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Dispersal governs the reorganization of ecological networks under environmental change

Patrick L. Thompson and Andrew Gonzalez

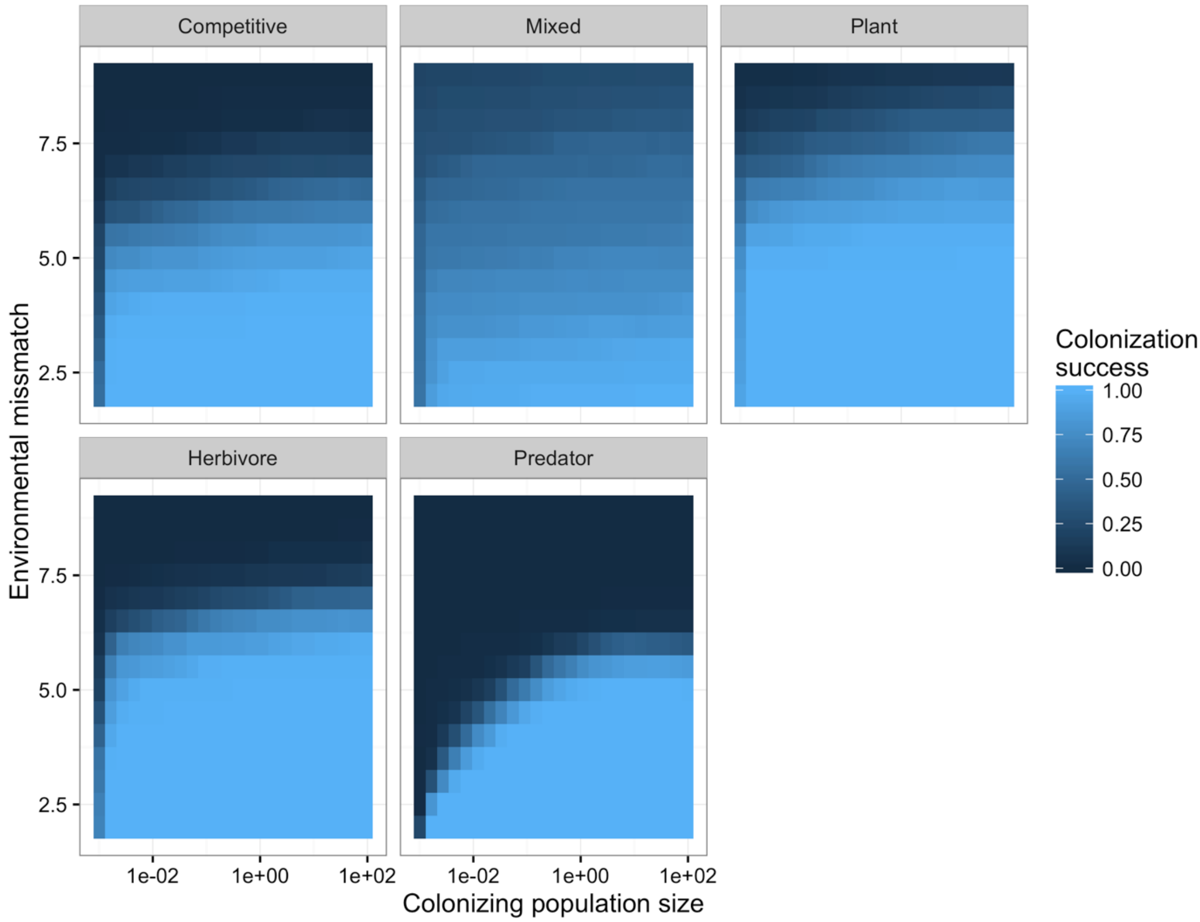

Figure S1. Colonization success of a focal species dispersing into a habitat patch that contains a community of resident species as a function of colonizing population size and the degree of environmental mismatch between the environmental optima of the focal species and the local environment of the patch. This figure is based on the results of 100 replicate simulations, each replicate used a new set of interspecific interactions drawn at random following the procedure described in the methods section.

This simulation demonstrates that the ability of a species to successfully colonize a new patch increases with the size of the colonizing population, but also depends on how close the environmental state of the patch is to the environmental optimum of the species. This is the case with all types of interactions. Regions of the graph where colonization success falls between 0 and 1 indicates conditions where there is interspecific variation in the ability for species to successfully colonize. This variation is the result of differences in species interactions between the resident species and the focal species.

For this simulation, we assume a local environmental optimum of 1 for the focal species, and an environmental optimum of 10 for all resident species. These values were chosen to ensure that the focal species would be excluded from the community when the environment matched the resident species. All species, including the focal species, start with an initial abundance of 10 in the patch, and the environmental value of the patch starts at 10. We ran simulations for a 1000 time steps to allow the community to reach equilibrium. We then reduced the environmental value so that it was suboptimal for the resident species, and closer to the optimum of the focal species. We contrasted new environmental values spanning the range of 2 to 9. After changing the local environment, we added all species back into the community through dispersal. We contrasted dispersing populations spanning the range between 0.001 and 100. We then ran the simulation for an additional 1000 time steps before determining whether the focal species was still present in the community. All parameters used in this simulation were identical to those described in the manuscript, except when specified otherwise.

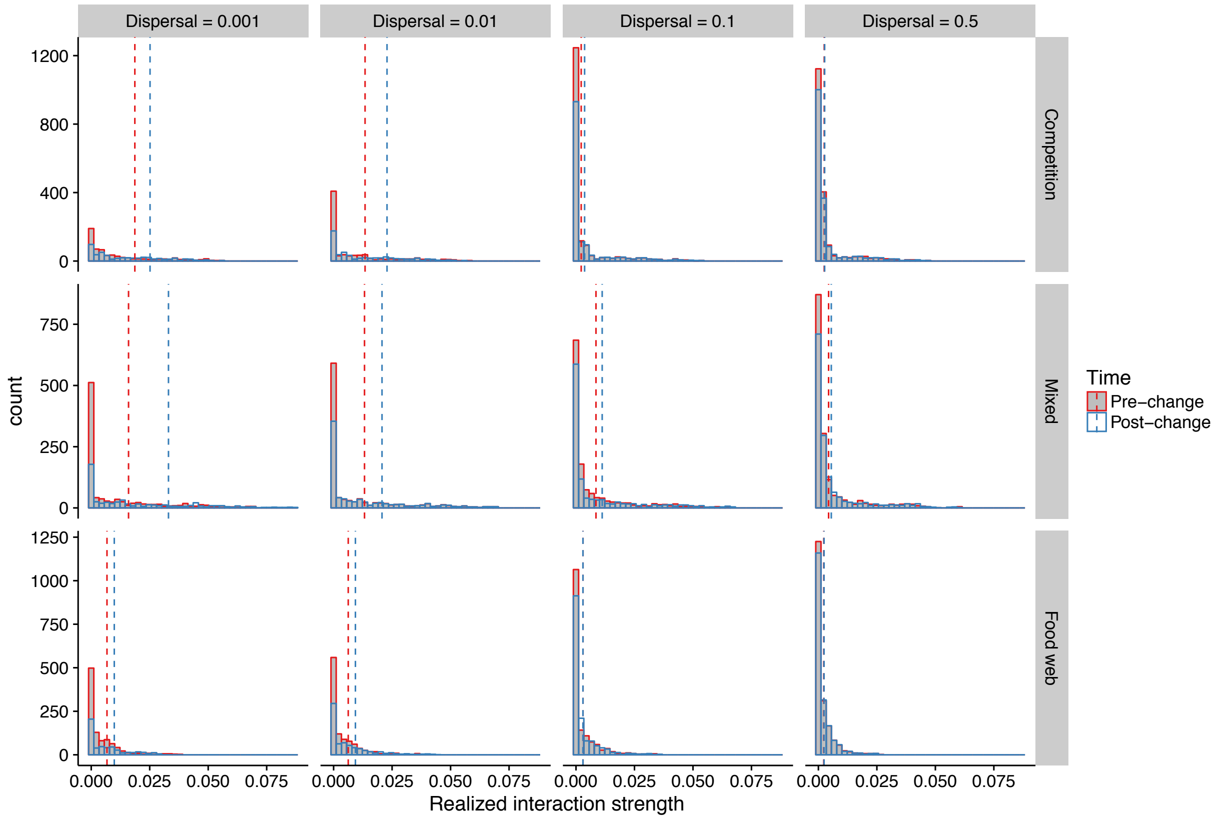

Figure S2. The distributions of realized interaction strengths in the species interaction networks from figure 1, both before and after environmental change. The dashed lines indicate the 0.75 percentile cut off. Interactions stronger than this cut off are shown in figure 1.

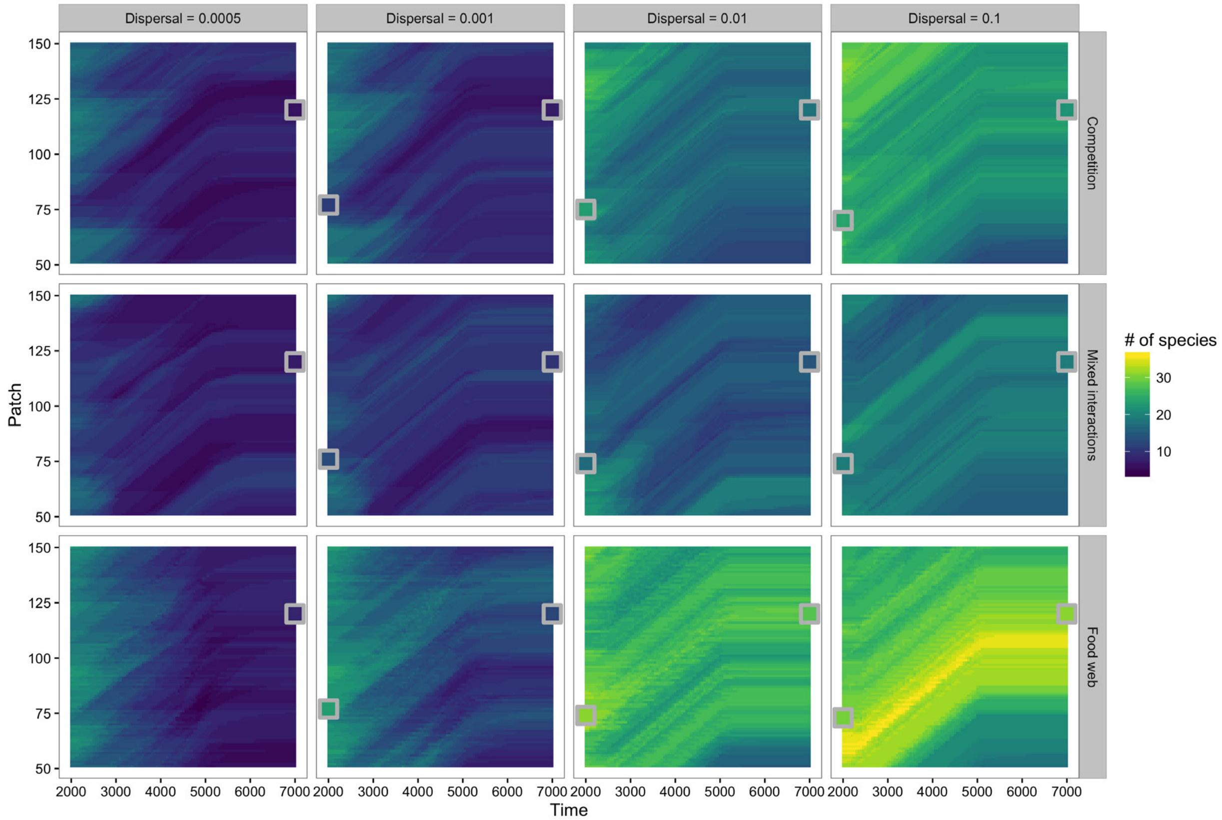

Figure S3. Heat maps indicating change in number of species through space and time in competitive, mixed, and food web interaction communities (rows) over the range of dispersal rates (0.0005 – 0.1; columns). The shade of each pixel indicates the number of species in the network in a given patch (y-axis) at a given time (x-axis). The maintenance of network properties is indicated by bands of the same colour that track the environment by shifting to higher numbered patches. Environmental change occurs from time step 2000 until 5000, after which the environments remain constant for 2000 time steps to allow the communities to reach equilibrium. The grey boxes show the location of the example networks from figure 1 (before and after environmental change).

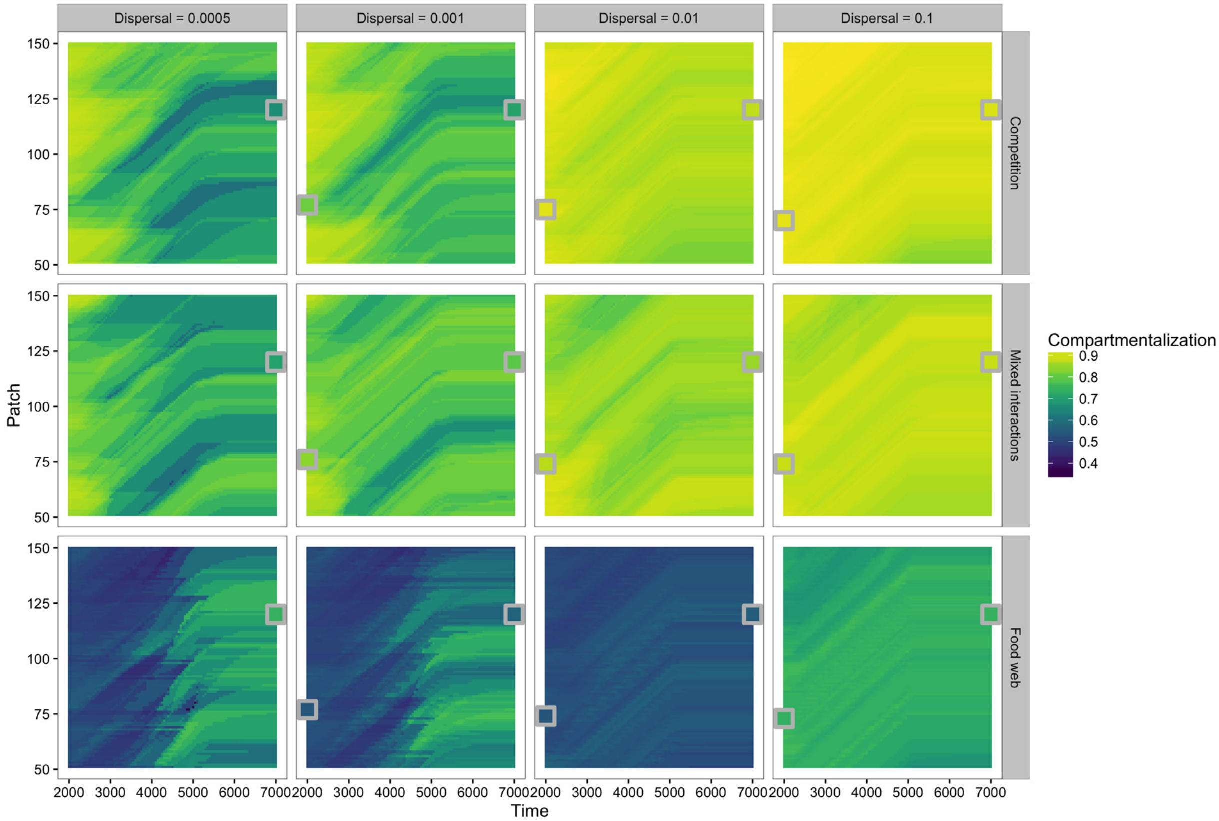

Figure S4. Heat maps indicating change in network compartmentalization through space and time in competitive, mixed, and food web interaction communities (rows) over the range of dispersal rates (0.0005 – 0.1; columns). The shade of each pixel indicates the network compartmentalization in a given patch (y-axis) at a given time (x-axis). The maintenance of network properties is indicated by bands of the same colour that track the environment by shifting to higher numbered patches. Environmental change occurs from time step 2000 until 5000, after which the environments remain constant for 2000 time steps to allow the communities to reach equilibrium. The grey boxes show the location of the example networks from figure 1 (before and after environmental change). Patches that are white have no compartmentalization.

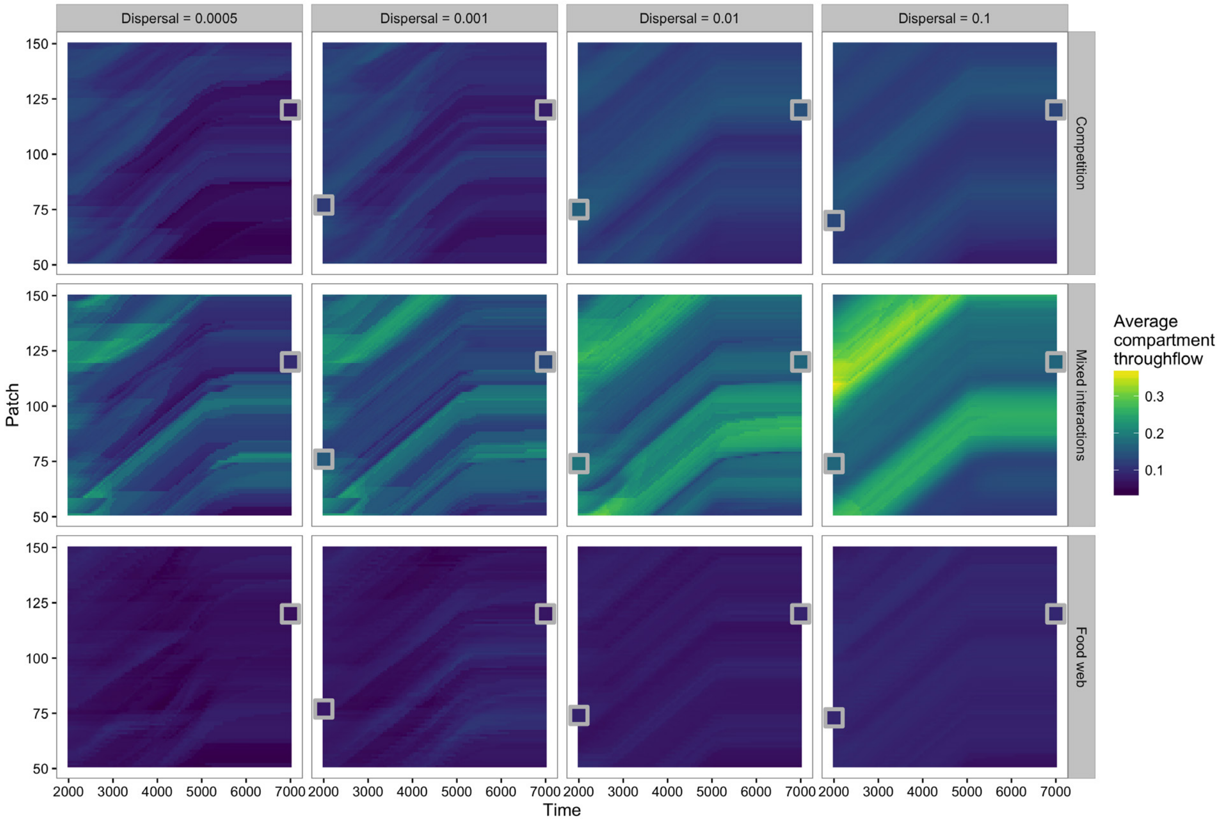

Figure S5. Heat maps indicating change in average compartment throughflow through space and time in competitive, mixed, and food web interaction communities (rows) over the range of dispersal rates (0.0005 – 0.1; columns). The shade of each pixel indicates the network compartmentalization in a given patch (y-axis) at a given time (x-axis). The maintenance of network properties is indicated by bands of the same colour that track the environment by shifting to higher numbered patches. Environmental change occurs from time step 2000 until 5000, after which the environments remain constant for 2000 time steps to allow the communities to reach equilibrium. The grey boxes show the location of the example networks from figure 1 (before and after environmental change). Patches that are white have no compartmentalization.

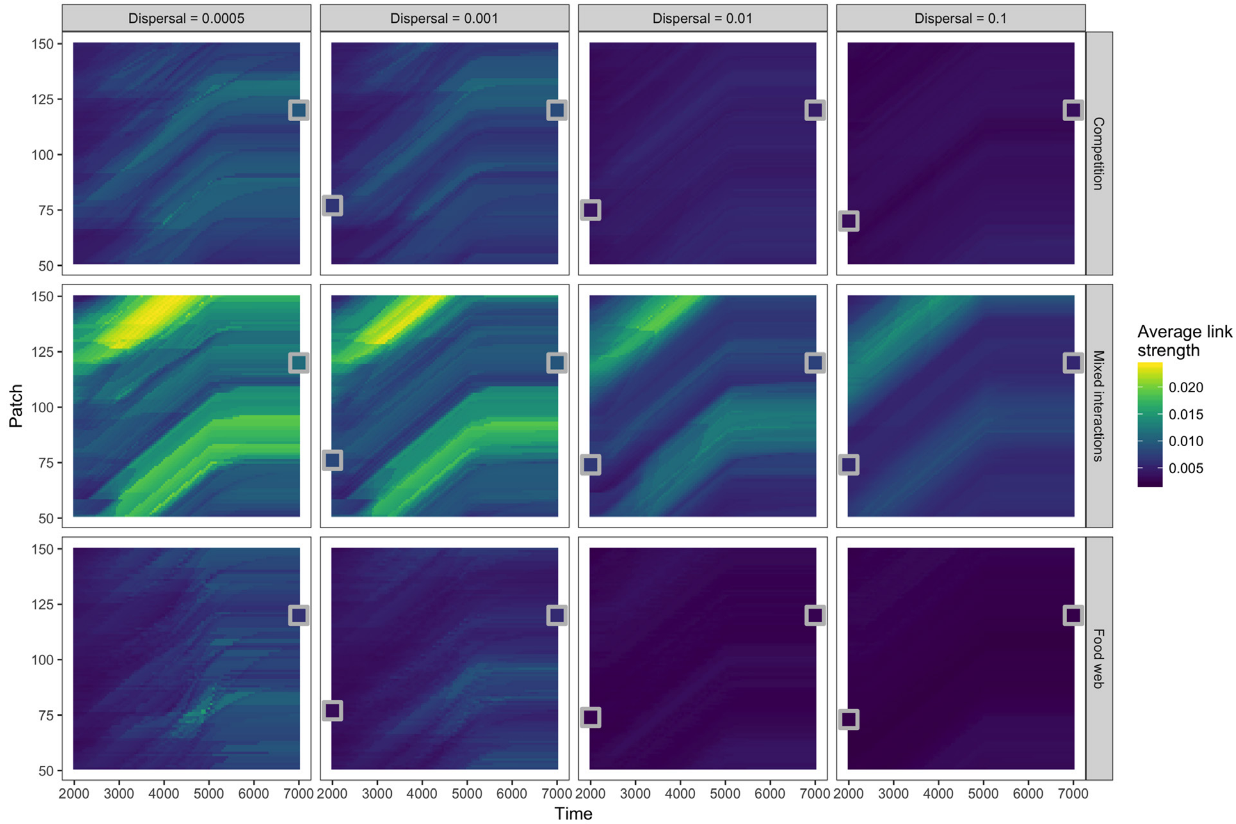

Figure S6. Heat maps indicating change in the average link weight through space and time in competitive, mixed, and food web interaction communities (rows) over the range of dispersal rates (0.0005 – 0.1; columns). The shade of each pixel indicates the average link weight in the network in a given patch (y-axis) at a given time (x-axis). The maintenance of network properties is indicated by bands of the same colour that track the environment by shifting to higher numbered patches. Environmental change occurs from time step 2000 until 5000, after which the environments remain constant for 2000 time steps to allow the communities to reach equilibrium. The grey boxes show the location of the example networks from figure 1 (before and after environmental change).

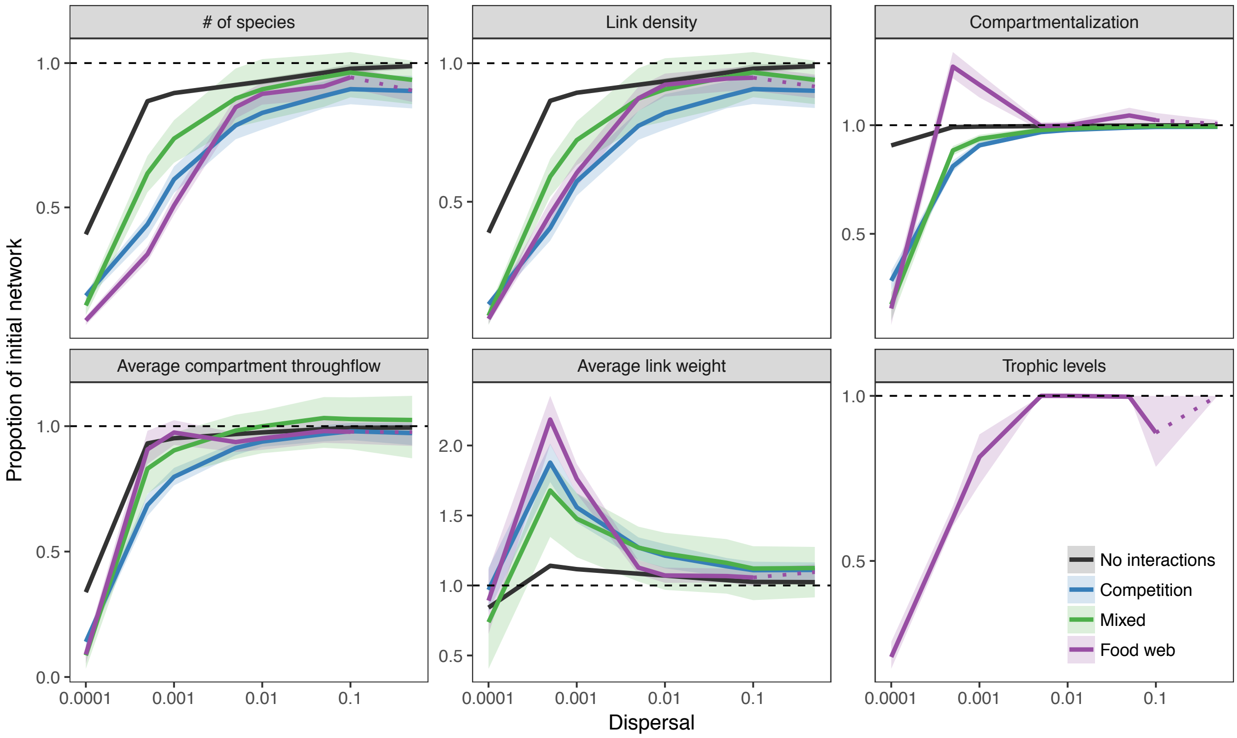

Figure S7. The mean proportion of the network properties in each final species interaction network compared to the network that was present in that patch before environmental change. Lines represent mean values across 100 replicate simulations and the ribbon represents the interquartile range. The food web line switches to dashed when dispersal is too high to allow the predators to persist, even before the environment changes.

Interactive Shiny App

Our Shiny app is an interactive version of the manuscript figures 1 and 4. It allows users to select an initial patch and then contrast how the network associated with a that environment or patch reorganizes as the environment changes. This contrast differs from the one used in the manuscript in that it does not contrast the most similar networks through time, because this calculation would make the app too slow. However, our reported results are quantitatively similar to the the contrast within a given environmental condition. Users can select different community types, dispersal rates, and network properties to compare.

The app requires an up to date version of *R*, and the following packages: *shiny, ggplot2, ggExtra, betalink, dplyr, and viridis*. This app was developed using *R* version 3.2.4, with the package versions from April 1, 2016.

To run the app, load the packages and then run the following code in *R*:
runGitHub("Range_shift_Shiny","plthompson")

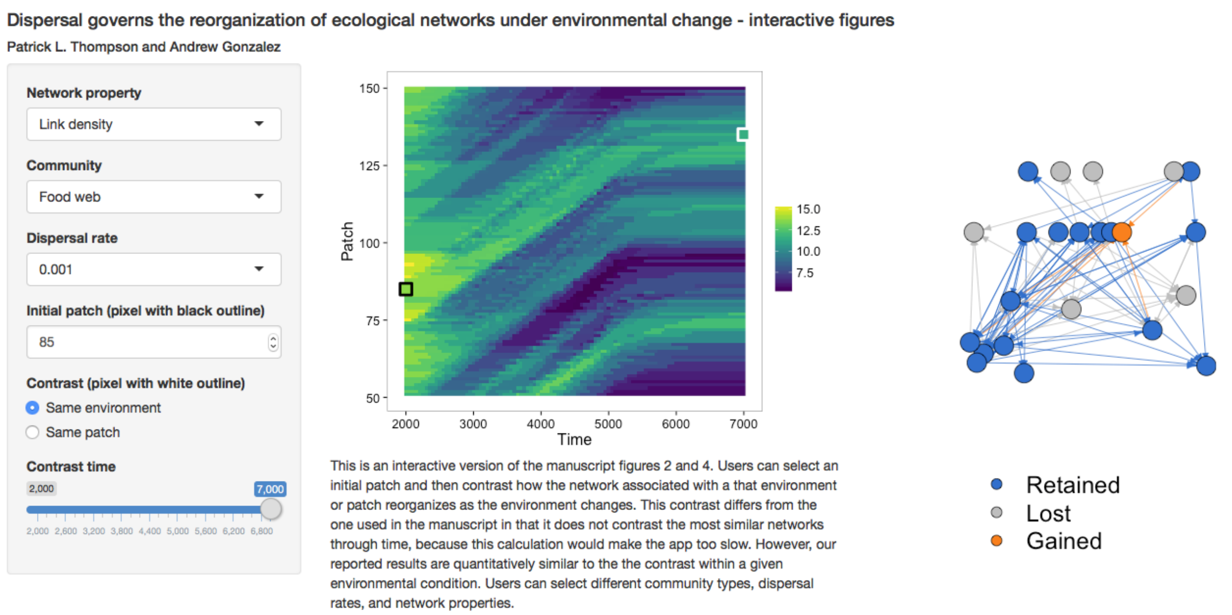

Figure S8. Screen shot of Shiny app.