

IFT - UNES

Ecological significance of imperfectly synchronized collective behaviors

Ricardo Martinez-Garcia (ICTP – SAIFR / IFT - UNESP) **ricardom@ictp-saifr.org**

School on Community Ecology: from patterns to principles

Population dynamics is an emergent phenomena



Well-mixed



 $\dot{x} = rx - \delta x^2$

Range residency / territoriality



(video from @BoixRichter)

Martinez-Garcia et al. 2019, bioRxiv 712182

Purely random movement Local perception



Cognition: "searching" Perceptual ranges



 $\dot{x} = rx - \delta x^2$

Martinez-Garcia et al. 2013, Phys. Rev. Lett.

Self-organized collective behaviors





Gregarious – solitary transition in the emergence of locust swarms





Imperfect synchronization is frequent in nature



Imperfect synchronization is frequent in nature





Month

How do "microscopic" collective behaviors and their features impact "macroscopic", populationlevel patterns?

What are the **causes** of this self-organized process?

What are the **consequences** of the self-organized structures on the (eco)system?

D. discoideum: asynchrony in the transition to aggregative multicellularity





F.W. Rossine

A.E. Sgro





T. Gregor

C.E. Tarnita

Some cells do not participate on the self-organized collective behavior



Loners die if exposed to prolongated starvation, but they persist for some time





Allyson E. Sgro

Tarnita*, Washburne*, et al., PNAS, 2015.

Theoretical work predicts selective benefits for loners in stochastic environments



Tarnita*, Washburne*, et al., PNAS, 2015.

Martinez-Garcia & Tarnita, PLoS Comp. Biol., 2016

And coupled with environmental heterogeneity could favor diversity

Spatial heterogeneity





Tarnita*, Washburne*, PNAS, 2015.

And coupled with environmental heterogeneity could favor diversity

Temporal heterogeneity



Are loners a heritable component of *D. discoideum* life-history?





Loners are a heritable component of *D. discoideum* life-history?



Q1: What are the mechanistic **causes** of loners?

Q2: What are the ecological **consequences** of the collective behavior?

What are the mechanistic causes of loners?

Proposal: loners are the result of stochasticity in the initiation of a quorum-based aggregation



What are the mechanistic **causes** of loners?



Mechanistic toy-model for loners emergence: infinite signal diffusion



Loners emerge from imperfect synchronization between two time scales

Infinite diffusion and
$$N \to \infty$$
 limit: $\rho_L \propto \begin{cases} \left(1 - \frac{\lambda}{\tilde{v}}\right), & \text{if } \lambda < \tilde{v} \\ 0, & \text{otherwise} \end{cases}$



Different genetic variants differ in partitioning behavior



Aggregation performance

What are the ecological **consequences** of the self-organized behavior?











Interactions in the developmental process make strains to **DIVERGE** in their aggregation performance



Aggregation performance

What are the ecological **consequences** of the self-organized behavior?



Changes in the self-organizing behavior due to mixing have profound impact on the diversity of the species

Further implications

Effect of loners on the integrity of multicellularity / sociality against free-riders?

Effect of imperfect synchronization on the persistence of coordinated behaviors

Constant birth-death rates



Individual age

"Traditional" Moran process



Jairo M. Rojas

Underlying spatial patterns: from microbes to landscapes



Underlying spatial patterns: from microbes to landscapes



Looking for postdocs, PhD and Master students!

ricardom@ictp-saifr.org

References:

Tarnita*, Washburne*, Martinez-Garcia, Sgro, Levin, PNAS 2015 Martinez-Garcia & Tarnita, PLOS Comp. Biol, 2016 Martinez-Garcia & Tarnita, Journal Theoretical Biology, 2017 Martinez-Garcia et al., PLOS Comp. Biol. 2018 Rossine*, Martinez-Garcia*, et al., PLOS Biology (in Press), 2020

Funding:









