

Trait-based higher-order interactions and species coexistence

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Outline

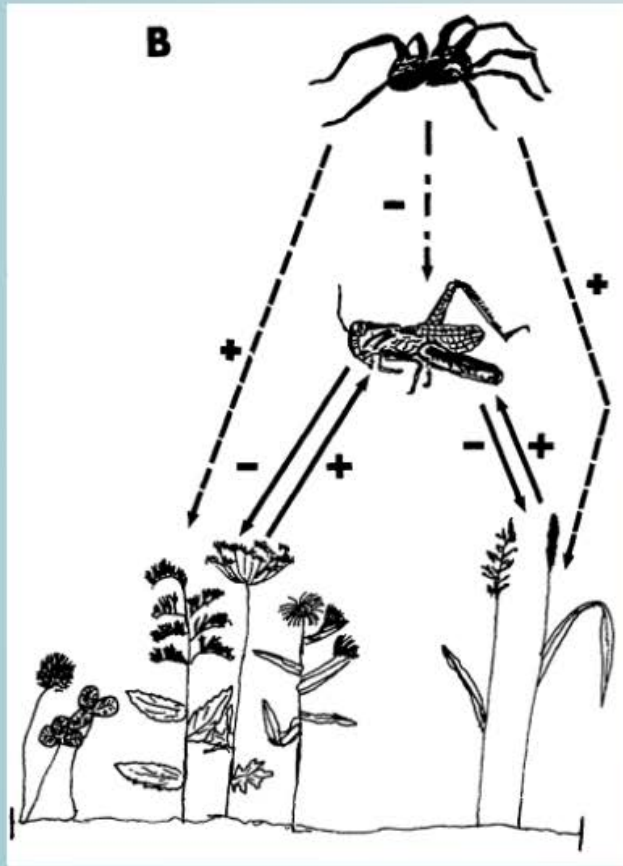
1. What are (trait-based) higher-order interactions?
2. A review of trait-based model results without higher-order effects
3. Understanding how trait-based higher-order interactions affect coexistence

Higher-order interactions

3rd species modifies interaction between 2 others

Higher-order interactions

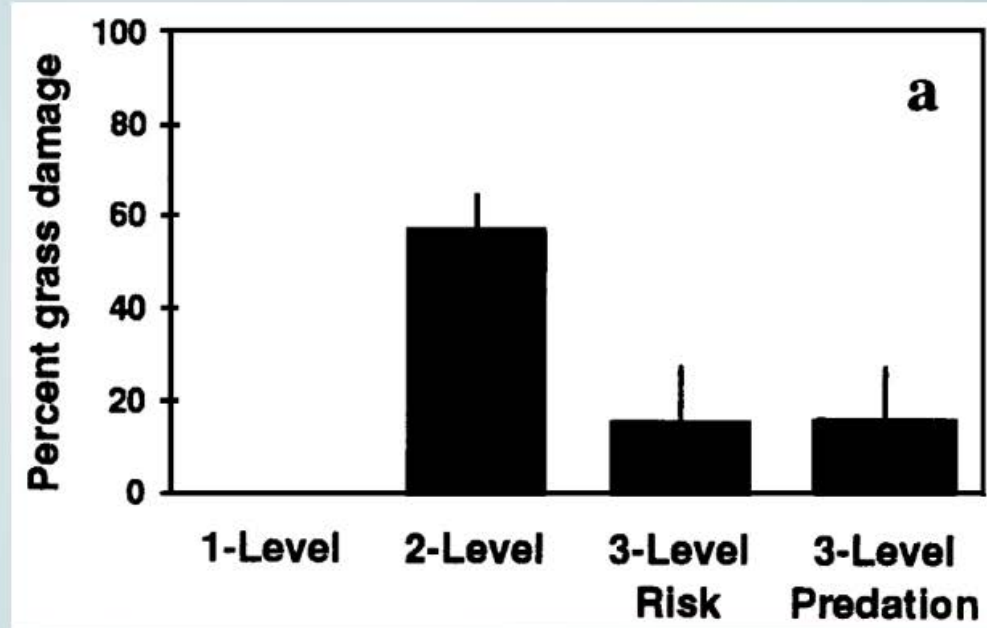
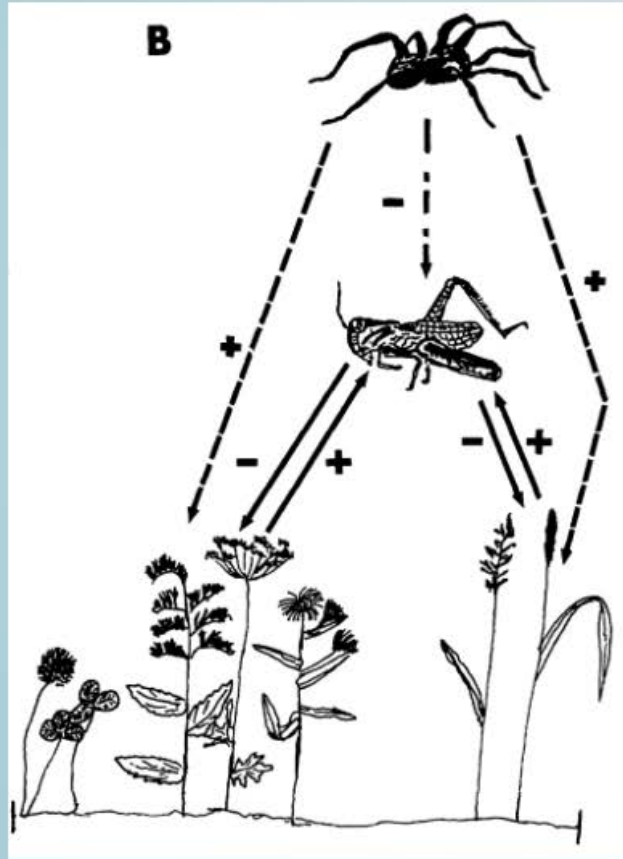
3rd species modifies interaction between 2 others



Schmitz et al. (1998 Ecology)

Higher-order interactions

3rd species modifies interaction between 2 others



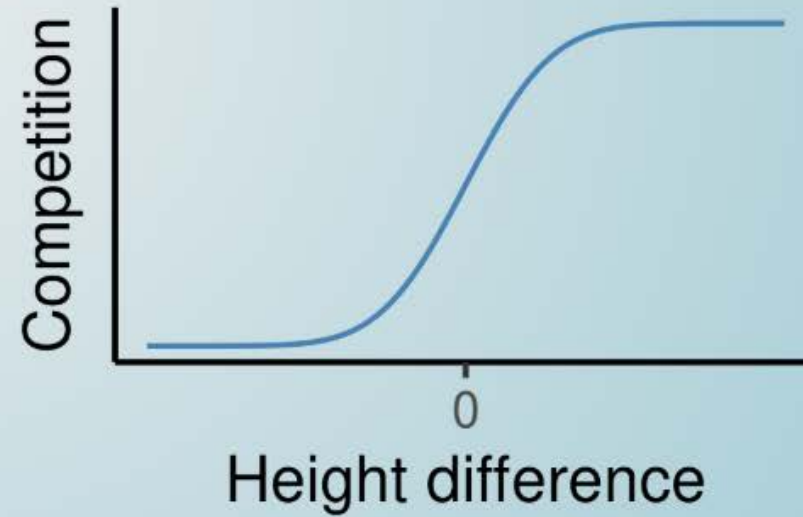
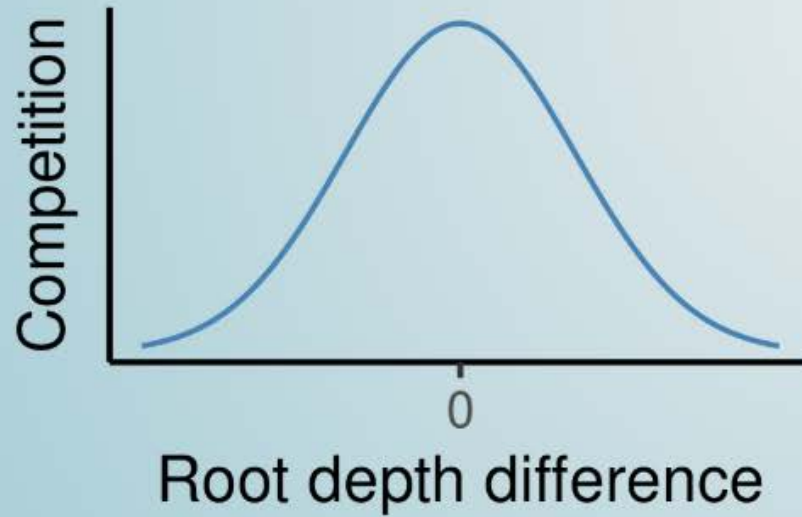
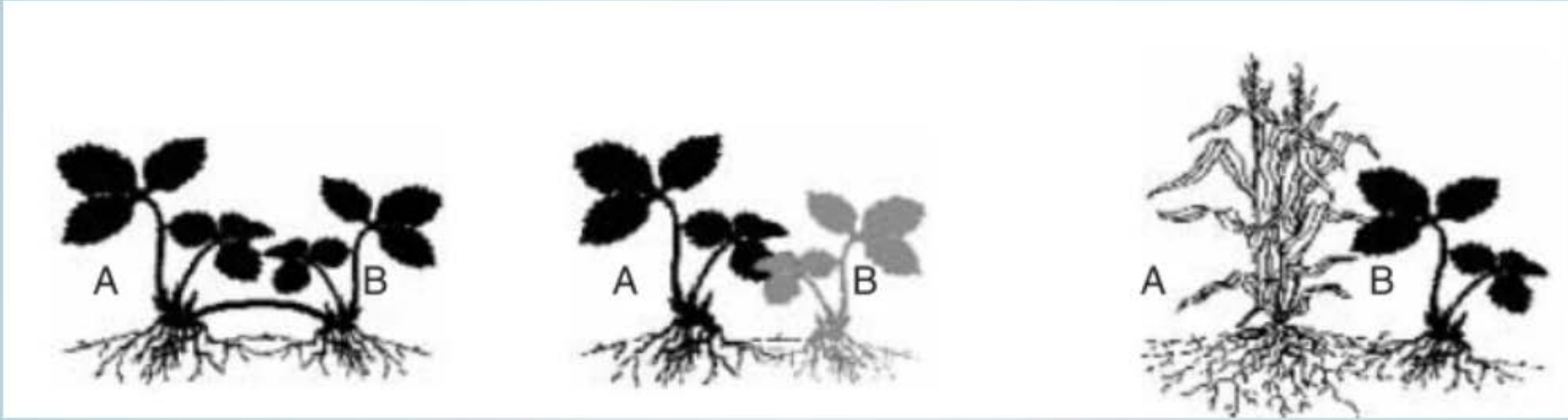
Schmitz et al. (1998 Ecology)

Beckerman et al. (1997 PNAS)

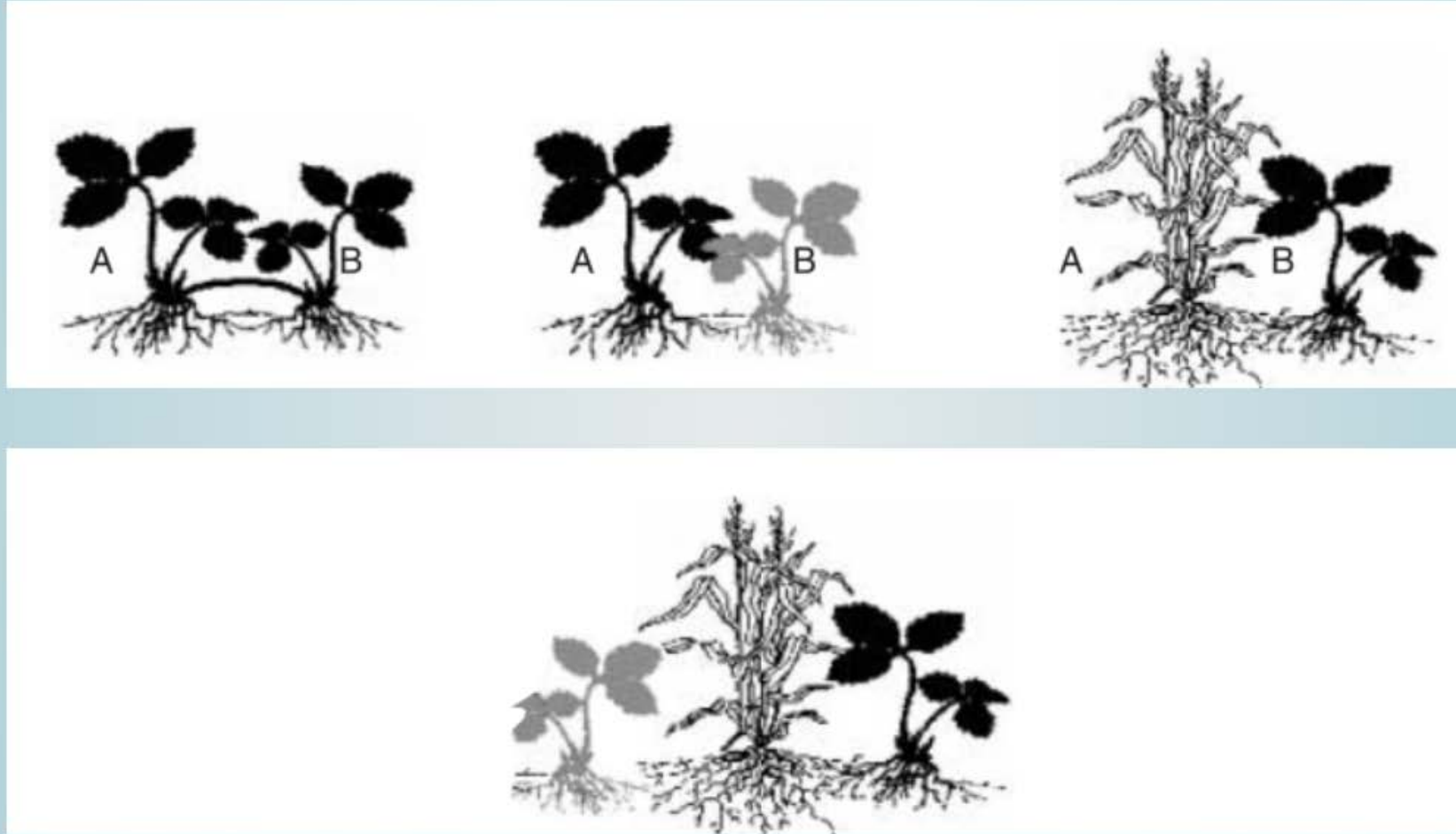
Trait-based pairwise effects



Trait-based pairwise effects



Trait-based higher-order effects

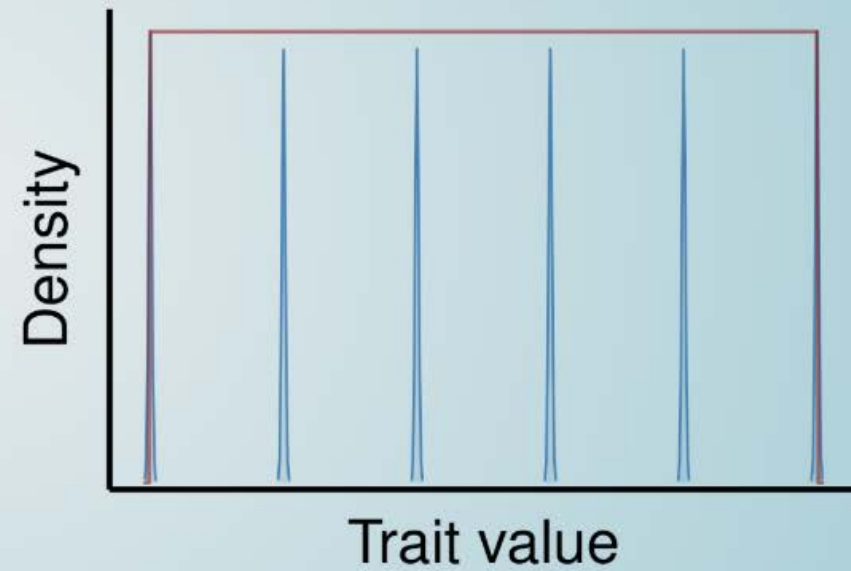
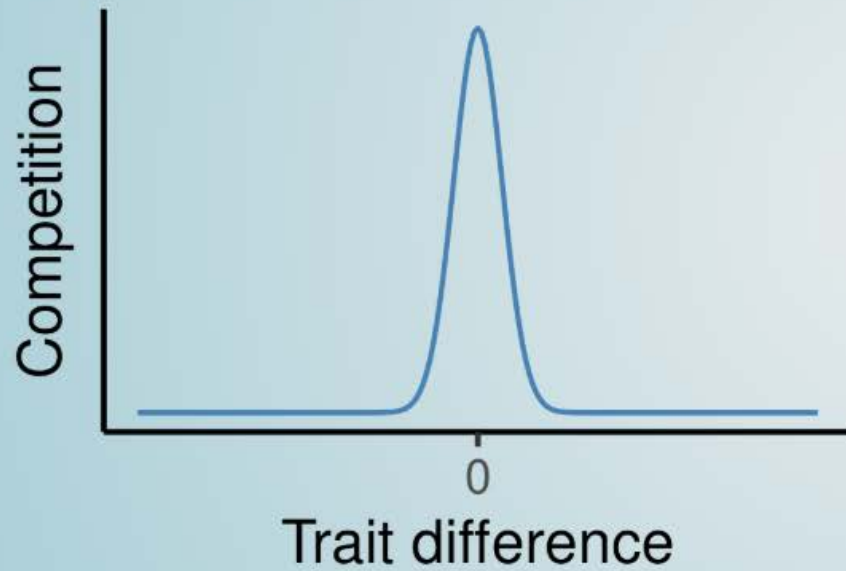


Coexistence in pairwise models

Average spacing between adjacent species $\sim$ width of kernel

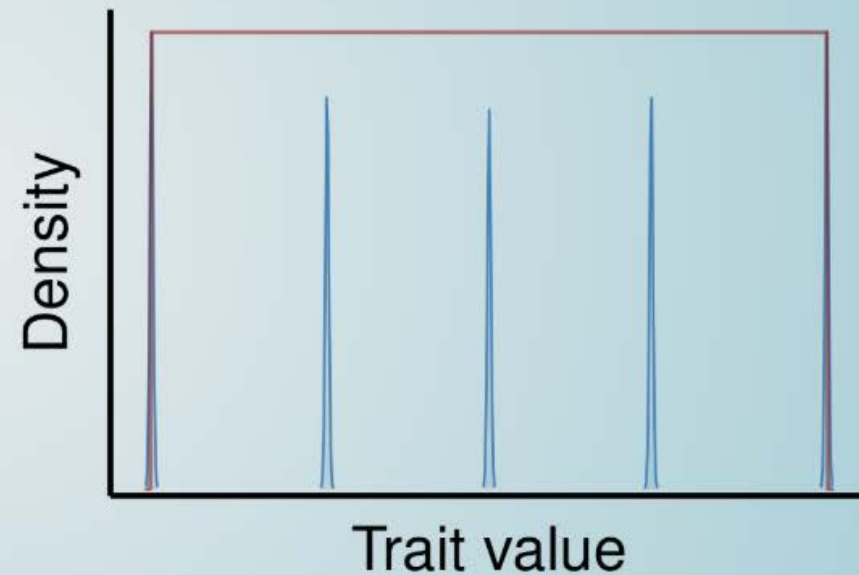
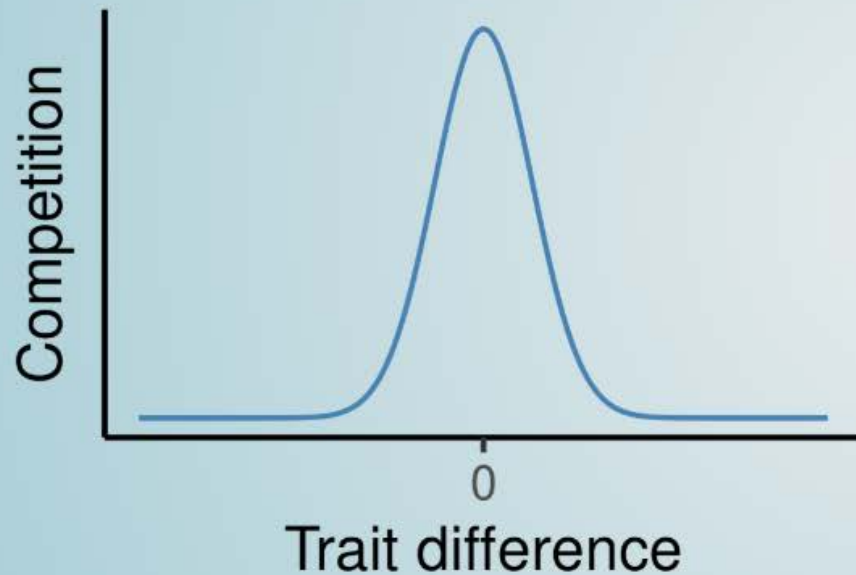
Coexistence in pairwise models

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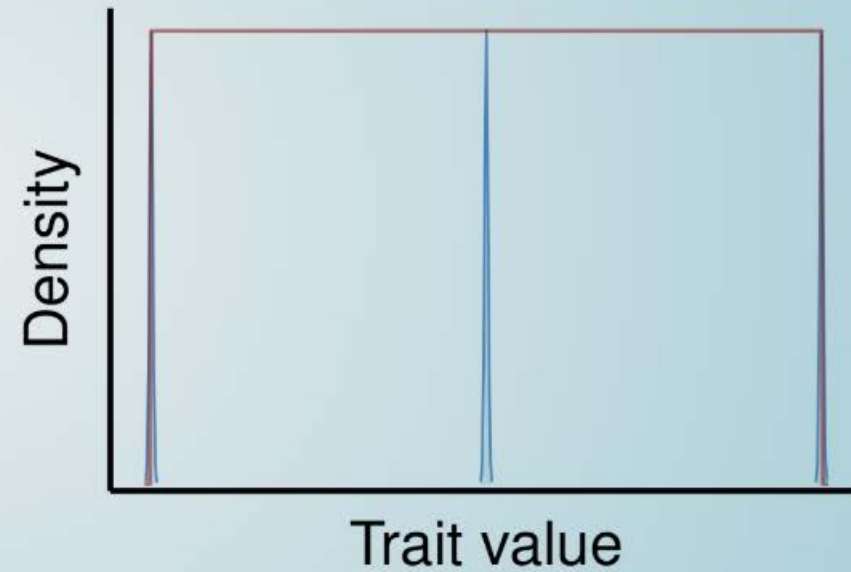
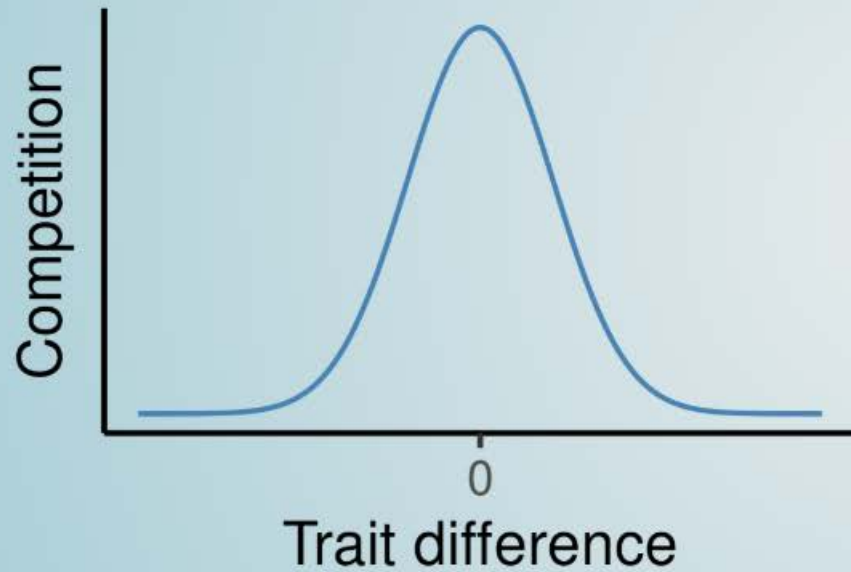
Coexistence in pairwise models

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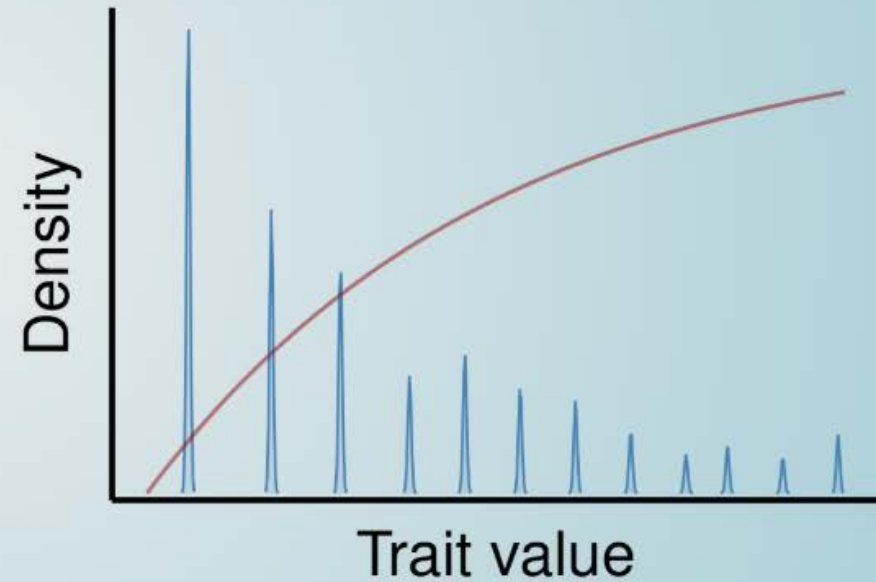
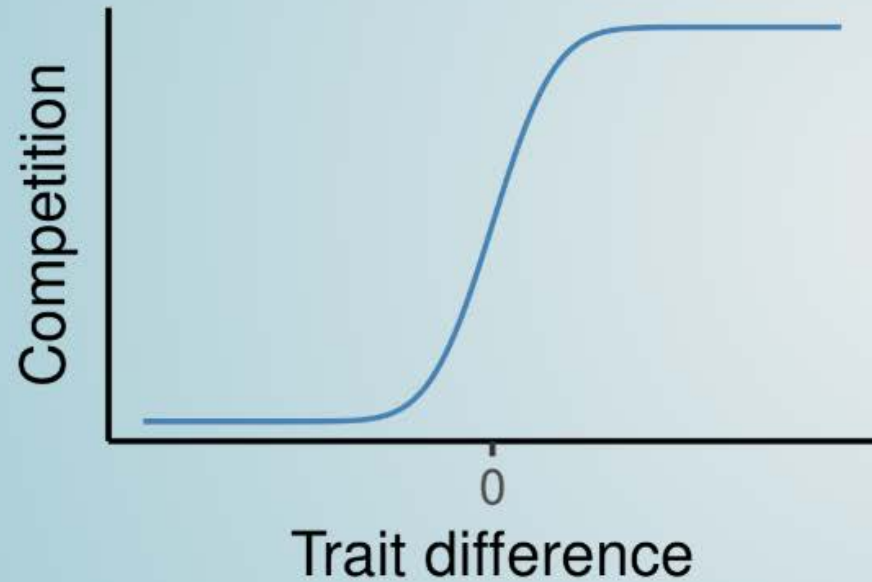
Coexistence in pairwise models

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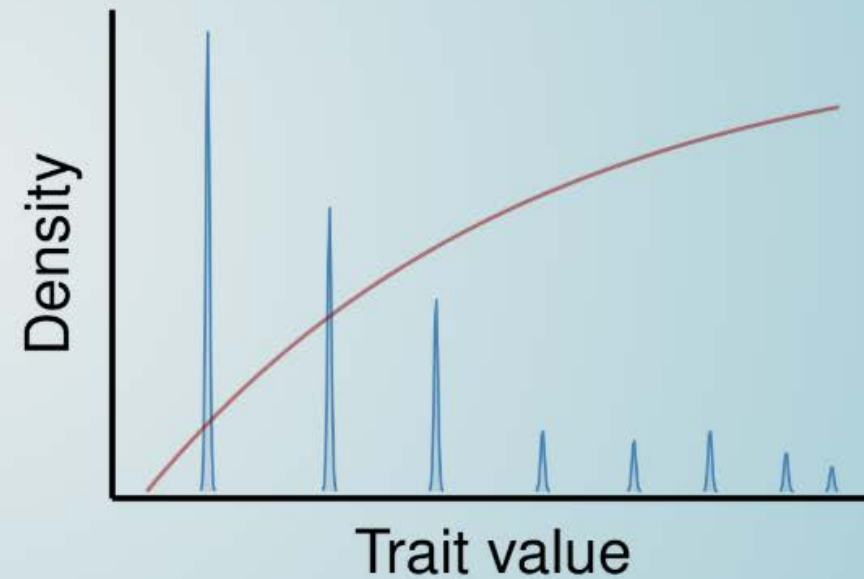
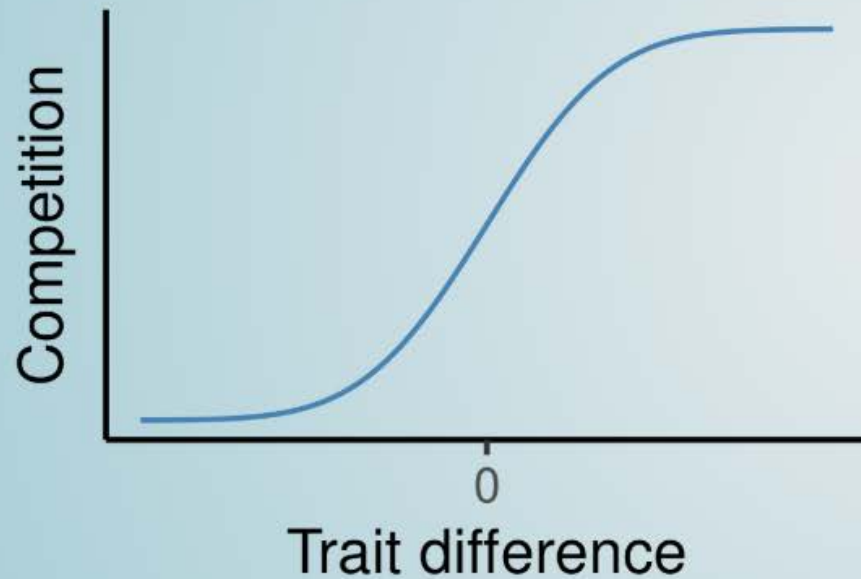
Coexistence in pairwise models

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Coexistence in pairwise models

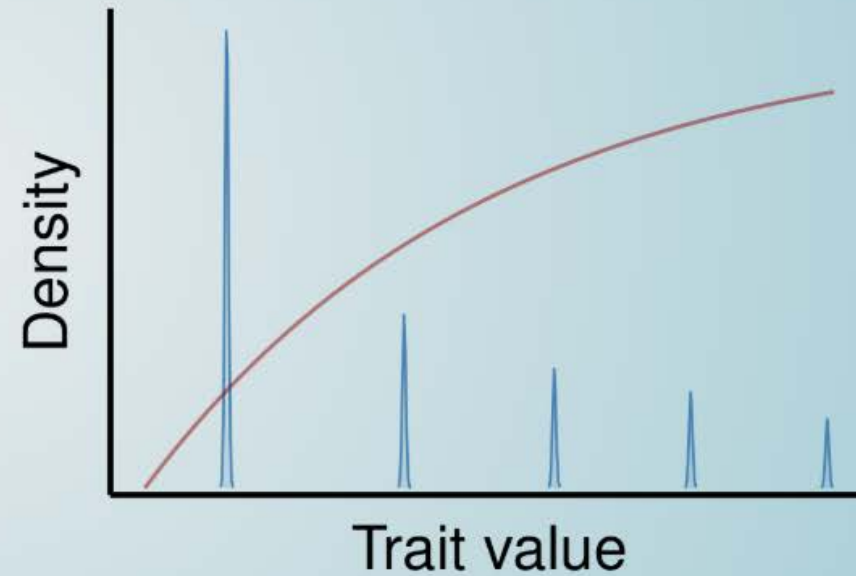
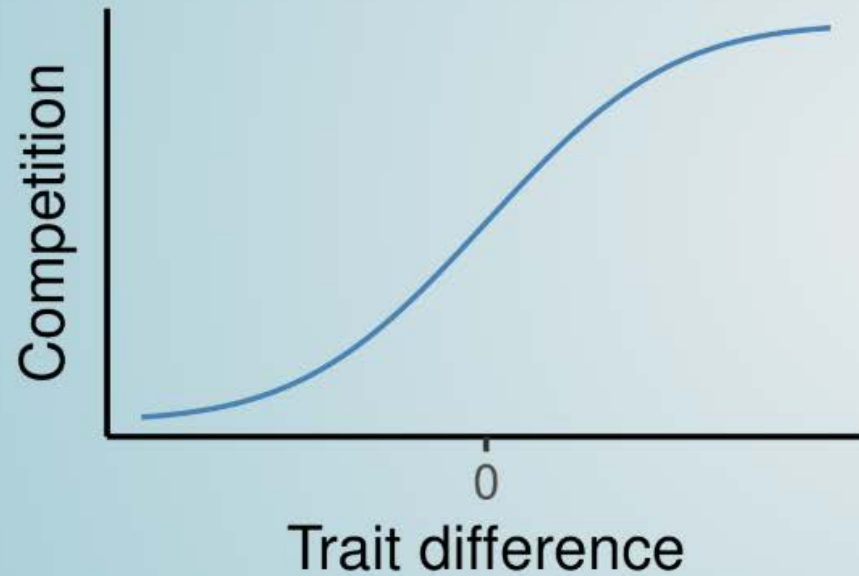
Average spacing between adjacent species $\sim$ width of kernel



Barabás et al. (2012 EER), D'Andrea et al. (2013 Am Nat)

Coexistence in pairwise models

Average spacing between adjacent species $\sim$ width of kernel



Coexistence in higher-order models?



Strategy: higher-order model $\rightarrow$ **pairwise** model with **effective** interaction kernel

Effective kernel $\sim$ pairwise kernel + higher-order kernel

Effective interaction kernel

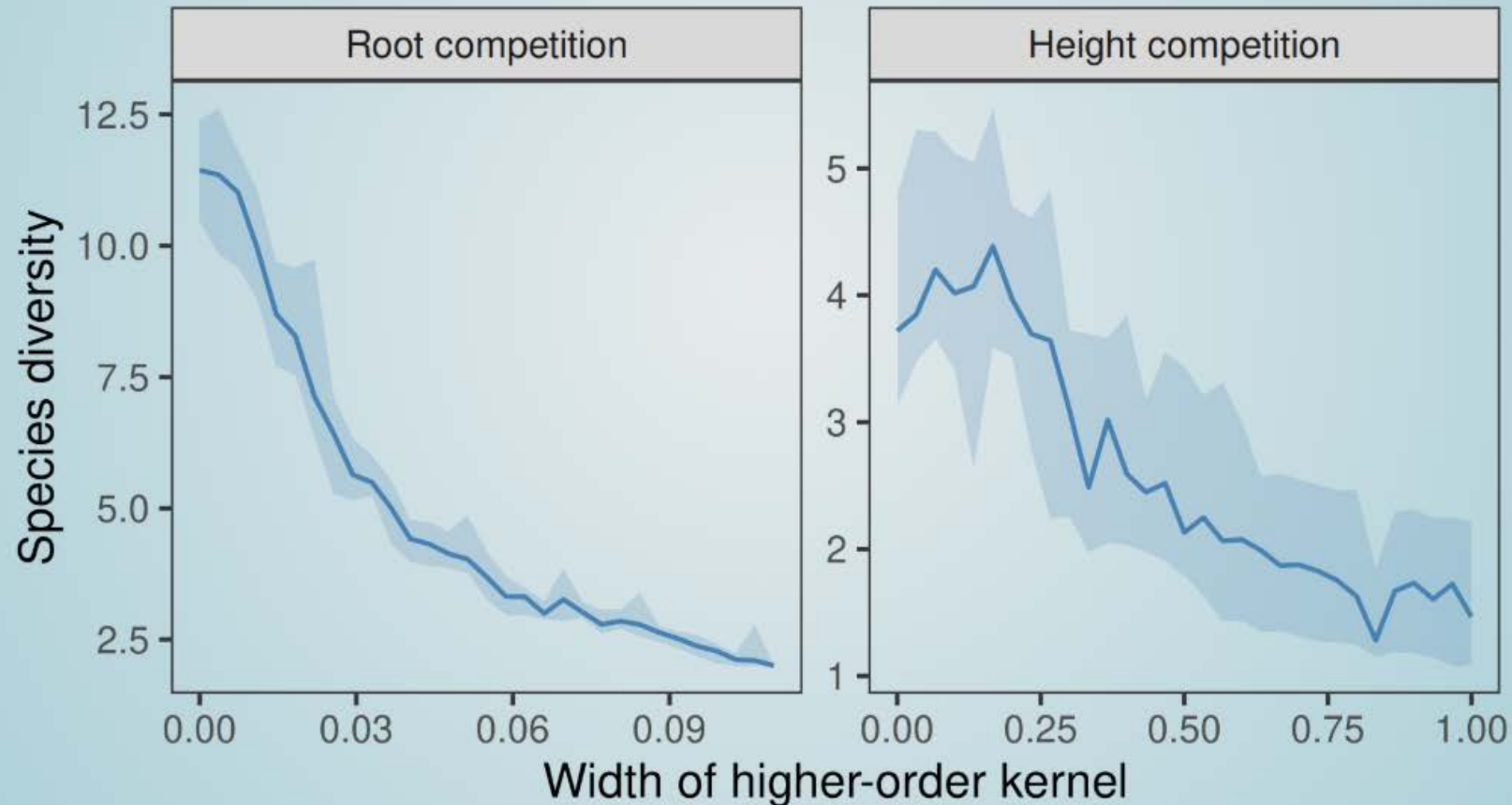
$$r(x) = b(x) - \int \alpha(x, y) N(y) \, dy \\ - \iint \beta(x, y, z) N(y) N(z) \, dy \, dz$$

Define $\alpha^{\text{eff}}(x, y) = \alpha(x, y) + \int \beta(x, y, z) N(z) \, dz$

Then: $r(x) = b(x) - \int \alpha^{\text{eff}}(x, y) N(y) \, dy$

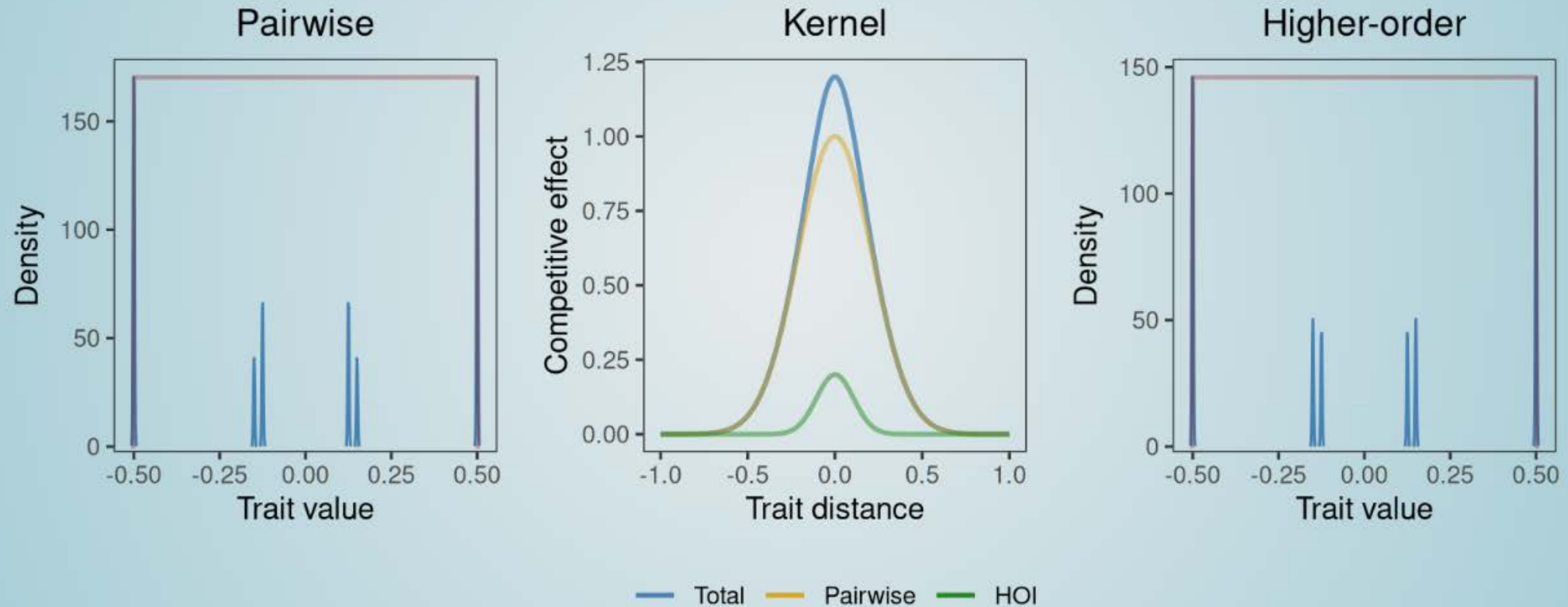
$\Rightarrow$ Shape of (pairwise + higher-order) drives coexistence?

Increasing higher-order width without pairwise effects



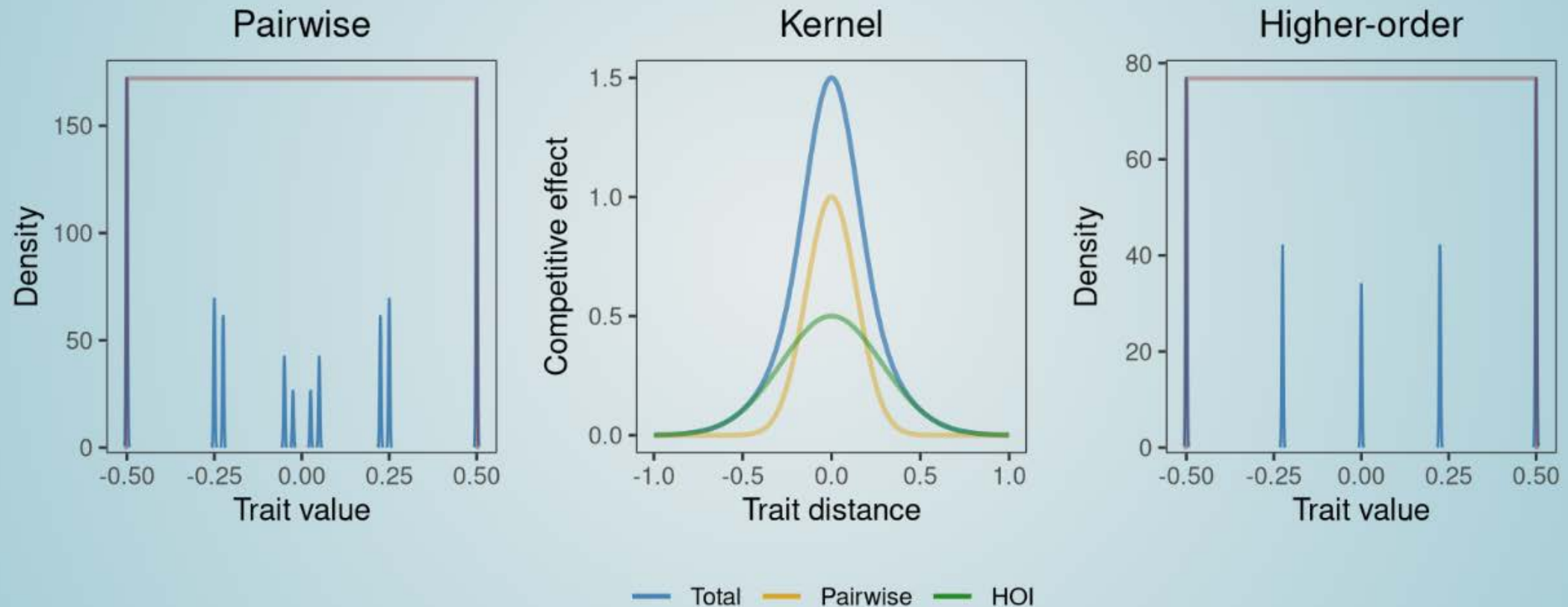
How kernel widths interact

Pairwise width $>$ higher-order width: no effect on diversity



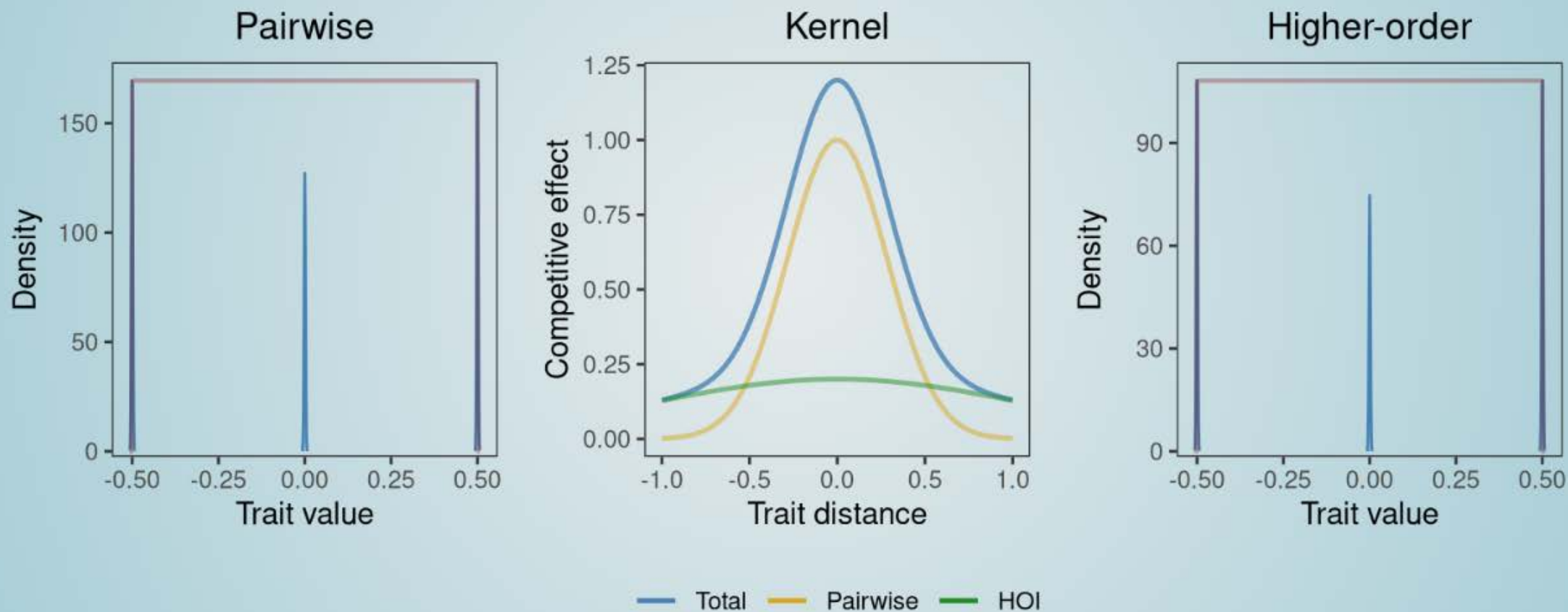
How kernel widths interact

Pairwise width < higher-order width: reduces diversity



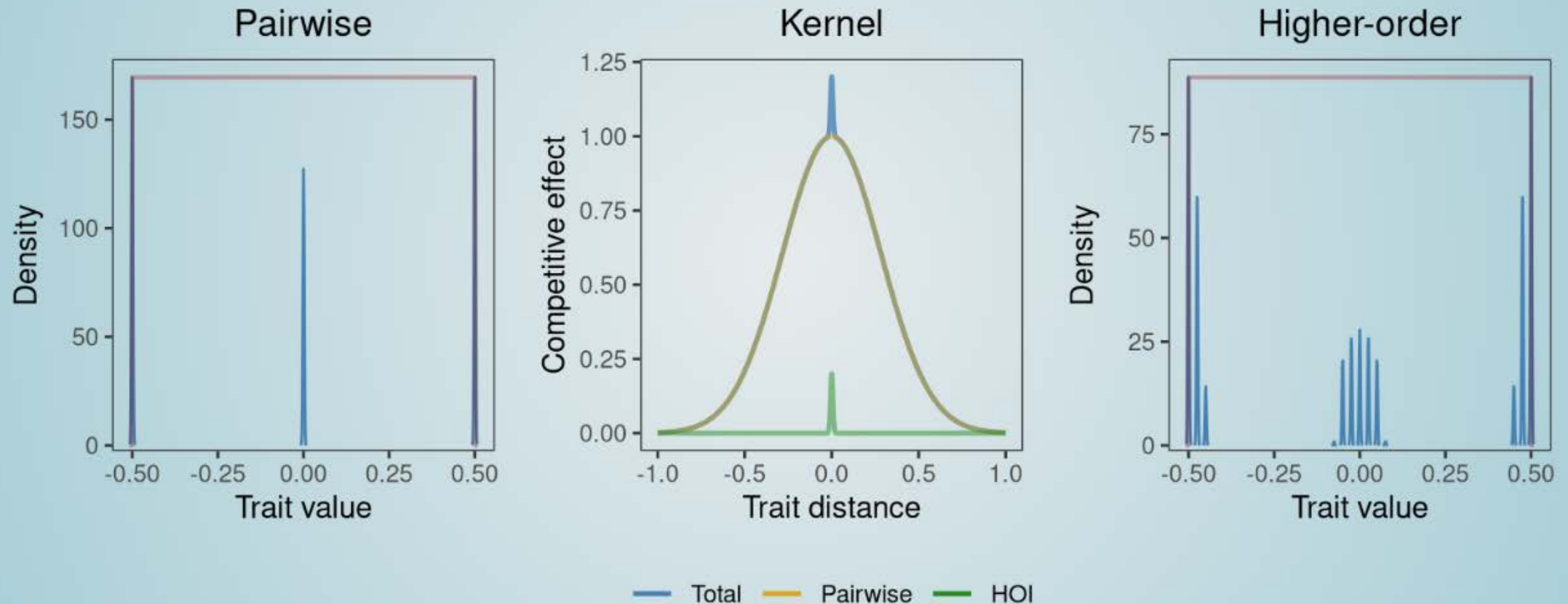
How kernel widths interact

Pairwise width $\ll$ higher-order width: again, no effect



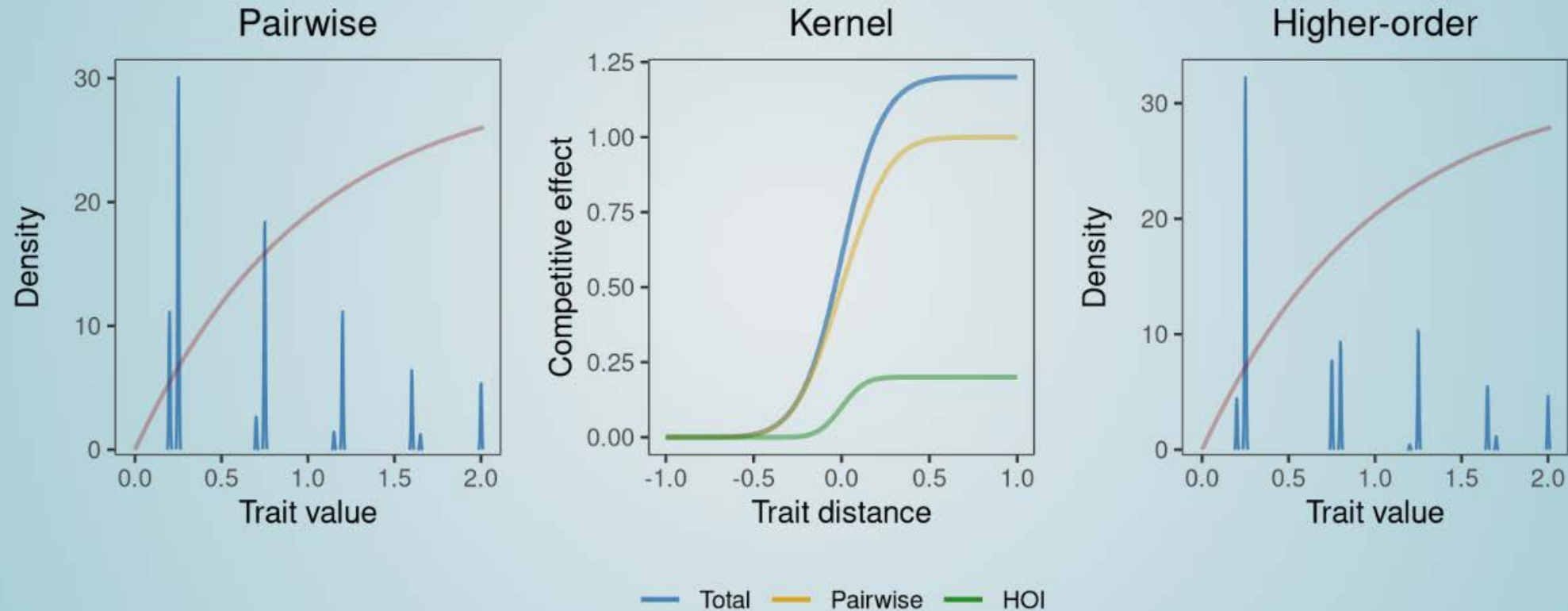
How kernel widths interact

Pairwise width $\gg$ higher-order width: promotes diversity



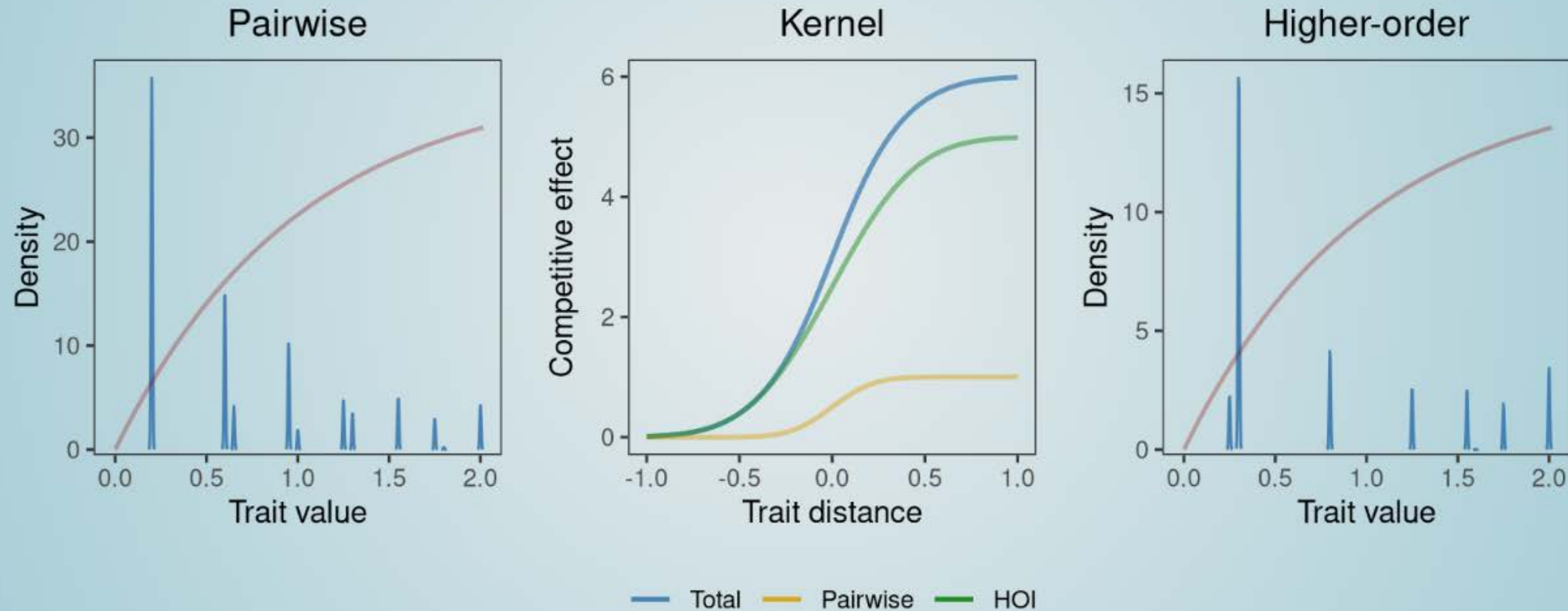
How kernel widths interact (height)

Pairwise width $>$ higher-order width: no effect on diversity



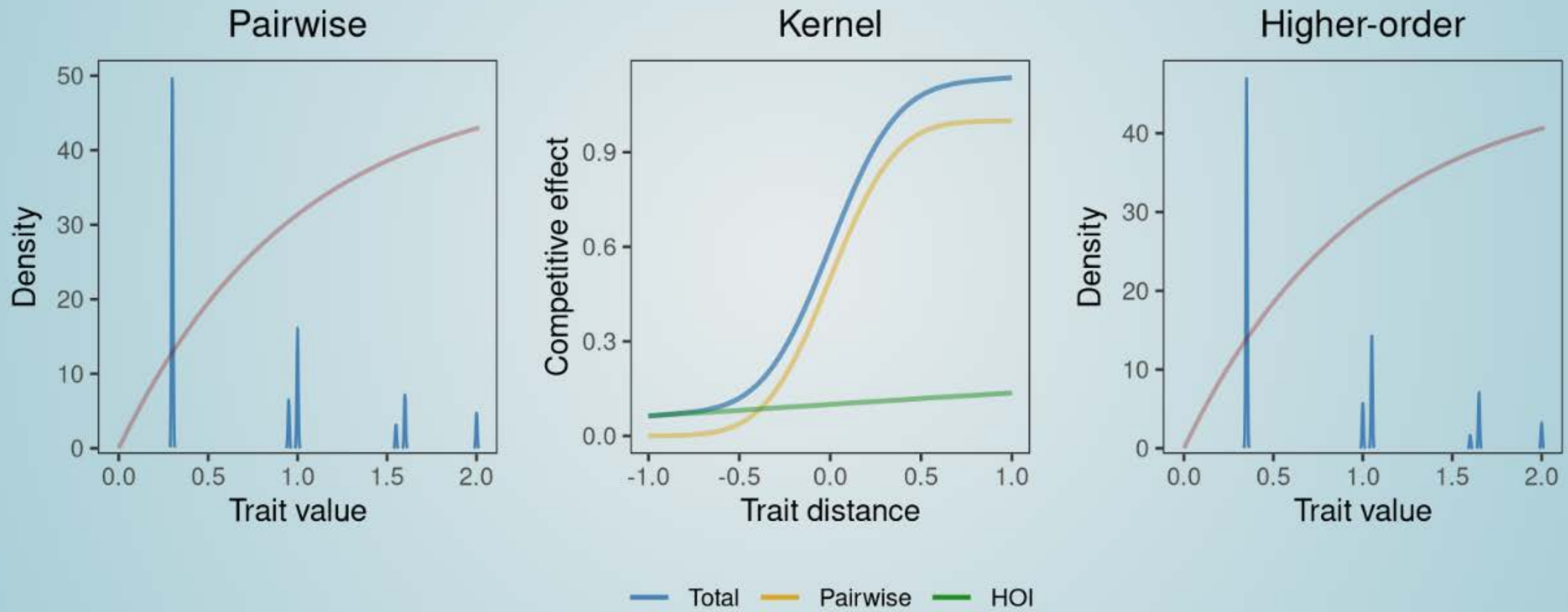
How kernel widths interact (height)

Pairwise width < higher-order width: reduces diversity



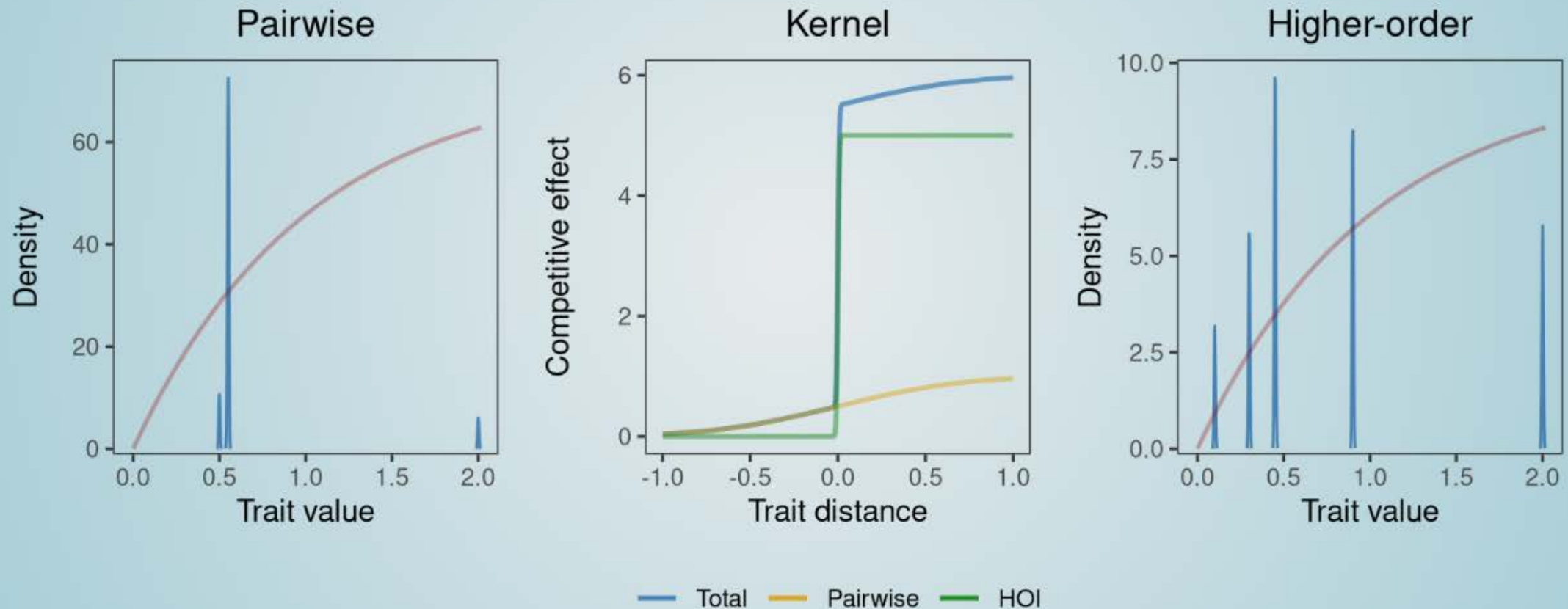
How kernel widths interact (height)

Pairwise width $\ll$ higher-order width: again, no effect



How kernel widths interact (height)

Pairwise width $\gg$ higher-order width: promotes diversity



Summary

- Effect of trait-based higher-order interactions on coexistence could be anything
- But we can predict the effect by analyzing the relative widths of the pairwise and higher-order interaction kernels

Acknowledgments

- Gaurav Baruah
- Robert John Chandran

