Supplementary Materials: How dispersal can affect biodiversity and vice versa while considering macroevolutionary processes

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Eco-evolutionary models

All models, i.e. M0, M1 and M2, were initiated at 5 Ma with three species, each with populations spread thought the suitable sites of each patch (i.e. sp1 on patch A, sp2 on patch B, and sp3 on patch C). Initial populations had niche width $\omega_i = 0.4$ and temperature niche optima equal to the local mean temperature $T_i = T_{mean}$. In short, M0 assume a fixed dispersal and competitive traits for all species within a simulation (n=2000). M1 breaks this assumption by allowing dispersal and competitive traits to evolve freely, thus diverging with time between species (n=2000). M2 adds a zero sum (i.e. a trade-off) between dispersal and competitive traits, assuming that no super species (i.e. $d_i = 1$, $l_i = 1$) are possible (n=2000). M0 serves as a reference and allowed the exploration of parameter ranges and sensitivity the system. The two alternative simulation scenarios (i.e. M1 and M2), referred to as counterfactuals, investigate the effects of manipulating different components of the model. Specifically, these counterfactuals involved modifying the underlying biological model specifically referent to the evolution and trade-offs between dispersal and competitive abilities, focusing on how dispersal and species interactions affect colonization and other emergent properties in our eco-evolutionary models.

This automatically made species within a simulation not only diverge between each other on their temperature optime T_i and niche widht ω_i (i.e. for M0, M1 and M2), but also on dispersal d_i and competitive l_i traits (i.e. for M1 and M2). For each counterfactual, we ran 2000 simulations with the same parameters for all models. This systematic exploration of alternative scenarios allowed us to assess the impact of specific model parameters on the resulting biodiversity patterns. We additionally run $XYZ = XYZ$ Specifically, we collected α, β and γ biodiversity metrics, colonization, speciation, extinction as well as trait proxies related to environmental and biotic suitability.

Initial conditions

We did a full factorial experiment ranging from extreme dispersal and competitive abilities $d_i = [0–1]$ $l_i = [0.9–1]$ and fixed $\Theta_s = 65$ (Figure 1) . For model M2 we impose the trade-off to the same parameters as in the other models, so that no initial species would have a "assumingly wrong" – meaning, wrong for consistency of M2. We randomized the seed at this stage, so that each single simulation could be reproduced.

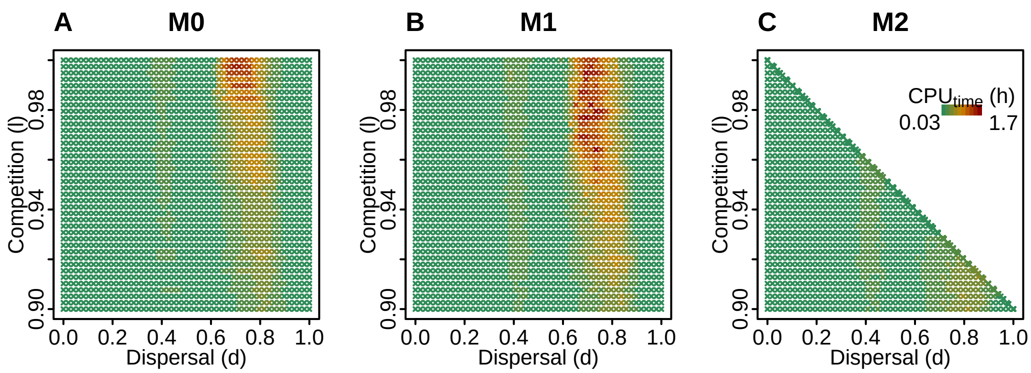


Figure 1: Initial competition and dispersal parameters for the main models and experiments. Colors show the CPU time per simulation (n=6000).

Results

M0 diversity statistics reflected our expectations on general patterns of diversity, such as highest spetiation rates at intermediary diversity diversity levels Figure 2 . Meaning that peaks of γ diversity relate with the spatial structure of our landscape. After investigation, all speciation events of simulations with dispersal $d_i < 0.1$ happened within patches, and mostly during the dynamic phase (Figure 3 A). Speciation within patches was only observed in M0, as for M1 and M2 dispersal quickly evolved beyond the critical and small. We also can notice the qualitative changes in speciation events for intermediary dispersal $d_i = [0.15 - 0.55]$, which started involving speciation events between patches C and D, but for patch D only at the dynamic time phase, i.e. 2–0 Ma (Figure 3 C).

Inspecting the community distances between all the patches, there is a clear effect of increase in community diversity with patch distance and dispersal ability Figure 6 . As expected **[refs]**, competition tends to decrease community distance overall where communities reach maximum diversity.

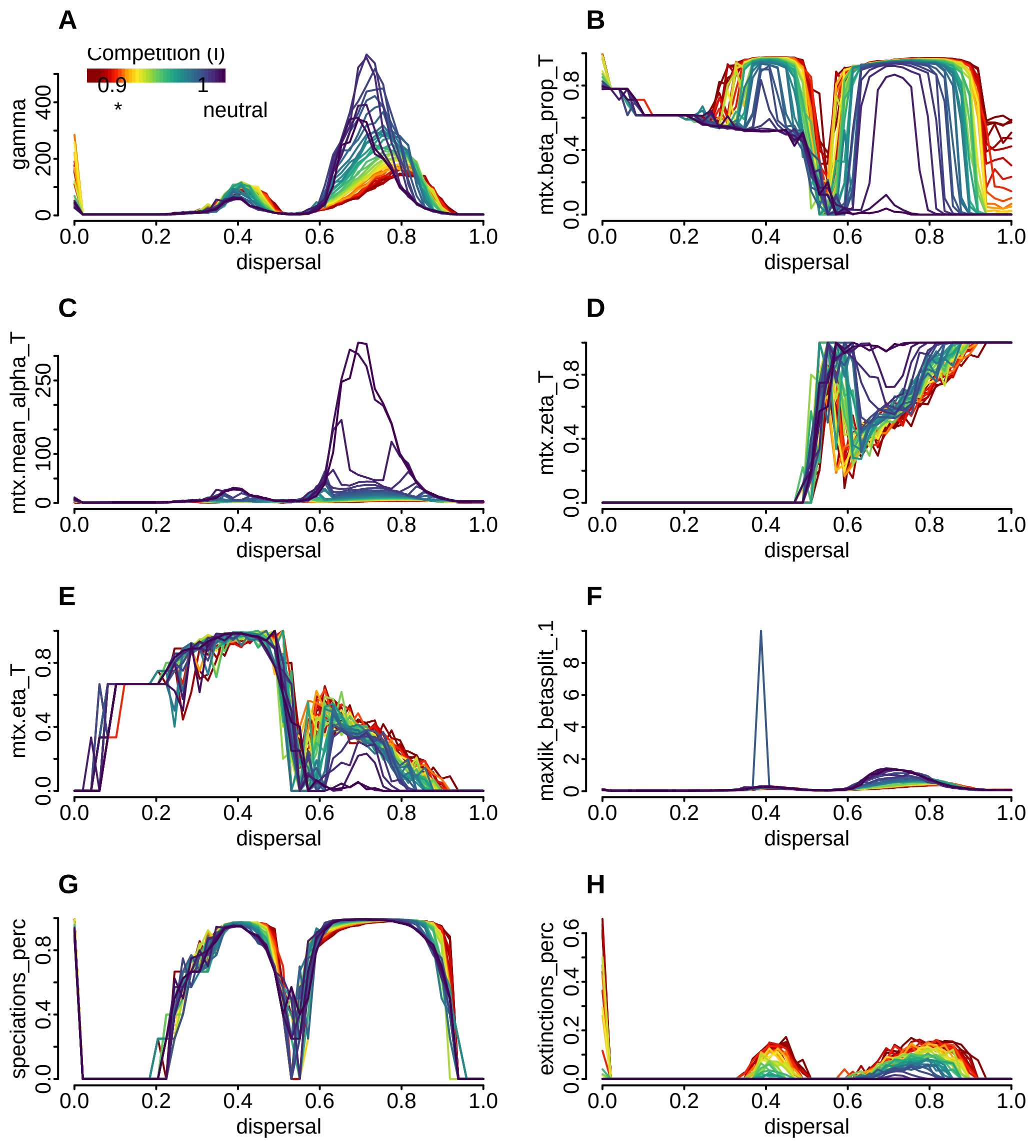


Figure 2: Summary statistics for M0 though dispersal. Each line corresponds to simulation within a same competitive value along dispersal ability.

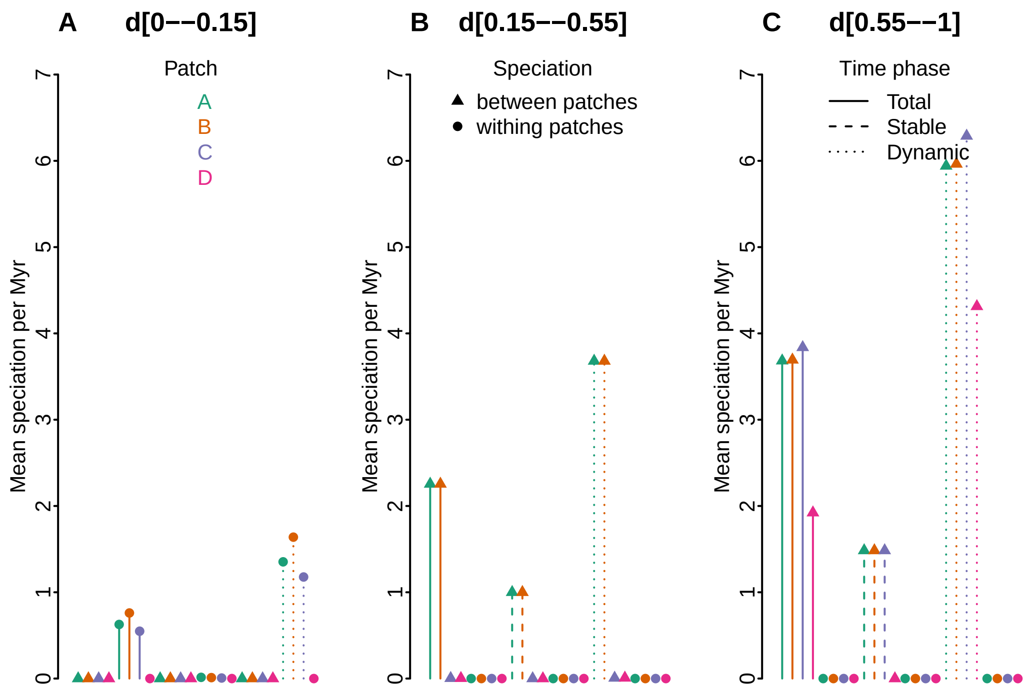


Figure 3: Mean speciation percentage for M0 with dispersal (A) smaller than, 0.15; (B) between 0.15 and 0.55; and (C) bigger than 0.55. We show for each patch (in different collors) and each phase (i.e. Total 4.5-0Ma, Stable 4.5-2.5Ma, Dynamic 2-0Ma) for speciation events between or within patches (respectively triangles and circles).

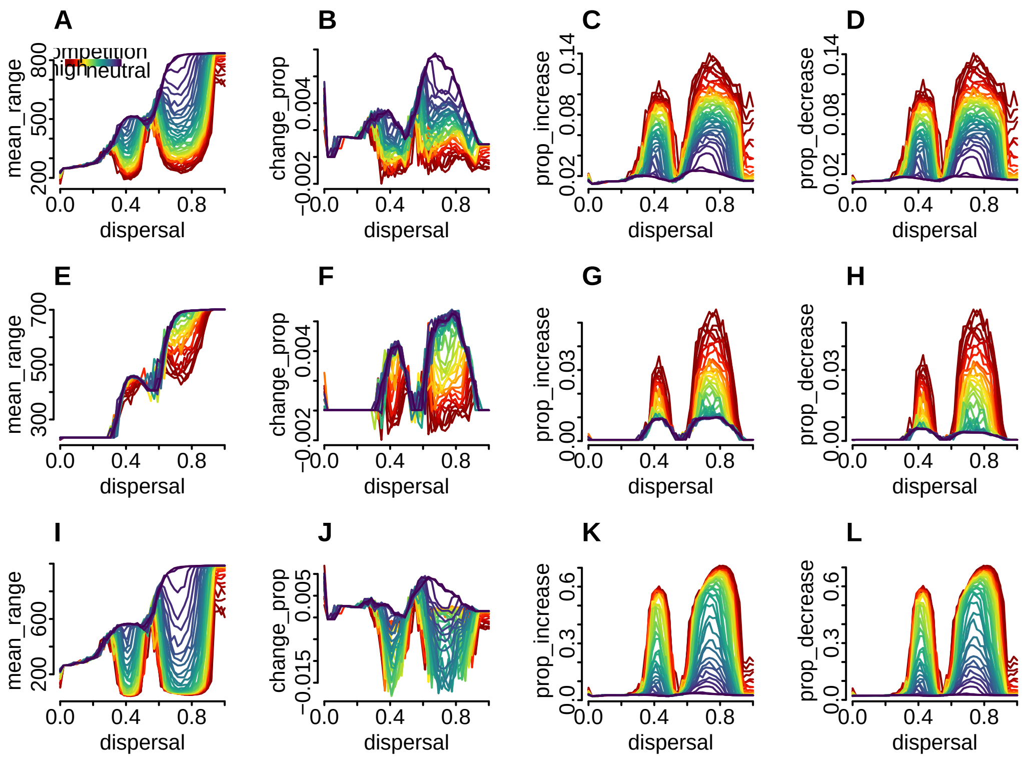


Figure 4: Spatial dynamics for M0 during Total 4.5-0Ma (A-D), Stable 4.5-2.5Ma (E-H), Dynamic 2-0Ma (I-L).

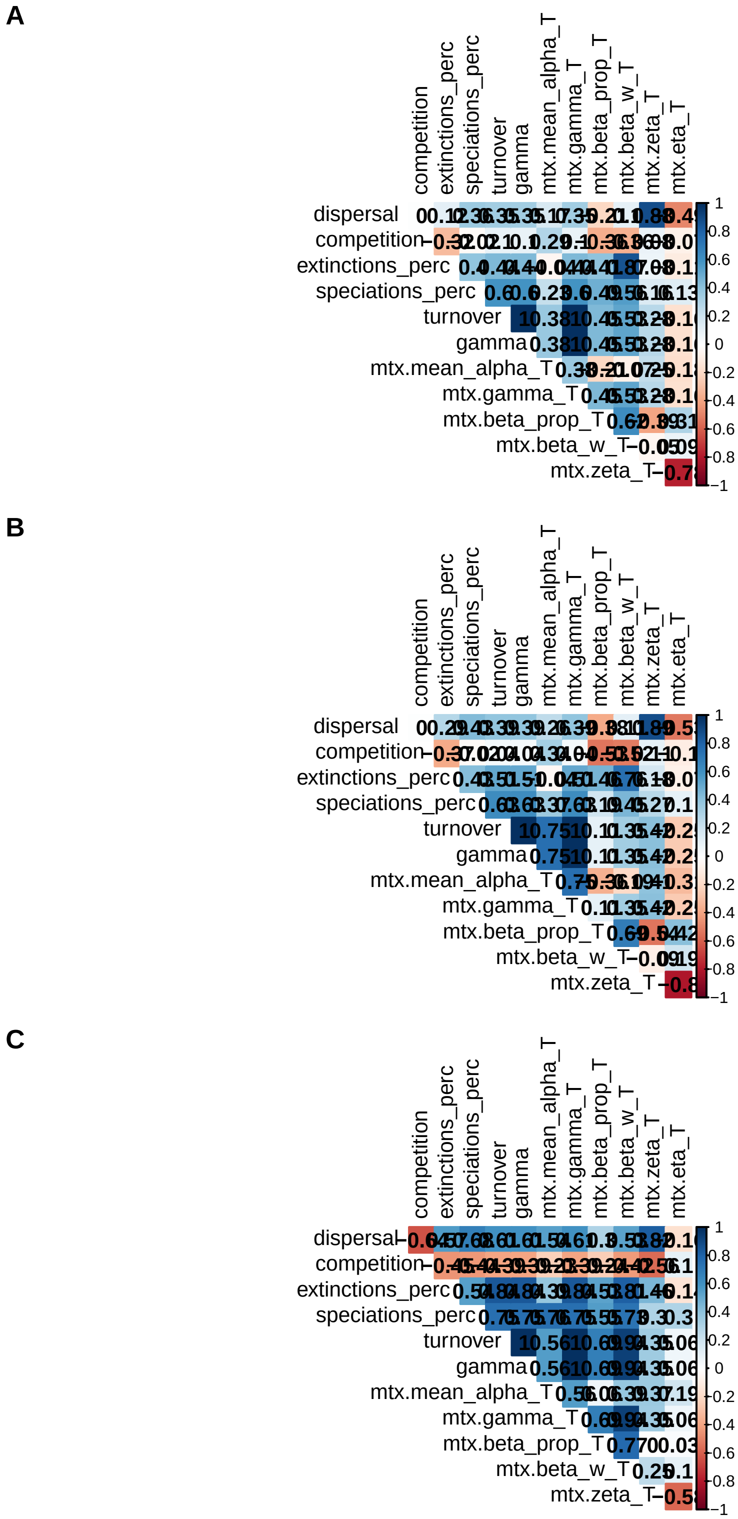


Figure 5: Correlations for hand-picked summary statistics for M0 (A); M1 (B) and M2 (C).

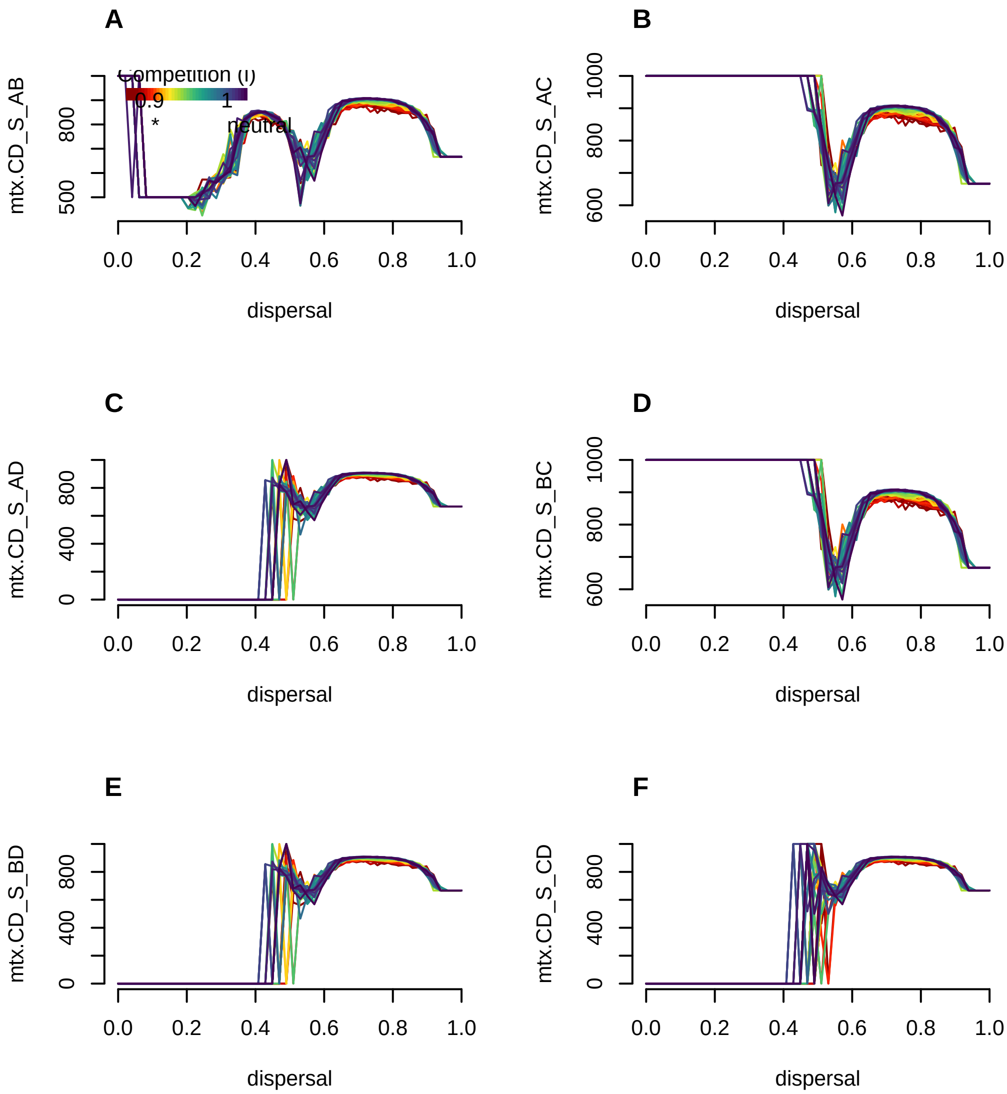


Figure 6: Community Distance betwen patches A, B, C and D for M0. Each line corresponds to simulations with a same competitive value.

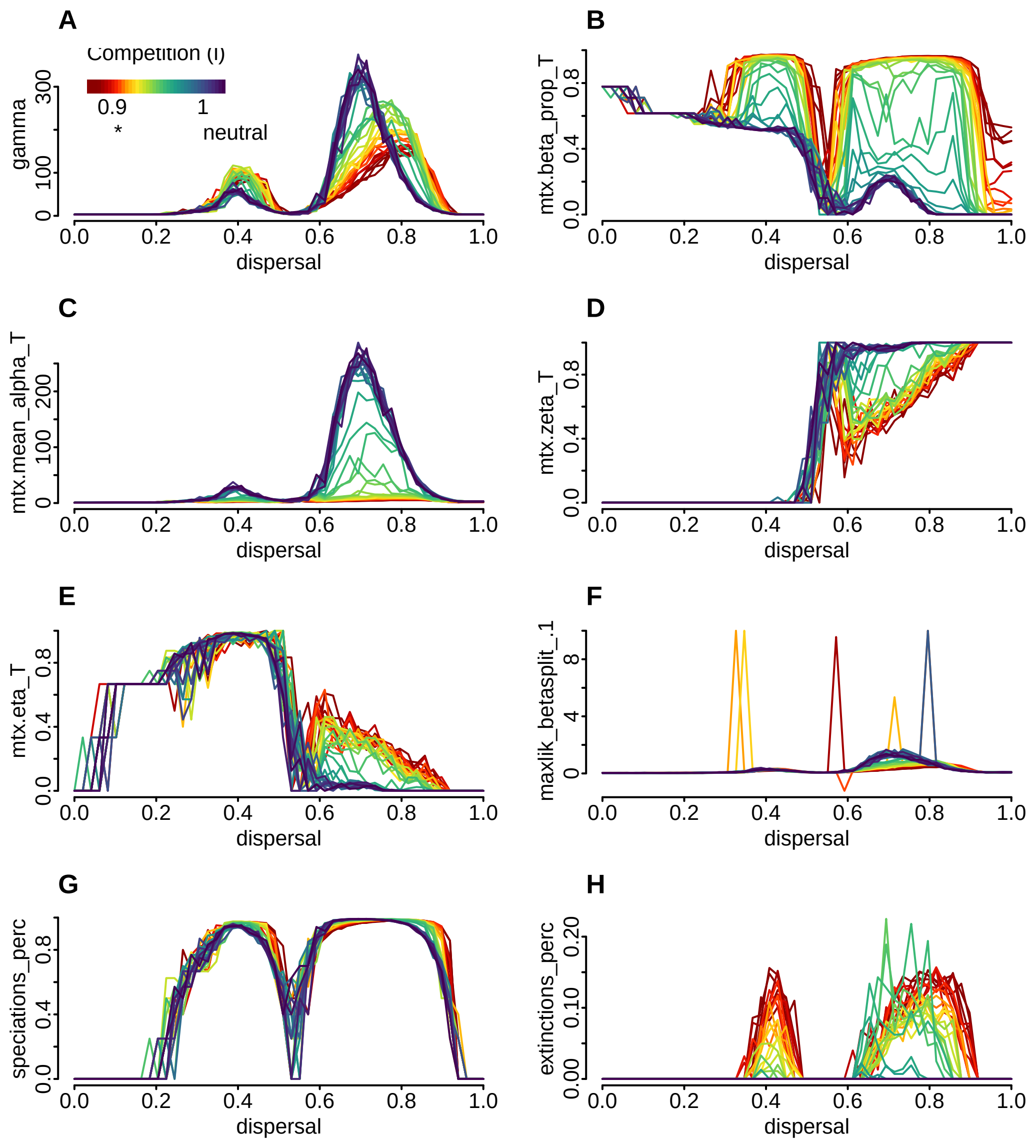


Figure 7: Summary statistics for M1 though dispersal. Each line corresponds to simulation within a same competitive value along dispersal ability.

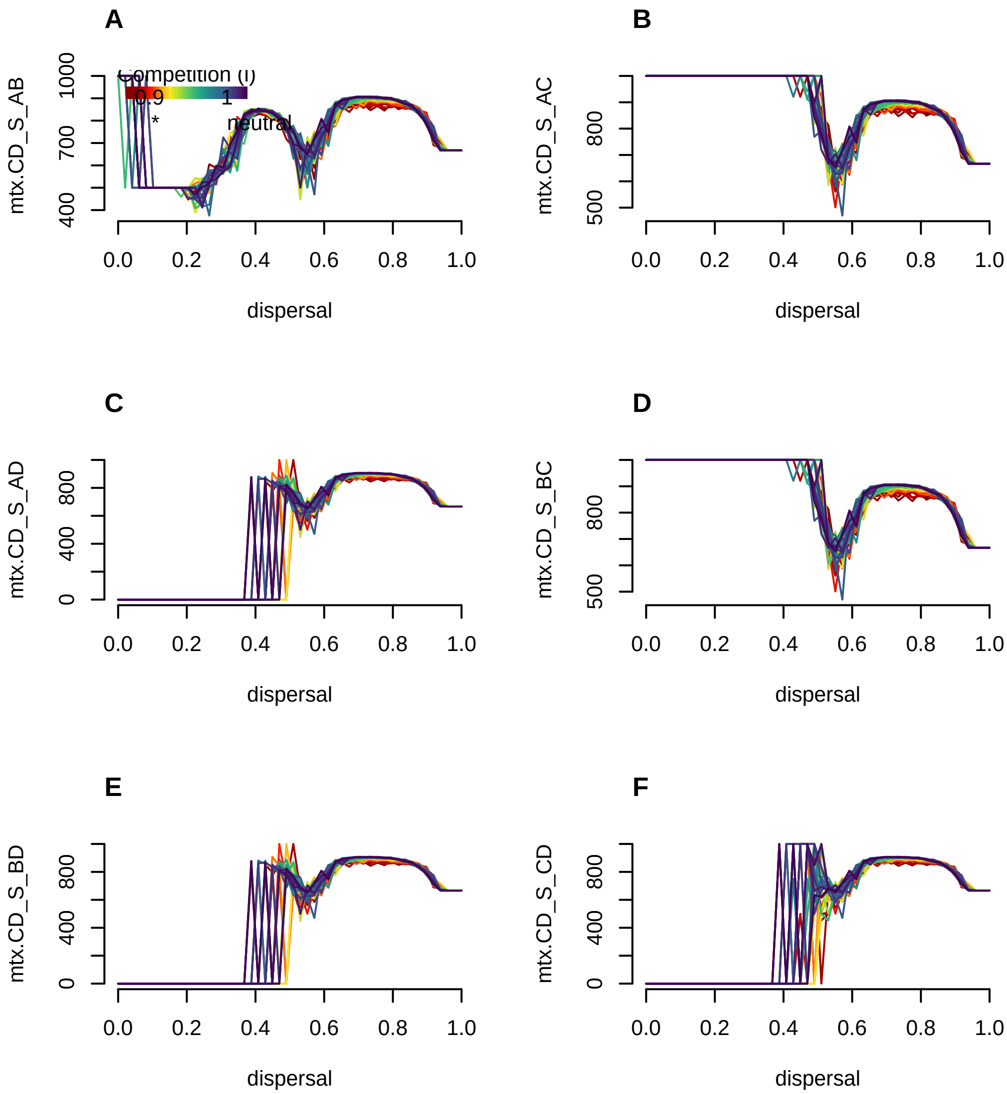


Figure 8: Community Distance betwen patches A, B, C and D for M0. Each line corresponds to simulations with a same competitive value.

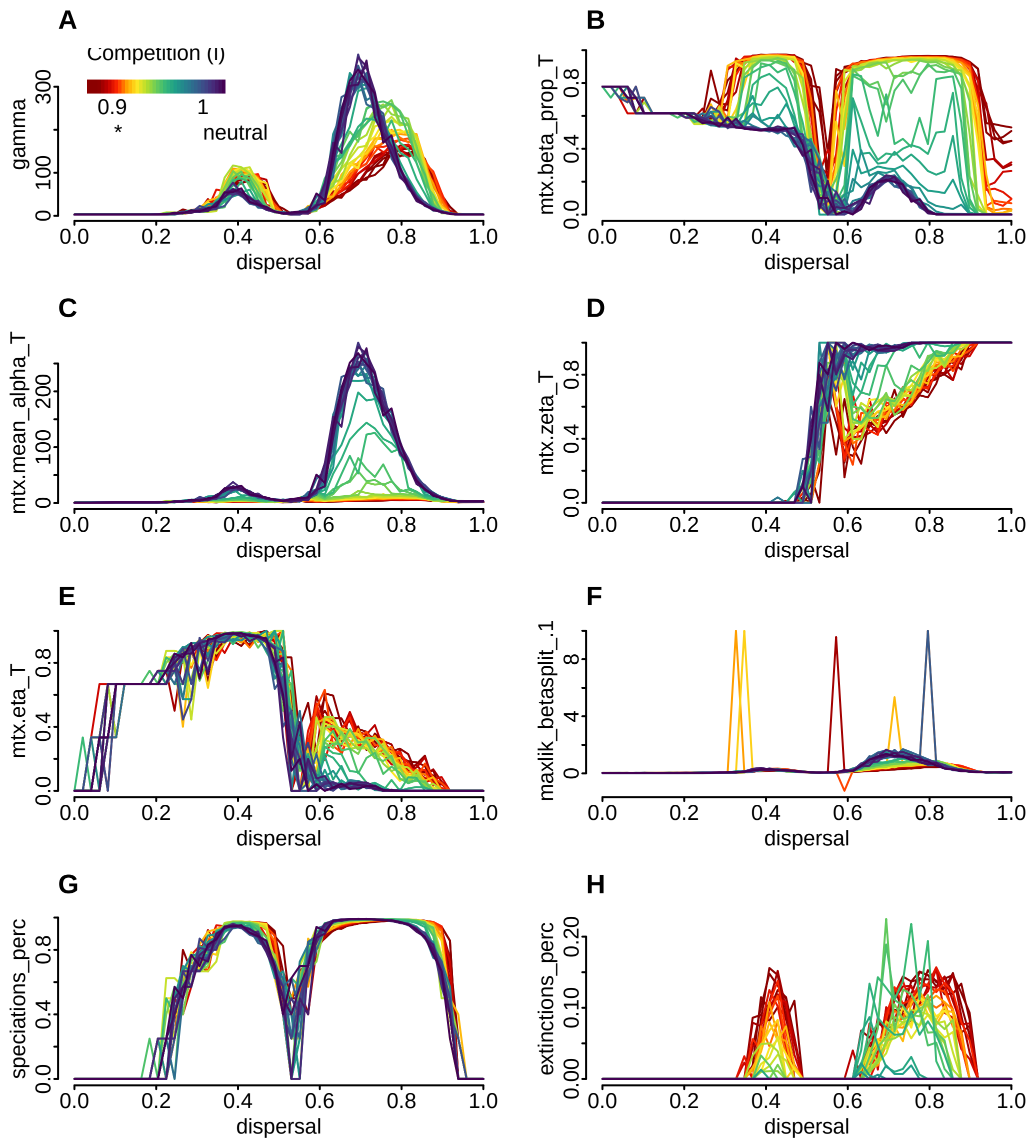


Figure 9: Summary statistics for M2 though dispersal. Each line corresponds to simulation within a same competitive value along dispersal ability.

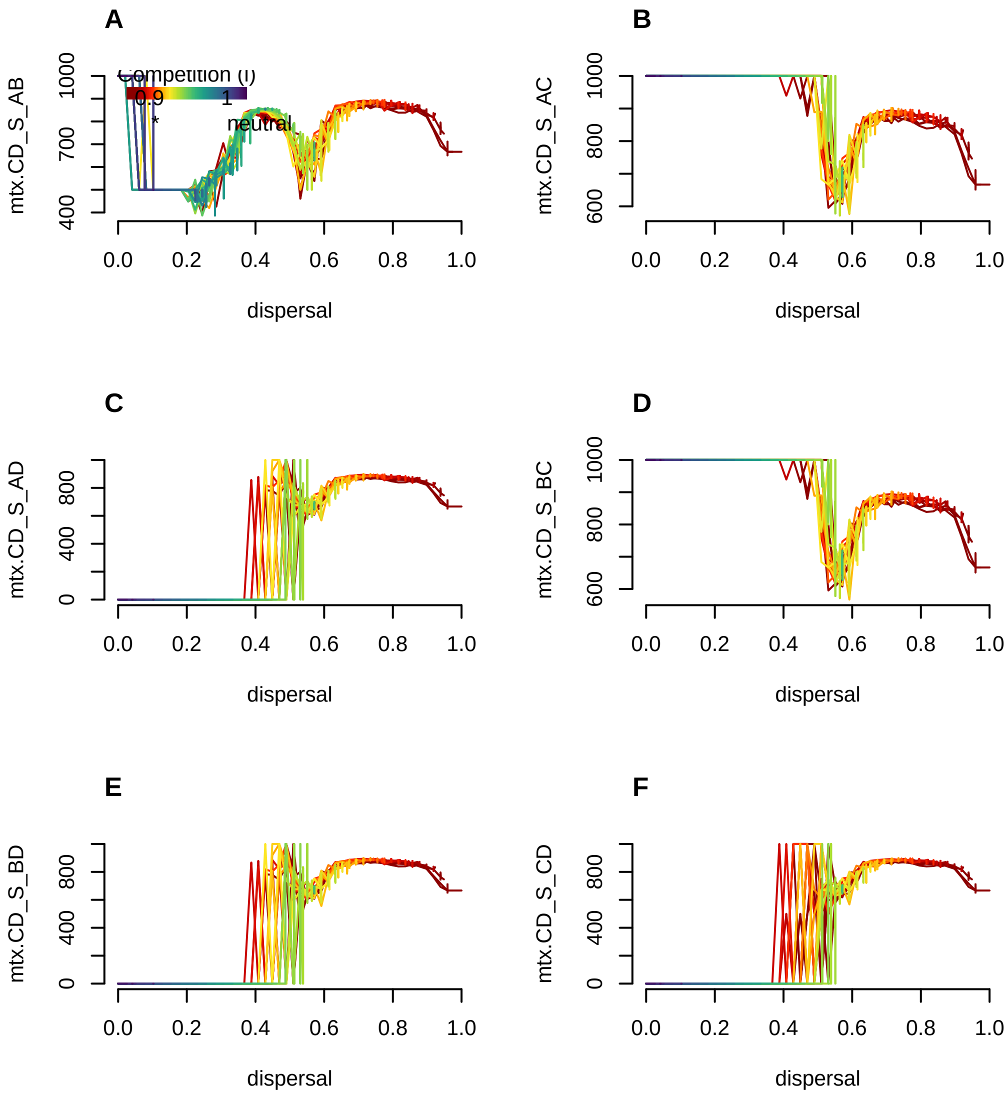
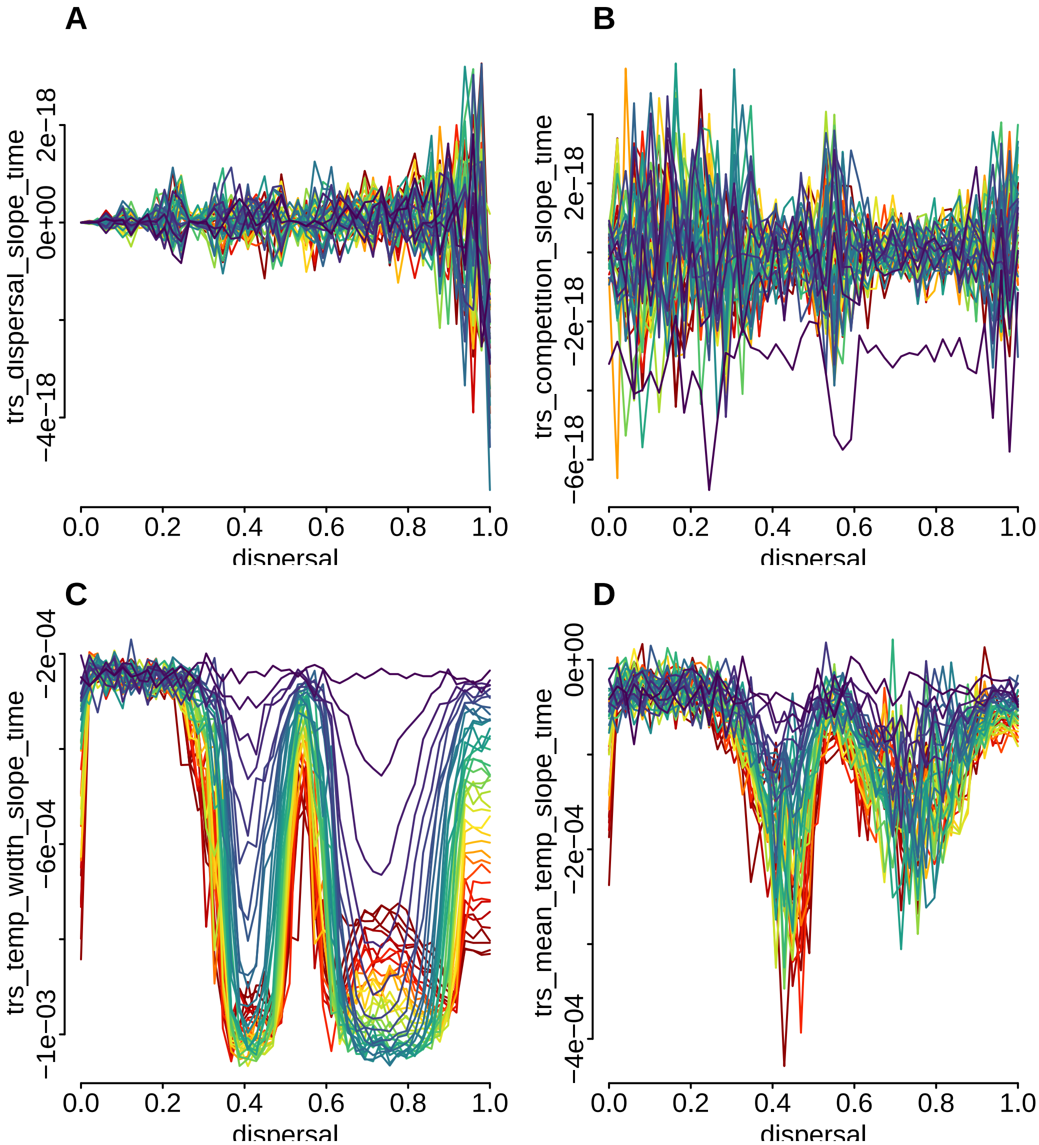


Figure 10: Community Distance betwen patches A, B, C and D for M0. Each line corresponds to simulations with a same competitive value.

Trait Changes



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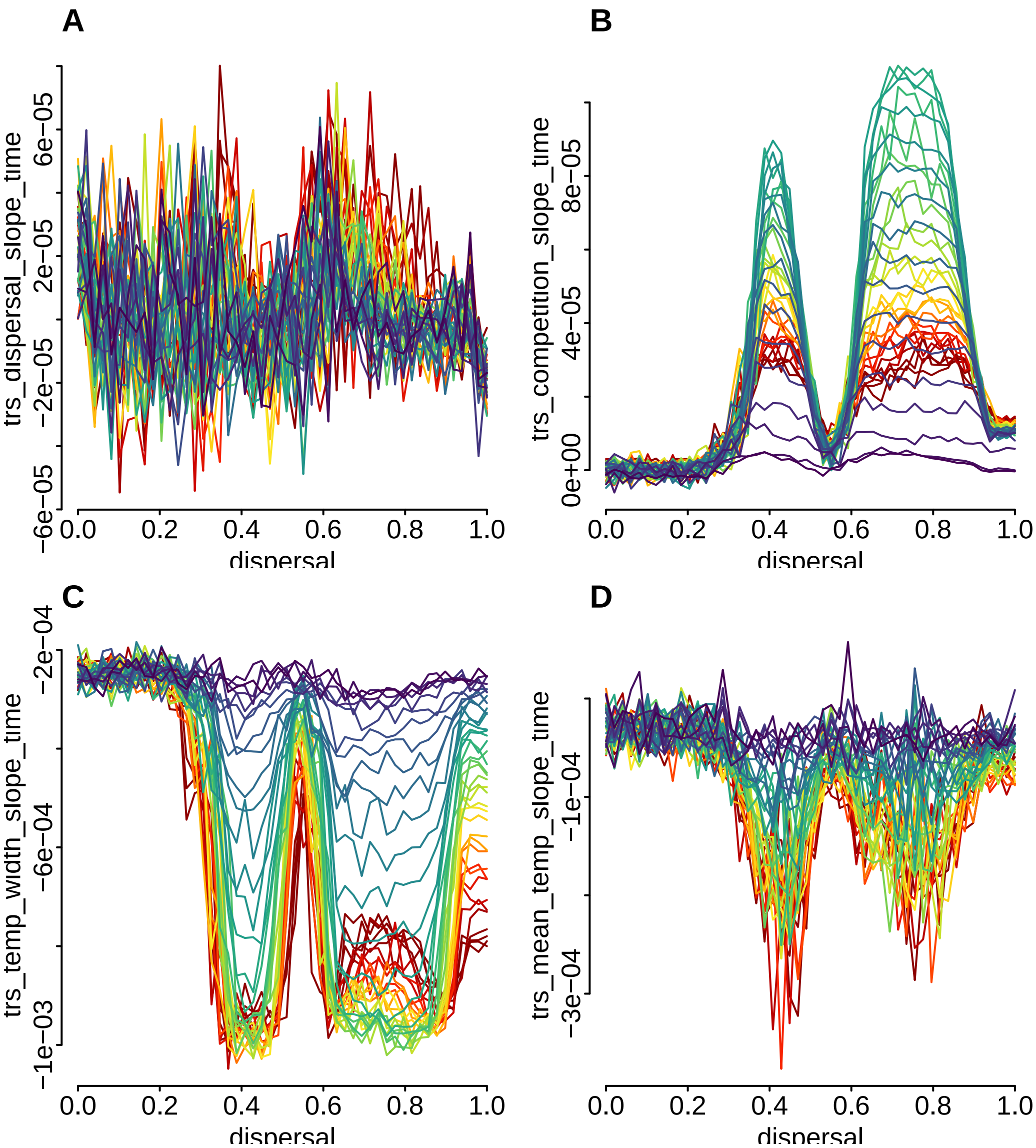

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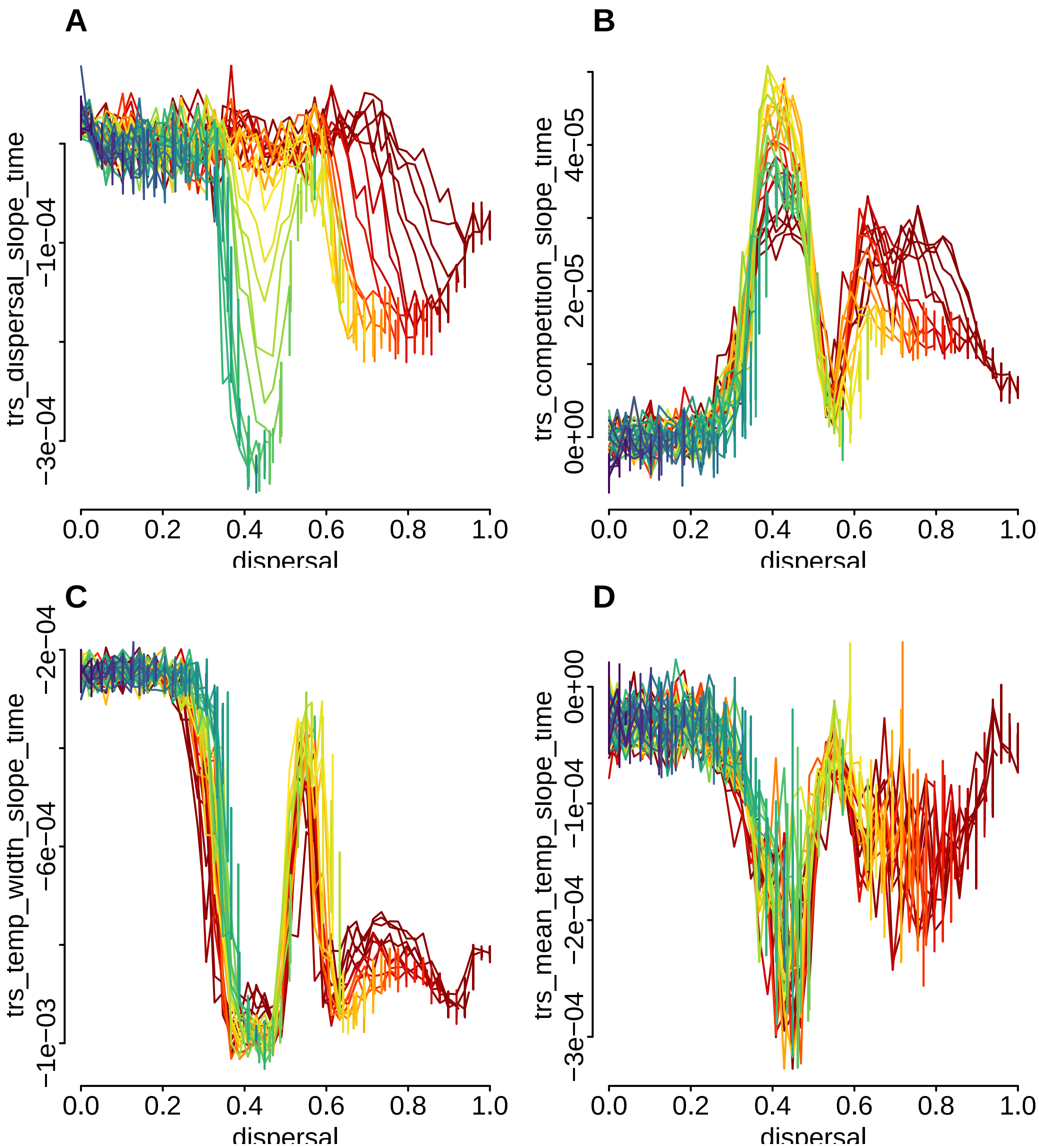

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