Electronic supplementary material

Model description

The model has a structure with a population of exploiters (e.g. insects) and an environment of victims (e.g. plants). Both exploiters and victims are equipped with traits essential to the model and will be explained below. Traits are constants or subject to mutations. Each individual exploiter and victim is evaluated by a fitness function. New generations are created by letting the most fit individuals reproduce. The offspring inherit the parents' traits but mutational changes and crossover (in the sexual model only) may occur. Generation times in evolving plants are longer than in insects. The model is a general exploiter-victim model, but was originally inspired by phytophagous insects and their host plants. Below, the models are described, but for all details we refer the reader to our original publications.

The exploiters

The exploiter population is modelled individually, each being equipped with an artificial neural net. We use a three-layer, feed-forward perceptron as a model for the perceptual system of the exploiters. The perceptron has two input nodes and one output node. The number of hidden nodes in the intermediate layer varies between 3-6. The net is fully connected with synapses in a feed-forward fashion. So called "bias signals" were applied to the nodes. Synapse values were limited to ±10. Each node (except the input nodes) is activated by a standard sigmoid threshold function (see Holmgren & Getz 2000). The output of the ANN is bounded between 0-1, and represents the exploiter's preference to the victim whose two signal cues are applied to the input nodes.

The fitness W_g^E of exploiter i depends on the resource value of the victims (h) it attacks (v_h), the intensity of the attack (e.g. the number of eggs the exploiter lays) on the victims ($e_{g,h}$; eqn 1), and the probability of attack success (e.g. the eggs hatching), and is given by the function

$$W_g^E = \sum_h e_{g,h} \frac{1}{1+\left(\dfrac{e_h}{v_h \varepsilon_{1/2}}\right)^{\alpha}} \qquad \text{(eqn A1)}$$

Here α is a parameter that determines the abruptness of the effects of density dependence. Parameter $\varepsilon_{1/2}$ sets at which value of the total attack of plant (e_h) the sigmoid fitness function returns half its maximum value. Hence, the number of offspring in the next generation is density dependent on each host. When individuals of the generation are created the nodes are subject to point mutations with a given probability. A mutation incurs a change to the weight drawn from a rectangular distribution with given limits. The probability of mutations and the limits of the rectangular distribution varied as a part of a sensitivity analysis. The fitness determines the number of offspring in the next generation.

In the sexual model with diploid, sexually reproducing insects, each insect has two vectors representing the parts of the insect's genome that codes for the structures associated with host plant selection in the insect's nervous system. Stored in the vectors are values representing the genetic expression of each gene in the above mentioned parts of the genome. Each position in the vectors corresponds to a specific synaptic weight in the insect's ANN. The value of a specific synaptic weight is the intermediate value of the two corresponding values in the vectors. During reproduction each parent produces a gamete that will become one of the offspring's vectors. The gamete is created by copying values from one of the vectors into the gamete and proceeding down the vector. With a given probability, crossover occurs, and the values of the gamete are instead read from the other parent continuing at the position where the crossover occurred. There are no restrictions on the number of crossovers that can occur during the creation of a gamete. The direction of the copying is always the same; hence the positions of the new values in the vectors correspond to the same synaptic weights as in the parents. A value in the gamete may mutate with a given probability. During mutation the value is modified with a random value within a fixed range.

The victims

In simulations where victims, e.g. plants, do not evolve, they are represented as homogeneous populations with different traits. When plants evolve, plant populations are modelled as a group of individuals that share their value as a resource to the exploiters, but exhibit variation in their signals. The signals consist of two cues that are subject to mutational changes with a fixed probability and drawn from a rectangular distribution of a given range. Range and probability have been varied as a part of a sensitivity analysis.

The fitness W_h^E of victim h is a sigmoid function of the size of the population of which it is a member (P_h), its egg-load (e_h), and its resource value to exploiters (v_h):

$$W_h^V = \frac{\beta}{1 + e^{\delta\left(dP_h + c_1 e_h + c_2\left(v_{MAX} - v_h\right) - \gamma\right)}} \, . \qquad \text{(eqn A2)}$$

Parameter β determines maximum fitness, δ is a slope parameter, and d is the intensity of density dependence. Parameter γ is a population growth rate parameter. Parameter v_{MAX} sets the maximum resource value a victim can have. The cost parameter for an egg-load is c_1, and for the defence against exploiters c_2. We require $c_1 > c_2$ since the victims trade off predation costs by expending fitness currency on defence (Norrström *et al.* 2006). The number of offspring of each plant in the next generation is given by rounding off the fitness upwards or downwards to the nearest integer. Which one is determined by distance weighted probability.