Periodical Cicadas: The Magic Cicada (Hemiptera, Tibicinidae, *Magicicada* spp.)

A.F. SANBORN

Abstract

A brief introduction to the biology of the periodical cicadas is provided. The taxonomy, distribution, broods, and life cycle are discussed. Even though these species receive significant attention from the scientific community, there are still advances being made in the study of these amazing animals.

Key words: *Magicicada*, periodical cicadas, life cycle, natural history.

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The periodical cicadas (*Magicicada* spp.) are arguably one of the most remarkable insects to inhabit the earth. The large numbers of adults that emerge over a short period of time at regular yearly intervals have peaked the interest of humans since the cicadas were first encountered. It is hard to ignore an animal that appears at regular intervals at densities up to 3.7 million ha^{-1} (DYBAS & DAVIS 1962a).

Fig. 1:
***Magicicada septendecim* (L.). Periodical cicadas are known for their black body and red eyes.**

The fascination with the periodical cicadas has continued to the present day with stories in the media when an emergence occurs and the investigations of these animals by a new generation of scientists.

Periodical cicadas are often mistakenly called "locusts". The confusion began when the first European colonists experienced an emergence. The sudden appearance of a large number of cicadas reminded the colonists of the plague of migratory locusts or grasshoppers found in the Old World (MARLATT 1907). The popular designation of "periodical locust" has remained in use to this day even though the cicadas are actually a different order of insect.

The first description of periodical cicadas in the scientific literature was by OLDENBERG (1666). He discussed the appearance of periodical cicadas and some of the damage they did to trees. References continued to be made to the periodical cicadas in the literature (e.g. KALM 1756) until the current nomenclature system was produced by Linnaeus and the individual species could be described.

The taxonomic history of the *Magicicada* species is surprisingly complicated for such an obvious animal that emerges in great numbers at regular intervals. The first *Magicicada* species (M. (*Cicada*) *septendecim* [L. 1758] [Fig. 1]) was named in the first volume to name animals using the scientific binomial nomenclature system, *Systema Naturae* (LINNAEUS 1758). A second and third species, M. *cassinii* (FISHER 1852) (Article 33.4 of the *International Code of Zoological Nomenclature* [ICZN 1999] states that *cassinii* should be the correct spelling since it was the original spelling but one most often encounters a spelling of *cassini* in the literature) and M. *tredecim* (WALSH & RILEY 1868), were described in the mid-nineteenth century. However, their status as a distinct species was debated over the next hundred years with various authors giving the organisms species rank while others treated them as a variety or race of M. *septendecim* (see summary in METCALF 1963). DAVIS (1925) described the genus *Magicicada* for M. *septendecim*, M. *cassinii* and M. *tredecim* as a way to separate the periodical species from other North American cicadas. It was ALEXANDER & MOORE (1962) who finally settled the dispute over how many species there actually were when they identified six species, three 17-year species (M. *septendecim*, M. *cassinii*, M. *septendecula* ALEXANDER & MOORE 1962) and three 13-year species (M. *tredecim*, M. *tredecassini* ALEXANDER & MOORE 1962, and M. *tredecula* ALEXANDER & MOORE 1962) based on morphological, behavioral, and acoustic differences. Even when it looked as though the taxonomy had finally been straightened out, a seventh species, M. *neotredecim* MARSHALL & COOLEY 2000, has recently been described (MARSHALL & COOLEY 2000). There are no gross morphological and behavioral differences between 13- and 17-year forms so their status as separate species is under debate.

To complicate matters further, it appears the difference between 13- and 17-year life cycles is the rate of growth of the early instars (WHITE & LLOYD 1975) and these differences may be the result of a single gene (LLOYD et al. 1983, COX & CARLTON 1991). There may be four species (the Decim pair, the Cassinii pair, the Decula pair and M. *neotredecim*) rather than the seven currently described species since the 13- and 17-year species have been successfully cross mated (LLOYD & DYBAS 1966). Genetic evidence, such as the mtDNA evidence that helped to separate M. *neotredecim* from M. *tredecim* (SIMON et al. 2000), may help to answer this question.

Magicicada species are distributed over most of the eastern and central United States (Fig. 2). The 17-year species have a more northerly distribution in the eastern range but continue south through Kansas and Oklahoma into Texas along the western edge of the distribution. In contrast, the 13-year species have a southerly distribution in the eastern United States but extend northward in the western portion of their distribution into central Illinois and across Missouri. This overall distribution can be further divided into yearly broods which are temporally isolated from one another.

MARLATT (1898) identified the broods with Roman numerals with I-XVII designating 17-year broods and XVIII-XXX designating 13-year broods. Brood I was arbitrarily assigned to the 1893 brood and will next appear in 2012. The 13- and 17-year broods that overlap emerge in the same year only once every 221 years. This keeps the gene exchange between 13- and 17-year species relatively low.

There are several hypotheses as to how brood formation occurred over time. One idea is that brood formation in the 17-year cicadas occurred through four year or one year accelerations (LLOYD & DYBAS 1966). Soon after the hypothesis was published, an unexpected four year acceleration was documented in suburban Chicago apparently due to extremely high population densities (LLOYD & WHITE 1976). Multiple accelerations have since been reported (see summary in WILLIAMS & SIMON 1995). Similarly, ALEXANDER & MOORE (1962) suggested that more northerly cicadas may have added another year to their life cycle during extreme cold periods separating new broods from the ancestral group.

The development of molecular techniques has raised another possibility. Genetic evidence suggests that large scale, permanent, four year accelerations have occurred in some 17-year cicadas to produce 13-year cicadas (MARTIN & SIMON 1988, MARTIN and SIMON 1990a, SIMON et al. 2000). By switching the life cycle, new broods, and it appears new species, are formed.

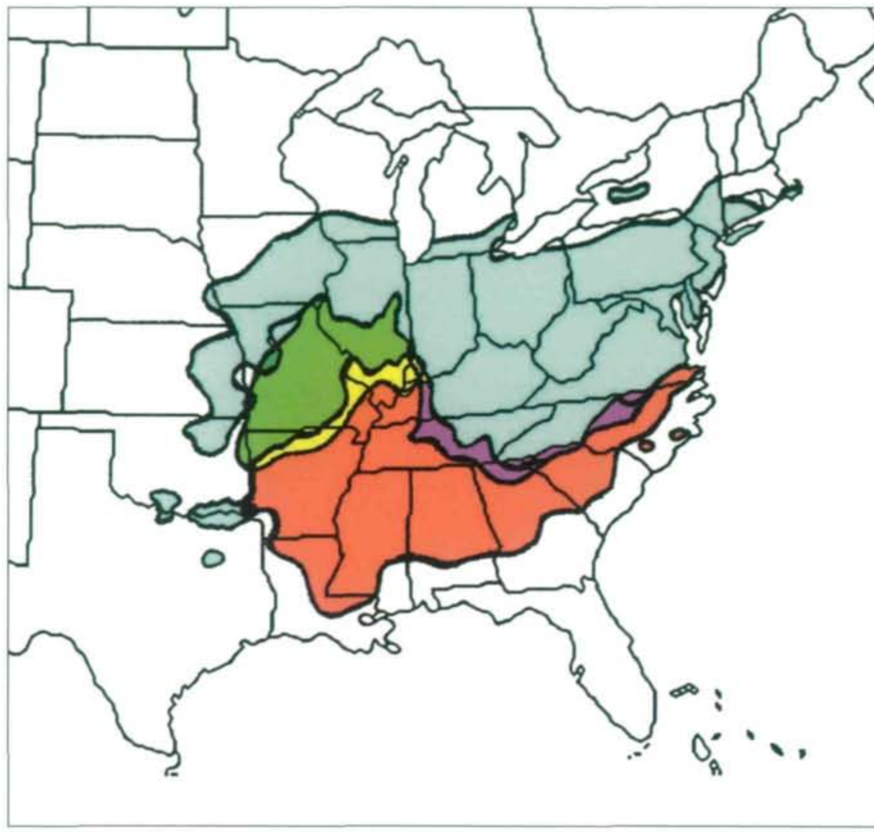

Fig. 2:
Distribution of *Magicicada* species. The distribution of the seventeen-year species is illustrated by the light blue area and extends across the northern and western distribution of the genus. Thirteen-year species have a more southerly distribution and extend northward up the Mississippi Valley as illustrated by the red area of the map. The most recently described species, *M. neotredecim*, was separated from the northernmost distribution of *M. tredecim* (the green area on the map) and appears to be a converted 17-year species. Yellow, purple, and gray areas represent regions of overlap between the species groups.

Periodical cicadas have the ability to synchronize their emergence over a relatively short time period, with the majority of the population emerging within 7-10 days (DYBAS & LLOYD 1962b, HEATH 1968, MAIER 1982). HEATH (1968) showed that adult periodical cicadas emerge when soil temperature at 20 cm reaches about 17.9°C and body temperature reaches 18.0°C. In addition, the emergence pattern was predictable based on the amount of sunlight and southern exposure that a particular habitat possessed. Therefore, temperature appears to be the trigger for emergence of the population.

However, this does not answer the question as to how periodical cicadas determine when 13 or 17 years has passed. KARBAN et al. (2000) appear to have answered the question of how cicadas determine the passage of time. They transplanted 15 year old cicada nymphs to the roots of peach trees they had manipulated to bloom twice a year instead of the normal single bloom. What they found was that

Fig. 3: **Large garbage bin outside of Brookfield Zoo during the 1990 periodical cicada emergence. Neighbors were encouraged to collect dead cicadas from their yards so the insects could be given to the zoo animals as a treat.**

the cicadas were fooled by the double blooming trees and emerged a year ahead of schedule. It appears the cicadas are counting physiological changes that occur within the host plant during a year to count the number of years they have been underground.

But why would an insect develop a long, periodic life cycle? The first step to becoming periodical cicadas is the evolution of a fixed development time that is longer than one year with the adults emerging only after this fixed time period has passed (HELIÖVAARA et al. 1994). The evolution of periodicity in *Magicicada* has been suggested to have begun with a protoperiodical condition as has been seen in other cicada species (WILLIAMS & SIMON 1995). A protoperiodical condition has been suggested to be initiated by variable weather conditions, particularly during the ice ages (LLOYD & DYBAS 1966, COX & CARLTON 1988, MARTIN & SIMON 1990b, YOSHIMURA 1997, COX & CARLTON 1998). Cold would extend the developmental time which would decrease the density of adults emerging from an original population. Low adult population densities would then select for synchronized emergences in restricted locations to increase the ability to survive and to reproduce. The prime numbers 13 and 17 would then be selected for because they are the least likely to coemerge and hybridize which would breakdown the synchrony in the populations (YOSHIMURA 1997, COX & CARLTON 1998). Predator avoidance has also been implicated in the development of the long life cycles (LLOYD & DYBAS 1966, ITÔ 1998).

Once the cicadas have emerged their main goal is to reproduce. Males will begin to assemble in large numbers and chorus. The calling songs of the males attract females to form large mating aggregations. Females chose which male will be a suitable mate based on his courtship song. After mating she will oviposit in particular host species and eventually the cicadas will disappear for another 13 or 17 years.

It seems the major complaints about periodical cicadas are their numbers, the sound they make, and the damage they do to trees. The numbers are required to survive predation as just about everything eats periodical cicadas when they emerge (MARLATT 1907, WILLIAMS & SIMON 1995). The sounds produced by the cicadas are the mating calls of the males trying to attract a female. Although the individual males produce sounds that are only about 44-84 dB at 50 cm (ALEXANDER & MOORE 1958, WEBER et al. 1987), periodical cicadas are by no means very loud for cicadas (SANBORN & PHILLIPS 1995). The shear number of periodical cicadas make the choruses very loud. Damage to trees can occur due to oviposition directly, but pathogens can also be vectored by the cicadas. The tendency for trees to drop their branches after heavy cicada oviposition causes the trees to look like they are severely damaged when the cicadas are actually ovipositing in a manner which minimizes damage to the tree (WHITE 1981). However, this "flagging" acts as a natural pruning so the trees end up more vibrant the next year (MILLER & CROWLEY 1998). Fruit trees and young trees are susceptible to severe damage and should be protected by placing cheese cloth over the plant until the emergence is over since chemical control is not a practical option (MILLER 1997).

Experiencing an emergence of periodical cicadas is truly an unique experience. Nymphs leave their shells on any vertical surface they can find: trees, fences, houses, automobiles, etc. In neighborhoods with dense old growth forest, the cicadas can come out in such large numbers that they are ever present. People normally do not like the invasion of cicadas but the superabundant food source can help other animals to be more reproductively successful (STREHL & WHITE 1986). In fact, Brookfield Zoo in suburban Chicago asked for their neighbors to collected dead cicadas from their yards and bring them to the zoo to be frozen as a treat for the animals (Fig. 3). Scientists are now beginning to answer long standing questions about the biology of periodical cicadas. It appears the new millennium will continue to provide insights into the Magic Cicada.

A more detailed analysis of *Magicicada* biology can be found in the reviews by MARLATT (1907) and WILLIAMS & SIMON (1995). Jo Ann White is also finishing a book on *Magicicada* that Monte Lloyd had begun prior to his death.

Zusammenfassung

Diese Arbeit bietet eine kurze Einführung in die Biologie der „Periodischen Zikaden"; Taxonomie, Verbreitung und Lebenszyklus werden diskutiert. Obgleich diese Zikaden schon seit langer Zeit besonders beliebte Studienobjekte sind, werden immer wieder neue, erstaunliche Erkenntnisse zur Taxonomie und Biologie veröffentlicht.

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Address of the author:

Dr. Allen F. SANBORN
School of Natural &
Health Sciences,
Barry University,
11300 NE Second Avenue,
Miami Shores,
FL 33161-6695, USA.