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Unusual Spring 2007 Weather Conditions Destroy Illinois' Peach Crop

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ABSTRACT

An unusually long warm period in late March and early April followed by several days with low temperatures in the low to mid 20s spelled doom for Illinois' 2007 peach crop. Dating back to 1899 there has been great inter-annual variability in Illinois peach harvests; however only four years—1982, 1985, 1990, and 2007—registered 'zero' harvests (< 1 million pounds). Examination of previous temperature conditions in these 'zero' harvest years identified that winters characterized by a large number of cold days ($T_{min} \leq 0°F$) and/or early spring temperature extremes, consisting of long (>10 days) extremely warm periods (average daily growing degree day, base 40°F, ≥ 15°F) followed by a multi-day cold period ($T_{min} \leq 27°F$), are capable of causing peach bud, blossom, and/or tree kill in Illinois. The statistical relationship between the number of winter days with $T_{min} \leq 0°F$ and Illinois' annual peach harvest was r = -0.40, suggesting that better yields can be expected following warmer winters.

INTRODUCTION

In mid-April 2007 fruit experts proclaimed that the spring weather conditions in Illinois had destroyed much of the berry, grape, and orchard crops in Illinois (Grant, 2007). Fruit experts also indicated it was the most devastating loss since the 1950s. The goal of this research is to identify the peach-damage weather conditions in 2007 and to assess past critical weather conditions associated with other years when little or no peach harvest occurred in Illinois.

Most of the fruit crops in Illinois are grown in the southern third of the state, where production developed for several environmental and economic reasons. The soils of the region were not as rich as the prairie soils of the northern two-thirds of the state, and the southern topography is rolling and hilly, making it much harder to cultivate for grain crops. The region's climate in winter and spring is milder than in areas further north, a preferred climate for fruit crops.

The initiation of fruit growing in the southern region of Illinois was promoted by the Illinois Central Railroad (IC), which had been built during the period from 1851 to 1856 when the state was largely unsettled. Funding to build this north-south oriented, 702-mile railroad by eastern financiers was induced by awarding them a federal charter of six square miles of land (then federally owned) for each mile of rail line built. Thus, to regain their investment, the owners had to sell these lands. After 1856 they were having trouble selling the hilly, poorer soil lands along their lines in southern Illinois. IC leaders also realized the need for fresh fruits and produce for a rapidly growing Chicago population. Thus, they saw an opportunity to promote fruit growing in southern Illinois in order to sell the land and obtain products to sell in Chicago (Stover, 1975). Fruit crops did not have to be planted and cultivated each year as did grain crops, and were thus better suited for the hilly terrain in southern Illinois. The IC promoted the fruit production and offered reduced shipping rates for fruit growers. Then, in 1857, the IC sponsored the Illinois State Fair held in Centralia, a rail hub of the IC. There the IC actively promoted fruit production in the areas along their lines south of Effingham and Vandalia. As a result, the growing of strawberries, grapes, apples, and peaches developed from Cairo northward. By the late 1860s, the IC was operating special daily "peach" trains consisting of 20 cars loaded with peaches from southern Illinois locales to Chicago on every day of the peach harvest (Stover, 1975). More than 95% percent of all peaches in Illinois are grown south of a line from Hannibal, Missouri, to Terre Haute, Indiana (Fig. 1).

Illinois' peach harvest levels peaked prior to World War II, decreasing into the early 1960s before leveling off at an average of approximately 15 million pounds per year to the present (Fig. 2). Dramatic inter-annual variability exists throughout the record suggesting that yields in some years were influenced by anomalous weather conditions.

Weather conditions affecting different fruits vary to some extent, and for this study, the state's peach crop was chosen for evaluating the weather of 2007 and conditions in past years. Weather conditions in peach growing areas during the late summer 2006 (July through September), a time when buds are typically set on peach trees, was generally average both in terms of precipitation (i.e., ranging from 75% to 150% of average) and temperature (i.e., ranging from -1°F to 1°F) and thus did not appear to have an influence on the 2007 harvest. Peach crops are vulnerable in winter and spring to two conditions (Gardner et al., 1952; Kramer and Kozlowski, 1960). One is to extremely low temperatures in winter (November-March), typically daily minimum temperatures (T_{min}) at or below 0°F, and the other is abnormally cold temperatures in spring ($T_{min} \leq 27$°F—a "hard" freeze) after the buds and/or blossoms have emerged (Chaplin, 1948; Grant, 2007; Wahle, 2007). Extreme cold in the winter damages the trees, roots, and buds, and reduces yields (Kramer and Kozlowski, 1960). Peach blooming in Illinois normally occurs from mid April to early May depending on variety (Wahle, 2007). A period with two or more cold days ($T_{min} \leq 27$°F) in the spring when the peach buds are blooming kills the blooms and destroys the crop (Chaplin, 1948; Gardner et al., 1952; Wahle, 2007).

The weather oddity of 2007 was the prolonged period of much above-average temperatures in March through early April that led to blooming of many fruit crops in late March, about a month earlier than normal (Fig. 3). Ensuing days with quite low temperatures occurred in early to mid April, not a frequent outcome, but one that devastated the early blooms (Grant, 2007; Wahle, 2007).

DATA AND APPROACH

Illinois Agricultural Statistics were used to assess annual peach harvest totals (National Agricultural Survey Statistics, 2007). The unit used to measure the quantity of harvested peaches changed twice between 1899 and the present, going from number of bushels to number of pounds to number of tons. For a uniform study all annual values were changed to number of pounds (Fig. 2). The top peach producing Illinois counties were identified (Fig. 1). Since the interest in this study focused on understanding the weather conditions that could devastate the Illinois peach harvest such as occurred in 2007, those years with less than one million pounds harvested (1982, 1985, 1990, and 2007)—*zero years*—were analyzed.

The winter and spring temperature conditions in Illinois's peach growing region were assessed using five long-term climate stations with good quality daily records: Anna, Du Quoin, Mt. Vernon, Effingham, and Jerseyville (Fig. 1). Daily minimum (T_{min}), maximum (T_{max}), and mean temperatures (T_{mean}) were assessed for these sites.

The number of cold season (November through March) days, defined as days with minimum temperatures (T_{min}) ≤ 0°F, were counted for each of the five stations and then related, using least-squares regression, to annual Illinois peach harvests (1899-2005). Pearson correlation coefficients (r-values) were determined.

For all "zero" harvest years, days with T_{min} ≤ 27°F (i.e., "hard" freeze) after March 1st were identified. The number of hard freeze days was determined for each spring "cold" period, a period that began and ended with a hard freeze day. March and April "warm" periods, those periods between days/periods with hard freezes were also examined. Using a base of 40°F, the number of Growing Degree Days (value determined by averaging the daily maximum and minimum temperatures and subtracting 40° from daily average temperatures greater than 40°F) was determined on a daily basis and accumulated in each warm period; an average daily GDD_{40} was then determined for each warm period. Based on the distribution of average daily GDD_{40}, an arbitrary "intensity" was assigned to each spring warm period. Those warm periods with an average GDD_{40} ≤ 12° (average daily temperature of 52°F or less) were considered "weak," those between 12° and 15° were considered "moderate," and those ≥ 15° "intense." The length of spring warm periods was examined and noted. Those warm periods that lasted more than 10 days were separated from those lasting fewer days. An example of how a warm period average GDD_{40} was determined is shown in Table I and was based on daily temperatures from Effingham for the period March 19 through April 7, 2007 (Fig. 3).

RESULTS

Impact of cold winter days on peach harvests

The relationship of the number of cold winter days (T_{min} ≤ 0°F) experienced at Mt. Vernon to annual peach harvests (Fig. 2) was examined for the period 1899 through 2005 using the Pearson correlation coefficient (r-value). For Mt. Vernon, the r-value for peach harvest to the number of cold winter days was -0.40; about 16 percent of the variation in annual peach harvests was explained by number of winter cold days. For Effingham the r-value was -0.42, for Jerseyville it was -0.38, for Du Quoin it was -0.39, and for Anna it was -0.39. The negative correlation coefficients indicate that as the number of winter cold days increases, the amount of peaches harvested the next summer decreases.

Winter temperature drops to T_{min} ≤ 0°F or several days/periods with T_{min} at that level can kill trees (especially young ones) or kill the dormant buds (Wahle, 2007). For the "zero" peach harvest years, the number of winter cold days experienced at Mt. Vernon varied from zero to 10 days (Table II). In contrast, the average number of winter cold days at Mt. Vernon for the period 1899-2005 was three. Three of the zero-year winters experienced two to three times the average number of winter cold days. The low number of winter cold days during 2006/07 suggested that other weather conditions were the primary reason for the loss of the 2007 peach crop.

Impact of spring warm and cold periods on peach harvests

The winter of 1981/82 was quite severe in Illinois producing 10 cold days at Mt. Vernon (Table II). The winter cold experienced at the northern two locations must have been enough to kill trees and buds as the spring conditions there did not suggest a significant temperature problem (Table III). Effingham and Jerseyville experienced two weak (average daily GDD_{40} ≤ 12°) warm periods followed by multi-day (≥ 2 day) cold (T_{min} ≤ 27°F) periods. For example, in spring 1982, Effingham experienced a 16-day warm period with an average daily GDD_{40} of 8.1°, followed by a cold period that had two cold days, then a second eight-day warm period (average daily GDD_{40} of 8.8°), followed by a cold period with five cold days. Whether these warm periods were intense or long enough to have buds emerge and bloom is doubtful (Wahle, 2007). The three southern locations experienced similar winter conditions as well as one long (> 10 day) moderate (average daily GDD_{40} between 12° and 15°) and intense (average daily GDD_{40} ≥ 15°) warm period followed by a multi-day cold period. If the winter cold of 1981/82 did not kill the trees or buds and ruin the peach crop in these locations these spring temperature extremes surely would have completely killed any blossoms that had emerged, eliminating any chance of a peach harvest.

The total loss of a peach crop in 1985 must be related to conditions primarily experienced during the winter as the spring temperature conditions (warm followed by freezing conditions) were not unusual (Table III). All sites experienced three or four weak warm periods (average daily GDD_{40} ranging from 4.7° to 10°), periods that would normally be too short, at the described intensity, to expose the peach bud or blossom to a significant freeze. The number of hard freeze days following these warm periods were generally one or two, generally too short to create significant damage to all varieties. If this crop's failure was related to unusually cold temperatures, the killing of buds and trees must have occurred due to the large number of very cold days in January and February of 1985.

Once again, severe winter cold conditions probably led to the failure of the state peach crop by killing trees and/or buds in 1990. However, if that wasn't enough, spring 1990 temperature extremes would have ended any hope of a crop across the entire region. Each station in the peach growing region experienced at least one long (> 10 days) and intense warm (average daily GDD_{40} ranging from 16.4° to 19.0°) period followed by a multi-day cold period, with the number of hard freeze days ranging from three to seven (Table III). These warm periods would have allowed buds to break and blossom (Wahle, 2007) before the period of freezing temperatures prevented any opportunity for the tree to set fruit.

The 2007 total peach crop failure was not at all related to the occurrence of winter cold periods as Mt. Vernon did not experience one day with $T_{min} \leq 0°F$. Peach trees and buds that safely made it through winter experienced two unusual warm periods, each followed by cold periods, the second of which was characterized by four or more cold, or hard freeze days ($T_{min} \leq 27°F$) at all sites (Table III). The first warm period lasted eight days and was of weak intensity at the two northern sites (Fig. 3) and moderate intensity at the three southern sites before a two day cold period occurred. Due to the intensity of the warm period, buds likely emerged at the southern sites for some varieties, but few if any emerged at the northern sites (Wahle, 2007). Then the second intense (average daily GDD_{40} ranging between 20.0° and 21.4°) warm period, which lasted between 16 and 19 days across the region, brought out most if not all blossoms that were then killed by the long cold period (each period experiencing between 4 and 6 cold "hard freeze" days) that followed in early April (Fig. 3). Of all years examined, this was the most intense warm period experienced. Only a handful of late variety peaches survived in Calhoun County, located between the Illinois and Mississippi River near the mouth of the Illinois River (University of Illinois, 2007). This minor victory in an otherwise "zero" year in Illinois may have been attributed to the fact that the buds and/or blossoms for some late varieties did not become totally exposed in the first or second warm period and thus survived the second long freezing period (Wahle, 2007).

SUMMARY

In 2007, Illinois suffered only its fourth year without a peach crop (harvest < one million pounds) since 1899. The key to the 2007 peach crop disaster is the fact that the prolonged high March and early April temperatures matched those normally occurring in late April/early May, and thus brought peach trees to their budding and blooming stages a month early. Normally these stages occur between mid April and early May when there is very little chance of below-freezing temperatures. But, cold days ($T_{min} \leq 27°F$) do commonly occur in late March and early April, and thus the early spring warmth of 2007 and early blooms were put in a highly vulnerable position for experiencing cold days which did occur in early April. Other crops including apples, grapes, strawberries, blackberries, and winter wheat also suffered major losses across the state due to these conditions.

The combination of a long (> 10 days) moderate to intense spring warm period followed by a multi-day (≥ 2 day) cold ($T_{min} \leq 27°F$) period in parts of, if not all, the peach growing areas has occurred in other zero (1982 and 1990) peach harvest years examined in this study. In years when twice or more the average number of cold winter days ($T_{min} \leq$

0°F) occurred (1982, 1985, and 1990) prior to the spring, enough damage to either the trees and/or buds occurred to dramatically reduce the statewide peach harvest.

Of the four zero peach harvest years in Illinois, 2007 stands alone as unique as it was not impacted by winter cold days. Other growing season weather conditions such as drought, high winds, hail, and others can further alter the quality and/or quantity of the harvests; however, extreme winter and spring temperature conditions as described in the text serve as the primary factors contributing to whether a peach tree puts fruit on in the spring.

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Figure 1. Location of primary peach growing counties (shaded) and five climate stations used in the study. Area south of line from Hannibal, Missouri, and Terre Haute, Indiana, is region where 95% of the peach crop in Illinois is harvested.

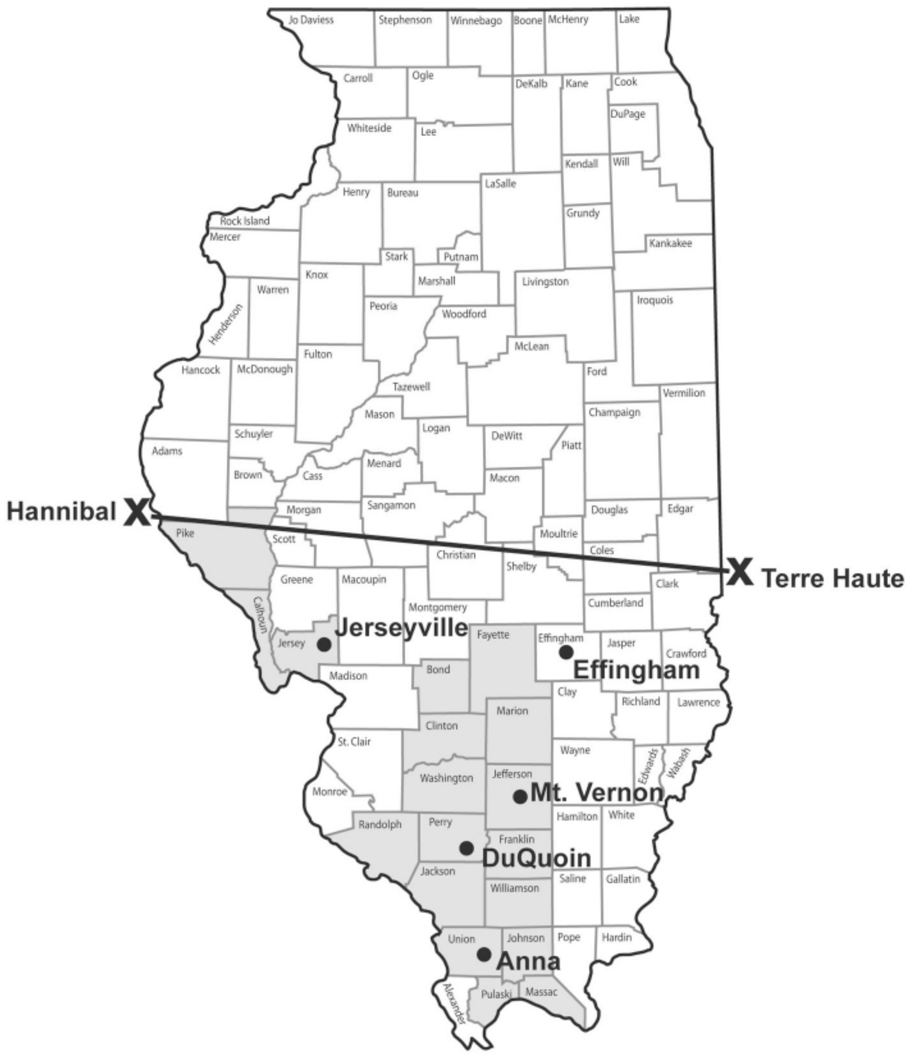

Figure 2. Annual Illinois peach harvests (million of pounds) and number of winter days when $T_{min} \leq 0°F$, 1899-2005.

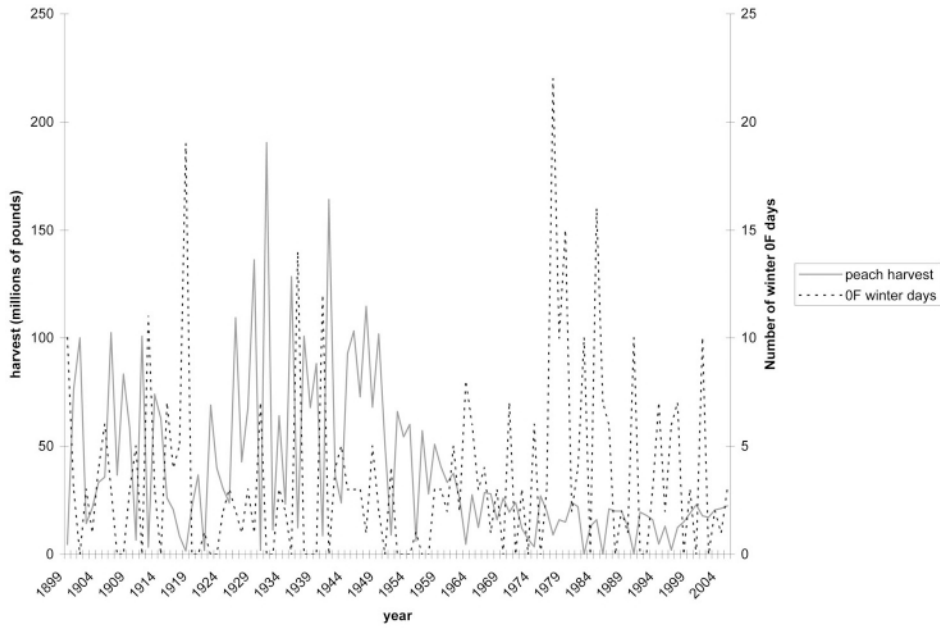

Figure 3. Observed and average daily temperatures (T_{max}, T_{min}, and T_{mean}) for Effingham, Illinois, between March 1, 2007 and April 20, 2007. When the observed daily T_{mean} is above 40°F, that day is accumulating GDDs.

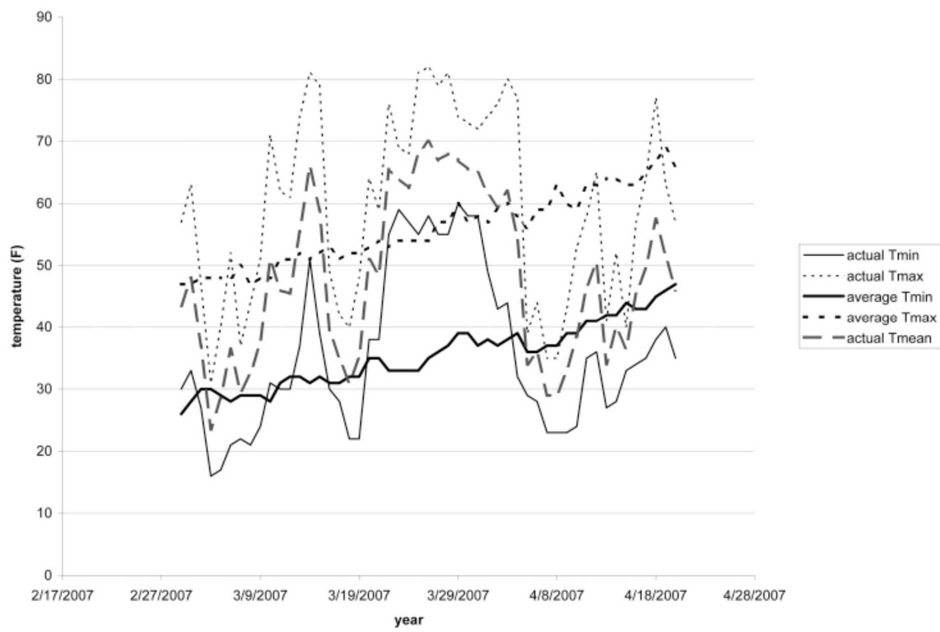

Table I. Daily temperatures (T_{max}, T_{min}, and T_{mean}) and GDD_{40} values are shown for Effingham for the period March 19 through April 7, 2007. $T_{min} \leq 27°F$ are underlined as they represent "hard freeze" days. All values in degrees (°F).

Date	T_{max}	T_{min}	T_{mean}	GDD_{40}	Status
March 19, 2007	48	<u>22</u>	35	0	hard freeze
March 20, 2007	64	38	51	11	warm period
March 21, 2007	59	38	48.5	8.5	"
March 22, 2007	76	55	65.5	25.5	"
March 23, 2007	69	59	64	24	"
March 24, 2007	68	57	62.5	22.5	"
March 25, 2007	81	55	68	28	"
March 26, 2007	82	58	70	30	"
March 27, 2007	79	55	67	27	"
March 28, 2007	81	55	68	28	"
March 29, 2007	74	60	67	27	"
March 30, 2007	73	58	65.5	25.5	"
March 31, 2007	72	58	65	25	"
April 1, 2007	74	49	61.5	21.5	"
April 2, 2007	76	43	59.5	19.5	"
April 3, 2007	80	44	62	22	"
April 4, 2007	77	32	54.5	14.5	"
April 5, 2007	39	29	34	0	"
April 6, 2007	44	28	36	0	"
April 7, 2007	35	<u>22</u>	29	0	hard freeze

Total warm period GDD_{40} = 359.5°

Average daily GDD_{40} for 18 day warm period = 20.0°, an <u>intense</u> warm period.

Table II. Number of winter cold days ($T_{min} \leq 0°F$) observed at Mt. Vernon, Illinois, for each of the "zero" Illinois peach harvest years.

Winter	Number of Days
1981/82	10
1984/85	7
1989/90	10
2006/07	0

Table III. Number of spring warm periods, length of each warm period (days) during the spring (bold are warm periods longer than 10 days), average daily GDD_{40} for each warm period (bold is moderate and italics is intense warm periods), number of spring cold days ($T_{min} \leq 27°F$) following each warm period (2 or more cold days are in bold), at each station during each "zero" year.

Year	Station	# Warm Periods	Warm Length	Average Daily GDDs (°)	Cold Days
1982:	Anna	4	**11**, 6, **17**, 8	6.9, 7, *16.4*, **14.9**	1, **4**, **2**, **4**
	DuQuoin	3	10, **17**, 7	3.9, **13.7**, *15.1*	**8**, **2**, **5**
	Mt.Vernon	3	3, **12**, 6	5.3, *15.3*, **13.7**	**6**, **3**, **4**
	Effingham	2	**16**, 8	8.1, 8.8	**2**, **5**
	Jerseyville	2	**12**, 8	8.4, 9.6	**3**, **5**
1985:	Anna	3	8, 5, **11**	8.3, 7.8, 10	1, 1, 1
	DuQuoin	3	7, 4, **11**	9.4, 8, 7.8	**2**, **2**, 1
	Mt.Vernon	3	7, 4, 10	8.1, 8, 6.8	**3**, **2**, 1
	Effingham	3	6, 10, **20**	6.5, 4.7, 9.7	**6**, **2**, 1
	Jerseyville	4	7, 4, **11**, **21**	5.3, 5.3, 5.6, 9.4	**2**, **2**, 1, 1
1990:	Anna	3	10, **15**, **12**	9.8, *17.9*, 9.8	**5**, **3**, 1
	DuQuoin	3	**11**, **14**, **11**	6.6, *19*, 9.8	**9**, **5**, 1
	Mt.Vernon	3	**13**, 10, 4	*17.3*, 7.5, 7.5	**6**, 1, 1
	Effingham	3	**13**, 10, 3	*17.5*, 6.6, 10	**7**, **3**, 1
	Jerseyville	4	**13**, 3, 9, 4	*16.4*, 7.7, 5.7, 9.5	**3**, **4**, **2**, 1
2007:	Anna	2	8, **19**	**13.9**, *20.7*	**2**, **4**
	DuQuoin	2	8, **19**	**13.9**, *20.7*	**2**, **4**
	Mt.Vernon	2	8, **19**	**13.6**, *20.8*	**2**, **4**
	Effingham	2	8, **18**	10.5, *20.0*	**2**, **5**
	Jerseyville	2	8, **16**	10.5, *21.4*	**2**, **6**