Modeling alternative stable states mediated by evolution in a metacommunity

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Results

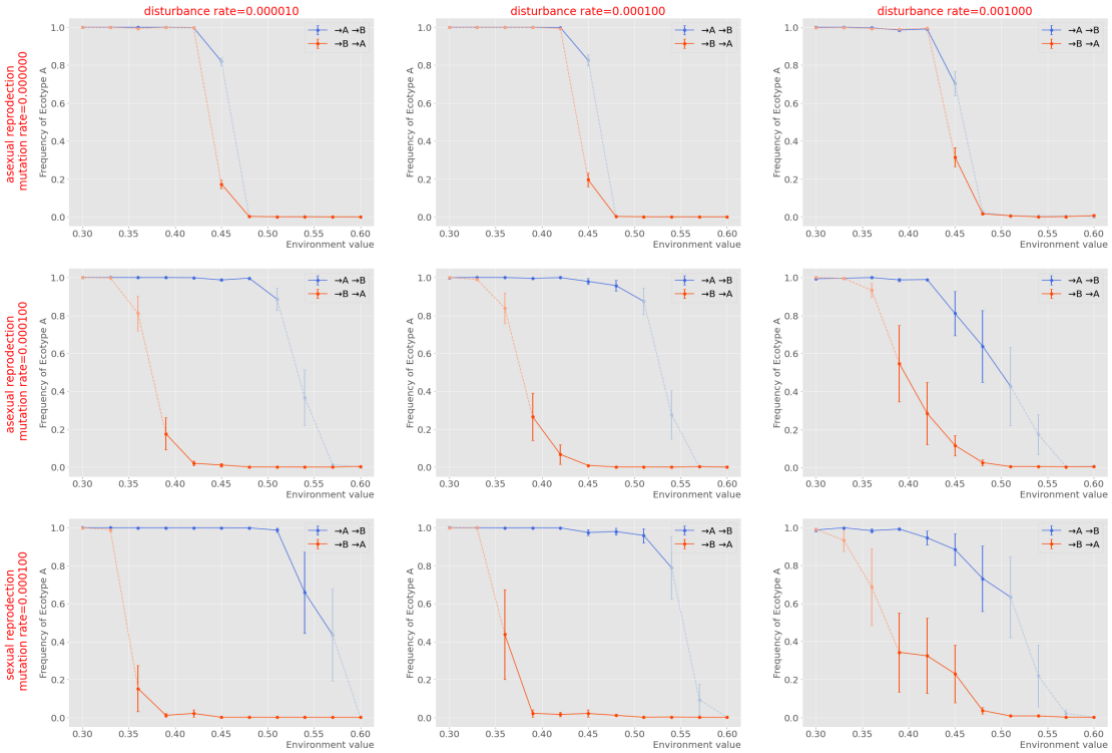

Fig. 1 The proportion of species 1 (Ecotype A) in the metacommunity landscape. The alternative stable states are mediated by evolution and disturbance. Priority effect can be triggered by different colonization orders. Two scenarios of colonization orders are considered. Species 1 (Ecotype A) colonized before the colonization of species 2 (Ecotype B), which is denoted as A→B. Species 2 (Ecotype B) colonized before the colonization of species 1 (Ecotype A), which is denoted as B→A.

Methods

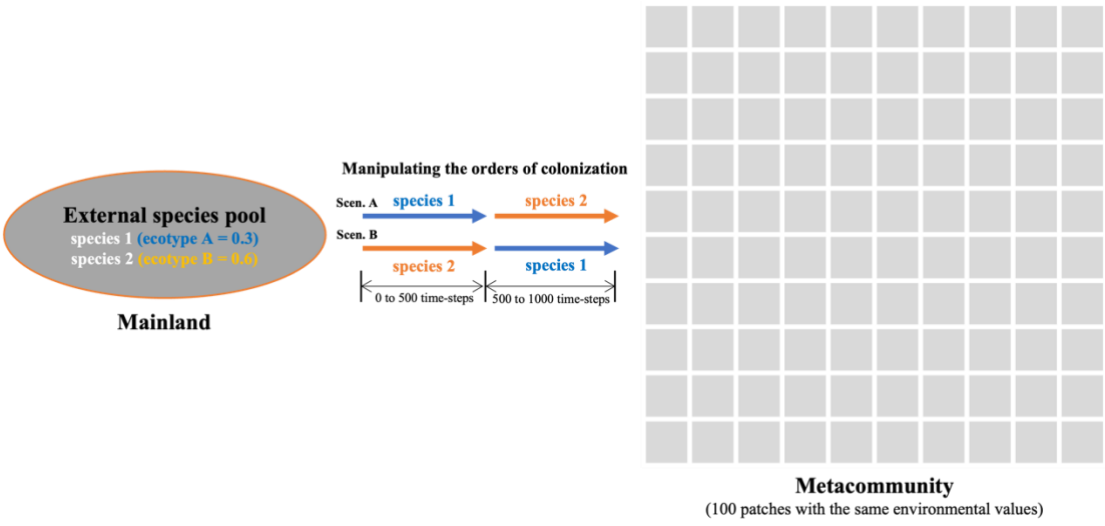

Fig. 2 Illustration explaining the islands-mainland model we built. The mainland, as an external species pool, is initially occupied by two species with different ecotypes. The set of patchy islands, as a metacommunity, is initially empty at the start of the simulation. In the simulation, two scenarios of manipulating the colonization orders of species are considered. In scenario (A), species 1 with ecotype A colonized the metacommunity for 500 time-steps first, and then species 2 with ecotype B colonized the metacommunity for the next 500 time-steps. In scenario (B), species 2 with ecotype B colonized the metacommunity for 500 time-steps first, and then species 1 with ecotype A colonized the metacommunity for the next 500 time-steps.

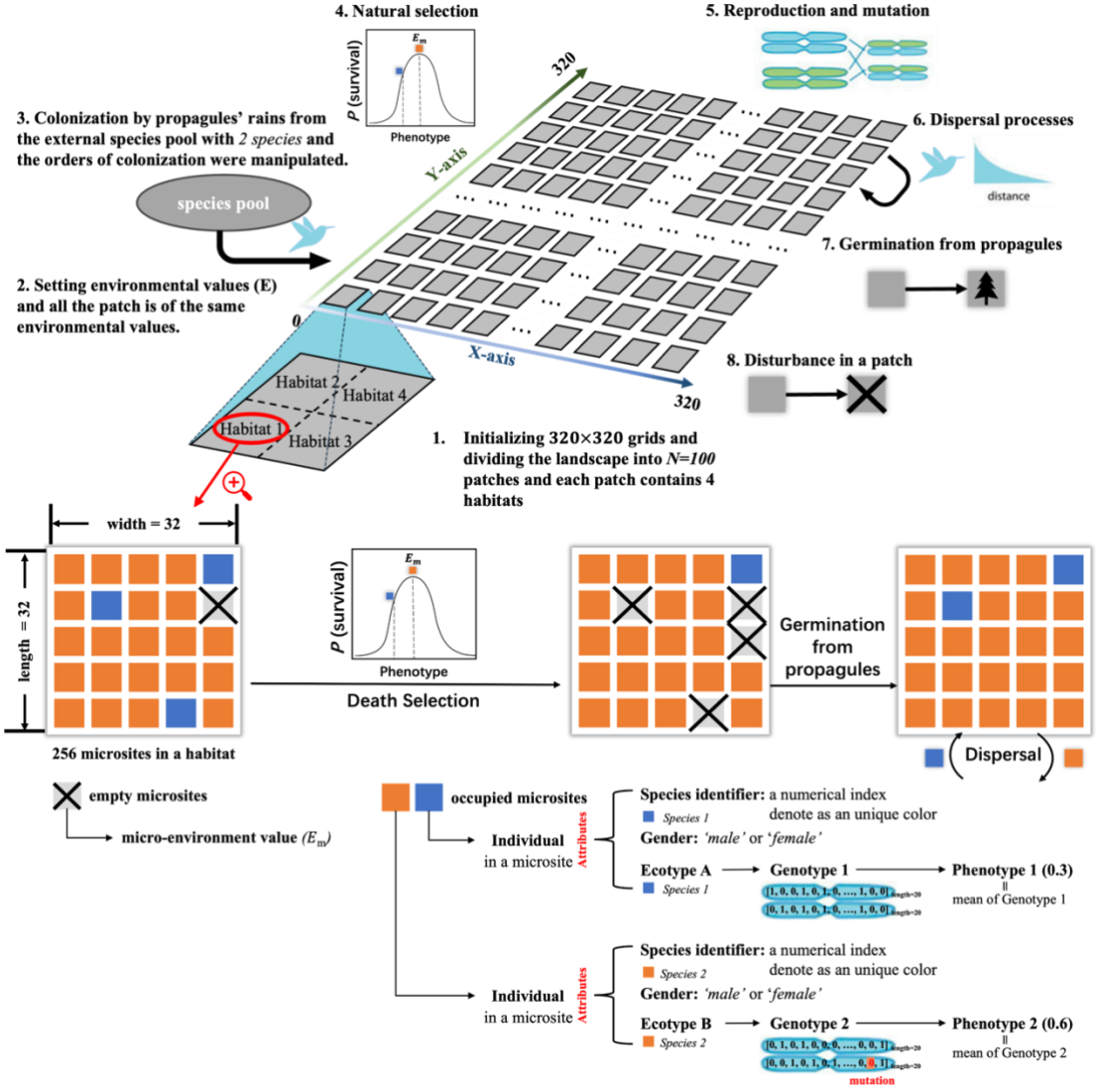

Fig. 3 Illustration explaining the model designs including the spatial scales of the metacommunity landscape and the scheduling of the eco-evolutionary processes in the simulation. The simulation, following an initialization, runs the sub-models of colonization, environmental selection, reproduction & mutation, dispersal, germination, and disturbance processes in orders within a time-steps. An islands-mainland model was created with an initially-empty metacommunity with a spatially explicit structure including patch and habitat scales and an initially-occupied mainland with 2 species as an external species pool for the subsequent community assembly in the metacommunity. There are totally 102400 grids (microsites) in the global metacommunity, which is divided into 100 patches in the landscape. The micro-environmental values in the grids obey a gaussian distribution with mean=e and variance=0.025 in the landscape. In the simulation, two scenarios of manipulating the colonization orders of species are considered. Pre-emptive competition is assumed such that one microsite can only be occupied by only one individual. Environmental selection

process is conducted according to the survival rate of an individual affected by the matching between the genetic-based traits value (i.e., phenotype or ecotype) of the individual and the micro-environment values in the microsites. Then, the propagules are born in the asexual or sexual reproduction process, followed by the dispersal process of the propagules with the assumption of an exponential decay model. The empty microsites in the landscape can be re-occupied by the propagules randomly sampled from the local offspring or the newly-arrivals by dispersal. Finally, a disturbance process of a patch occurs with a probability that all the individuals and propagules are dead in the patch. The model is run for 1000 time-steps to reach an equilibrium state.

Table 1 The main sub-models and their summative description

Sub-models	Description
The landscape	The initialization procedure of the metacommunity landscapes including the habitats number, the patches number & location and the environmental gradients of the landscape. The initialization procedure of the mainland as a species pool including the species number and their initial traits values.
Individuals	Its unique attributes including *species identifier*, *gender*, *age*, *phenotypes (traits values)*, and *genotypes*.
Environmental selection	The matching between micro-environment and the individual's phenotype in the microsites
Reproduction and mutation	Three modes including: Asexual reproduction, Sexual reproduction and the mixture of the twos.
Colonization and dispersal	The individuals colonize the empty microsites by propagules' rains and the individuals disperse in the landscape in two ways of dispersal between patches or dispersal within a patch.
Dormancy	The propagules failed to colonize could be in dormancy and will not undergo environmental selection
Disturbance	All the individuals in the habitat or patch would be dead.

Table 2. The parameters space in the simulation

Parameters	Values
reproduction mode	'asexual' or 'sexual'
mutation rate	0, 0.0001
disturbance rate	0.00001, 0.0001, 0.001
Environmental mean value (e)	0.30, 0.33, 0.36, 0.39, 0.42, 0.45, 0.48, 0.51, 0.54, 0.57, 0.60