Effects of evolution on the stability of communities

Diversity increases stability (before 1970, Elton, Odum)

Stable if and only if:
$s\sqrt{(nC)}<1$

Stability decreases diversity (May 1973)

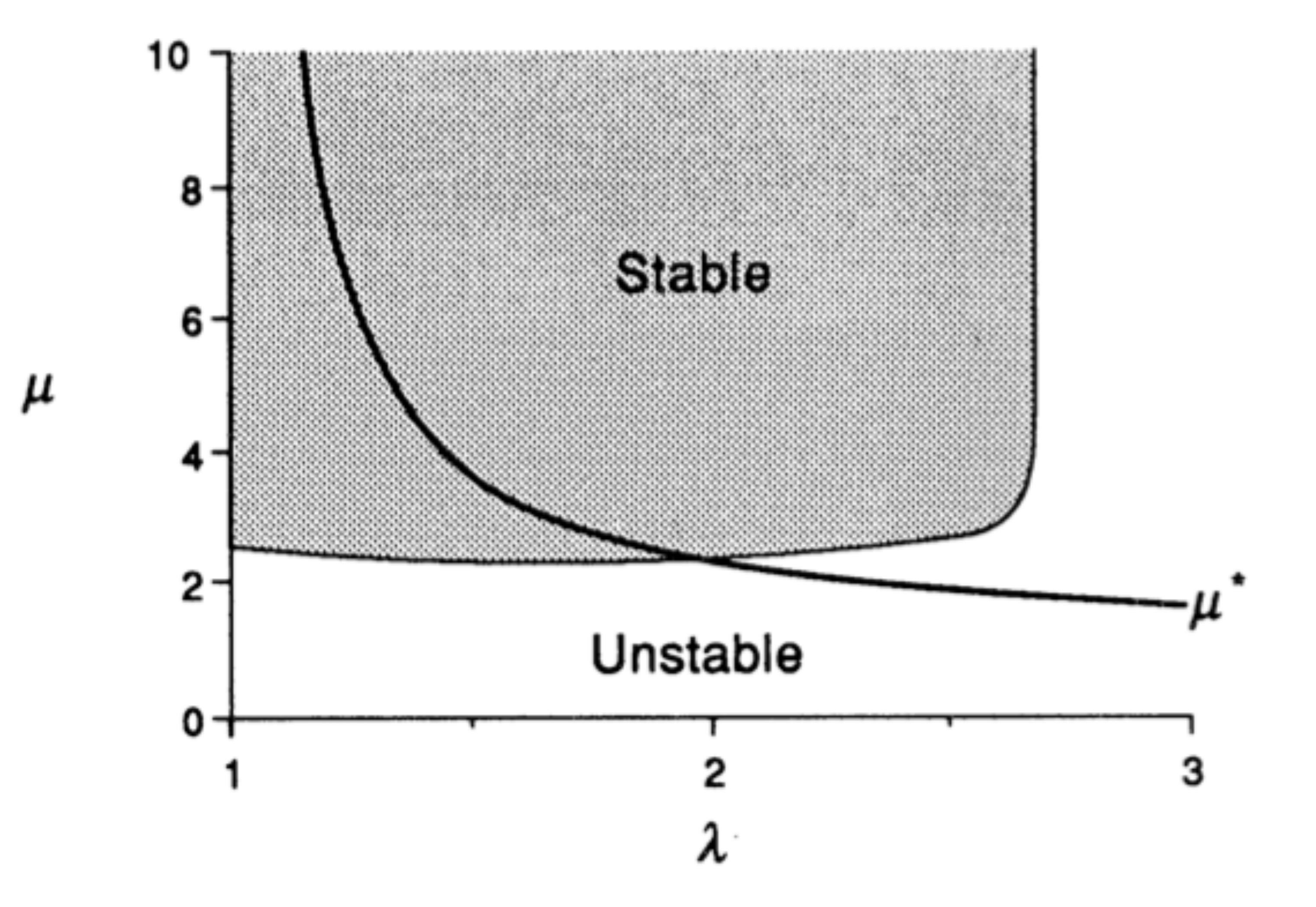
Hypotheses and shortcomings

-hyp of May: all types of interactions, interaction strengths drawn at random on a given interval [-s,s]

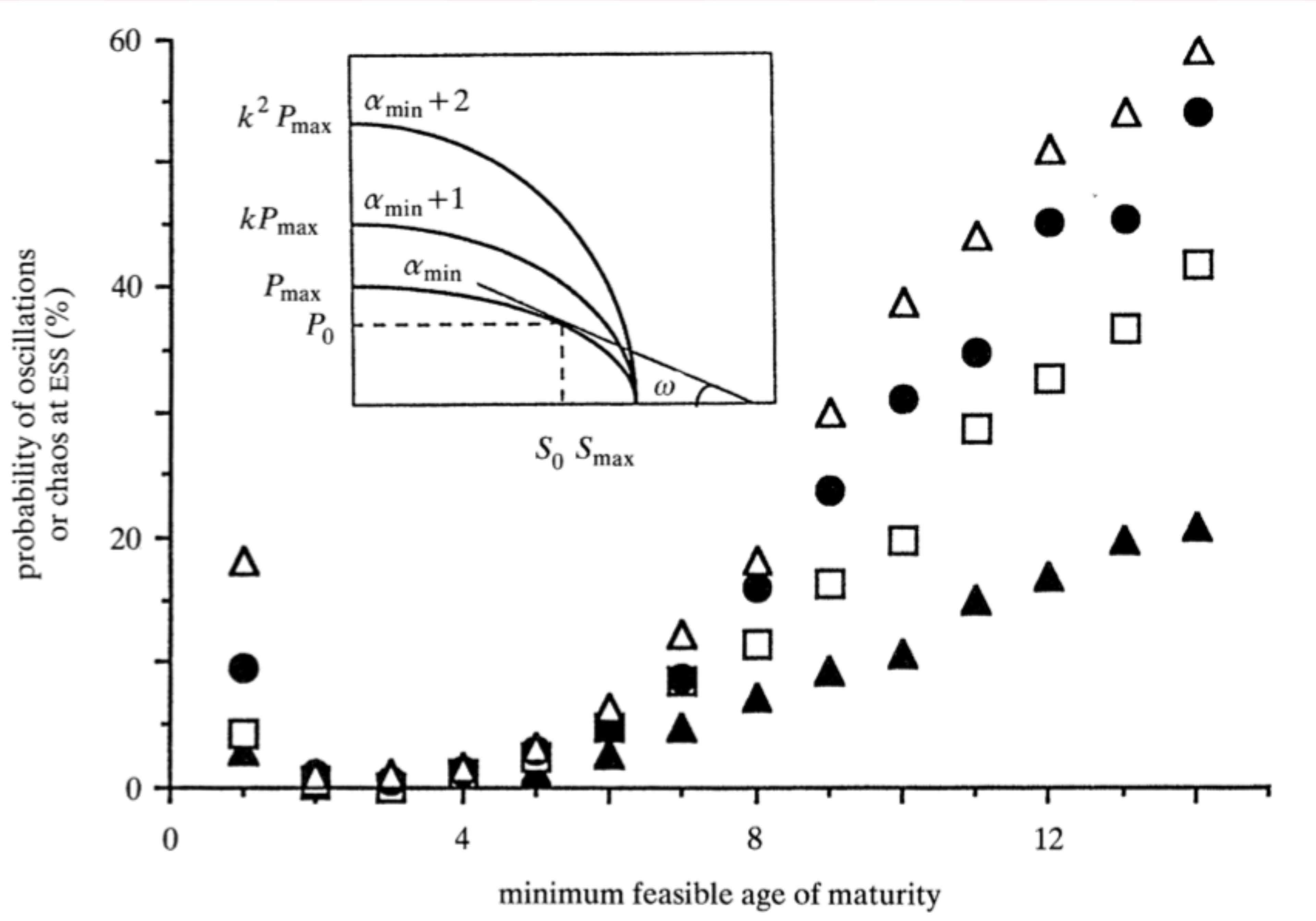
-adding food web constraints (conversion efficiency, self-regulation of higher trophic levels, donor control) increases stability (De Angelis 1975)

-Interaction strengths are not random because they depend on the assembly process

-Interaction strengths are not random because of species evolution/coevolution



Effects of evolution on stability (Van Baalen & Sabelis 1993)



Effects of evolution on stability (Ferrière & Gatto 1993)

Generalities

Effects of evolution on stability depend on:

-population structure (Ferrière & Gatto 1993)

-spatial components (Van Baalen & Sabelis 1993, Hochberg & Holt 1995)

-non linearities of the fitness function, due for instance to "complex" functional responses (Abrams & Matsuda 1997, Abrams 2000).

Common hypotheses of previous models

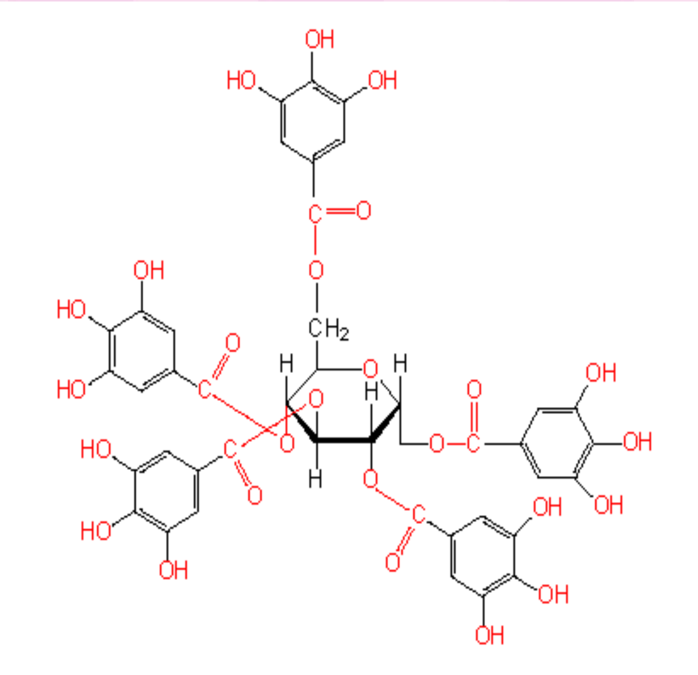
-Models based on evolution of one species or evolution in a trophic context (predator-prey or host-parasite)

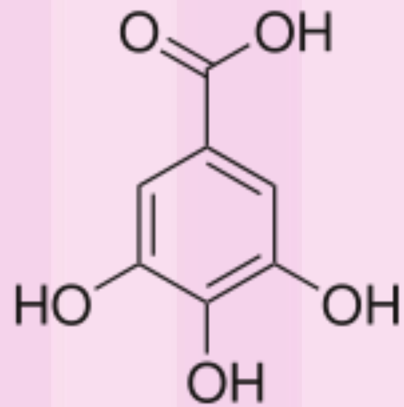
-Costs associated to the traits are allocation costs

-What about the effects of evolution on stability for other interaction types?

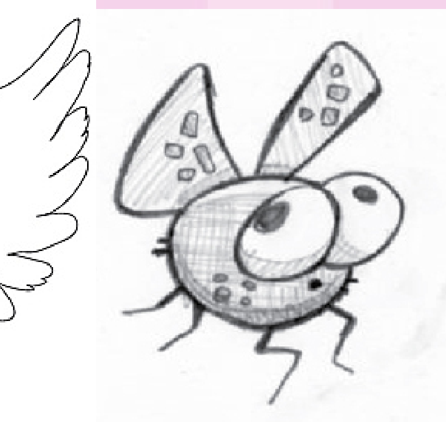
-For other types of costs?

Allocation costs





Ecological costs



Allocation and ecological costs (Strauss et al. 2002, Müller-Schärer et al. 2004)

Goals

Determine how the effect of evolution on stability depends on:

1) Interaction type

2) Cost associated to phenotypic trait

3) Diversity of the community

Interaction type and cost type: hypotheses

-two-species LV model

-Equilibrium is stable

-Determine the direction of evolution using adaptive dynamics

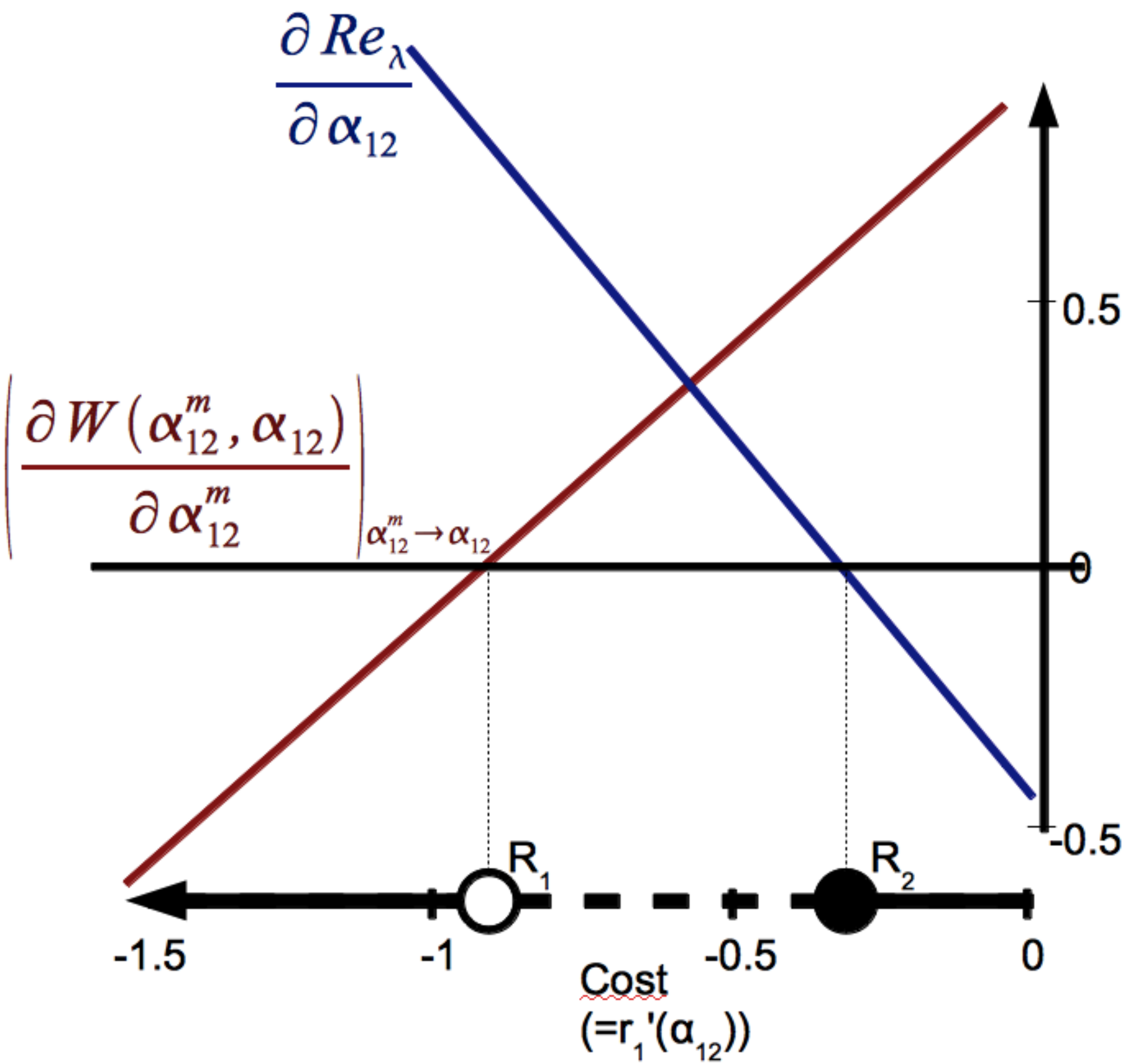
-Effect of the invasion by the next selected mutant on the resilience of the system.

$$\begin{cases} \frac{dN_1}{dt} = N_1(r_1 + \alpha_{11}N_1 + \alpha_{12}N_2) \\ \frac{dN_2}{dt} = N_2(r_2 + \alpha_{21}N_1 + \alpha_{22}N_2) \end{cases}$$

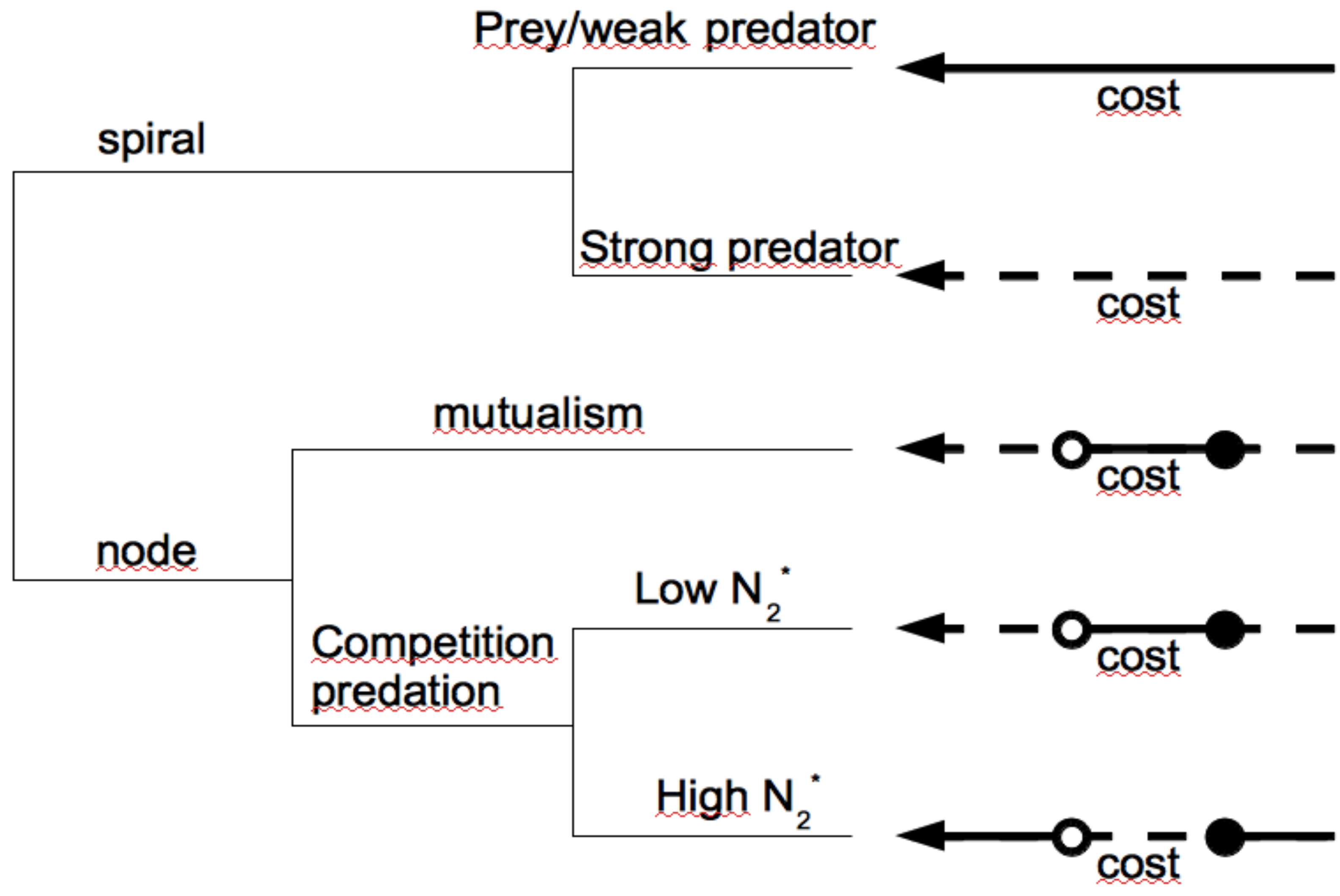
$$\lambda_{1,2} = \frac{Tr(J^*) \pm \sqrt{Tr(J^*)^2 - 4Det\,(J^*)}}{2}$$

$$\frac{dRe_\lambda(x(t))}{dt} = \frac{\partial Re_\lambda}{\partial x}\frac{dx}{dt} \propto \frac{\partial Re_\lambda}{\partial x}\left(\frac{\partial W(x_m, x)}{\partial x_m}\right)_{x_m \longrightarrow x}$$

A simple model



Mutualistic interaction, allocation trade-off



Summary of results, allocation costs

A few general results

-For trophic interactions, spiral cases with allocation costs lead to all or nothing results: always stabilization if prey or "weak" predator, destabilization else.

Consequence: overall more probability of stabilization when trophic interaction.

-Extreme cost scenarios more often lead to stabilization.

-Results are qualitatively similar for the two cost types.

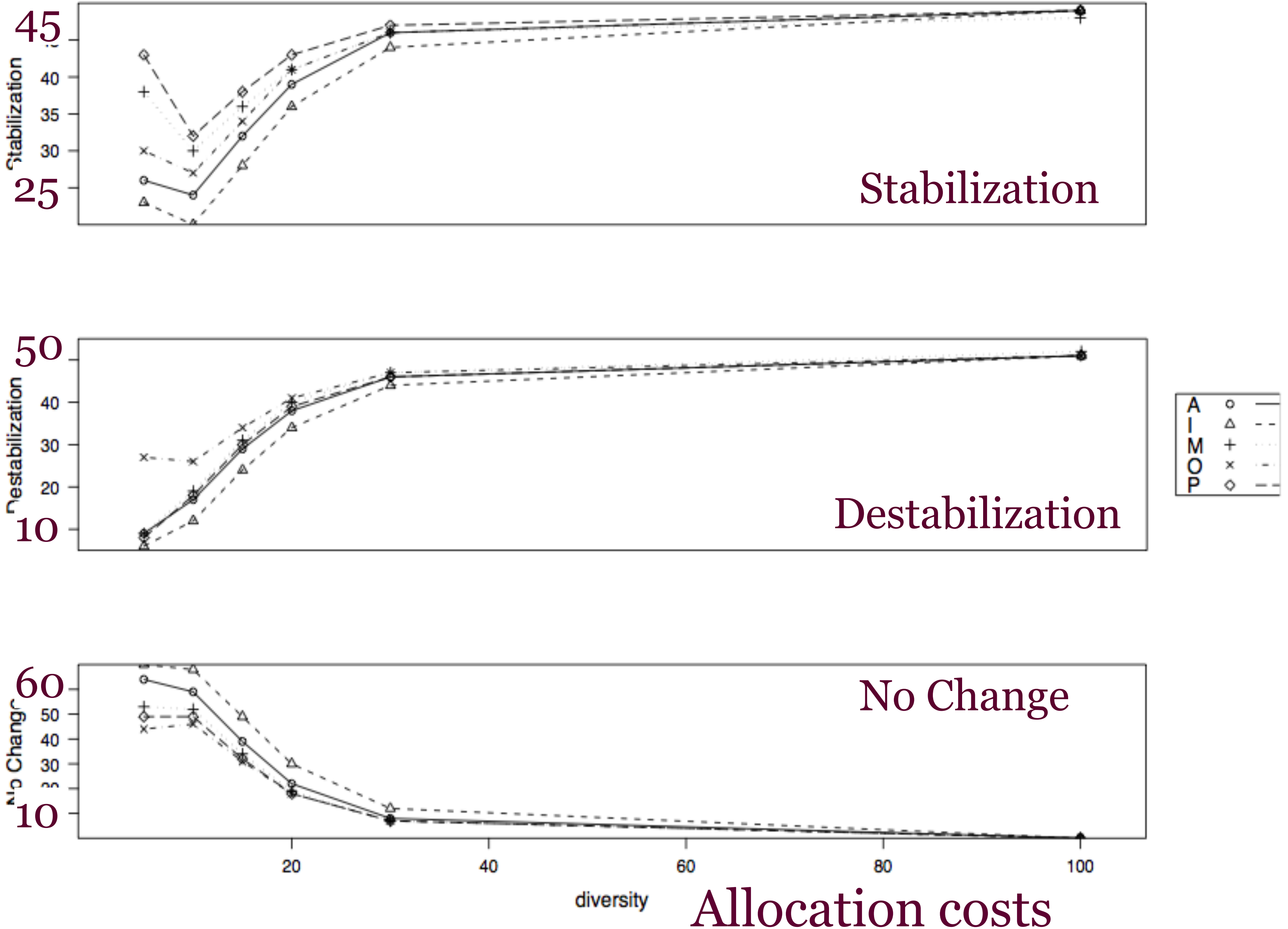
On the effects of diversity

-Communities are made using May's recipe.
C=0.1
s=0.2
n varies between 5 and 100

-Check that equilibrium is stable and positive; record resilience.

-Use fitness gradient to determine next successful mutant; record new resilience.

-allocation costs: 140000 communities
ecological costs: 880000 communities
In total over 20 millions of mutations.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Stabilization
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No Change
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80
100
diversity
Allocation costs

First results

-Many mutations do not affect the resilience at low diversity (compartments in the community)

-This is less true for ecological costs than for allocation costs

-Probability of neutral mutation decreases when community size increases.

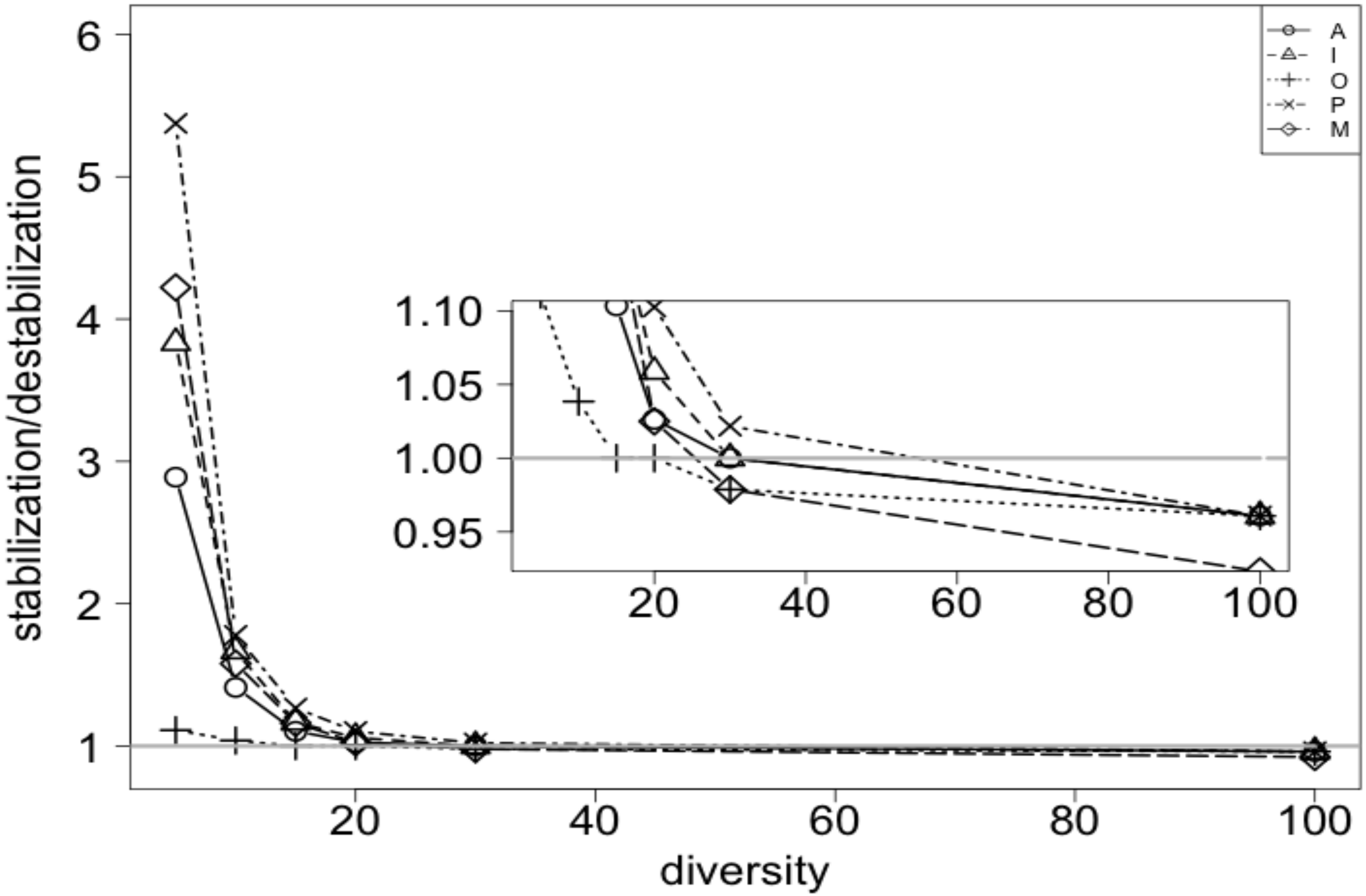
-All interactions are not equal in terms of contribution of evolution to stability.

-Qualitative similarity between allocation and ecological costs

How does it affect May's results?

-Recall: May: More diversity begets less stability when communities are randomly assembled.

-Evolution may counteract this if:
*It overall leads to more stability regardless of diversity
or
*Its effect on stability is positive for high diversity communities.



Overall effects (allocation costs)

General conclusions

-Little qualitative effects of the cost types.

-Evolution most often stabilizes communities.

-Evolution is destabilizing at high diversity, therefore may not counteract the destabilizing effect of diversity observed by May.

-Evolution of trophic interaction is more often stabilizing compared to other interactions.

-Even more so when they are weak, which reinforce the results of McCann et al. (1998).