Supporting Information

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SI Methods

Calibration of the Coffee Farm Model. During its design, the coffee farm model's structure and foraging theory were tested and found to reproduce a variety of observed patterns, even before calibration (1). For this study, we calibrated the model to field observations, using a hierarchical approach starting with bird foraging behavior, followed by population-level foraging patterns (which emerge from foraging behavior and parameters for food and foraging in the various habitat types), and ending with coffee berry borer (CBB) consumption (which depends on foraging behavior, foraging on other food sources, and parameters for CBB). For individual-based models, the hierarchical approach has the advantages of calibrating the underlying individual-level mechanisms before calibrating the full-model results that emerge from what individuals do (2), and limiting the number of calibration simulations to a feasible number.

We performed manual calibration experiments, running the model with various parameter value combinations and examining the results to identify combinations that caused the model to meet specific criteria. We took this approach instead of an optimization approach because uncertainty in the calibration criteria and data did not justify a more precise calibration, and because it was computationally tractable.

The first step in calibration was to adjust parameters for individual foraging habitat selection to fit 474 observations of the distances between locations of individual birds at 1-h intervals (1). These observations were approximately lognormally distributed; the natural logs of distances between hourly observations had a mean of 3.5 m and an SD of 1.0 m. The corresponding distribution of hourly movement in model results was sensitive to the model's foraging time step and the radius over which birds are assumed to select habitat cells at each step. We calibrated these two parameters by running the model with five values of the foraging time step (1–5 min) and three levels of foraging radius (the current cell plus 8 surrounding cells, the 13 cells with centers within a radius of 10 m, and the 21 cells with centers within 12 m) and then identifying the combination that best produced the observed lognormal distribution. The calibration experiment ran the model for 20 d, sufficient for the distribution to stabilize, then output the distance between each bird's location and its location 1 h earlier, once per hour over 1 d. One simulated landscape was used for all of the experiments. A foraging time step of 3 min and sensing area of nine cells (birds select among their current cell and the eight surrounding cells) provided the best fit, closely reproducing the observed mean with a simulated SD of 0.7 m.

We next calibrated the prey parameters (i.e., prey production and foraging success) of each landscape type to target values of bird densities and foraging times (mean hours per day that birds forage). The first calibration target, based on several types of observations (3) and the potential limitations and biases of each, was a landscape-wide mean density of 15 birds/ha. The second calibration target was that bird density in shade coffee should be roughly twice that in forest, a target based on published density estimates for small insectivorous birds in coffee habitat (4–7). The third calibration target was bird densities two to three times higher in shade coffee compared with sun coffee, observed at a study site with characteristics similar to those in the model (8). The final calibration target was a mean foraging time of 10–11 h/d. This range is lower than the typical dawn-to-dusk foraging behavior of real birds demonstrated in radiotelemetry studies (9), because the model does not let birds forage longer than the minimum to meet their daily maintenance consumption and does not represent any nonforaging behaviors that use up time during the day.

We began the calibration of bird densities and foraging times by varying the prey production and foraging success parameters of all habitat types by the same ratios and observing the resulting bird densities and mean hours spent foraging on the last simulated day. These preliminary experiments showed that the calibration targets were best met by increasing food production and reducing catchability parameters. Thus, we generated 13 levels of prey production in each habitat type by multiplying precalibration values by factors ranging from 1.0 to 1.6 in steps of 0.05, and generated 11 levels of foraging success by multiplying precalibration values by factors ranging from 0.3 to 0.8 in steps of 0.05. We then applied all 143 combinations of those levels to each of five replicate landscapes, all with the baseline area of each habitat type. The results of this experiment indicated that precalibration values of prey production should be multiplied by ~1.2 and foraging success should be multiplied by ~0.4. We used a similar experiment varying only prey production for forest habitat to calibrate the relative densities of birds in forest and high-shade coffee.

The calibrated prey parameters (Table 1) met the calibration targets. The simulations using five replicate landscapes produced a mean (over the final 100 d) of 15 birds/ha and 10.0 h of foraging per day. The simulated mean density of feeding birds was 11 birds/ha in forest, 21 birds/ha in shade coffee, and 8 birds/ha in sun coffee.

Calibration of CBB dynamics was based on field observations that indicate birds reduce CBB infestation rates (compared with rates in exclosures that prohibit bird consumption of CBB) by 30–50% in shade coffee and by 50–70% in sun coffee (8, 10). To calibrate the model toward these targets, we adjusted the most uncertain CBB parameter, *CBB-success*, which reflects how easily birds can capture the CBB. We executed model runs with 11 values of this parameter (1.0–3.0 times the precalibration value of 420 m^2/h) in five replicate landscapes, and recorded the mean reduction in infestation rates caused by birds at the end of the 151-d simulation. The best fit to the target CBB infestation reductions were at a *CBB-success* value of approximately 1,100 m^2/h. This value corresponds to a time of 1 min to remove half of the CBB from a cell, which is not unreasonable because these prey, although small, are visually conspicuous in predictable, exposed locations on coffee berries and likely require minimal handling. The model produced slightly lower CBB reductions than those seen in shade coffee (20–25%) and higher reductions than those seen in sun coffee (80%). These differences will affect absolute predictions of CBB control by birds, but would be expected to have less important effects on relative predictions, such as the direction of change in infestation rates with changes in habitat availability.

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