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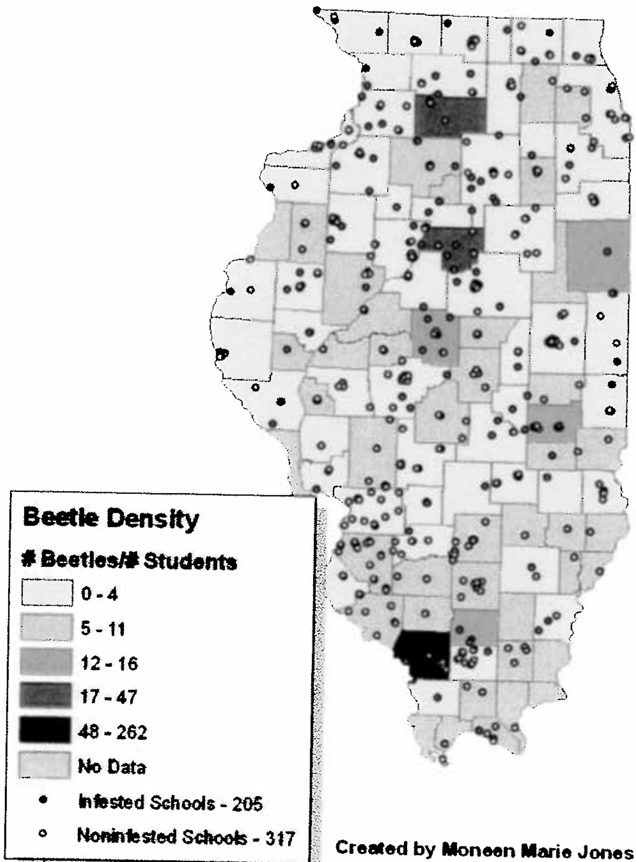
Beetle Densities Throughout Illinois Counties



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Distribution of Multicolored Asian Ladybird Beetle *Harmonia axyridis*

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Distribution of Multicolored Asian Ladybird Beetle *Harmonia axyridis* (Coccinellidae) across Illinois

Moneen M. Jones & Erick Howenstine
Northeastern Illinois University

The Multicolored Asian ladybug, Harmonia axyridis, has been spreading throughout the United States and Canada, raising concern that it may displace non-pest organisms or become a pest itself to agricultural growers or humans generally. A telephone survey of 855 elementary and secondary schools was conducted across 93 Illinois counties in November 2005. GIS methods were used to determine H. axyridis presence and abundance in regards to number of vineyards, rural vs. urban location, local environmental conditions, nearby agricultural crops, and quarterly weather conditions. Beetle presence was positively correlated to winter wheat planting, number of surrounding trees, matrix of setting, and negatively related to number of surrounding vineyards. Beetle abundance was positively correlated to proximate vegetation and negatively related to urban intensity of surroundings. This method demonstrates that phone surveys can locate problem pest areas statewide in a short amount of time, which can then be used to plan integrated pest management projects.

Introduction

The multicolored lady beetle *Harmonia axyridis* is a semiarboreal, aphidophagous predator (LaMana & Miller 1995) imported from Asia to the United States as a biocontrol agent. The beetle is known to colonize many food crops including wheat, potatoes (Nault & Kennedy 2002), corn (Colunga-Garcia & Gage 1998; Nault & Kennedy 2002; Musser, et al. 2004), alfalfa, soybean, winter wheat (Colunga-Garcia 1998), apple saplings and several tree species (Lucas, et al. 2002) where they prey on aphids. However, their impact as biological control agents has mainly been demonstrated in apples where they effectively control *Aphis spiraecola* (Brown & Miller 1998). *H. axyridis* beetles are predacious as both immatures and adults. Adults are known to consume between 90 and 270 aphids per day, while larvae can consume up to 1,200 aphids during their development (Yaxin 2003).

Despite the economic benefit of *H. axyridis* in control of aphids, there is a growing concern that it may also impact negatively in its exotic range. Since its introduction into the USA (LaMana & Miller 1995;

Elliott et al. 1996) and Canada (Coderre, et al. 1995; Hoebeke & Wheeler 1996; McCorquodale 1998), the beetle has continued to increase its range, causing a decline in native ladybug populations (Brown & Miller 1998). Examples of native lady beetles reportedly affected by *H. axyridis* introduction include Convergent ladybug (*Hippodamia convergens*) in Pennsylvania (Wheeler & Stoops 1996), Spotless lady bird beetle (*Cycloneda sanguine*) in Florida (Michaud 2002), Sevenspotted lady bird beetle (*Coccinella septempunctata*) in eastern West Virginia (Brown &Miller 1998) and Ninespotted ladybug (*Coccinella novemnotata*) in the eastern US (Wheeler & Stoops 1996). The argument that *H. axyridis* is responsible for the decline of native lady beetles has also been reported elsewhere in the world (Yasuda & Ohnuma 1999).

In addition to ecological impacts, *H. axyridis* is currently emerging as an important crop pest and a nuisance species. In Illinois it has been reported to destroy corn plant tissues (Spencer & Isard 2003). In Ohio, the beetle has been found to feed on ripe fruits of peaches, apples, raspberries, plums, pears, and grapes. Ohio wines were especially affected by the beetle's taste and odor that masked the underlying grape characteristics (Kovach 2004). Since the Illinois wine industry contributes greater than $60 million towards its economy (Malkovich 2005), *H. axyridis* can become a serious social and economic concern. Unlike other species of Coccinellid which aggregate in clusters outdoors (Douglass 1930; Lee 1980), *H. axyridis* typically hibernates around homes and buildings in North America (Jones & Boggs 2001; Ratcliffe 2002; Koch 2003; Hahn & Kovach 2004; Huelsman & Kovach 2004; Nalepa et.al. 2004), causing considerable annoyance to people. Contrary to other lady beetles, *H. axyridis* has been reported to bite humans (Ratcliffe 2002; Kovach 2004) and induce allergy in some people (Hahn & Kovach 2004; Huelsman & Kovach 2004). When disturbed, Asian lady bird beetles react by reflex bleeding of a liquid which is not only foul smelling, but also can permanently stain walls and furniture (Jones & Boggs 2001; Ratcliffe 2002; Huelsman & Kovach 2004). Because of these negative attributes, the USDA officially documented *H. axyridis* as a pest species in 2002 (Ratcliffe 2002). It is the only lady beetle species on the North Central Integrated Pest Management Center's Pest Alert site (2005).

Despite the presence of this beetle in Illinois and the likely economic impact, little is known about its distribution. Understanding the spatio-temporal distribution of an important pest species and the factors underlying its distribution is an important prerequisite for designation and implementation of a pest control program. The present study was conducted to assess the statewide distribution of *H. axyridis* in Illinois.

Methodology

Study area

With its north-south orientation, spanning 400 miles, Illinois includes several climate zones and therefore distinct agricultural regions as well. Illinois weather is influenced by the sun, weather systems, topography, urban areas, and Lake Michigan. The elevation of the Shawnee Hills in southern Illinois increases precipitation in that area by 10 to 15% (Illinois Water Survey 2003). Illinois also has several large urbanized areas and rural land with a population of approximately 12 million individuals that reside within 102 counties (Illinois Census 2000). While ten times as many people live in urban areas than rural, Illinois ranks 7th in agricultural farm cash receipts and exports $3.4 billion in agricultural goods (Illinois Department of Commerce and Economic Opportunity 2005).

Telephone survey

In order to cover the entire State of Illinois we designed a telephone survey to measure presence and abundance of *H. axyridis*. Maintenance personnel in 901 schools were contacted using a geographically stratified random sampling method shortly after migration by Asian ladybeetles had begun. Illinois state law requires schools to receive regular maintenance and economies of scale and local demand assure that the elementary and secondary schools are somewhat similar in size. Maintenance personnel are easily contacted by phone during working hours and educational institutions are more likely than private homeowners or businesses to participate in a short academic survey.

The initial sampling pool was achieved by placing a 13.65 x 13.65 mile grid .jpeg file over a state map of Illinois to create 400 cells covering the state. From each cell two or three schools were randomly selected for a total of 901 schools of the 5,357 listed in the 2004-2005 Illinois State Board of Education website (2005).

To increase the reliability of the results, surveys were initiated 3 days after *H. axyridis* was noticed on or near Northeastern Illinois University's (NEIU) campus on November 4, 2005. The survey continued for a one-month period and consisted of three weeks of active data collection. This occurred shortly after the beetles would have entered the schools and would therefore be fresh in the minds of custodial staff.

Respondents (all custodians or their proxies) were asked to estimate the number of Asian ladybugs recently seen on or inside their buildings. They were asked to estimate the density of trees within 200 yards of buildings by choosing the best fit answer (no trees, few/scattered trees, abundant trees), and to describe the general surroundings within one quarter of a mile (very agricultural, mixture of farmland and developed, very built up). School enrollment was taken from public sources and used to standardize for building size. The survey method satisfied a reliability test for the phone survey and consisted of surveying four nearby schools by phone followed by comparing results by direct inspection.

Environmental data

Climate data for September through December 2005 were obtained from the Illinois State Water Survey's Center for Atmospheric Science (2005). Schools were "assigned" climate data according to regional location as shown in Table 1. One hundred thirty nine vineyards of the 155 listed in an Illinois vineyards database were geocoded by zip code. Using a 10-mile buffer the number of vineyards near each school was measured. In addition, six different crop yields were collected at the county level and urbanized areas were attained by comparing school addresses to a GIS layer of designated places. GIS data and information from the United States Census Bureau were used to determine whether schools fell within a designated census area. The bivariate variable urban vs. rural was recorded for each school. Precipitation data indicated below normal rainfall for most areas in 2005.

Crop Data

Agricultural statistical data for 6 Illinois crops -- corn (2005), hay (2004), oats (2005), wheat (2005), sorghum for grain (2004), and soybean (2005) -- were gathered from the National Agricultural Statistics Service (2004). Weight in tons for hay was converted to bushel equivalent (60 pounds per bushel), to standardize the measuring unit. Data for schools whose 10-mile buffer crossed county boundaries were estimated from all relevant counties proportionate to area. Buffers crossing state boundaries used local Illinois data as a proxy for non-Illinois crop regions. Predominant crops are listed in Table 1.

Table 1. Average Daily Temperatures and Precipitation

REGION	TEMP (F)	PRECIP (inches)	PRECIPDEV (inches)	Predominate Crops (yield in bu. Equivalent)
CEN	54.50	8.25	-0.82	Hay, Corn
W	54.40	8.56	-0.88	Corn, Hay
NE	52.60	6.45	-2.64	Corn, Hay
NW	51.60	6.32	-2.54	Corn, Hay
WSW	55.80	10.22	0.90	Hay, Corn
SW	57.60	12.56	1.95	Hay, Corn
ESE	56.20	10.10	0.22	Hay, Corn
E	54.00	9.54	0.64	Hay, Corn
SE	58.10	10.46	-0.02	Corn, Hay

Source: Illinois State Water Survey 2005. www.sws.uiuc.edu/atmos.

Data Analysis

Beetle presence figures from the phone survey served as the dependent variable in logistic regression analyses. Abundance data were analyzed using univariate ANOVA with beetle abundance as dependent variable and all abundance data were divided by school enrollment to standardize for variations in building size. Independent variables included those from the survey (tree density within a 200 yard perimeter, coded description of quarter-mile surroundings) as well as those attained by way of external data and GIS analysis (the number of vineyards within a ten mile radius, urban or rural location, quarterly temperature and precipitation data, and six separate Illinois crop yields). For the benefit of county extension offices, which are often charged with infestation abatement, results will be reported not only by school but also by county.

Results

Although we were unable to reach thirty-eight percent (321) of the schools after 642 callbacks, the telephone survey method resulted in relatively even coverage. Thirty-nine percent of the surveyed Illinois schools were infested and 70 Illinois counties of the 93 surveyed (75%) were found to have *H. axyridis* (see Appendix & Figure 1). When comparing the ratio of beetles to students (density) in each county

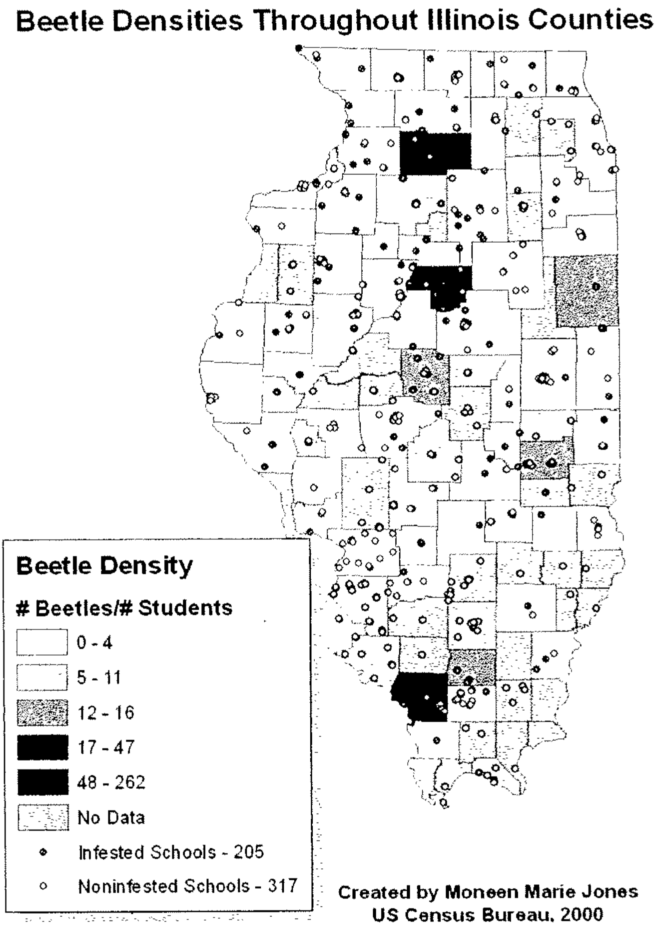

Figure 1. *Beetle Densities in Illinois Counties.*

(#beetles/#students), the beetle infestation ranged from 0 to 262 to one, with the two most infested counties being Jackson (11,000 beetles; 262 beetles/student) and Lee (121,305 beetles; 47 beetles/student).

Beetle Presence

Surrounding Environment

With a α 0.05 probably of Type I error, I conclude there was a negative linear response (see Table 2) between beetle infestation and school location, where rural schools were more likely to be infested than urban schools ($p < 0.05$). The survey question, a subjective assessment of quarter-mile surroundings, also showed a greater percentage of schools in "very agricultural" settings (50%) were infested compared to those in "very built up" areas (35%) (Table 3).

Table 2. Logistic Regression Results

Criteria	B	Std. Error	Df	Sig.
Number of Vineyards	-0.263	0.106	1	***0.013***
Perimeter (# of Trees)	.227	.119	1	.056
No Trees	-0.079	0.449	1	0.861
Few Trees	-0.533	0.289	1	0.065
Abundant Trees	0.041	0.295	1	0.889
Surroundings	-.198	.093	1	***.034***
Very Agricultural	0.612	0.300	1	***0.042***
Mixture	0.329	0.352	1	0.349
Very Built Up	0.189	0.225	1	0.400
Agricultural Crops				
Wheat	0.014	0.006	1	***0.023***
Soy	0.012	0.039	1	0.754
Oats	0.013	0.009	1	0.158
Sorghum	-0.004	0.005	1	0.457
Corn	-0.012	0.013	1	0.363
Hay	0.005	0.003	1	0.170
Precipitation	-0.260	0.149	1	0.081
Temperature	0.046	0.149	1	0.760

* Significant results are italicized.

We also found that the immediate perimeter – within 200 yards of the school building -- appears to be related to infestation, with 33% infestation from those reporting no or few trees nearby and 46% infestation among schools reporting scattered or abundant trees. An inverse relationship was found between the number of vineyards, surroundings, and precipitation amounts. A positive relationship was seen between wheat crop yield and the number of trees within a 200-yard perimeter of a surveyed school.

Table 3. Local Environment and Infestations

Location of School	Number of Cases	Number of Infested	Proportion of Infested
GIS MEASURE OF URBAN/RURAL			
In Urban Area	370	134	35%
In Rural Area	152	71	50%
SURVEY: QUARTER MILE RADIUS			
Very Agricultural	66	33	50%
Mixture of Farm & Developed	206	84	41%
Very Built up	250	88	35%
SURVEY: 200 YARD PERIMETER			
No Trees	37	14	38%
Few Trees	410	157	38%
Abundant Trees	75	34	45%
TOTAL SCHOOLS	522	205	39%

Correlations of Beetle Presence to Abiotic and Biotic Factors

A few independent factors were found relevant to predict beetle presence (Table 3). While the association ($R^2 = .158$) meant just 16% of the variance of the beetle presence is accounted for by these 11 factors, coefficients of determination are often smaller percentages for field studies. The significant contributors were perimeter tree intensity, wheat harvest, vineyards within ten miles, and whether or not the school was located in an agricultural area ($p < 0.05$) for predicting the presence of *H. axyridis*. Tree density and wheat yield were positively interrelated, with urban setting negatively correlated with beetle presence as one might expect. However, the greater number of vineyards within a ten mile radius statistically *decreased* the likelihood of infestation. Lower precipitation was associated with increased Ladybug presence, but only with a lower level of significance ($p < .10$).

Beetle Abundance

Abundance in Urban and Rural Areas

A univariate analysis of variance showed that rural schools were significantly ($p < .005$) more likely to have a greater number of beetles compared to urban schools. Rural schools reported infestation rates four times greater than urban ones (Table 4).

Table 4. Urban/Rural Schools and Beetle Abundance

Group (n = 205)	Number of Infested Schools	Number of Total Schools	Number of Beetles	Total Student Enrollment	Average Number of Beetles Per Student
Urban Areas	134	370	148,480	48,238	3
Rural Areas	71	152	243,448	20,852	12
Total	205	522	391,928		

Correlations of Beetle Abundance to Multiple Factors

After examining the 11 independent variables (Tables 2 and 3) and their correlation to beetle abundance, surroundings and perimeter were the only significant predictors ($p < 0.005$). Excluding perimeter and surroundings, the R^2 was 0.017, and only 2% of the variance of the beetle abundance in the sample can be accounted for by these criteria. The R^2 was slightly greater for perimeter/surroundings (0.047) suggesting that these two factors contribute 5% of the prediction. Similar to the results for beetle presence/absence, perimeter tree intensity and quarter mile surroundings were highly significant factors ($p < 0.05$) for predicting beetle abundance. Tukey HSD post hoc tests ($p < 0.05$) showed the greatest difference in beetle abundance to be between areas of abundant trees and no trees as well as very agricultural and very built up areas. The more highly vegetated the immediate vicinity, the more beetles found. Likewise, the less built up the surroundings, the greater the beetle abundance. One can conclude from both of these tests that vegetation encourages the abundance of beetles, and this is true not only for immediate surroundings, but within a quarter mile radius as well.

Discussion

Asian Ladybug Presence and Abundance

Crops

Even though soybeans and corn are planted in every Illinois county it is wheat, in 91% of counties, that is the best indicator for beetle presence in Illinois. The presence of *H. axridis* in relation to wheat may have resulted from the presence of wheat and its predominant pest – aphids -- immediately prior to the study. Ninety one percent of the infested schools surveyed were located in a county that yielded wheat. The fall harvest of Illinois soybeans and corn began late September 2005 and was mostly completed by the first week of November (National Agricultural Statistics Service 2005). Planting of winter wheat takes place at the same time. Nault and Kennedy (2002) found *H. axyridis* colonizes in wheat, potato, and corn fields but reproduces only in wheat and potato fields; aphids are the predominant pest of wheat. Their findings are supported by research that suggests *H. axyridis* is attracted to structures near late-season aphid infestations (Nalepa et al. 2003). When it comes to crops, wheat can be considered the best predictor for *H. axyridis* presence during their aggregations. The predictive effect of wheat is not strong, however; no crop was found to be a significant predictor of beetle abundance.

Vineyards

It seems odd that beetle presence appeared to decrease in relation to the presence of vineyards. One would expect that they would be an attractant and a source of food. There are a number of possible explanations for this result. It is possible that the ten-mile buffer was too large, that the zip code centroid location lacked the necessary precision, or perhaps the vineyard size in acres needs to be taken into greater account. It is also possible that the decrease is a result of competition with other insects, intraguild predation (Polis & Holt 1992), *H. axyridis* cannibalism, lack of quality or adequate prey, or specific insecticides and fungicides used in vineyards. Regarding beetle abundance, results were insignificant with a correlation of determination (R^2) of .045.

Urban Areas

There seems to be a relationship between presence of *H. axyridis* and location in urban (very built up) vs. rural (very agricultural) areas. When measuring abundance, beetles appeared to be attracted to hibernation sites in rural areas compared to urban ones. One explanation may simply be proximity of prey. There may be another explanation. During diapause, *H. axyridis* has been known to migrate long distances using air currents and orienting themselves towards peaks or perpendicular objects in the distance (Hodek et al. 1993). In flight, beetles have also been noted to have an affinity for the contrasting linear elements (Nalepa et al. 2003). Many of these, such as rooflines, exterior walls, chimneys, gutters, and drainpipes are naturally found on buildings. Thus, beetle ecology could account for the greater number of beetles in the schools surrounding fields than in urban areas. The beetles may simply be landing on the first linear cue they see while navigating the air currents.

Climatic Influence

In areas with less precipitation in the months preceding the survey, the probability of beetle presence increased. It may be relevant that overall Illinois precipitation rates between September and December 2005 were 35% below normal. Plants experiencing stress from drought conditions have been shown to be conducive to rapid aphid growth and reproduction since stressed plants are less able to ward off the damaging effects of aphids than are healthy plants (Berlandier 2004; Krupke et al. 2005). Climate shifts may help to explain why areas with less precipitation would have a greater probability of aphid predators as well, including the Asian Ladybeetle.

Tree Intensity and Surroundings

The most striking effect found for presence and abundance of beetles was as expected – they appear to prefer hibernation sites in buildings which are amongst trees. As the density of trees increased immediately surrounding school buildings, both presence and abundance increased. Considering that *H. axyridis* was introduced as an arboreal aphidophagous predator (Koch 2003), this is a gratifying, but not surprising result. Huelsman and Kovach (2004) previously concluded that most of the infested homes in their study were in wooded areas.

Conclusion

This study has established baseline data of *H. axyridis* presence in Illinois. Not only does it show that the Asian Ladybeetle infestation has covered the entire state of Illinois spanning large climate differences over 400 miles, it also shows that the density of proximate vegetation, the presence of wheat, precipitation, and a rural setting are all positive indicators of infestation, abundance, or both. Infestations seem particularly common near the center of the state and are particularly severe in several north central counties. Abundance data in particular may be subject to reporting error or exaggeration, so extreme cases may warrant direct observation. Unfortunately, such verification was not possible with the resources available in this study.

What is not known is the effect of these infestations on native species of ladybeetle or on Illinois crops, but previous research suggests that these effects may be detrimental to the former and mixed in regard to the latter.

This study introduced a method for data collection which can be conducted relatively rapidly, is inexpensive, and can easily cover large areas on short notice. Because of several unique aspects of the *H. axyridis* (particularly the indoor aggregation but also the size, color, shape and tendency to bite), this method worked particularly well for *H. axyridis*. While field methods such as sweep netting, sticky cards and backlight traps are essential for precise local measures of infestation, the phone survey technique appears to be quite valuable for a quick rough measure which can cover a region of any size. In sum, the results mainly substantiated existing literature suggesting that the technique is reliable.

For a copy of the survey tool, please contact Moneen Jones, at Department of Natural Resources College of Agricultural Consumer and Environmental Sciences S520 Turner Hall 1102 South Goodwin Avenue, Urbana, IL 61801

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Appendix 1. *H. Axyridis* in Illinois Counties

County	Beetles	Number of Students	Beetle per student	Number of Schools
Adams	7328	3484	2.10	9
Bone	200	1050	.19	2
Boone	400	225	1.78	1
Brown	1000	90	11.11	1
Bureau	16540	1938	8.53	8
Carroll	13	601	.02	2
Champaign	618	2811	.22	6
Christian	2100	260	8.08	1
Clinton	74	191	.39	1
Coles	62828	3853	16.31	5
Cook	210	609	.34	2
Crawford	67	775	.09	2
Dekalb	10	350	.03	1
DeWitt	5540	809	6.85	2

Douglas	2000	312	6.41	1
Edgar	1775	1097	1.62	4
Effingham	136	230	.59	3
Fayette	605	535	1.13	2
Franklin	3475	239	14.54	3
Fulton	5815	859	6.77	3
Greene	48	350	.14	1
Hancock	12	351	.03	1
Henry	2615	1633	1.60	5
Iroquiois	9000	570	15.79	2
Jackson	11000	42	261.90	1
Jasper	2	148	.01	1
Jefferson	1000	120	8.33	1
Jersey	120	180	.67	1
JoDavies	1332	702	1.90	3
Kankakee	270	720	.38	2
Kendall	150	120	1.25	1
Knox	322	852	.38	3
Lake	3000	1222	2.45	3
LaSalle	8222	2577	3.19	9

Lee	121305	2603	46.60	5
Livingston	157	1250	.13	2
Logan	14695	944	15.57	5
Madison	300	1043	.29	4
Marshall	1100	480	2.29	2
Massac	2200	200	11	1
McDonough	360	570	.63	4
McHenry	1650	1807	.91	3
McLean	1135	3168	.36	8
Mercer	248	747	.33	2
Monroe	100	677	.15	1
Montgomery	615	642	.96	4
Morgan	100	175	.57	1
Moultrie	115	583	.20	2
Ogle	262	1150	.23	4
Peoria	3165	2557	1.24	7
Piatt	20	400	.05	1
Pike	2200	1027	2.14	2
Randolph	2100	348	6.03	2
Rock Island	583	1411	.41	6

Sangamon	1080	2610	.41	5
Schuyler	105	600	.18	2
Shelby	400	575	.70	2
St. Clair	6525	630	10.36	2
Stark	100	275	.36	1
Stephenson	487	1645	.30	5
Tazewell	103	880	.12	3
Union	3	300	.01	1
Vermillion	1270	1030	1.23	3
Wayne	100	97	1.03	1
White	227	294	.77	2
Whiteside	6760	1635	4.13	6
Will	600	1100	.55	2
Williamson	245	550	.45	2
Winnebago	210	1290	.16	3
Woodford	73476	1718	42.77	6