### Time delays induce synchronization and chaos in complex ecological communities

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### Modeling ecological communities

- Communities are complicated
- Many species
- Multiple environmental factors
- What to include in models?



# Ime ceavs

- Non-instantaneous response in dynamics
- Delays arise when reciprocal feedback with environment is considered
- Also due to - maturation times
  - resource renewal
  - seasonality
- When are they important?







# Lotka-Volterra with delay

biomass density of species i  $dx_i(t)$  $\frac{dx_i(t)}{dt} = x_i(t) \left[ 1 - x_i(t) + \sum_j \alpha_{ij} x_j(t - \tau) \right]_j$ 

time delay

interaction matrix

### Lotka-Volterra with delay



Time delays can induce synchronization

## Lotka-Volterra with delay

### In community with predatory-prey pairs delay can induce chaos



# Summary

- Time delays are inevitable in models of ecological communities
- We proved when they are important, and when they are not
- In competitive communities they can induce synchronization
- In predator-prey communities they can induce synchronization and chaos
- Framework experimentally testable in microbial communities

### Thank you for your attention!

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