Evolution of coexisting density compensation strategies in the Maynard Smith and Slatkin equation

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http://www.ufz.de/index.php?en=10623
Introduction: Niches, coexistence mechanisms and the paradox of the plankton

► Classic picture: Competitive exclusion -> Niche partitioning

► Problem: Often, several species appear to coexist within one niche
  ► Hutchinson ‘61 Paradox of the plankton
  ► Hubbel ‘01 - UNTB

► A number of equalizing/stabilizing mechanisms exist which are based on the spatio-temporal dynamics of resources / competitors
  ► E.g. storage effect, colonization-competition trade-offs

► Relative Nonlinearity of Competition
  ► Different relative competitive strength at different resource levels
  ► Huisman ‘99, Nature
The Maynard Smith-Slatkin model

Graphic from http://spongebob-plankton.tripod.com

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The Maynard Smith-Slatkin model

\[ N(t+1) = \frac{r \cdot N(t)}{1 + (r - 1)(N(t)/K)^b} \]

- Discrete time steps
  - Non-overlapping generations

- 2 free parameters r and b
  - Both act positively on growth
  - \( r/b \) combination determines shape
Properties of the MMS model

- For large r/b chaotic population dynamics
  - The larger r/b the stronger the fluctuations

- r/b determines reproductive success in fluctuating environments. Larger b mean
  - Higher average growth at low fluctuations
  - Lower average growth at high fluctuations

- Self-induced fluctuations and fluctuation-dependent growth may stabilize the coexistence of 2 or more different b/r strategies!

Münkemüller, T.; Bugmann, H. & Johst, K. 
Hutchinson revisited: Patterns of density regulation and the coexistence of strong competitors 
*Journal of Theoretical Biology, 2009, 259, 109-117*
Questions:

► Will evolution lead to coexisting strategies in the MMS equation?

► Are these coexisting strategies evolutionary stable?
Methods: Model description

► Individual-based

► Each individual has its own r/b strategy and reproduces according to the MMS equation

\[ N(t+1) = \frac{r \cdot N(t)}{1 + (r - 1)(N(t)/K)^b} \]

► Scheduling within one generation
  ► Reproduction (Poisson-distributed)
  ► Mutation of b (r, …) (small probability, normally distributed mutation)
  ► External disturbance (uniform)

Graphic from http://spongebob-plankton.tripod.com
Results: Coexistence and invasibility

Confirms the results of:
Münkemüller, T.; Bugmann, H. & Johst, K.
Hutchinson revisited: Patterns of density regulation and the coexistence of strong competitors
*Journal of Theoretical Biology, 2009, 259, 109-117*
Conclusion:
- Existence of coexisting b-strategies in the MMS model

Question:
- b subject to evolution, what is going to happen?
Evolution of $b$: ESS and the influence of disturbance

- Only one ESS
- Depends on $r$ and on the external disturbance
Other factors tested:

- Coevolution r/b
  - One ESS
  - Left skewed shape favored

- Intraspecific < interspecific competition
- Evolution of intraspecific competition and niches
  - At no costs, intraspecific competition is always disfavored
Conclusions

► For populations development governed by the MMS equation, relative nonlinearity of competition acts as stabilizing coexistence mechanism

► Coexistence only an intermediate state during evolution:
  ► Evolution towards one single ESS
  ► Depends on the disturbance regime
  ► Evolution is slow because of the stabilizing effect

► Possibilities for evolution to coexisting strategies:
  ► Physiological trade-offs
  ► Conjecture: Shifts in the disturbance regime on larger time/spatial scales may be sufficient to maintain coexistence