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Numerical simulation for persistence of prime-numbered life cycles in periodical cicadas

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Abstract: Periodical cicadas are the most extraordinary insect in the world for the longest lifecycle in insects, completely synchronous emergence, extreme aggregation, strong site tenacity, and of all, 17- and 13-year prime numbered cycles.

Many hypotheses have been presented to explain evolution of long perfectly synchronized cycles, e.g., predator satiation, synchronization with predator cycles, and larval competition. These hypotheses explain the origin and/or maintenance of periodical cycles, but not the origin of prime number cycles.

Recently it has been suggested that the prime numbered cycles was selected for among various cycles, because of the rarity of co-emergence and resulting hybridization with other cycles. This hybridization hypothesis explains the origin of prime number cycles: weather cooling starting in the glacial period invokes a historical chain resulting in prime number cycles. However, hybridization due to co-emergence is never tested to lead the selection of prime number cycles.

We demonstrate this selection process is mathematically possible using an extremely simple numerical model. This model is a discrete simulation model with three parameters: larval survival per year; clutch size; emergence success. Reproductive intervals from 10-year to 20-year compete for survival in the simulations. The model makes three key assumptions: a Mendelian genetic system, random mating among broods of different life cycle lengths, and integer population sizes. Besides, longer-interval phenotypes have larger broods but suffer higher total mortality than shorter-interval broods. The life-cycle length of hybrids is assumed to be Mendelian inheritance with shorter-cycle dominance. The integer population size is round-down each generation to include negative effects of small population sizes. As a control, the simulation is also run with round-up processes.

Our results show rapid disappearance of non-prime number cycles and strong persistence of prime-numbered cycles. The results clearly show the advantage of infrequent co-emergence in prime number cycles. The selection of only 13- and/or 17-year cycles appear only under extremely limited conditions, i.e., at the verge of extinction. This suggests that the evolution of periodical cicadas is extremely rare events which may have happen in some refugia in the central-to-east United States.

Keywords: *Periodical cicadas, computer simulation, synchronous emergence, hybridization, extinction*

Abstract only