Stabilizing mutualisms through investment cycles, phase diffusion, and spatial bubbles

Boza, G.[1,2], Kun, Á.[1,2,4], Scheuring, I.[3], and Dieckmann, U.[1]

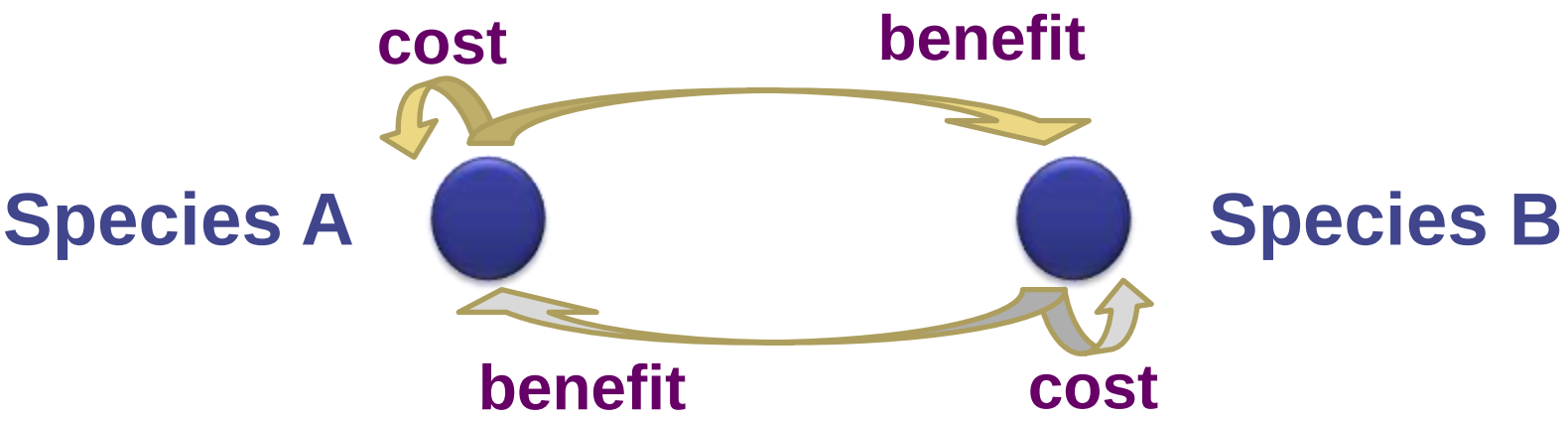
1- Evolution and Ecology Program, IIASA International Institute for Applied Systems Analysis , Laxenburg, Austria

2- Department of Plant Taxonomy and Ecology, Eötvös Loránd University , Budapest, Hungary

3- Research Group of Ecology and Theoretical Biology, Eötvös Loránd University , Budapest, Hungary

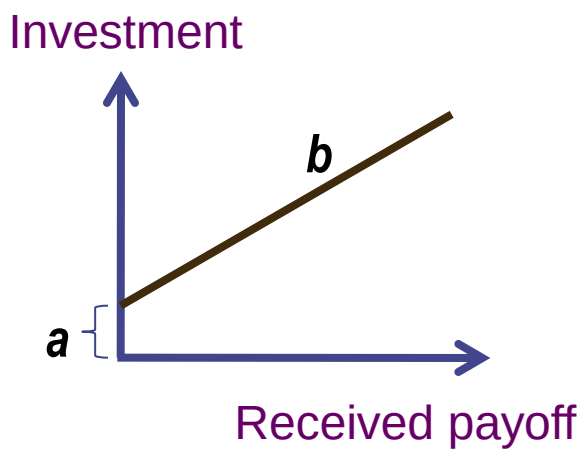
4- Parmenides Center for the Study of Thinking, Munich, Germany

Reciprocal mutualistic interactions



The Iterated Prisoner's Dilemma model describes repeated interactions,and also approximates continual interactions

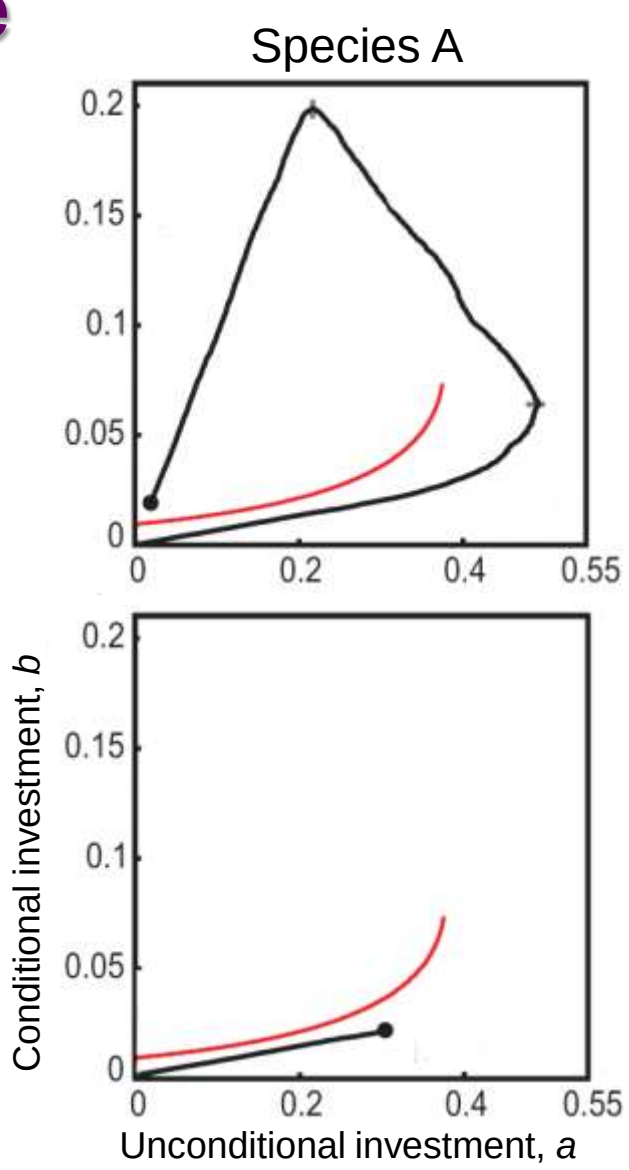
Investment cycle in continuous iterated prisoner's dilemma game



$$I_t = a + b \bullet payoff_{t-1}$$

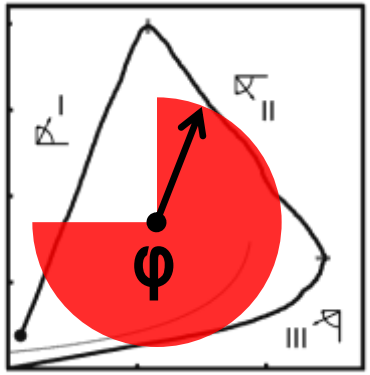
Unconditional investment

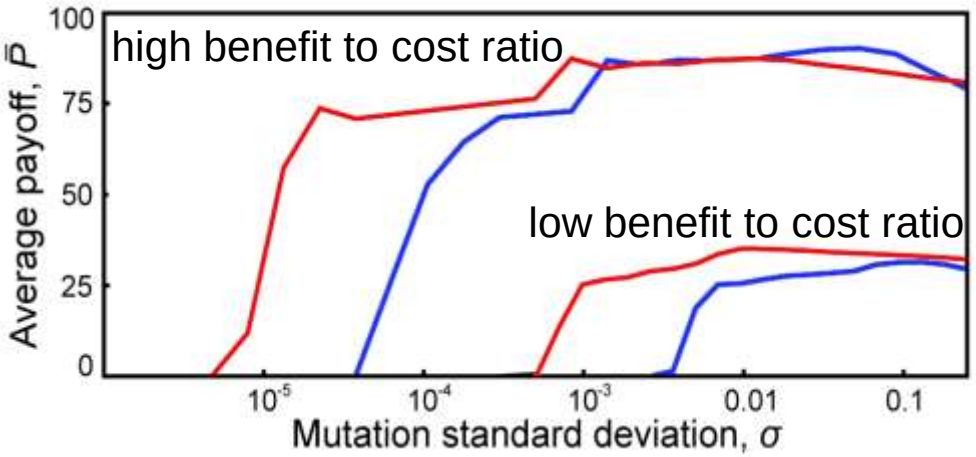
Conditional investment

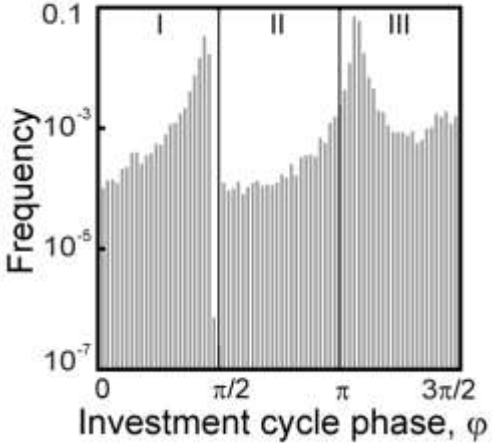


Mutation variance and phase diffusion

monomorphic strategy pair → **increase of mutation variance** → **polymorphic population**



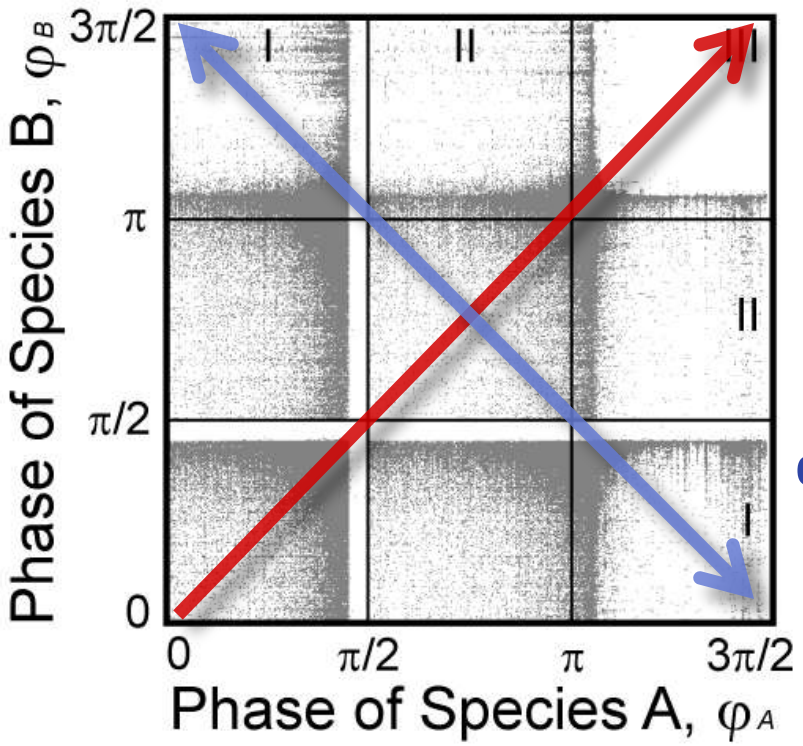




spatial population structure

well-mixed population structure

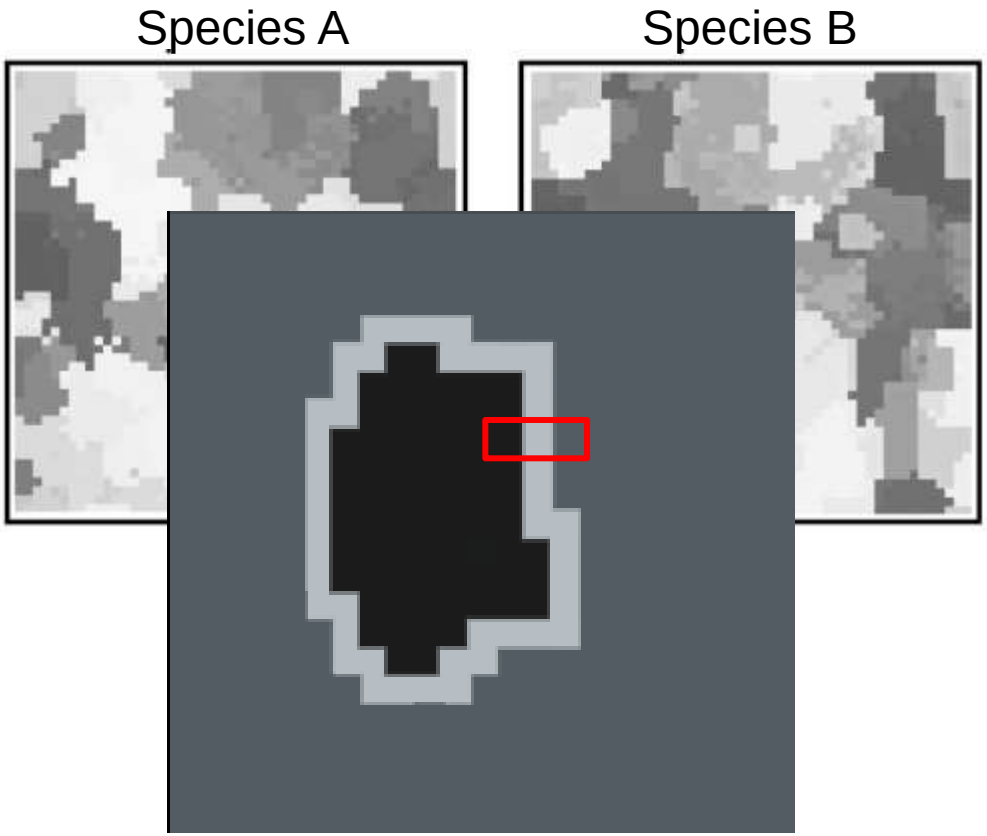
Polymorphism of investment phases and interaction types

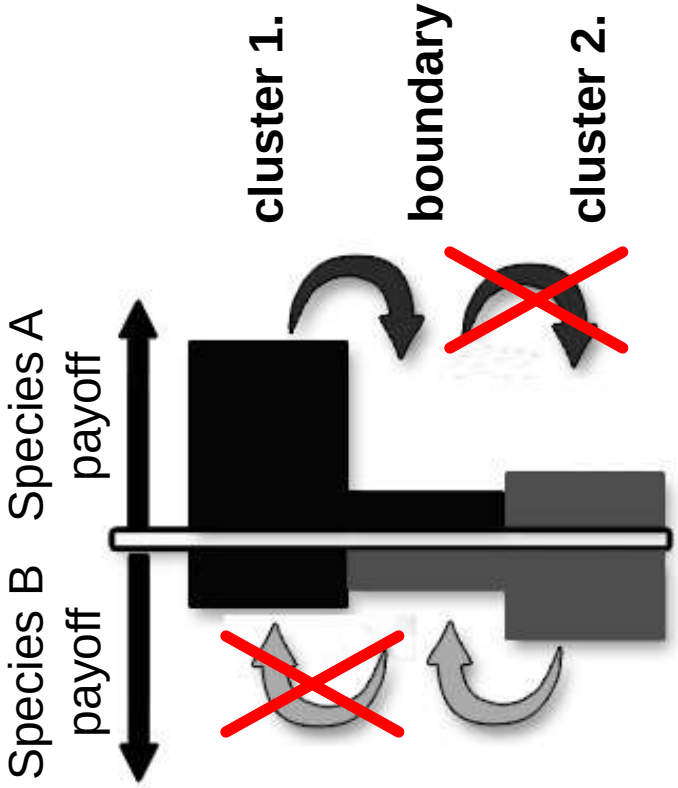


similar phases: balanced payoffs → **mutualism**

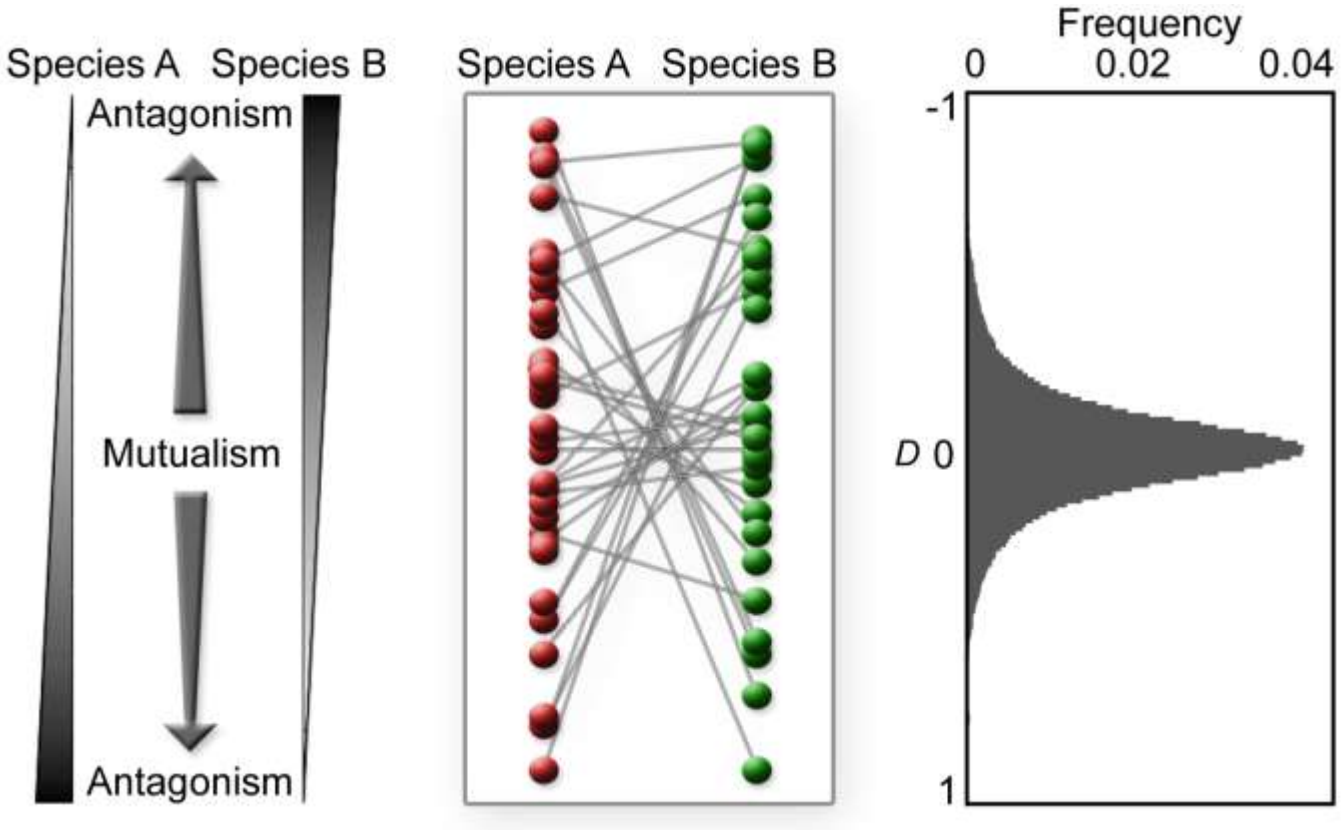
different phases: unbalanced payoffs → **antagonism/ exploitation**

Dynamic spatial mosaic structure





Polymorphic nature of mutualistic interactions



D = payoff difference between the partners

Conclusions

- Mutualism is inherently unstable
- Above a threshold, evolution drives strategy pairs through investment cycles
- Mutation-generated polymorphism of strategies leads to phase diffusion along the investment cycle
- This polymorphism stabilizes mutualism at the population level
- Spatial mosaic structure further promotes mutualism stability, through a mechanism that is fundamentally different from the role of space in intraspecies cooperation

Conclusions

- Mutualism cannot always be understood as a stationary (+,+)–interaction, but may instead represent a polymorphism of investment levels and interaction types varying both in space and in time.

Thank you for Your attention !

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