Dispersal Evolution: Bridging the gap between the two H's.

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Who are the two H's?

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(Hamilton & May 1977)

A. Hastings
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Competition between relatives

Spatial heterogeneities

The model

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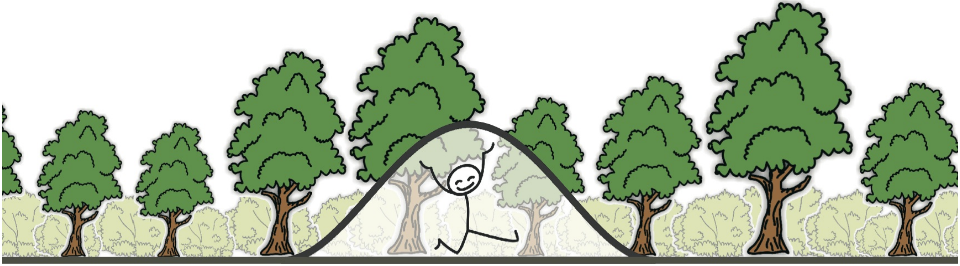
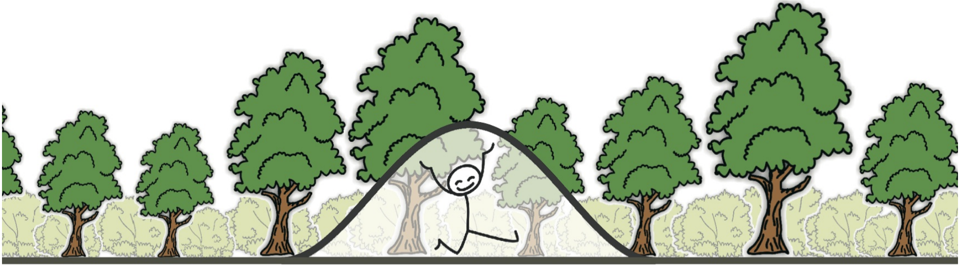


Suppose that

- two (or more) distinct types of individuals are present
- that **only** differ in their dispersal behaviour (kernel).



The model

Formally: The model equations

$$\partial_t N_T = -\partial_x J_T + N_T r,$$
$$\partial_t p_i = \frac{1}{N_T}\left(-\partial_x J_i + p_i \partial_x J_T\right).$$

- N_T ... density of the total population
- p_i ... frequency of dispersal strategy i
- r ... local growth rate
- J_i and J_T ... fluxes of type-i individuals and total flux

Carrying capacity

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The abundance of resources defines a **carrying capacity** κ.

- No dispersal: Population density attains carrying capacity.
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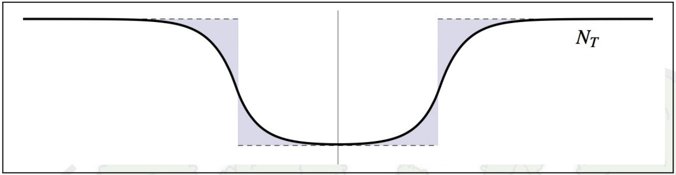

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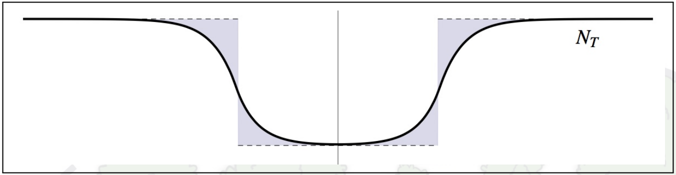


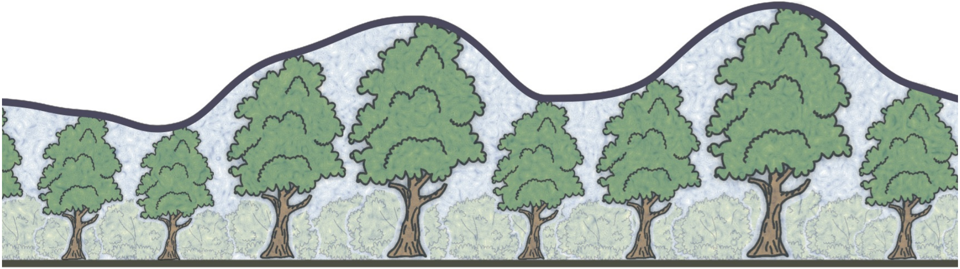
Definition

We call a dispersal strategy **balanced** if $N_T = \kappa$ is a stable solution of the population density dynamics (given that all individuals adopt the dispersal strategy).

Balanced dispersal is evolutionarily stable

Result 1

Dispersal evolution leads to balanced dispersal strategies.



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⇒

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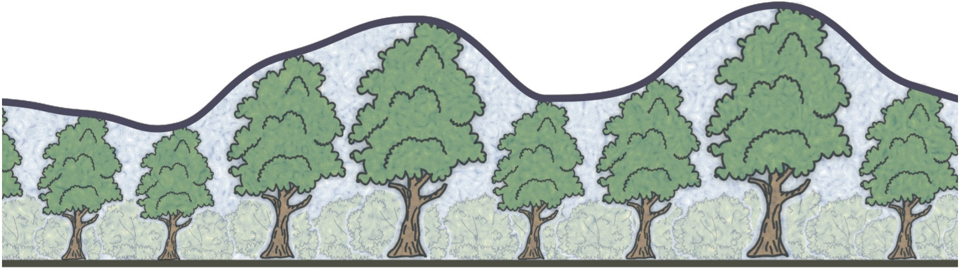

Dispersal evolution at carrying capacity

Consider two dispersal types, R and I, that are both balanced and let the variances of their dispersal kernels be V and $V+v$.

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Then, the "faster" type never decreases in total abundance, since

$$\partial_t \int N_I \, dx = \frac{vN_T}{2} \int (\partial_x p_I)^2 \, dx \geq 0.$$

Result 2

Within the class of balanced dispersal strategies, increased dispersal is selected for.

Sampling in finite populations

Stochastic sampling between generations keeps p_I heterogeneous; the sampling variance is $\frac{p_I(1-p_I)}{2N_T}$.

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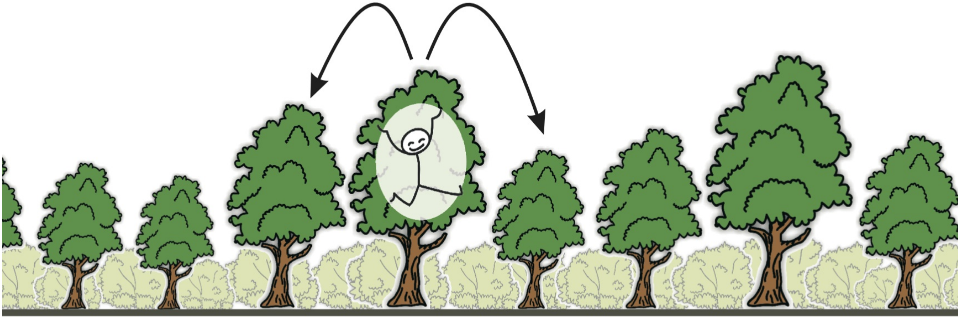
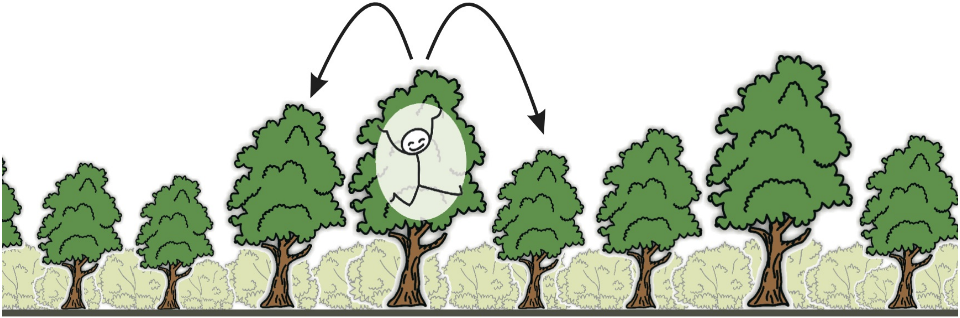
Note

The continuous equations cannot quantify the selective advantage of increased dispersal in this case. Details of the spatial scale matter!

Discrete time and space



Discrete time and space



+ stochastic sampling between generations.

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In the stochastic model, we are interested in the **expected change** in total abundance of the faster type.

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Result 3 (mathematical version)

$$\mathbb{E}\left[\Delta \mathcal{N}_I^{total}\right] = m\mathcal{I}\mathcal{N}\sigma_p^2(1-\rho),$$

where

- $\mathcal{N}$ is the number of individuals per patch,
- $\mathcal{I}$ is the number of patches in the habitat,
- m is the increase of migration rate of the faster type,
- σ_p^2 is the spatial type-frequency variance, and
- ρ is the correlation of type frequencies between adjacent patches.

Discrete time and space

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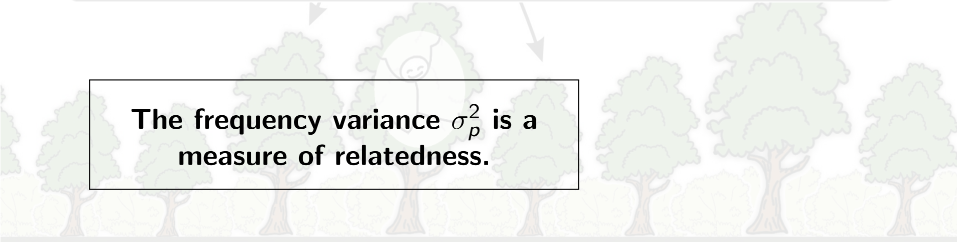

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The selection pressure for increased dispersal is **proportional to the variance in type frequencies** induced by sampling between successive generations.

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$\Rightarrow$

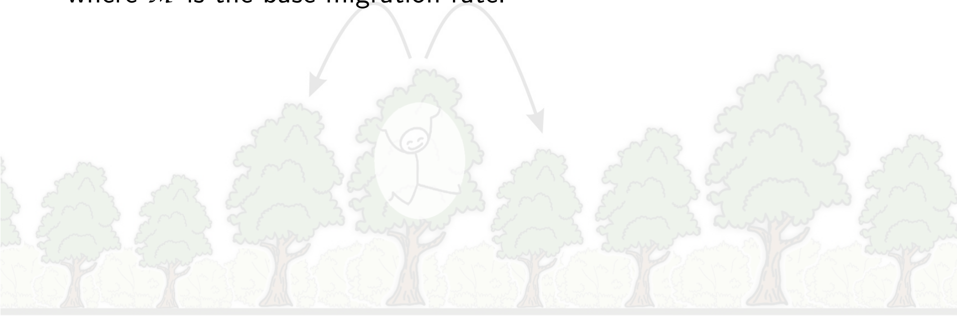
W.D. Hamilton

Remark I

Let P be the average frequency of the faster type, then

$$\mathbb{E}[\Delta P] \approx \frac{m}{4\mathcal{N}\mathcal{M}} P(1-P),$$

where $\mathcal{M}$ is the base migration rate.



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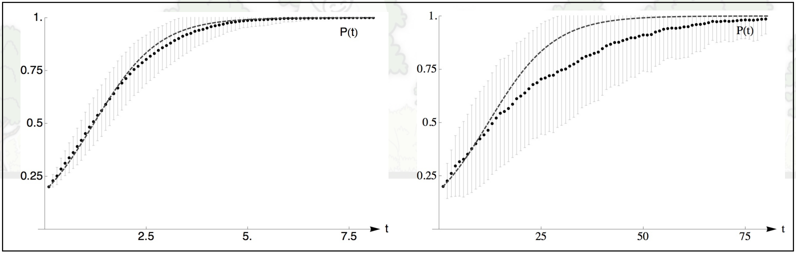
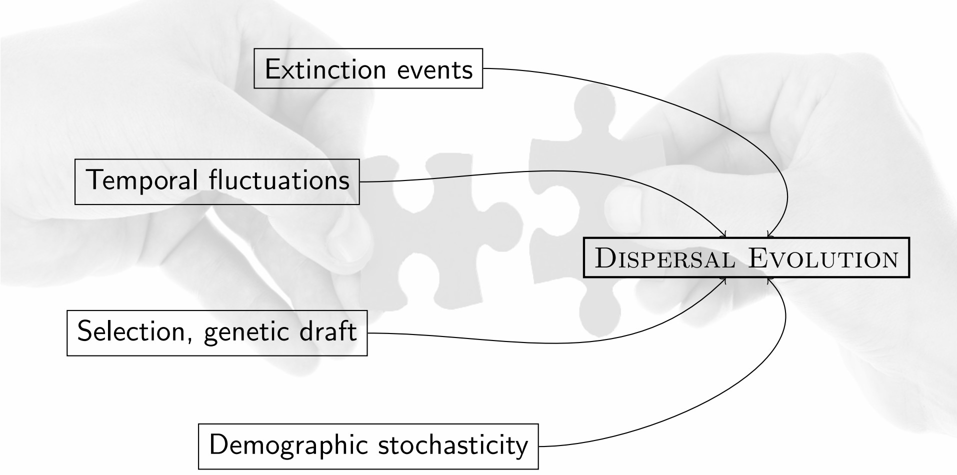
- It can be used to compare with numerical simulations.



Remark II

Variability in type frequencies can emerge due to all kinds of stochastic influences, not only random sampling.



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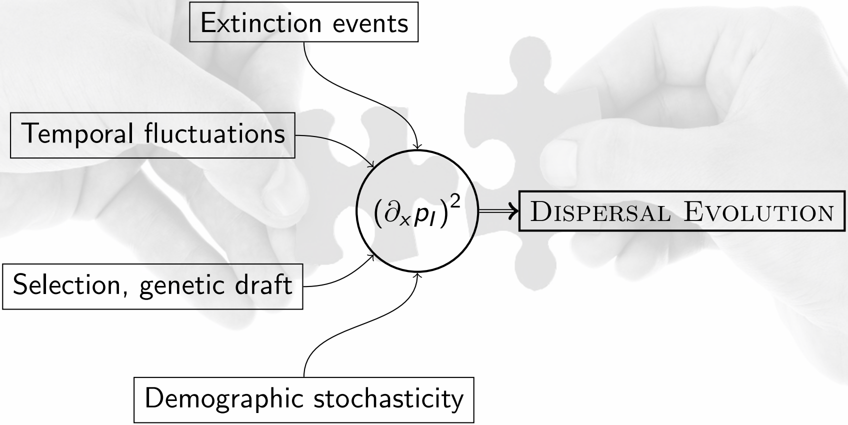

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2. Within the class of balanced dispersal strategies, increased dispersal is selected for by, e.g., stochastic sampling. The emerging sampling variances directly translate into measures of relatedness.
3. Details of spatial scaling matter to quantify this effect. This shows a limitation to the use of continuous differential equations.
4. The spatial variance of type frequencies can capture various stochastic factors that influence the evolution of dispersal. Does this unify different aspects of dispersal evolution?

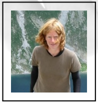
Acknowledgements

Nick Barton

Acknowledgements

H. Uecker

T. Paixão



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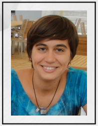
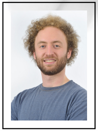
S. Sarikas



J. Polechová



D. Weissman

Thank you for your attention!