

# The Distribution of Periodical Cicada Brood III in 1997, with Special Emphasis on Illinois (Hemiptera: *Magicicada* spp.)

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## Introduction

The 13- and 17-year periodical cicadas (*Magicicada* spp.) of eastern North America are remarkable for the complex biogeographic relationships among their broods, which are regional associations of multiple species bound to a common emergence schedule. The majority of periodical cicada broods are parapatric with other broods that appear one year before or one year after (Marlatt 1923), a pattern consistent with the hypothesis that new broods form via the subdivision of existing broods. However, formal testing of brood-formation hypotheses is made difficult by the ambiguities of existing maps. Thus, one priority in periodical cicada research is to develop maps that are more detailed and accurate than existing ones. Examples of newer maps include Hardy's county-level map of the 1946 Brood III emergence in Iowa (Hardy 1947), Simon's (1988) reworking of Marlatt's (1923) maps based on new collection data; Stannard's (1975) series of partial brood maps showing the distribution of periodical cicadas in Illinois, Irwin and Coelho's (2000) map of the Illinois portion of Brood III, and Kritsky et al.'s maps of Broods X and XIV (Kritsky 1992; Kritsky et al. 2005). All of these maps have helped refine our understanding of periodical cicada broods and their biogeographical relationships.

Prior to the 1997 emergence of periodical cicada Brood III (the "Iowan Brood"), we began a project to produce new, georeferenced brood maps. In the intervening years, other projects, such as elucidating the *Magicicada* pair-forming mechanism (Cooley and Marshall 2001, 2004), describing the cryptic species *M. neotredecim* (Marshall and Cooley 2000), and testing hypotheses for its evolution (Stannard 1975; Simon et al. 2000; Cooley et al. 2001; Cooley et al. 2003; Cooley et al. 2006) monopolized our efforts. Consequently, we never published our early data, although we continued to map periodical cicada emergences and accumulate more data.



As inexpensive GPS devices became available, they changed the specific ways in which we collected records and made it possible for us to publish data from later years more quickly (Cooley et al. 2004; Cooley et al. 2009; Cooley et al. 2011; Cooley et al. 2012). Yet the general techniques we used dated back to those first developed for the 1997 emergence of Brood III.

Here we present digital versions of historical maps, and a general description of our mapping techniques and criteria first employed during the 1997 emergence of Brood III. We also present a map of our unpublished data from 1997 along with Simon's unpublished records of the 1980 emergence of Brood III and Irwin and Coelho's (2000) previously published records of the 1997 emergence. Because each group worked independently (and at different times), the datasets are complementary; Simon's 1980 records provide broad coverage throughout the range of the brood, Irwin and Coelho (2000) provide general coverage in Illinois, and our unpublished records specifically target brood edges in Illinois. In addition to maps, we also include detailed distributional notes for the Illinois portion of Brood III to facilitate comparison with Stannard's (1975) maps and notes.

## Methods

We digitized maps in Marlatt (1923), Hardy (1947), and Stannard (1975) by obtaining high-quality digital scans of the figures in each publication. We then georeferenced each figure by adding control points and employing the "adjust" transformation in ArcGIS 9.3. Once each figure was georeferenced, we digitized it to create a shapefile. Marlatt's basemap is an unknown projection and contains some distortions, so positions of datapoints are not located with high precision. For Hardy's map, we started with the ESRI-supplied "detailed counties" base layer derived from U.S. Census 2000 TIGER line data, and

we used the digitized version of Hardy's Fig. 1 to select and annotate the corresponding counties in the "detailed counties" base layer (ESRI, Redlands CA).

We used several approaches to map the presence/absence of periodical cicadas, each appropriate for specific conditions or research goals. On each day that we collected records, we made every effort to begin our search at a location where cicadas were known to be present, in order to establish that conditions were appropriate for cicada activity and to judge whether we could locate cicadas on the basis of male songs (e.g., warm conditions) or whether we should proceed by looking for perched, inactive cicadas (e.g., in cool or stormy weather) or for emergence skins, emergence holes, or oviposition scars (e.g., late in the season). We also tried to end each mapping session with a positive record to verify that conditions remained appropriate for cicada activity. Where possible, we noted the species composition of choruses; we found that we

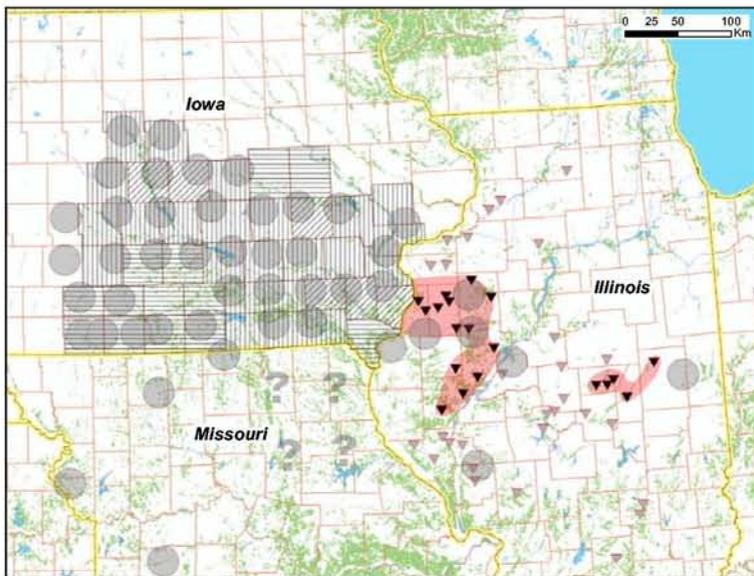


Fig. 1. Historical maps of periodical cicada Brood III.

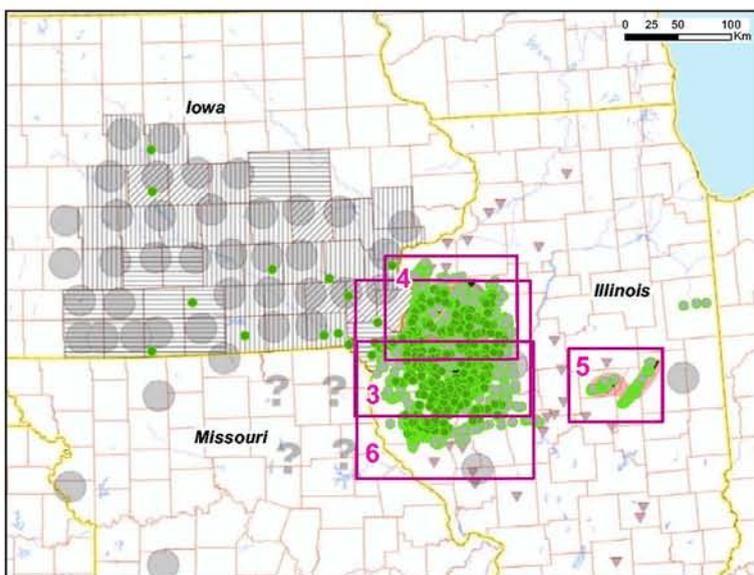


Fig. 2. New records of periodical cicada Brood III superimposed on historical maps. Locations of zoom maps are outlined in violet and numbers correspond to figures.

### Figure legends

For all figures, green shading represents temperate broadleaf deciduous forest in the NCLD 2001 landcover database. Large gray circles and large gray question marks are Brood III records included in Marlatt's Fig. 6 (Marlatt 1923). Inverted black triangles are positive records, and inverted gray triangles are negative records from Stannard's Fig. (Stannard 1975). In Fig. 1, Stannard does not distinguish between negative records for Broods III and XXIII, so all negative records are included. Horizontal fill indicates counties in Iowa where Hardy's Fig. 1 (Hardy 1947) records *M. septendecim* during the 1946 emergence of Brood III, vertical fill indicates Iowa counties where Hardy recorded *M. cassini*, and inclined fill indicates counties where he recorded both species (*M. septendecim* may be patchy in Iowa, and the species was not named until 1962). Small green circles represent our positive records for *Magicicada* Brood III, and small gray circles represent our negative records.

could hear dense choruses of the *Magicicada* -*cassini* species from a closed vehicle at highway speeds, and that we could hear extremely dense *Magicicada* -*decula* choruses at speed with car windows open. However, weak or distant *Magicicada* -*decim* choruses were difficult to hear from a moving vehicle and were sometimes difficult to distinguish from ambient noise (highways, construction, mowing, etc.). We also collected voucher photographs, recordings, and specimens as circumstances permitted. As we searched, we noted the densities of cicadas present, using the following categories: 0) no cicadas present, even though weather and habitat conditions were appropriate for periodical cicada activity; 1) scattered or single individuals present; 2) light choruses in which individual calls were distinguishable and in which sound was not always continuous; and 3) dense choruses of continuous sound and in which individual calls blended together.

We used **Intensive Transects** to make fine-scale maps of brood boundaries, using the categories above. In the Midwest, deciduous trees (and thus, periodical cicadas) often follow drainages. As the network of county and state roads permitted, we entered drainages and crisscrossed the brood boundary, driving slowly back and forth between areas of emergence within the brood and areas that were several miles beyond where we could find cicadas, if possible searching until we entered a new drainage. While crisscrossing the brood boundary, we noted the presence or absence of cicadas at 0.1 mile intervals, and once we had collected a long series of negative records, we doubled back to find areas within the brood, to confirm that conditions were appropriate for us to continue mapping.

We used **Spot Searches** at irregular intervals, depending on availability of suitable habitat or if we thought we heard a cicada. To conduct a search, we shut off the car engine and listened for up to several minutes. If conditions warranted, we also searched the area for physical evidence of periodical cicadas. We confirmed the presence of single cicadas only if two investigators heard a song, if one investigator heard more than a single song, or if we found physical evidence such as nymphs, adults, shed skins, or cicada carcasses.

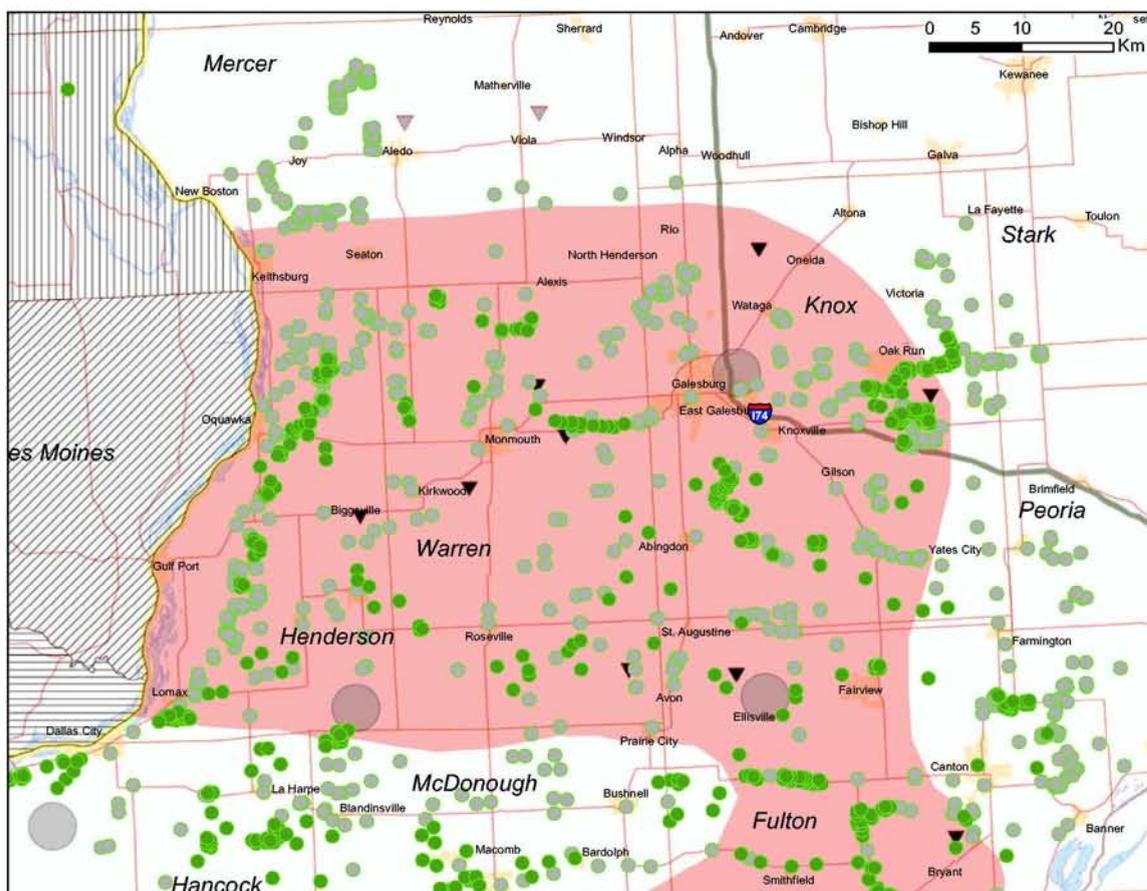


Fig. 3. Brood III in McDonough County and neighboring counties in west-central Illinois.

We used **Long-Distance Transects** to cover distance quickly in order to determine the overall distribution of a brood. Using this method, we drove at normal highway speeds with windows open and looked and listened for evidence of cicadas, recording only positive records. We used this method to make quick checks of particular localities, and if we identified a location of particular interest, or if we needed more information about species composition and density, we could switch back and forth between intensive and long-distance methodologies.

We collected data in detailed, high-quality state road atlases (DeLorme, Yarmouth ME 1:150,000 scale), noting records by marking positive records in pencil as small dark circles and negative records as open circles, using landmarks (especially creeks/rivers), road features, and the car odometer to accurately place the circles to within 0.1 mile accuracy or better. We also periodically noted time, temperature, weather conditions, chorus densities, and species present. When maps were unavailable, we took records with detailed notes including street addresses, distances to intersections or landmarks, etc. We later digitized these records using various software packages (ArcGIS, Street Atlas, Google Earth).

Locality information collected by Simon 1980 was not the result of a survey designed to produce a comprehensive map of periodical cicada occurrences but rather information recorded in the process of collecting specimens for genetic studies that examined diverse areas of the species range including peripheral and central populations. Methods for locating cicada populations in sunny versus

overcast conditions were similar but the mapping effort was not exhaustive and did not involve transects. Exact localities were recorded and later georeferenced from field notes. Irwin and Coelho's 1997 records were collected using a Magellan GPS device (Irwin and Coelho 2000).

## Results

All georeferenced historical maps are available on the Cicada Geospatial Data Clearinghouse (<http://magicicada.org/about/geospatial.php>; Fig. 1). We collected a total of 1,274 positive records and 1,589 negative records (Fig. 2). We spent the majority of our time searching in Illinois; thus, our map offers little new information about the distribution of Brood III in Iowa and Missouri, except that most of our Iowa records contain additional *Magicicada* species not noted by Hardy (1947). We confirmed the existence of Brood III in McDonough County, IL near Fandon (Alexander 1968), and we found Brood III emergences extending along the Mississippi River south of Nauvoo in Hancock County (Fig. 3). Brood III populations also extend southwest to the watershed between Carthage in Hancock County and Golden in Adams County. We found scattered cicadas in the Bear Creek and Panther Creek drainages, and we found isolated Brood III populations on bluffs along the southeast side of the floodplain near the confluence of the Illinois and Sangamon Rivers. We also found Brood III populations in northern Morgan County, IL.

We found no evidence of Brood III in Mercer County, IL, where both Marlatt (1923) and Stannard (1975) reported populations in the Edwards River drainage, although

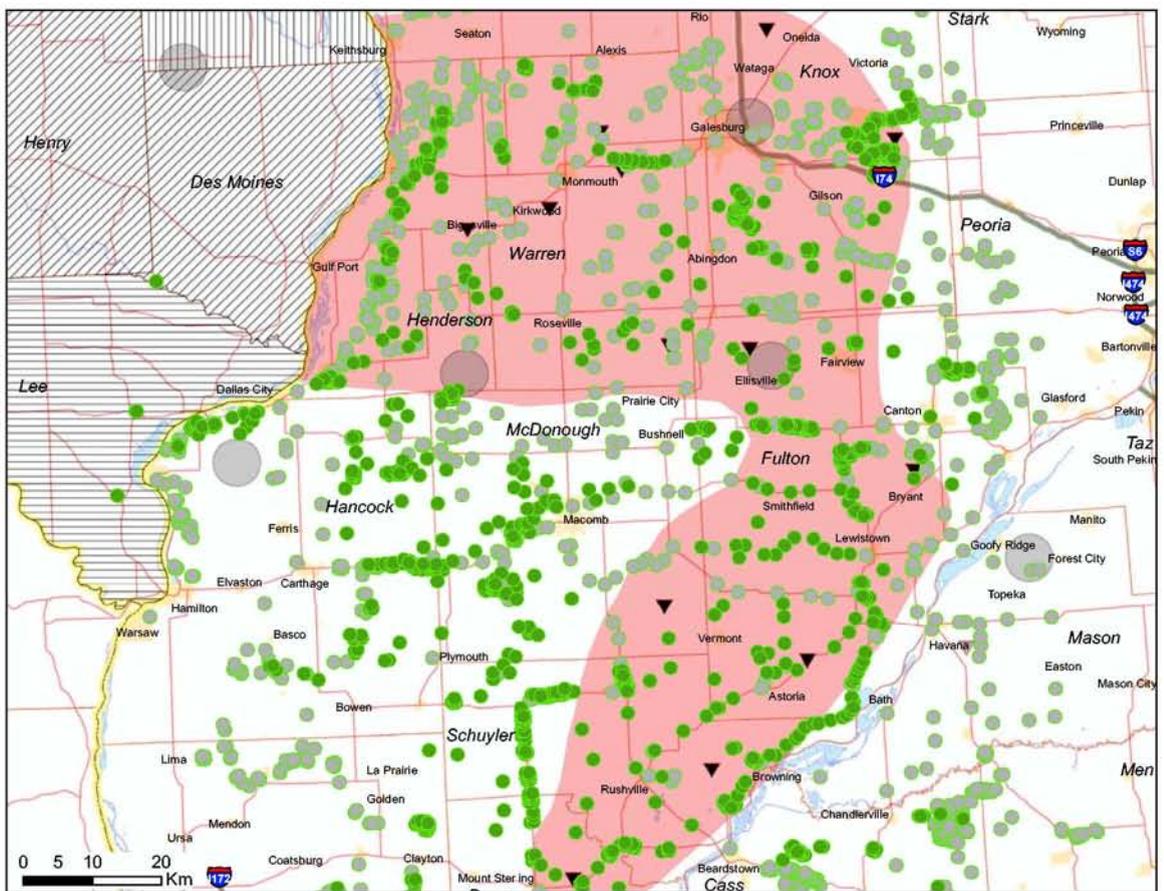


Fig. 4. Brood III in Knox County, IL and neighboring counties.

our searches in southeastern Mercer County were not exhaustive. However, we did find populations in Warren County, less than a mile south of the Warren/Mercer County boundary, in the Henderson Creek drainage. We also found a population in Louisa County, IA due west of Mercer County, IL. We found no evidence of Brood III in Mason

County, IL east of the Illinois River, where Marlatt (1923) placed a Brood III record, although some areas of potential habitat along lower Sangamon River, near its confluence with the Illinois River, have not yet been searched (Fig. 3). We also searched extensively in northwest Knox County, IL and found no evidence of Brood III, despite Stannard's (1975) Brood III record there; the nearest populations we found correspond to Stannard's east-central Knox County record (Fig. 4).

We also found no evidence of emergence in DeWitt County, IL (Fig. 5), confirming that the "large numbers" of cicadas emerging in DeWitt County in 1963 did not belong to Brood III (Stannard 1975) but instead belonged to Brood XXIII, which also emerged in 1963 (Lloyd et al. 1983). We found only seven individual cicadas emerging in Champaign and Piatt Counties, IL, providing further conformation that the eastern disjunct portion of Brood III proposed by Stannard does not exist.

## Discussion

Our map of the 1997 emergence of Brood III varies from earlier maps, just as the earlier maps vary from each other. Marlatt (1923) does not record periodical cicadas in several Iowa counties where Hardy (1947) does, and Marlatt (1923) also includes several far-flung records in eastern Illinois and central Missouri (and even Nebraska, Ohio, and West Virginia) that are clearly spurious and not supported by other literature (e.g., Stannard 1975). Each of these earlier maps differs in significant ways from ours.

Some of these variations among maps are due to differences in record criteria and collection methodologies.

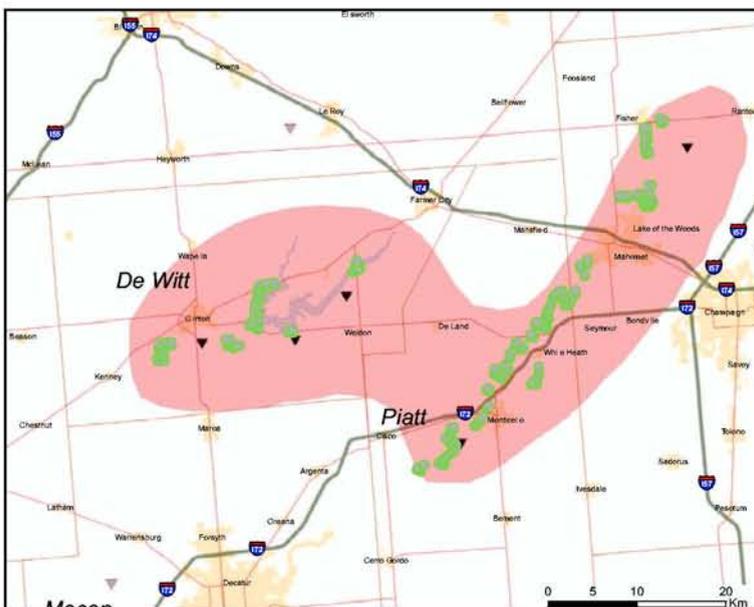


Fig. 5. Brood III in DeWitt County, IL and neighboring counties.

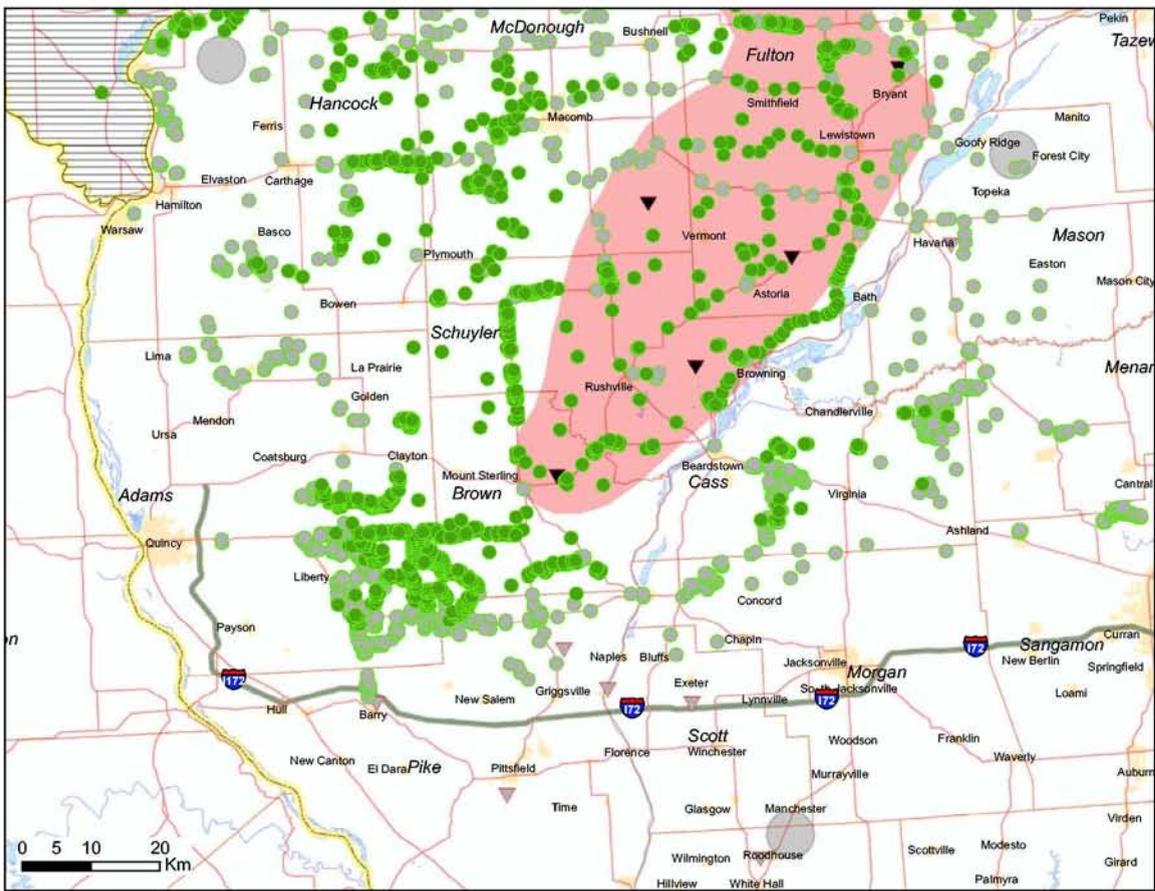


Fig. 6. Brood III in Adams, Brown, and neighboring counties in western Illinois.

Earlier maps do not always distinguish between sightings of small numbers of cicadas and full-blown emergences. In addition, earlier maps are expected to represent brood boundaries differently from ours, because earlier maps are often at county-level resolution (e.g., Hardy 1947), while our map is at 0.1 mile resolution or better. We also do not attempt to draw a line depicting the perimeter of the brood as in Stannard's map (1975); we believe that our approach of fixing the brood boundary by flanking it with detailed positive and negative records better represents the convolutions of the boundary as it follows drainages and patchy vegetation. Other differences seem to be matters of interpretation. While Stannard suggested that all Illinois populations of Brood III are disjunct from Iowa populations (Stannard 1975), in many places, floodplain soils and forests separate Illinois and Iowa portions of the brood, and these habitats typically lack periodical cicadas no matter where they occur. Thus, for all practical purposes, the separation of the Illinois and Iowa portions of the brood is no different from the separation of any periodical cicada populations on opposite sides of a large river.

Other differences between our map and earlier maps seem best explained by differences in search area and search effort. For example, like Irwin and Coelho (2000), we found extensive emergences of Brood III in Brown and Adams Counties, IL (Fig. 6) that were not noted by Marlatt (1923). We also found emergences in Hancock, McDonough, Schuyler, Adams, Brown, Cass, and Pike Counties where Stannard does not appear to have searched. On the other

hand, like Stannard (1975), we found no evidence of periodical cicadas in Mason County, IL (Fig. 6), where Marlatt (1923) shows emergences of Brood III. Since these earlier maps do not include detailed information about the density or contiguity of the populations in these locations, it is difficult to know whether these earlier data points represent scattered cicadas or full-blown emergences.

A more significant issue is Stannard's (1975) disjunct eastern portion of Brood III. Lloyd et al. (1983) suggested that the "limited emergences" Stannard reported were off-cycle stragglers, and that the "large numbers" Stannard reported from DeWitt County, IL were a disjunct population of Brood XXIII, which co-emerged with Brood III in 1963 and thus could be a source of confusion. Our data are the first explicit confirmation of Lloyd et al.'s (1983) interpretation of these records, since we found no populations of periodical cicadas in DeWitt County during 1997, and the handful of scattered cicadas we found in Champaign and Piatt Counties, IL during 1997 appear to have been stragglers, or off-cycle cicadas from other broods (Marshall et al. 2011). Kritsky and Meyer (1976) found extensive Brood XXIII emergences in DeWitt County in 1976, and during the 2002 emergence of Brood XXIII, we also found extensive populations of Brood XXIII in DeWitt County, IL in the locations thought by Stannard to belong to Brood III. These results confirm Lloyd et al.'s (1983) hypothesis that the DeWitt County populations are indeed an unusual disjunct population of periodical cicadas, but one belonging to Brood XXIII rather than Brood III.

Our map of the 1997 emergence of periodical cicada Brood III is the most complete map of the brood to date, and some of its details differ from earlier maps. No simple generalization about whether earlier maps overestimate or underestimate brood boundaries is possible, since earlier maps omit some portions of Brood III and include other locations where we found no populations of Brood III. We urge caution in comparing maps to make inferences about changes in brood boundaries, because even though differences could result from range extension or contraction, differences may also reflect differing search effort, different record criteria, or even simple errors. Because the methodology underlying earlier maps is not explicit, it is difficult to judge the underlying causes of map differences, and thus the most conservative conclusion is that there is no strong evidence of range shifts over time. The issue of range shifts may be revisited later; we hope that by publishing both our map and methods in the most explicit manner possible, we can provide a baseline for mapping other generations or broods of periodical cicadas and for evaluating the stability of brood boundaries.

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