THE ROLE OF RELATIVE NONLINEARITY IN STABILIZING COEXISTENCE

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Lottery model

- Study systems: iteroparous populations
  - Coral reef fishes
  - Perennial plant community
- Lottery competition: space as limiting resources
  - Juveniles competing for available space left by dead individuals
Recruitment variation and population dynamics

example from coral reef fishes

Stegastes diencaeus
Stegastes dorsopunicans

% MAXIMUM RECRUITMENT

83 84 85 86 87 88 89 90 91 92 93

YEAR

data from Robertson, 1995
Recruitment variation and population dynamics
— example from coral reef fishes

ADULTS

Environmental response: Reproduction

Competitive Response: Mortality at recruitment because space is limited

Fluctuation Insensitive: Adult Survival

RECRUITED LARVAE

Environmental Response: larval survival

JUVENILES

Fluctuation Insensitive: Larval Survival
Coexistence mechanisms arising from recruitment fluctuations
Exogenous fluctuations give rise to two distinct coexistence mechanisms

1. The storage effect
   - Temporal niche partitioning
     - Species-specific environmental response
     - Covariance between environment and competition
     - Buffered population growth

![Graph showing recruitment data for Stegastes diencaeus and Stegastes dorsopunicans from 1983 to 1993.](data from Robertson, 1995)
Exogenous fluctuations give rise to two distinct coexistence mechanisms

2. Relative nonlinearity

- Species have growth rates of different curvature as a function of the magnitude of competition
- Difference in death rate

Total competition in the community from all individuals due to limiting resources
How Relative nonlinearity promotes coexistence e.g. perennial vs annual

When Species 2 is abundant, it drives large fluctuations in competition

Species 1 perennial
Species 2 annual
How Relative nonlinearity promotes coexistence
e.g. perennial vs annual

When *Species 1* is abundant, it reduces the fluctuation in competition.
Relative nonlinearity: e.g. perennial vs annual
----- how it promotes coexistence

- Both species drive fluctuations in competition in a direction that favors the other species

Criteria for coexistence

- Stable coexistence: each species can recover from low density

- Recovery rate = Average Fitness difference
  + The storage effect
  + Relative nonlinearity

- Stabilizing effect
  \[ \begin{align*}
  >0 & \quad \text{stabilize coexistence} \\
  <0 & \quad \text{destabilize coexistence}
  \end{align*} \]
Criteria for coexistence

- Stable coexistence: each species can recover from low density
- Recovery rate = Average Fitness difference + Stabilizing effect

- Stabilizing effect
  - >0 stabilize coexistence
  - <0 destabilize coexistence
Hypotheses: what makes relative nonlinearity important?

- Factors affecting the relative importance of the two mechanisms
  - Differences between adult death rates
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  - Species differences in sensitivities to the environment (differences between the variances of the environmental responses)
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- Factors affecting the relative importance of the two mechanisms
  - Differences between adult death rates
  - Correlations between environmental responses
  - Species differences in sensitivities to the environment (differences between the variances of the environmental responses)
Results: magnitude of environmental fluctuations

- Stabilizing effect increases with magnitude of environmental fluctuation.

![Graph showing the relationship between stabilizing effect and strength of environmental fluctuation.](image)
But magnitude of environmental fluctuations changes both mechanisms proportionally.
Results: differences in death rate

- The importance of relative nonlinearity increases with differences between adult death rates
Results: differences in death rate

- The importance of relative nonlinearity increases with differences between adult death rates.
Results: correlation between environmental responses

The importance of relative nonlinearity increases with the correlation between the environmental responses (synchrony between species).
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- The importance of relative nonlinearity increases with the correlation between the environmental responses (synchrony between species).
The importance of relative nonlinearity increases with species’ differences in sensitivity to environmental fluctuations.

- Common sensitivity to environment fluctuations
- Shorter-lived species has higher sensitivity
Results: Species specific sensitivities in environmental fluctuation

- Relative nonlinearity does not always stabilize coexistence
  - Stabilizes when shorter-lived species are more sensitive to environmental fluctuations
Results: Species specific sensitivities in environmental fluctuation

- Relative nonlinearity does not always stabilize coexistence
  - Destabilizes when shorter-lived species are less sensitive to environmental fluctuations
Conclusions about relative nonlinearity

- ‘Weaker’ mechanisms can be stronger, under narrow restrictions
  - mostly relative nonlinearity is weaker than the storage effect
- The increasing importance of relative nonlinearity is characterized by a weakening of the storage effect
- Relative nonlinearity can also easily be a destabilizing mechanism
  - The Storage effect plays a positive role much more often than relative nonlinearity
- Further research is needed to understand the full complexities of relative nonlinearity
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