Evolving the Core Design Principles: Group Dynamics and the Emergence of Sustainability

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CSSSA 2013 - Santa Fe, NM

Supported by National Science Foundation award EPS-0904155 to Maine EPSCoR Sustainability Solutions Initiative.

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Motivation

Background

Elinor Ostrom

Courtesy of Indiana University.

Ostrom's Design Principles

1. Clear Boundaries: social and environmental
2. Fairness: proportionality between benefits and costs
3. Collective-choice
4. Monitoring
5. Graduated sanctions
6. Conflict resolution
7. Self determination
8. Nested governance

Ostrom, E. (1990). Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press.

What more do we need?

- Cooperation
- Change over time
- Resource dynamics
- Endogenous Institutions

Cultural Evolution

Cultural Evolution

- Boyd and Richerson, 1985, Culture and the Evolutionary Process, Chicago
- Cavalli-Sforza and Feldman, 1981, Cultural Transmission and Evolution. Princeton

The Evolutionary Recipe

- variation
- selection
- inheritance

Scales of Selection

A) natural selection (individuals)

B) kin selection (families)

C) sexual selection (partners)

D) group selection (groups)

E) multilevel selection (all of the above)

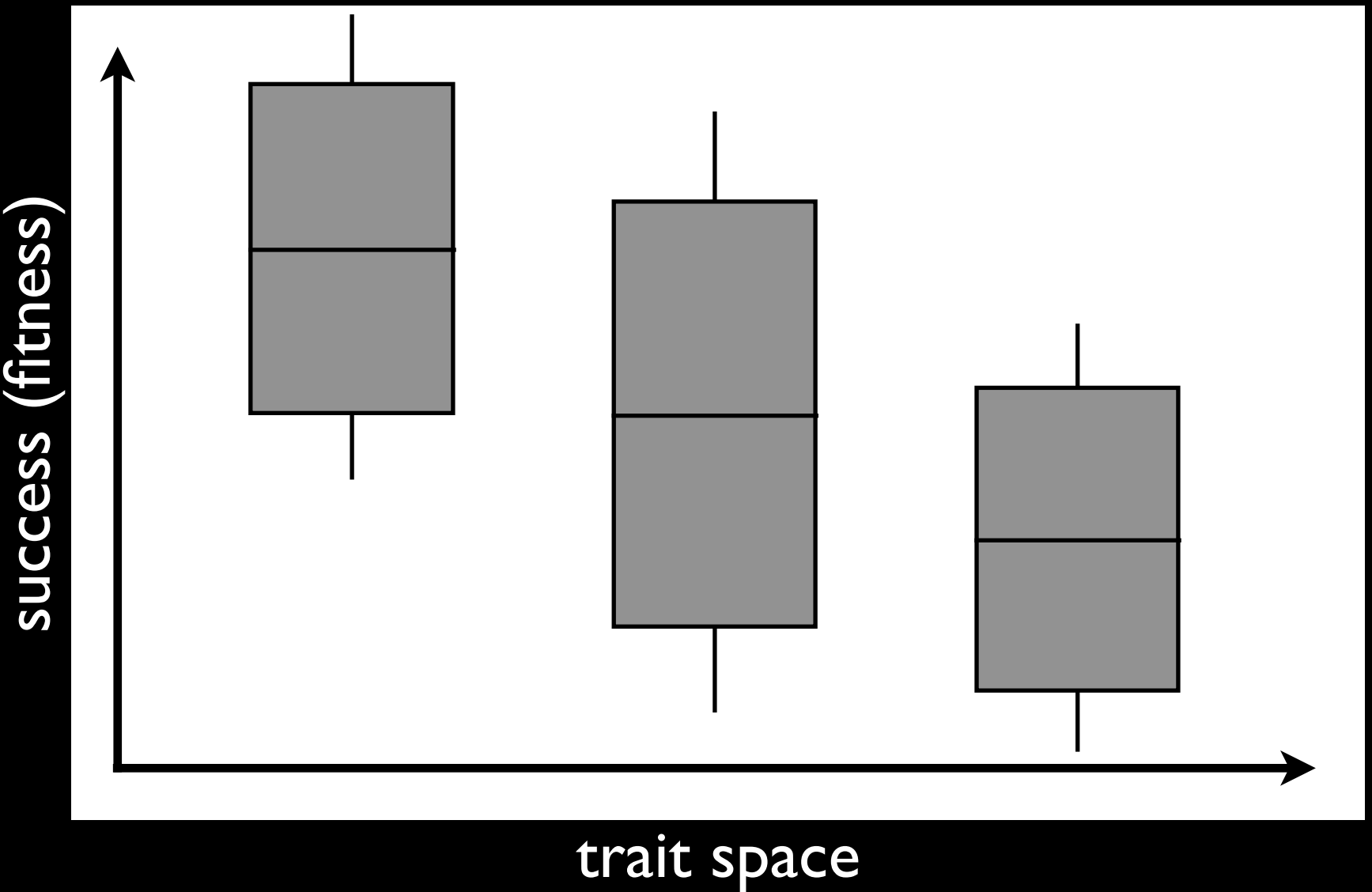
Institutions Evolve

- Sethi, R., & Somanathan, E. (2000). The evolution of social norms in common property resource use. *American Economic Review*, 86, 766-788.*s*
- Ostrom, E. (2000). Collective action and the evolution of social norms. *Journal of Economic Perspectives*, 14, 137-158.
- Bowles, S., Choi, J.-K., Hopfensitz, A., 2003. The co-evolution of individual behaviours and social institutions. *Journal of Theoretical Biology*, 223, 135–147

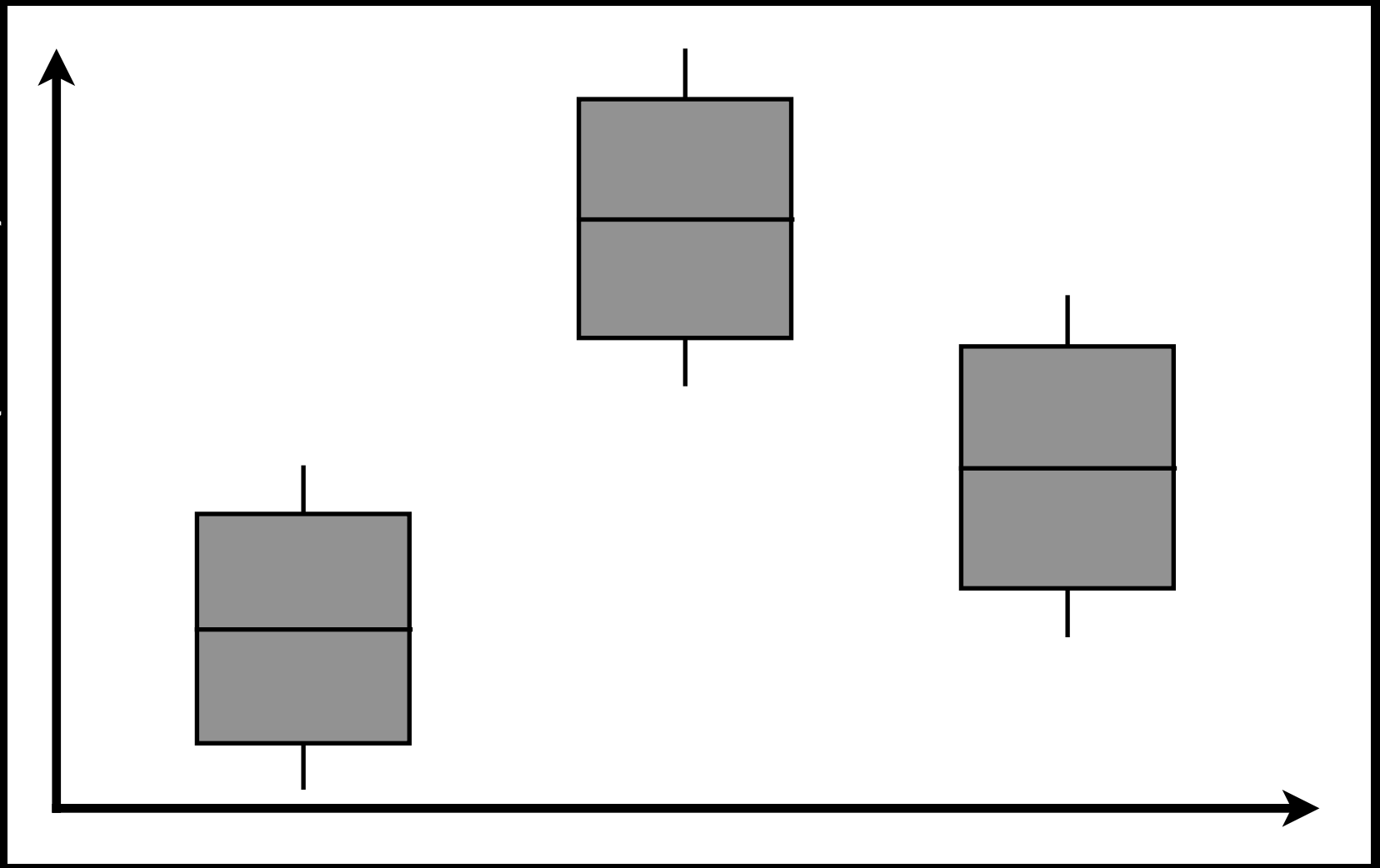
Institutions evolve by multilevel selection

- Henrich, J., 2004. Cultural group selection. Co-evolutionary process and large-scale cooperation. *J. Econ. Behav. Organ.* 53, 85–88.
- Traulsen, A., Nowak, M.A., 2006. Evolution of cooperation by multilevel selection. *PNAS* 103, 10952–10955.
- Van den Bergh, J., & Gowdy, J. M. (2009). A group selection perspective on economic behavior, institutions and organizations. *Journal of Economic Behavior and Organization*, 72, 1-20.

Group Selection as ANOVA



Group Selection as ANOVA



Group Selection Works

160% increase in clutch size

Muir, W., 1996. Group selection for adaptation to multiple-hen cages: selection program and direct responses. Journal of Poultry Science 75, 447–458.

Posted to Flickr by USDAgov at http://flickr.com/photos/41284017@N08/6354331371

Group Selection Works

increased cannibalism in flour beetles

Wade, M., 1976. Group selection among laboratory populations of Tribolium. Proceedings of the National Academy of Science 73, 4604–4607.

Group Selection Works

Human cooperation is group-centric

Apicella, Marlowe, Fowler & Christakis, (2012) Nature 481, 497–501.

Public Goods Experiments

- Gürerk, Irlenbusch, & Rockenbach (2006) subjects "voted with their feet" and migrated to punishment institution.
- Puurtinen and Mappes (2009) groups compete, winning group extracts earnings from losing group. Group competition enhanced cooperation.
- Sääksvuori, Mappes, & Puurtinen (2011) punishment produces higher individual and group payoffs during competition, but punishing groups had more equal payoff distribution.
- Tan and Bolle (2007) found that cooperation increased due to competition with and without incentives to win

Molly Hayden, U.S. Army Garrison Grafenwoehr Public Affairs
http://www.army.mil/article/69655/

Choi, Bowles, 2007. The coevolution of parochial altruism and war. *Science* 318, 636–640.

The Battle of Agincourt.
http://www.britishbattles.com/100-years-war/agincourt.htm

→Group-competition accelerates cooperation.

Can it drive more sustainable outcomes?

Research Question

- Can cultural group selection accelerate the emergence of institutions of sustainable resource management?

Epstein's Postulate

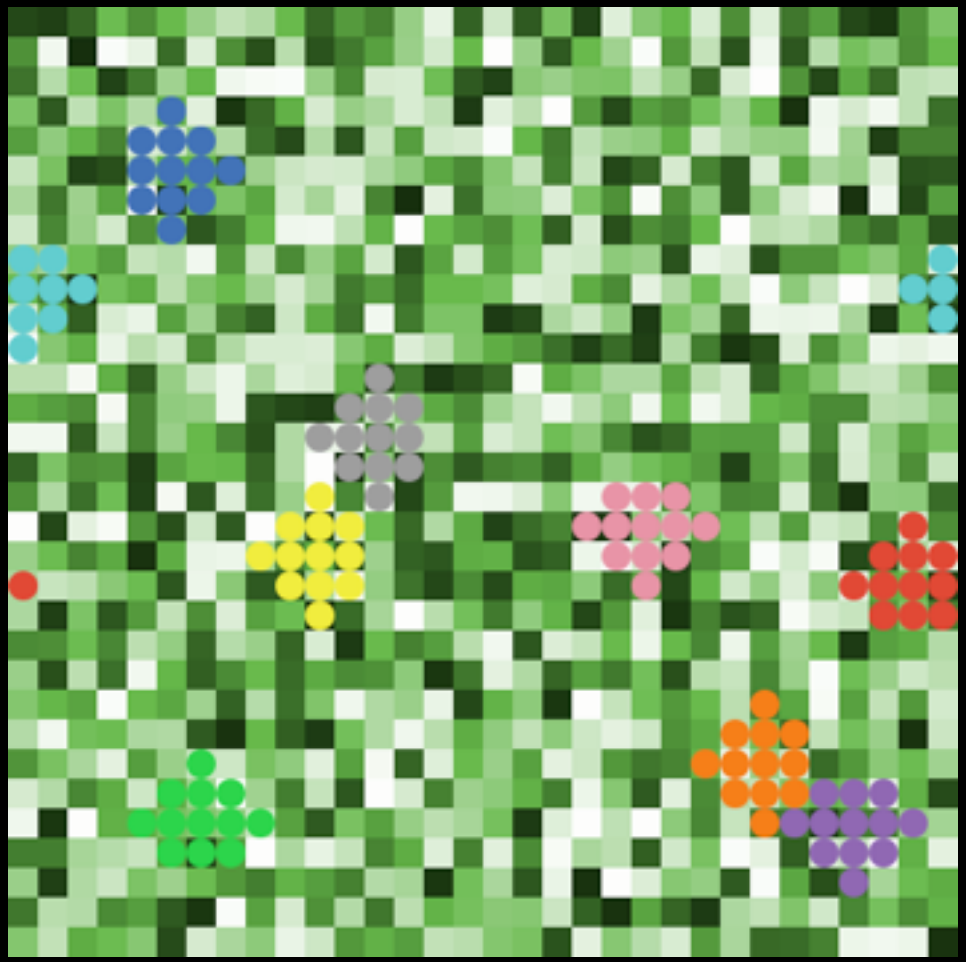
$$(\forall x)(\neg Gx \supset \neg Ex)$$

where x is an emergent phenomenon,
for all x, not generating x implies not explaining x

- Or: if you can't generate it, you don't understand it.

Epstein (2006). Generative social science: Studies in agent-based computational modeling. Princeton.

Model Design



- simple agents (no choice, strategy)
- endogenous institutional evolution
- with success-biased imitation
- limited resources
- free-riding
- track selection at both individual and group levels

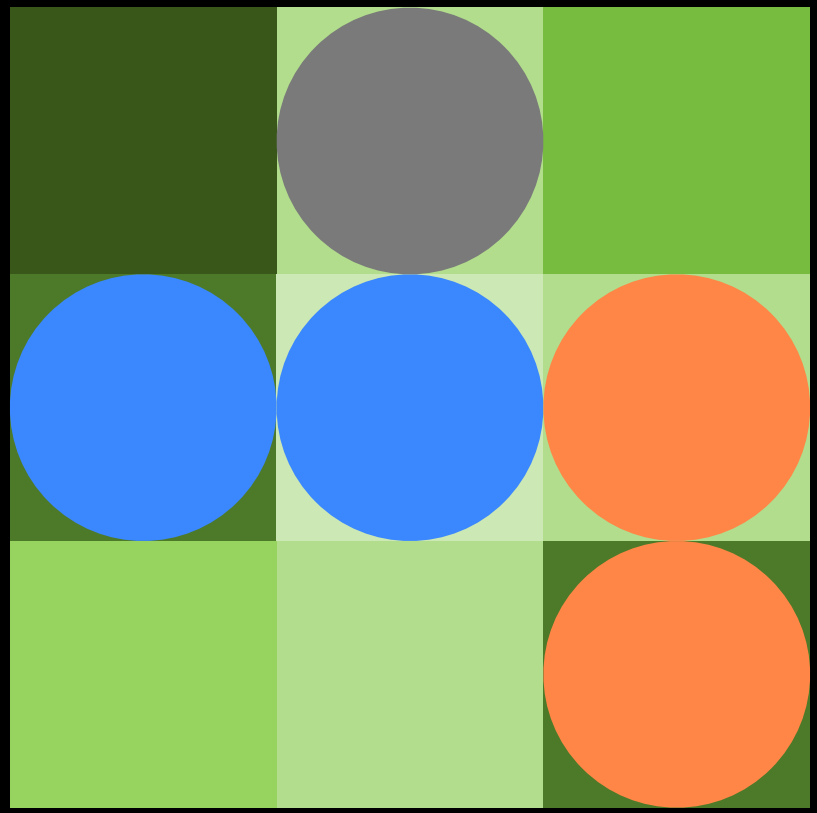
Model Design

- Agents:
  - Harvest renewable resources with carrying capacity and MSY
  - Pay costs of living, C_L and reproduction, C_R
  - Vertical inheritance of parental traits
  - Imitate successful peers

Social Norms

- Boundary Defense (property - Ostrom Principle #1)
  - costly to protect resources
- Cooperative Economic Production (dyadic public goods game with harvested resources)
  - cooperation dilemma

Flexible Property



Agent Traits

Status
(location, wealth, neighbors, local resources)
Harvest norms
(low, high)
Property rights norm
(private, group, open)
Cooperative economic production norm
(no one, group, anyone)
Group marker
(0-9)

Simulation Process

1) Patch defense
2) Harvesting
3) Production
4) Pay cost of living
5) Death
6) Reproduction
7) Migration
8) Imitation
9) Patch growth
10) Aging
11) Cap resources

Hypotheses

1. When conservation is costly, sustainable resource management requires social institutions (sharing and boundary defense).
2. When conservation, sharing, and boundary defense are ALL costly, they require group selection to emerge and persist.
3. For group-level selection to occur, social group markers must be present.

Experimental Treatments

Allow evolution only certain cultural traits.

Table 2. Simulation treatment conditions and hypothesis tests.

#	Treatment	Production	Property	Markers	Hypothesis
1	no norms			Y	1
2	no property	Y		Y	1
3	no production		Y	Y	1
4	both norms	Y	Y	Y	1, 2, 3
5	no markers	Y	Y		3

1000 time steps, 1000 runs for each treatment

Price Equation

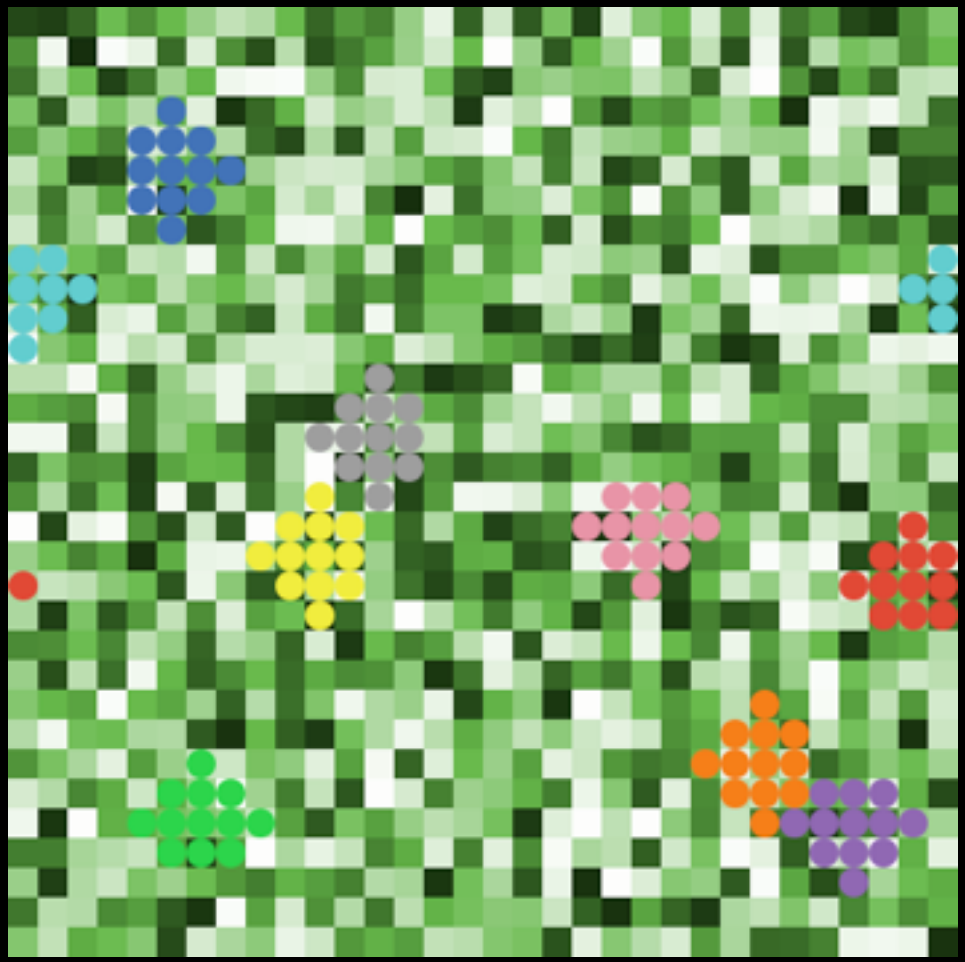
$$\overline{w}\Delta\overline{z} = Cov(w_i, z_i) + E(w_i \Delta z_i)$$

The Price equation is a general statement about the statistical requirements for evolution (Frank 1995). expressed as where w is fitness, and z is the trait under selection across individuals i.

$$\overline{w}\Delta\overline{z} = \underbrace{Var(z_g) \cdot \beta(w_g, z_g)}_{\text{group selection}} + \underbrace{E[Var(z_{ig}) \cdot \beta(w_{ig}, z_{ig})]}_{\text{individual selection}}$$

The multi-level extension of the price equation for individuals i and groups g (McElreath & Boyd 2007).

Initial Conditions



Results

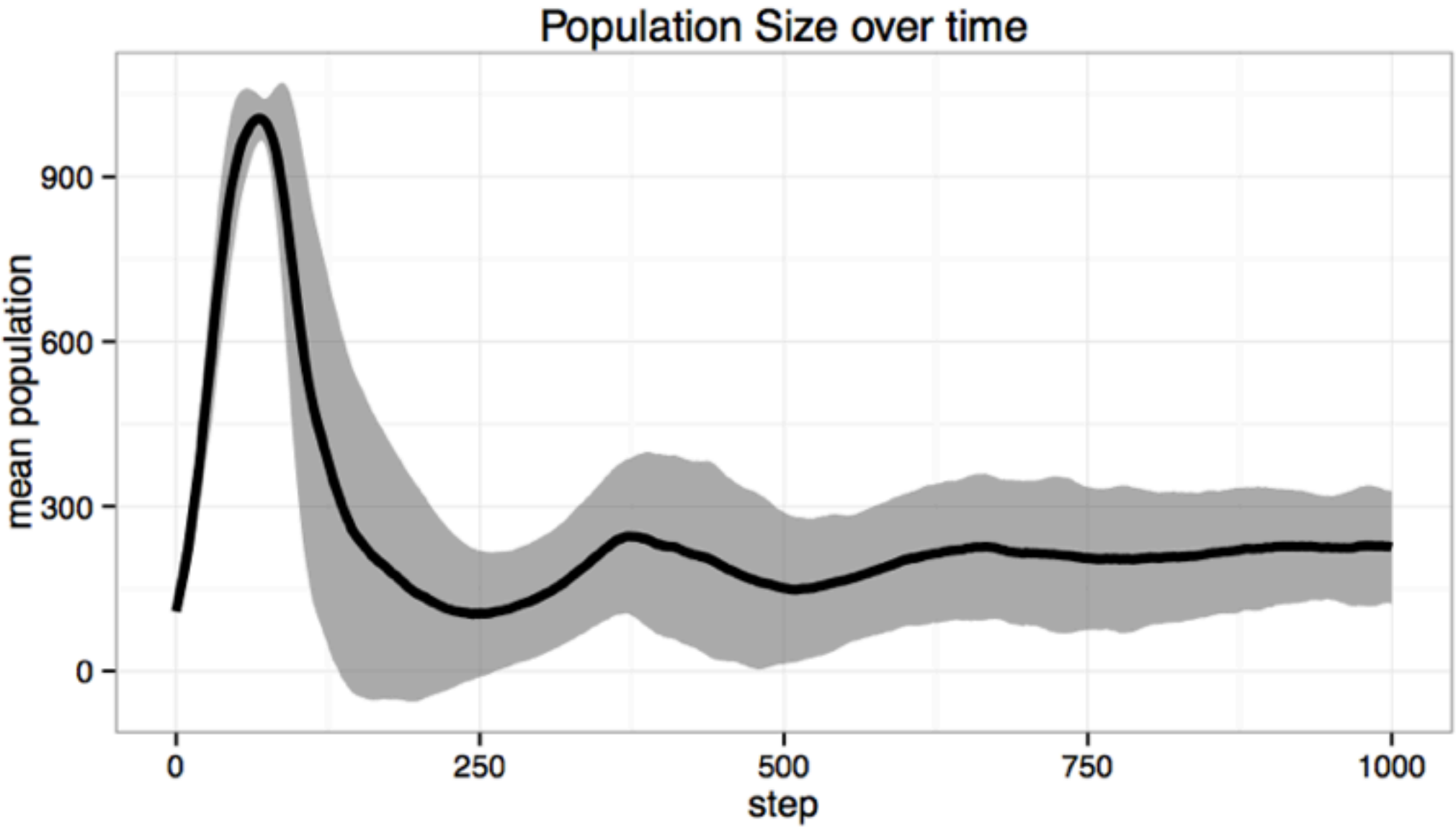


Fig. 1. Simulated populations undergo an initial boom and bust in all conditions. (1000 simulation mean ± SD)

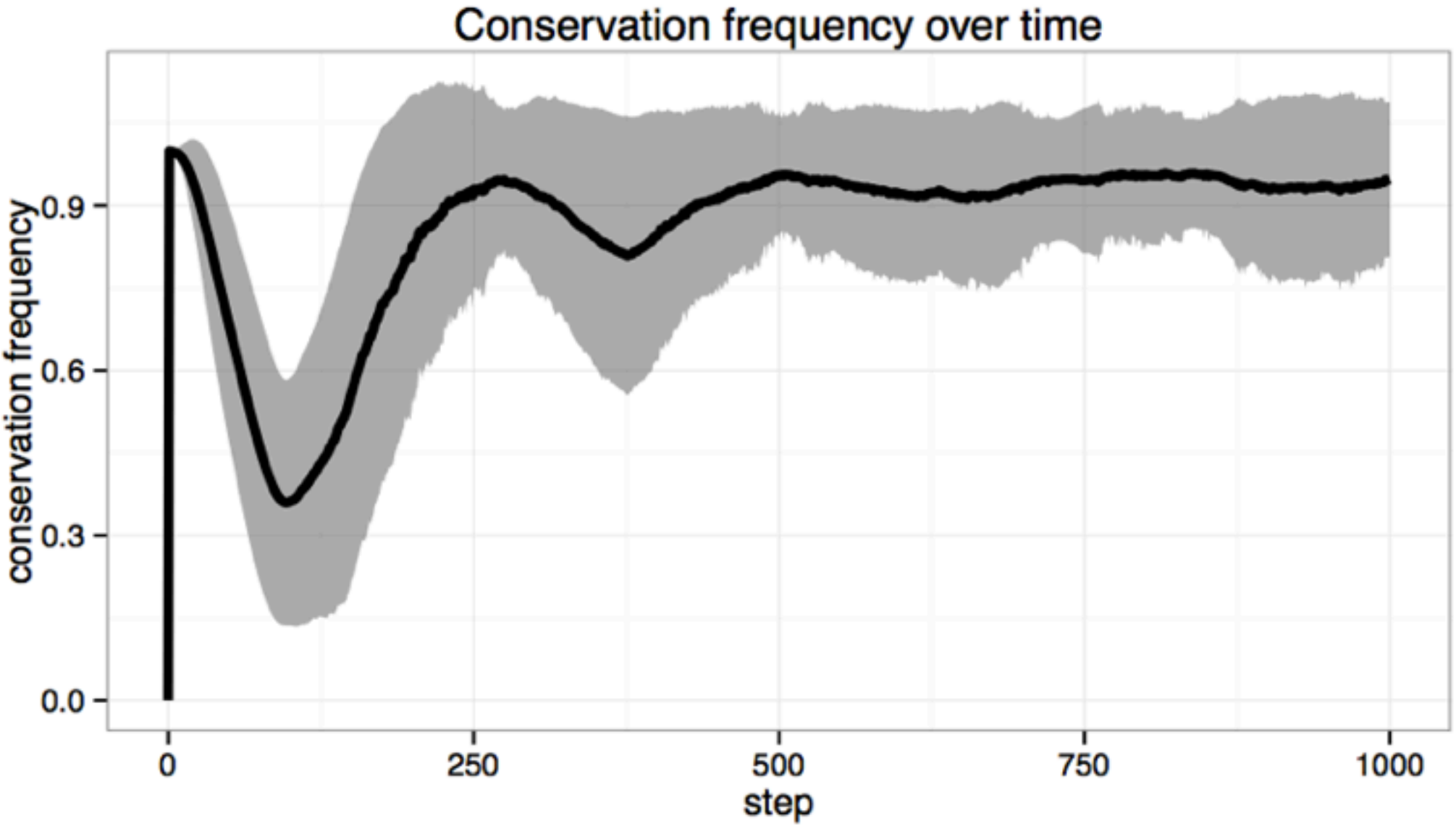
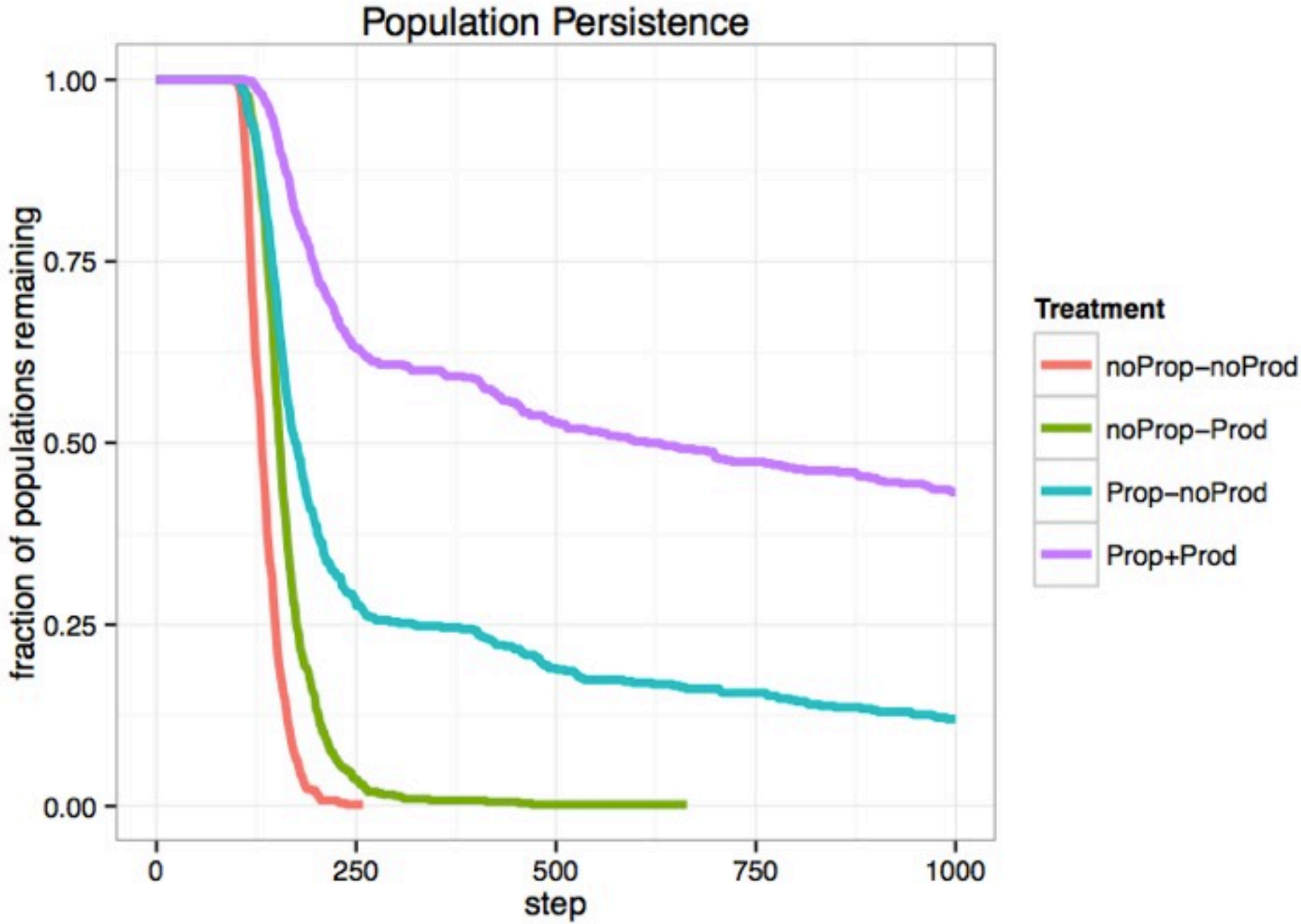
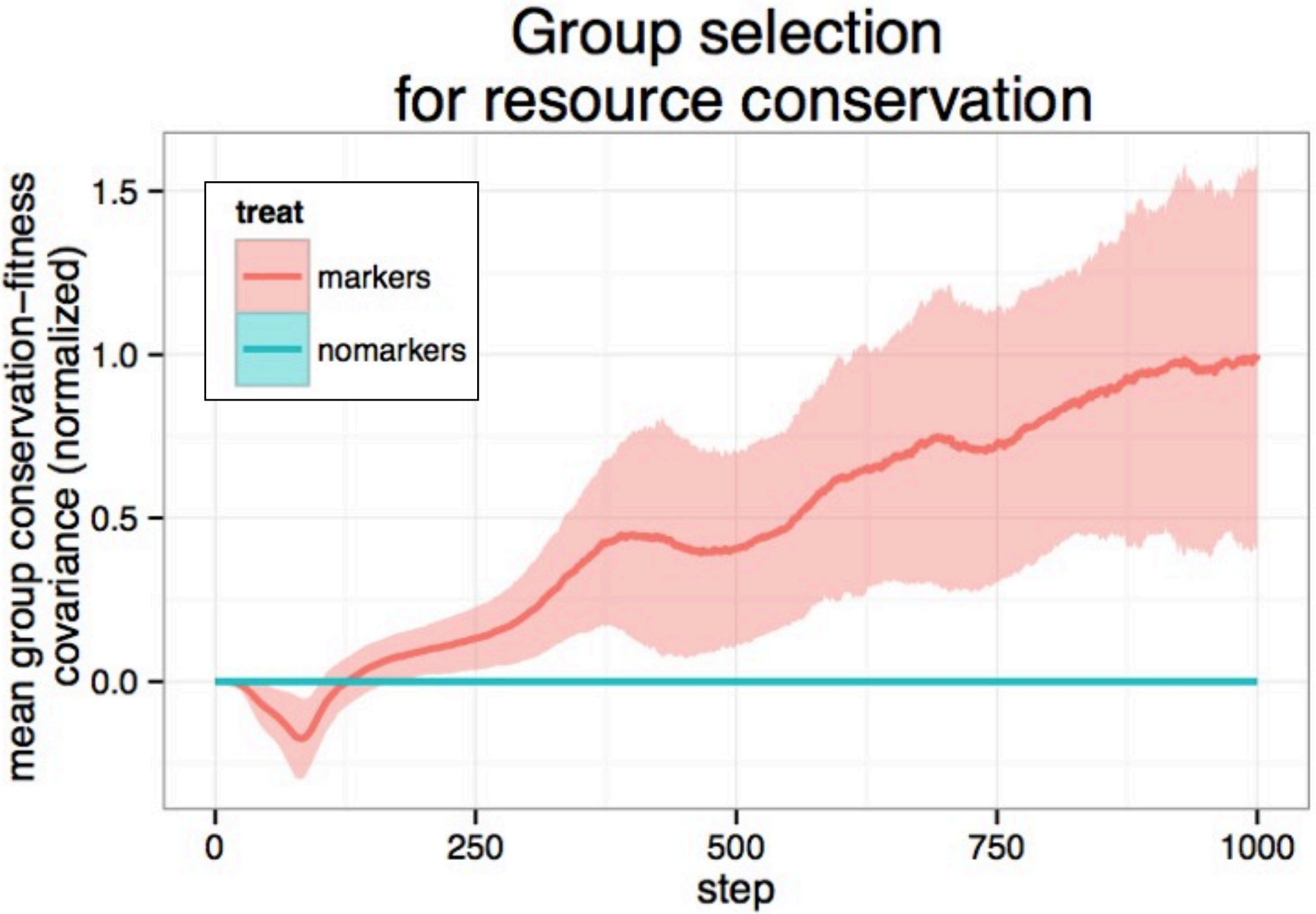
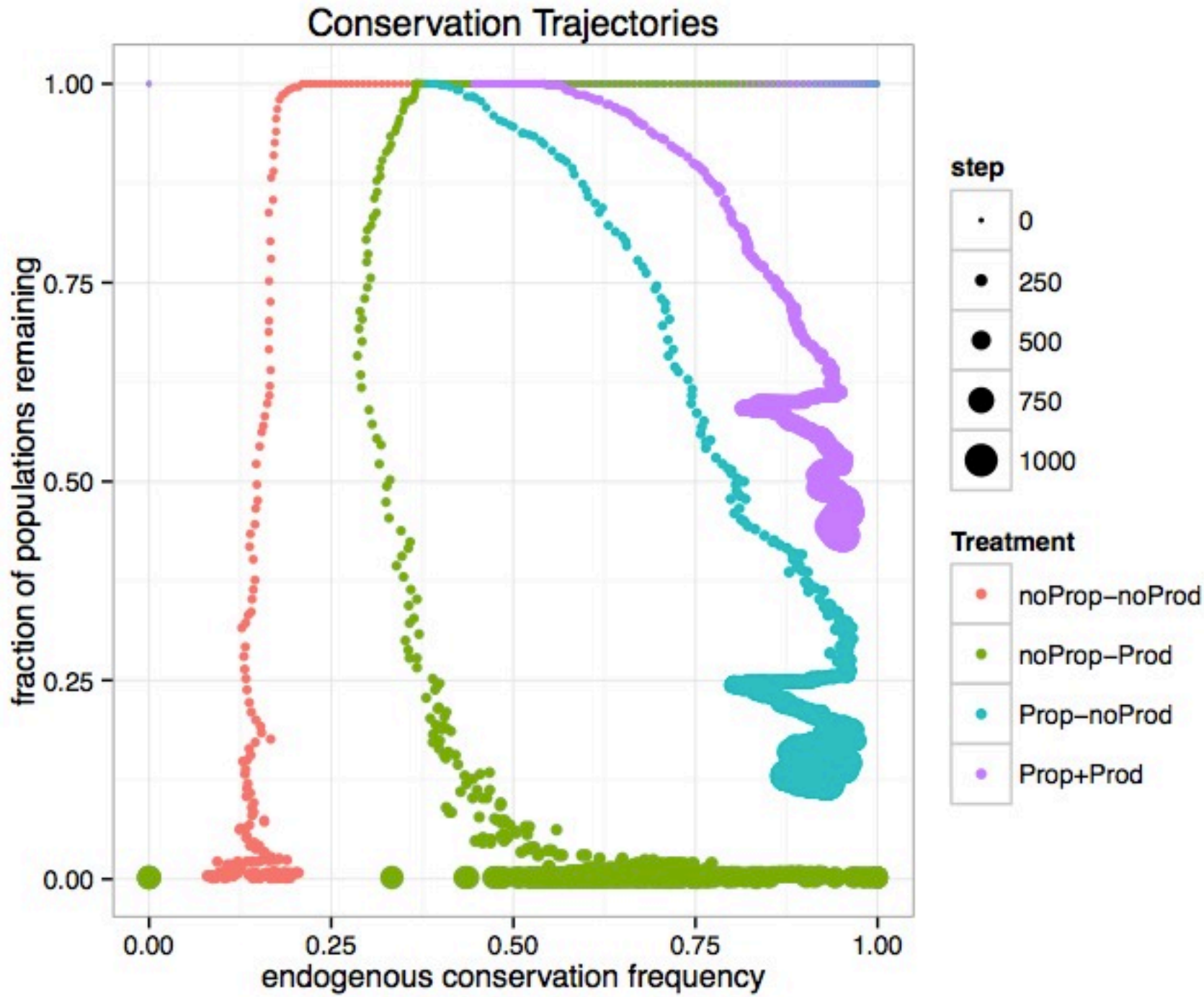


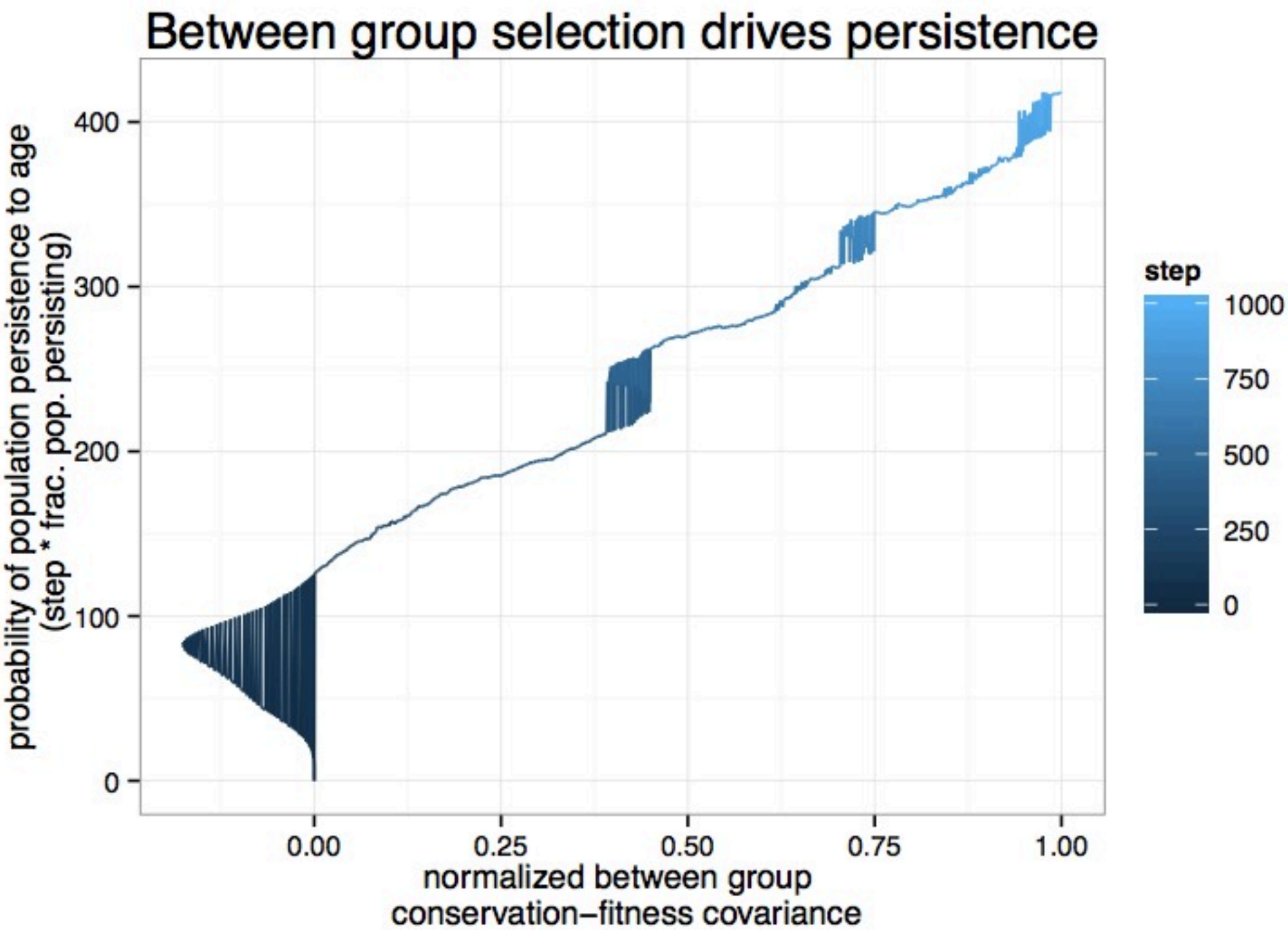
Fig. 2. Conservation frequency grows to high levels in populations that persist. (1000 simulation mean ± SD)



Populations persist when the norms of property and production are allowed to evolve.


Group selection
for resource conservation
mean group conservation–fitness
covariance (normalized)
1.5
1.0
0.5
0.0
treat
markers
nomarkers
0
250
500
750
1000
step


Conservation Trajectories
fraction of populations remaining
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
endogenous conservation frequency
step
0
250
500
750
1000
Treatment
noProp−noProd
noProp−Prod
Prop−noProd
Prop+Prod


Between group selection drives persistence
probability of population persistence to age
(step * frac. pop. persisting)
400
300
200
100
0
0.00
0.25
0.50
0.75
1.00
normalized between group
conservation−fitness covariance
step
1000
750
500
250
0

Summary

1. Group level selection requires social marking (no surprise)
2. Group level selection can drive the emergence of sustainable institutions (societies)
3. Population persistence varies with institutional adoption (none < production < property < both)

Conclusions

- The Cultural Multi-Level Selection Framework is a useful framework for studying the emergence of and persistence of sustainable institutions.
- Group-Level Selection of Cultural Traits drives cooperative institutional evolution.

Further Analysis

- Add more institutional features and Ostrom principles.
- Change & test parameters: returns to cooperation, property defense costs, imitation strategies
- Explore new stylized ecological conditions (working group)

Thank You!

Questions?