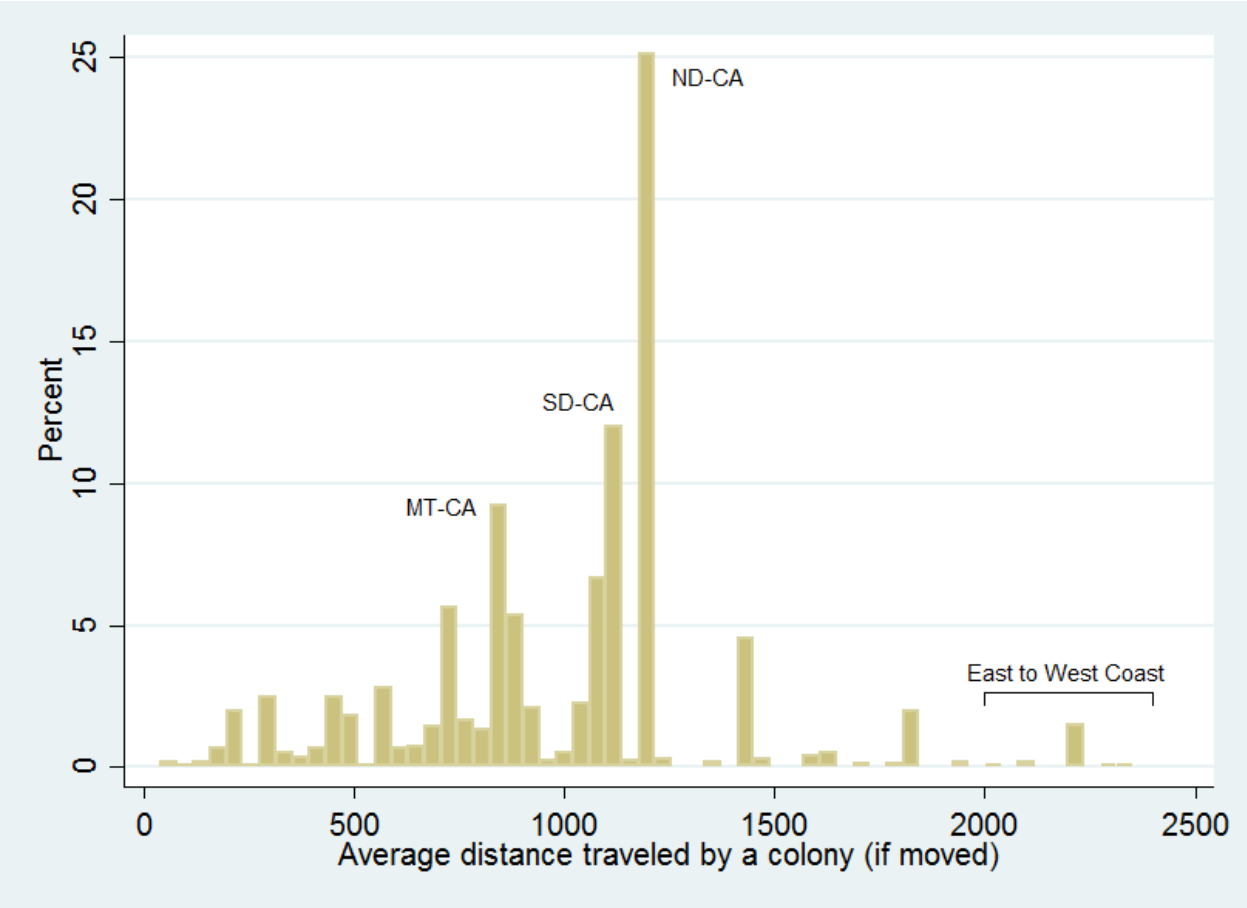
Figure 8 shows the distribution of average distance between states that colonies were moved between January 1, 2016 and July 1, 2016. Spikes can be seen in the bins containing the distance between California and North Dakota, South Dakota, and Montana. Colonies moved to the East Coast travel more than 2,000 miles. Movement between states on July 1, 2016 and January 1, 2017 follows a similar pattern (Figure 9).

Figure 8 – Average distance between states that colonies were moved between January 1, 2016 and July 1, 2016



Source: USDA, Economic Research Service analysis using USDA, National Agricultural Statistics Service, Colony Loss Survey (USDA-NASS 2017a).

Figure 9 - Average distance between states that colonies were moved between July 1, 2016 and January 1, 2017



Source: USDA, Economic Research Service analysis using USDA, National Agricultural Statistics Service, Colony Loss Survey (USDA-NASS 2017a).

Discussion: Colony Loss, Movements, and Implications for Wild Pollinators

Every year, beekeepers must decide whether, when, and where to move their honeybees to produce honey, service pollination contracts, and provide their honeybees access to good forage. Each trip comes with costs and benefits to honeybee health and the beekeeper's bottom line. In this section, we put the movements of honeybee colonies into a larger context and discuss areas of future research.

Honeybees are used as an input to agricultural production by providing pollination, but they are in turn affected by agricultural production, such as through conversion of grasslands to agricultural land and exposure to pesticides. Finally, while honeybees are often mentioned alongside wild pollinators and viewed as part of natural ecosystems, honeybees are in fact managed livestock with the ability to negatively impact wild pollinator populations.

A number of factors, including forage quality, pests, diseases, and pesticides, have been identified as contributing to elevated levels of colony loss over the past decade (Paudel et al. 2015, Smart et al. 2016, Otto et al. 2016, Mullin et al. 2010, Spivak and Le Conte 2010) as well as a decline in the population of wild pollinators (Steffan-Dewenter and Westphal 2008, Rose et al. 2014, Potts et al. 2010, Potts et al. 2015). Literature on the impact of travel on honeybee health is sparse, though beekeepers note that long-distance travel is a stressor to honeybee health (Benjamin 2008).

While both honeybees and wild pollinators can pollinate agricultural crops, the increase in field size and mono-cropped areas (MacDonald et al. 2013) means that large growers can no longer rely solely on wild pollinators, which require diverse forage resources and nesting habitat and have a shorter flight radius than honeybees, for their pollination needs. Kennedy et al. (2013) find that wild bee abundance was higher in diversified and organic fields and in landscapes comprising more high-quality habitats than around farms in highly intensified and simplified agricultural landscapes.

Honeybees are bred to produce honey and pollinate agricultural crops, which bloom during certain times of the year. Moving large numbers of colonies of honeybees around can put pressure on wild pollinators, which must compete with honeybees for pollen and nectar sources. The fact that resident honeybee colonies experience declines in colony health and honey production when other colonies are moved into the area (Abbott 2018), suggests that wild pollinators may feel similar

pressures. Geldmann and González-Varo (2018) find that high densities of honeybees associated with beekeeping can exacerbate declines in wild pollinators, as honeybees compete with wild species for resources and spread diseases to wild pollinators via shared flowers.

Both honeybees and wild pollinators benefit from programs that increase forage resources, such as the Conservation Reserve Program, which next to the most common practice (grasslands) has a dedicated pollinator-friendly conservation practice (CP-42). The USDA-NRCS Environmental Quality Incentives Program (EQIP) has 37 conservation practices that can be used to create or enhance pollinator habitat, including planting cover crops, planting wildflowers and native grasses in buffers, and improving management of grazing lands (USDA, 2015).

Conclusion

There is a growing demand for honeybee colonies to provide pollination services for crops. This demand is driven primarily by one event, the flowering of almond trees in February in California. Almond acreage has grown from 640,000 acres in 2007 to 1 million acres in 2017, with the almond bloom drawing in nearly 1.5 million honeybee colonies from as far away as the East Coast. Honeybee colonies also migrate to the Southeast and Southwest in the Fall and Winter to pollinate fruits and vegetables.

The largest single source of these honeybee colonies is the Northern Great Plains. This region provides good summer forage, including large areas of grasslands and farm acreage enrolled in the Conservation Reserve Program. Beekeepers move their colonies into this region after pollinating crops in the Winter and Spring, such that acreage enrolled in the Conservation Reserve Program in the Northern Great Plains and other uncultivated land can be characterized as supporting the production of honeybee-pollinated crops throughout the U.S. While in the Northern Great Plains,

these colonies produce nearly half of the honey produced in the U.S. However in recent years, forage in this region has declined due to increases in corn and soybeans and decreases in acreage enrolled in the Conservation Reserve Program (Hellerstein et al. 2017).

This movement from honey-producing regions in the summer to other areas of the country to pollinate crops means that honeybee colonies travel long distances on flat-bed trucks multiple times a year. The average colony moved over 1,000 miles in the year starting July 1, 2016. Colonies that were moved into California by January 1, 2017 were moved over 2,000 miles since the previous Fall.

With a growing demand for pollination services and a diminishing supply of grasslands in the Northern Great Plains more and more colonies are being crowded into the remaining areas with good forage. When honeybee colonies are crowded together, competition for forage resources can result in a decline of honey production and colony health. States, such as South Dakota and Montana, have instituted exclusion zones as a way to limit crowding by assign property rights to beekeepers. Competition for forage and the spread of diseases can also affect wild pollinator populations.

Our analysis quantifies for the first time how honeybees are moved across the U.S. to meet the demand for pollination of various crops and which regions are main destinations for honeybees in particular seasons. It can help inform efforts to improve honeybee health, including targeting programs for pollinator-friendly landcovers, such as the Conservation Reserve Program, to states that honeybees are most likely to visit. Information on colony movements can also be used by state and federal agencies seeking to manage the provision of forage resources to both honeybees and wild pollinators, in order to secure a stable population of wild and managed pollinators for agricultural and natural ecosystems.

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