

## OBSERVATIONS ON PERIODICAL CICADAS (BROOD X) IN INDIANA AND OHIO IN 2004 (HEMIPTERA: CICADIDAE: *MAGICICADA* SPP.)

Gene Kritsky, Jennifer Webb, Michael Folsom, and Margie Pfister: Department of Biology, College of Mount St. Joseph, Cincinnati, Ohio 45233 USA

**ABSTRACT.** Periodical cicadas belonging to Brood X emerged in parts of western Ohio and throughout most of Indiana in 2004. The first emerging cicadas were found on 9 May. Most areas were reporting emerging cicadas by 14 May, one week earlier than the average historical emergence date of 20/21 May. Average April temperatures were found to predict the day in May when the emergence would begin. The average soil temperature on the morning after the emergence began was 18.3 °C. Periodical cicadas were observed dispersing into areas that had been cleared since the previous emergence. Some periodical cicadas belonging to Brood XIV emerged four years early, joining the eastern edge of Brood X. Approximately 85.3% of the eggs laid in deciduous trees hatched, and some of the nymphs had molted to the second instar by 31 December 2004.

**Keywords:** Periodical cicadas, Brood X, cicadas, Indiana, Ohio

Periodical cicadas belonging to Brood X emerged in May and June 2004 throughout parts of western Ohio and most of Indiana. All three periodical cicada species, *Magicicada septendecim*, *Magicicada cassini*, and *Magicicada septendecula* emerged during the 2004 emergence. This brood last emerged in 1987, when the senior author mapped its distribution in Ohio (Kritsky 1987) and in Indiana with Frank N. Young, Jr. (Young & Kritsky 1988). The oldest historical record of Brood X was made by the Reverend Andreas Sandel, who briefly described its 1715 emergence in Philadelphia (Kritsky 2004). The first record of the brood in Ohio dates to 1817 in Clermont County, east of Cincinnati, and the oldest records in Indiana come from several towns that recorded cicadas in 1834. Indiana, in particular, has an impressive history of periodical cicada studies, with state maps that date back to the 1885 emergence of Brood X. Except for 1953, every Brood X emergence in Indiana since 1885 has been mapped out by entomologists associated with the state (Kritsky 2004).

The emergence of periodical cicadas, like the appearance of a comet, is a predictable phenomenon, which promotes opportunities for experimentation. We planned to look for meteorological factors that would predict when in May the emergence would begin, to

map the extent of the brood in Indiana and Ohio, to re-examine the soil temperature as an environmental trigger to initiate the emergence, to assess the effects of clear cutting and replanting during the intervening years between emergences, to determine egg hatch rates, and to check the status of some of the offspring of the 2004 emergence at the end of 2004.

### METHODS

To determine which meteorological factors might predict when in May the emergence would begin, it was necessary to gather weather information from the National Oceanic and Atmospheric Agency for previous emergence years. Newspapers and other observations were scoured to find records that specified the first day of emergence. The meteorological records for those years were used to develop a model to predict the beginning date of the 2004 emergence.

To determine the first day of emergence and to re-examine the work of Heath (1968), who found that periodical cicadas emerge when the soil temperature reaches 17.8 °C, fifteen sites were selected on the campus of the College of Mount St. Joseph and on the grounds of the Sisters of Charity Motherhouse in western Cincinnati. The sites represented a diversity of conditions, including shade/sunlight, degree

of slope, and compass orientation. Soil temperature readings (using a digital soil thermometer) and visual surveys for cicada activity were conducted at the sites twice a week from the 31 March to 5 May, and daily from 5 May until the emergence began.

Several approaches were utilized in mapping the statewide distributions of periodical cicadas. Letters and e-mails received from people living in emergence areas provided many data points, which were supplemented by calling county extension agents and state parks to verify that cicadas had been observed. Further information was obtained by driving through emergence areas and recording locations with a global positioning device (GPS). The time-consuming GPS mapping was performed in eastern Cincinnati to determine the eastern boundary of the brood, which will be compared to the western boundary of Brood XIV when that brood emerges in 2008.

To assess the effects of urban development on periodical cicadas, cicada activity was monitored in a recently built housing development, which was cleared of trees for construction in 1994. This site was well within a densely populated Brood X area, with mature woods approximately 400 m away. The development was visited daily during the emergence to determine whether cicadas emerged or dispersed into the area. Cicada choruses in the development were monitored using a RadioShack® digital sound level meter mounted on a tripod.

Egg hatch rates were determined by collecting branches with egg nests in mid-September and carefully removing and counting the eggs. The hatch rate consisted of the number of hatched eggs divided by the total number of eggs found.

Finally, cicada nymphs were excavated in late December 2004 by digging under trees that were heavily scarred by cicada oviposition. The depth to which the nymphs had burrowed was measured using a standard tape measure.

## RESULTS AND DISCUSSION

Heath's (1968) model that periodical cicadas emerge when the soil reaches 17.8 °C suggested that there might be a meteorological predictor that would indicate when a periodical cicada emergence would begin in a given

year. Published papers and newspaper accounts going back to 1868 were surveyed to find records that specifically stated on what date an emergence of Brood X or Brood XIV had begun in Cincinnati. Considerable variation was found for the start dates. Exact dates could not be located for many emergence years, but a few were firmly established. In 1885, cicadas started to emerge in Cincinnati on 28 May (Dun 1886). Newspaper reports published in the *Cincinnati Enquirer* provided information about the emergences in 1936, 1940, and 1953. In 1936, the insects started to appear on 19 May, while in 1940 they had not emerged by 1 June; in 1953, however, they started emerging on 18 May. The senior author recorded that the 1987 emergence started on 15 May, and in 1991 it started on 11 May. The average of these first emergence dates sets the historical start of a cicada emergence as 20/21 May.

The emergence start date was compared with the average of April high temperatures, average April low temperatures, and average overall April temperatures for 1936, 1953, 1987, and 1991. Information from 1940 could not be used because a precise emergence date could not be established for that year, and no accurate temperature readings were available for 1885. A high correlation was found between average April temperatures and the emergence date ( $R^2 = 0.99$ ). The formula determined to predict the beginning of a cicada emergence was  $E = (19.465 - t)/0.5136$ , where  $E$  = emergence start date in May and  $t$  = average April temperatures in °C.

The emergence formula was used to predict that the 2004 emergence would start on 14 May, nearly a week earlier than the historical average. Figure 1 shows how the emergence began in 2004. The first cicadas were observed at one of the 15 monitoring sites on 9 May. On 12 May, three locations had evidence of emerging cicadas. Twenty-four hours later, six of 15 sites had cicada emergences. On 14 May, cicadas had emerged at 80% of the sites. All the stations had emerging cicadas by 17 May. Thereby, showing that the formula can effectively be used to predict a narrow range of dates during which an emergence will begin.

Such information is important to homeowners, gardeners, city parks, and arboreta. Those individuals, wanting to protect their trees from

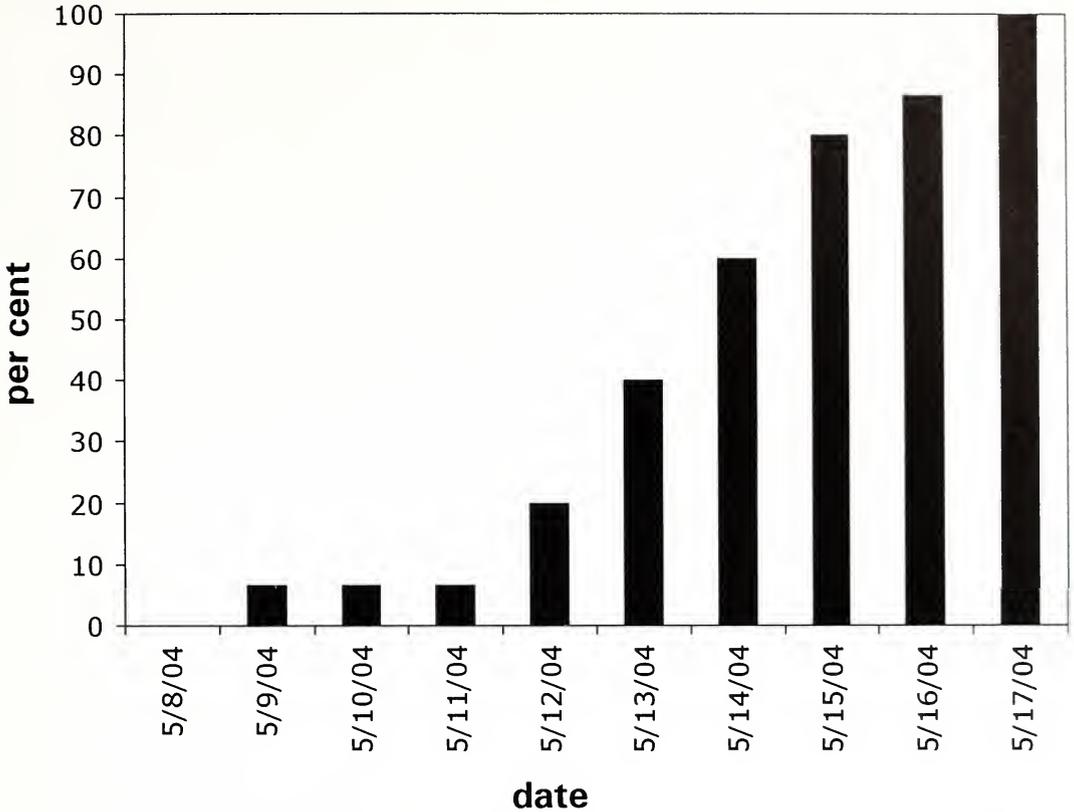


Figure 1.—The 2004 emergence of periodical cicadas started on 9 May and was widespread by 17 May.

damage, may wrap the young trees with lightweight fabric to prevent the cicadas from ovipositing on the terminal branches. However, care should be taken not to keep the trees wrapped for too long, as this may block sunlight and limit the trees' growth. When our prediction was announced to the public on 1 May, those who needed to protect their trees were given the opportunity to plan when at-risk trees should be wrapped.

The College of Mount St. Joseph Cicada Watch website received over 900 e-mails from Indiana and Ohio. Moreover, county extension offices from every county where periodical cicadas had emerged in the past were contacted to verify if cicadas had emerged in 2004. Periodical cicadas were reported from 82 counties in Indiana and 28 counties in Ohio. A map of the county distribution is presented in Fig. 2. The heaviest numbers of cicadas were reported in southwestern Ohio and throughout southern Indiana. In southwestern Ohio, the eastern edge of Brood X was found to be ap-

proximately 1600 m west of Point Pleasant along the Ohio River. The boundary ran north to Clertoma and extended northwestward to Symmes Township, where it continued on a northern transect.

Areas in Madeira, which experienced dense Brood XIV cicada populations in 1991, had a moderate emergence this year. Trees that were planted after 1987 (when Brood X last emerged) but before the 1991 emergence of Brood XIV were found to have cicada skins and holes at their bases. These cicadas were Brood XIV cicadas that had accelerated to emerge four years early. This phenomenon is the scenario that Kritsky (2004) presented to explain how broods might change in distribution over time. The area will be surveyed again in 2008, when Brood XIV will next emerge, to determine the extent of overlap between the two broods. Smaller pockets of accelerating cicadas were also reported in Ohio's West Union in Adams County and in Chillicothe in Ross County.

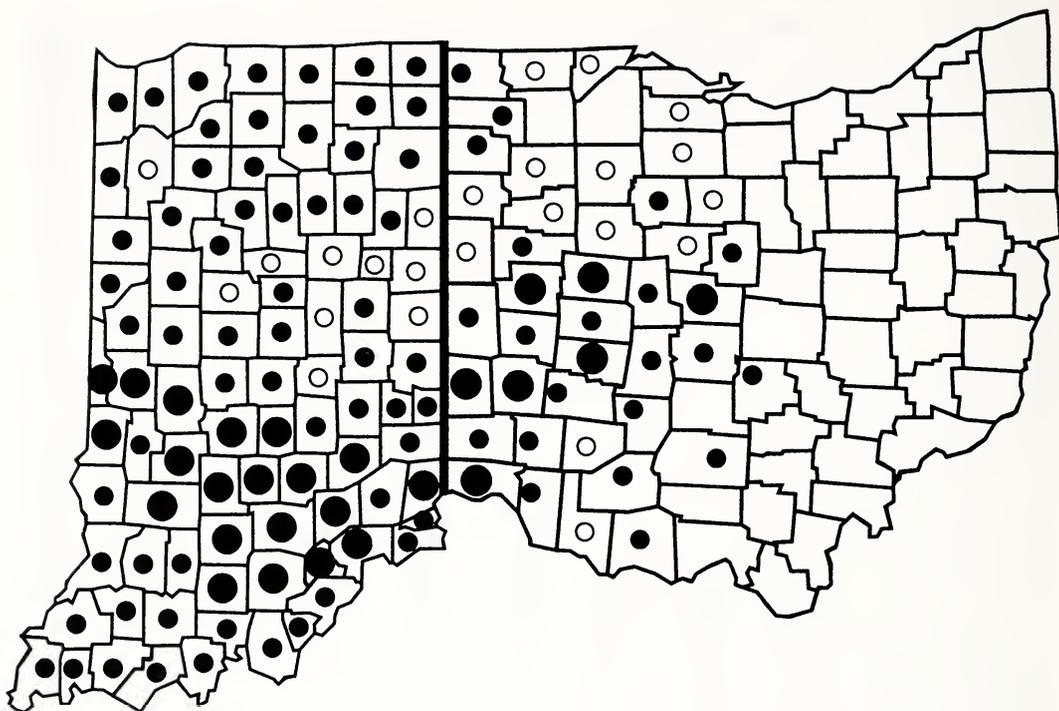


Figure 2.—The Indiana and Ohio distribution of periodical cicadas in 2004. The large circles represent counties reporting dense populations, smaller circles represent counties with isolated pockets of periodical cicadas, and open circles represent counties where cicadas had been reported in the past, but apparently did not emerge during 2004.

Heath's (1968) model that cicadas emerge when the soil temperature reaches  $17.8^{\circ}\text{C}$  was re-examined by taking soil temperature readings between 1000 h and 1200 h at each of our 15 study sites. The soil temperatures on the first day of cicada emergence ranged from  $16.6^{\circ}\text{C}$  to  $20.1^{\circ}\text{C}$  with an average temperature of  $18.3^{\circ}\text{C}$ . This supports Heath's 1968 study that periodical cicadas have a temperature threshold of approximately  $17.8^{\circ}\text{C}$  that aids in triggering the mass emergence. As Heath (1968) reported, we also found that cicadas emerged first from south-facing locations in full sun.

No cicadas emerged under any of the trees in the housing development that was monitored. However, by the last week of May, periodical cicadas had dispersed into the area from mature trees no closer than 400 m away, and they formed chorusing centers that were measured at sound levels up to 96 dB. Oviposition in the development was very high, which promises a large emergence in 2021.

The loudness of a mixed species chorus de-

pended on the distance between the sound level meter and the chorus. When sound level of a single chorus was measured at various distances, it was found that the loudness decreased by approximately 2 dB for every 3.05 m of distance between the chorus and the measuring device (Fig. 3). This relationship may provide an estimate of the loudness of a chorus when measuring distant trees.

The cicada eggs began to hatch in late July. Egg nests from ginkgo, red oak, and American linden were examined; and a hatch rate of approximately 85.3% was established for eggs laid in branches that had not broken or wilted. Egg nests from flagged branches yielded egg hatch rates of 47.2% ( $n = 301$ ) in red oak and 48.3% ( $n = 302$ ) in American linden. White (1981) found that the number of eggs that die in flagged branches depended on how long the branch remained alive after oviposition. The longer the branch remained alive the greater the hatch rate.

Periodical cicadas nymphs, hatched from the eggs laid during the 2004 emergence, were

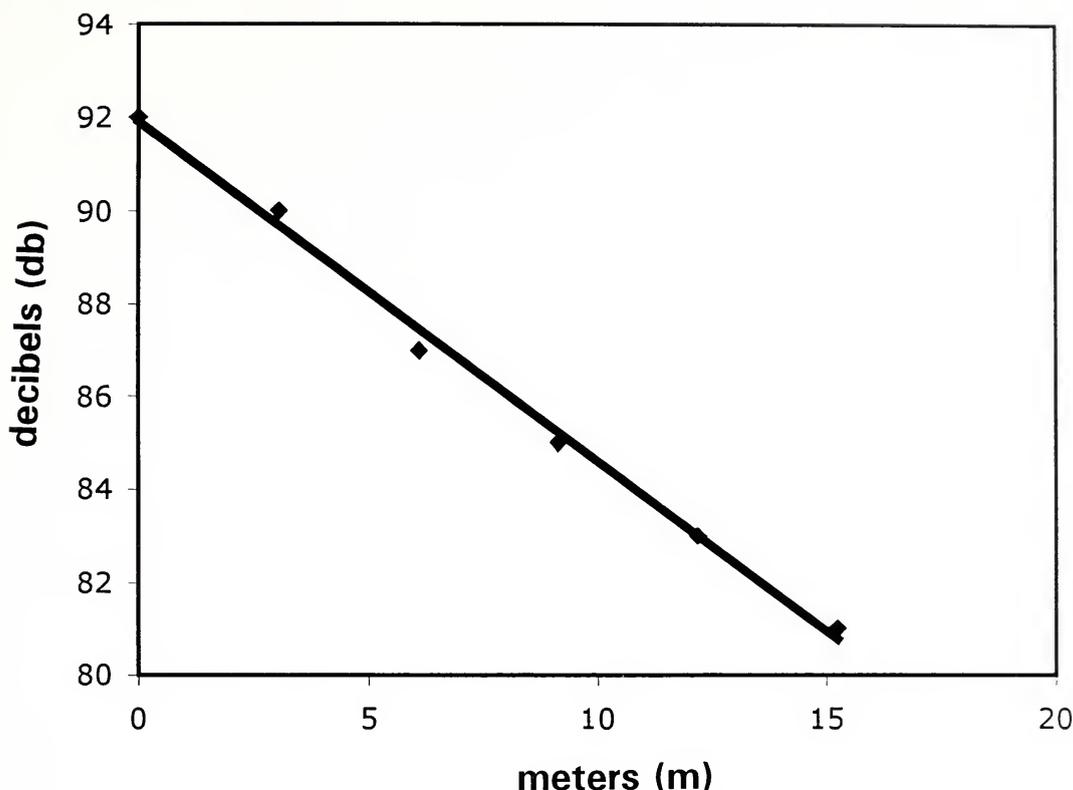


Figure 3.—Decline in periodical cicada chorus loudness when measured at increasing distances. The sampled chorus was composed primarily of *Magicicada cassini*.

excavated on 31 December 2004. The nymphs were found between 16.5 and 28 cm deep below the topsoil and in the uppermost clay layer, which places them below the freeze line of the area. Both first and second instar nymphs were found, indicating that many had molted to the second instar within five months after hatching.

#### ACKNOWLEDGMENTS

We thank the Ohio Biological Survey and Ace Pest Control for financial support of the mapping project. We also thank Robert Waltz and Gala Erland for help with contacting county agents, Christopher Buelterman for his help with the thousands of e-mails, and Jesse Smith for designing the College of Mount St. Joseph Cicada Watch Website and reviewing this manuscript. We also thank Robert Waltz, James Curry, and James Berry for their valuable suggestions that improved this manuscript. Thanks are also due to the thousands of people who sent us their observations of the 2004 emergence.

#### LITERATURE CITED

- Dun, W.A. 1886. Observations on the periodical cicada. *Journal of the Cincinnati Society of Natural History* 8:233–234.
- Heath, J.E. 1968. Thermal synchronization of emergence in periodical “17-year” cicadas (Homoptera: Cicadidae, *Magicicada*). *American Midland Naturalist* 80:440–448.
- Kritsky, G. 1987. The 1987 emergence of the periodical cicada (Homoptera: Cicadidae: *Magicicada* spp.: Brood X) in Ohio. *Ohio Journal of Science* 88:168–170.
- Kritsky, G. 2004. *Periodical Cicadas: The Plague and The Puzzle*. Indiana Academy of Science, Indianapolis, Indiana.
- White, J. 1981. Flagging: Host defences versus oviposition strategies in periodical cicadas (*Magicicada* spp. Cicadidae, Homoptera) *Canadian Entomologist* 113:727–738.
- Young, E.N. & G. Kritsky. 1988. Observations on periodical cicadas (Brood X) in Indiana in 1987 (Homoptera: Cicadidae). *Proceedings of the Indiana Academy of Science* 97:323–329.

*Manuscript received 17 February 2005, revised 2 May 2005.*