Supporting Online Material

Materials and Methods

Cicada collection and field sites

I collected 18,000-20,000 *M. septendecim* and *M. cassini* adults with insect nets during the 2002 emergence of Brood VIII at the Powdermill Nature Reserve near Rector, PA, USA and the 2003 emergence of Brood IX near Athens, WV, USA. Cicada collections included biomass from male and female individuals of *M. septendecim* and *M. cassini* in naturally occurring proportions. Cicadas were frozen within 1-4 hours after collection, and used in experiments 1-14 days later. These collections represented approximately 13.3-19.7 kg of live cicada biomass, or 4.8-7.0 kg dry mass. In 2002, I conducted soil nitrogen experiments at the Powdermill Nature Reserve (Carnegie Museum of Natural History) on mesic, low slope, fine-loamy soils of the Ernest series, in areas forested with *Acer rubrum* and *Quercus* species. In 2003, I conducted soil microbial experiments and soil nitrogen experiments in Glen Alton, VA, USA (USDA Forest Service) on mesic, low slope, Cotaco loam soils dominated by *Quercus* species. American bellflower experiments were conducted in 2003 on high-slope, shale-derived soils at the Wilderness Conservancy of Mountain Lake, VA, USA. All field sites were located within the broad geographic range of the concomitant cicada emergence and were less than 1 km from an active cicada chorus, but no site received substantial ambient cicada litterfall due to the spatial patchiness of these emergences.

In order to investigate documented spatial and temporal variability in naturally occurring cicada densities (*SI*), I conducted direct measurements of cicada densities during the 2002 emergence of
Brood VIII and the 2004 emergence of Brood X. In 2002, a census of emergence holes in twenty-five haphazard 1 m² quadrats at the Powdermill Nature Reserve in western Pennsylvania documented emergence densities ranging from 6 to 504 cicadas m⁻² (mean=95.92, SD=104.81) in an area of <4 ha. In 2004, I conducted a census of 216 open basket traps distributed at 18 sites spanning 120 km in the range of Brood X in order to assess dead cicada deposition. Twelve traps were distributed at 5-10 m intervals at each site in order to assess cicada deposition across a wide range of habitats and microsites extending from Potomac and Shenandoah River floodplains in eastern Maryland and northern Virginia, to Appalachian ridgetops in West Virginia and western Maryland. I collected and counted dead cicadas from traps at 5-9 day intervals during the adult cicada phase. This census documented a right-skewed, leptokurtic distribution of densities ranging from 0 to 1848 cicadas m⁻² (mean=56.94, SD=134.63, Fig. S3). While these 2004 deposition data demonstrate the high variability of naturally occurring cicada deposition densities in both space and time, subsequent data suggest that these measures may be highly conservative estimates of actual cicada litterfall due to scavenger losses from the open basket traps, especially at lower densities. Individually marked dead cicadas placed in collection baskets revealed site-specific losses of 30-100% (mean=72%, SD=15.86%) in 48 h. Despite these conservative measures, these direct observations indicate the magnitude and variability of natural cicada densities, and support the range cicada densities previously reported in the literature (SI).

The total nitrogen content and stable isotope ratios in 10 *M. septendecim* cicada carcasses (5 male, 5 female) were measured at the University of California, Davis Stable Isotope Facility using a continuous-flow mass spectrometer following standard methods.
Soil nitrogen experiments

In 2002, thirty-three 1 m² forest plots were randomly assigned to receive four levels of manipulated cicada litterfall density: 0 (control, \( N = 11 \)), 30 (\( N = 10 \)), 60 (\( N = 10 \)) or 300 (\( N = 2 \)) cicadas m\(^{-2}\). Unbalanced replication was necessary due to constraints on the quantity of collected cicadas in this first year. In 2003, eighty-eight 1 m² forest plots were randomly assigned to receive four levels of manipulated cicada litterfall density: 0 (control), 60, 120 or 240 cicadas m\(^{-2}\) with balanced replication (\( N = 22 \)). In both years, cicadas carcasses were scattered by hand onto the forest floor. These treatment levels were chosen to span the range of naturally-occurring cicada densities.

In both years, a buried-bag ion-exchange resin (IER) method was used to assay mineralized soil nitrogen availability. This method uses IER beads buried in fine mesh bags to bind ammonium and nitrate ions in the soil, and provides a reproducible, relative index of mineralized nitrogen availability to plant roots (S2). While several recent studies have illustrated the importance of mycorrhizally facilitated organic nitrogen uptake in some ecosystems (S3), this assay is the most appropriate method for assessing the plant-available nitrogen pools in temperate forest soils (S3). Because this is an in situ field method with limited disturbance, the buried bag IER method effectively mimics the uptake of mineralized nitrogen by plant roots in competition with microbes and subject to on-site abiotic conditions (S2).

IER bags were buried at the center of each plot using a single 10 cm deep incision parallel to elevational isolines and oblique to the soil surface. Cicada carcasses were hand-delivered to experimental plots as a one-time pulse on June 2, 2002 in the first experiment and June 1, 2003 in the second experiment. In order to evaluate the phenology and persistence of cicada litterfall
effects in 2003, a first set of IER bags was buried for 30 days, and a second set was buried for the subsequent 70 days of the experiment. Analysis of nitrate and ammonium concentrations were conducted blind by the University of California, Davis DANR Analytical Lab following standard methods (S2).

These experiments were analyzed as completely randomized designs using repeated measures least-squares polynomial regression analysis of covariance (ANCOVA), to test the hypotheses that cicada litterfall density is positively correlated with soil nitrate and ammonium concentrations. Plotwise initial measures of gravimetric soil moisture and estimated % plant cover were used as covariates in the 2003 analyses. These covariates were judged to be non-collinear by examination of variance inflation factors. Lack-of-fit tests were used to determine the simplest appropriate model order. The Brown-Forsythe and O’Brien tests were used to confirm the assumption of homoscedasticity. Subsequent regression analyses were used for each collection set to evaluate the magnitude of the cicada litter effect at each period. Soil nitrate and ammonium data were log transformed prior to analysis to meet the assumptions of normally distributed residuals in ANOVA and polynomial regression. Shapiro-Wilk tests confirmed assumption of normally distributed residual variation.

**Soil microbial experiments**

In 2003, five subsample soil cores (2.5 cm diameter by 5.0 cm depth) were taken from each of 22 replicate forest plots in the control and 120 cicadas m⁻² treatment plots described above. Equivalent soil disturbance was evenly distributed in all plots, to avoid uncontrolled effects in other experiments. Soil samples were collected 7 d and 28 d after the initial cicada litterfall pulse. These subsample soil cores were immediately homogenized and frozen for blind PLFA
analysis at the Scow Soil Microbial Ecology lab at the University of California, Davis. PLFA analysis exploits the specificity of phospholipid membrane structure in functional and taxonomic groups of microbes to provide information about the microbial community composition \((S4)\). These methods allow quantitative measurements of total microbial biomass, and the abundance of bacterial and fungal groups. For many applications, the PLFA method surpasses other microbial census techniques such as BIOLOG plates and substrate-induced respiration (SIR) in measures of community resolution and non-selectivity \((S4)\). These data were analyzed in repeated measures ANCOVA to test the hypothesis of positive cicada litterfall effects on bacterial and fungal biomass. Initial measures of soil organic matter and estimated percentage plant cover were used as covariates in this analysis. These covariates were robust to analyses of the variance inflation factor. Planned contrasts were used at each collection set to evaluate the magnitude of the cicada litter effect at 7 days and 28 days. Brown-Forsythe and O’Brian tests were used to confirm assumptions of homoscedasticity.

**American bellflower experiments**

A natural population of 100 American bellflowers was randomly assigned to receive 0 cicadas or 10 cicadas placed by hand on the soil surface immediately below the plant. This initial treatment cicada density corresponds to approximately 140 cicadas m\(^{-2}\), although the high slope of the site and heavy rains during the experiment probably resulted in substantial carcass loss during the course of the experiment. This experiment was established on June 25, 2003, and plants were collected on September 8, 2003, after these plants had flowered and set seed. Seed mass was measured as the mean individual seed mass from a sample of 50 seeds collected from the terminal fruits of each plant. Samples of foliage from the terminal leaves of each plant were
analyzed blind for total nitrogen, total carbon, and $\delta^{15}$N concentrations using a continuous-flow mass spectrometer at the University of California, Davis Stable Isotope Facility. Initial counts of stem number were taken when the experiment was established; these counts describe natural initial variation due to prior herbivory and growth, and were used as covariates in a one-way ANCOVA to test the hypothesis that the expected seed mass of cicada-supplemented American bellflowers ($N=39$) is greater than the seed mass of control plants ($N=33$). These covariates were robust to analyses of the variance inflation factor. ANOVA was used to test the hypothesis of greater foliage nitrogen content in cicada-supplemented plants ($N=30$) compared to control plants ($N=29$). A one-tailed test of significance is appropriate for both the seed mass and foliage nitrogen concentration analyses because previous studies with this species have established a strong a priori expectation of the effect direction, reflected in the directional hypotheses. ANOVA with a two-tailed test of significance was used to evaluate the hypothesis of increased $\delta^{15}$N enrichment in the foliage of cicada-supplemented bellflowers ($N=30$) compared to the foliage of control plants ($N=29$). Brown-Forsythe and O’Brian tests were used to confirm assumptions of homoscedasticity in all analyses.
Supplementary figures

Figure S1. The cumulative brood distribution of *Magicicada* species. Figure modified with permission from (S5).
Figure S2. Results from initial soil nitrogen experiments conducted during the 2002 emergence of Brood VIII. Cicada litterfall increases indices of (A) ammonium and (B) nitrate availability in forest soils over a range of cicada deposition densities. A similar experiment was conducted during the 2003 emergence of Brood IX with greater replication over intermediate cicada densities (Fig 2).
Figure S3. Distribution of cicada carcass fall densities from open basket traps over part of the 2004 Brood X range. These cicada deposition densities are likely to underestimate actual cicada litterfall densities, due to scavenger losses from traps.
References and Notes


