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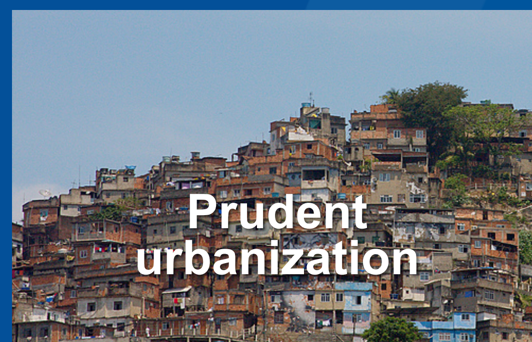
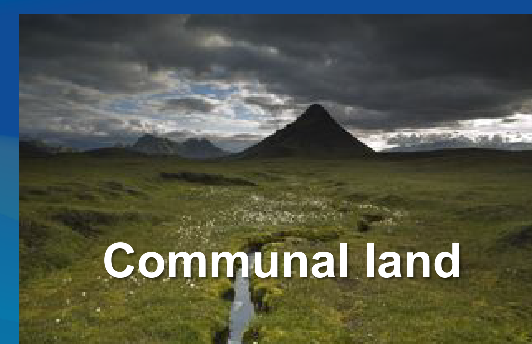
Features of Complex Adaptive Systems

1. Rapid adaptation
2. Codependent agents
3. Emergent phenomena
4. Tipping points
5. Self-organized criticality
6. Social dilemmas
7. Stakeholder diversity

6 Social Dilemmas

Common Goods and Social Dilemmas





7 Stakeholder Diversity

Approaches for Social Planners

When agents are heterogeneous, social planners can

- Analyze stakeholder impacts
- Optimize for one stakeholder
- Promote compromise across stakeholders
- Optimize across stakeholders

FISH and FISHERIES

FISH and FISHERIES, 2013, **14**, 554–579

Fish life history, angler behaviour and optimal management of recreational fisheries

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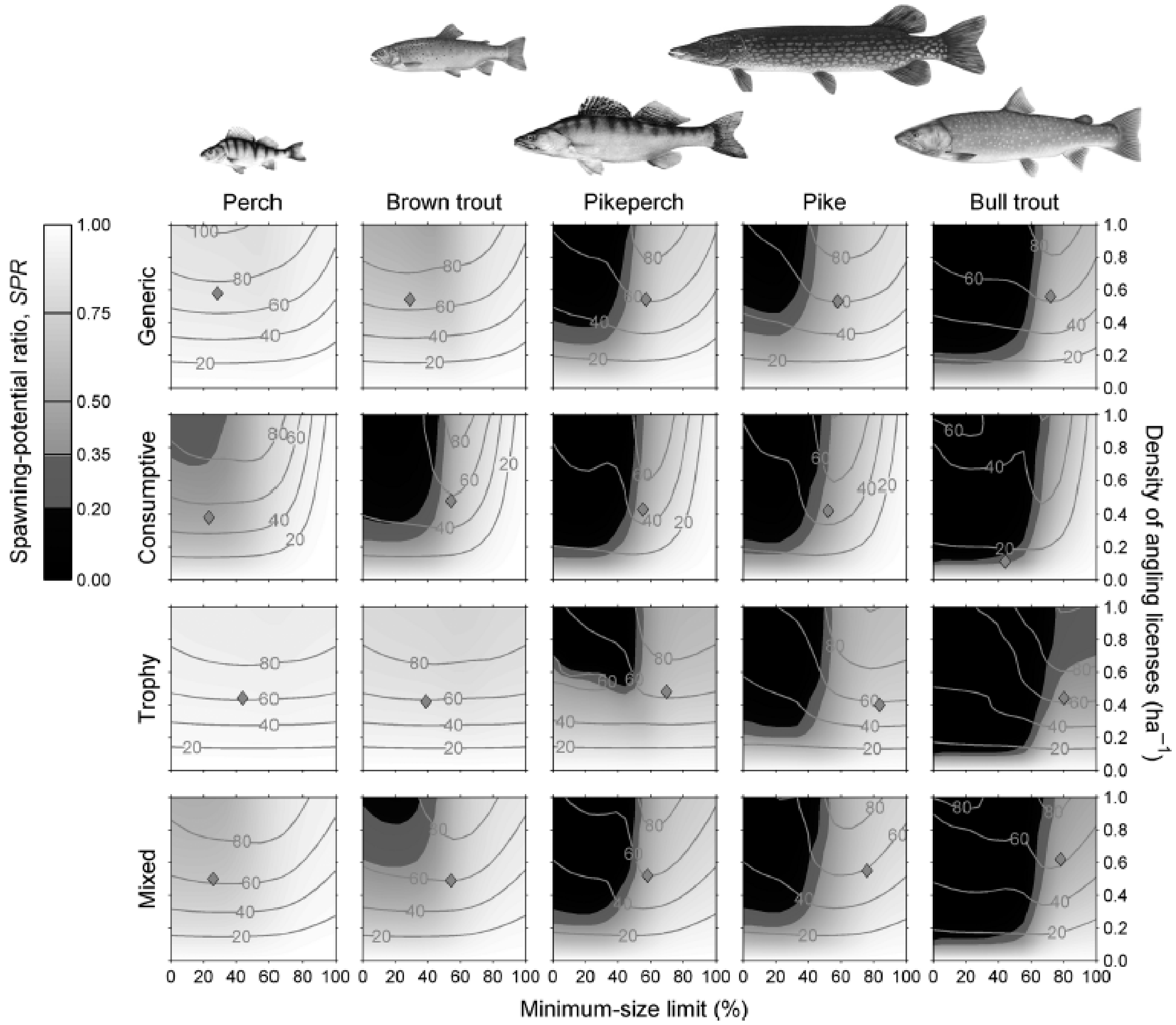
Three Angler Types

	Angler types		
	Generic	Consumptive	Trophy
Fishing preferences			
Importance of fishing to lifestyle	•	●	⬤
Tolerance of minimum-size limits	●	•	⬤
Tolerance of license costs	•	●	⬤
Interest in catch rates	●	⬤	•
Interest in the challenge of catching fish	•	●	⬤
Interest in average fish size	•	●	⬤
Interest in trophy-sized fish	●	•	⬤
Tolerance of crowding	⬤	●	•
Fishing practices			
Skill level	•	●	⬤
Propensity to perform voluntarily catch-and-release	●	•	⬤
Size of fish targeted by fishing gear	●	●	⬤

Different Impacts of Three Angler Types

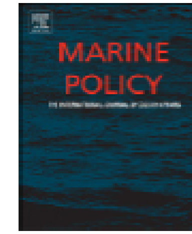


Marine Policy 39 (2013) 172–181

Contents lists available at SciVerse ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol



A bio-economic analysis of harvest control rules for the Northeast Arctic cod fishery

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ARTICLE INFO

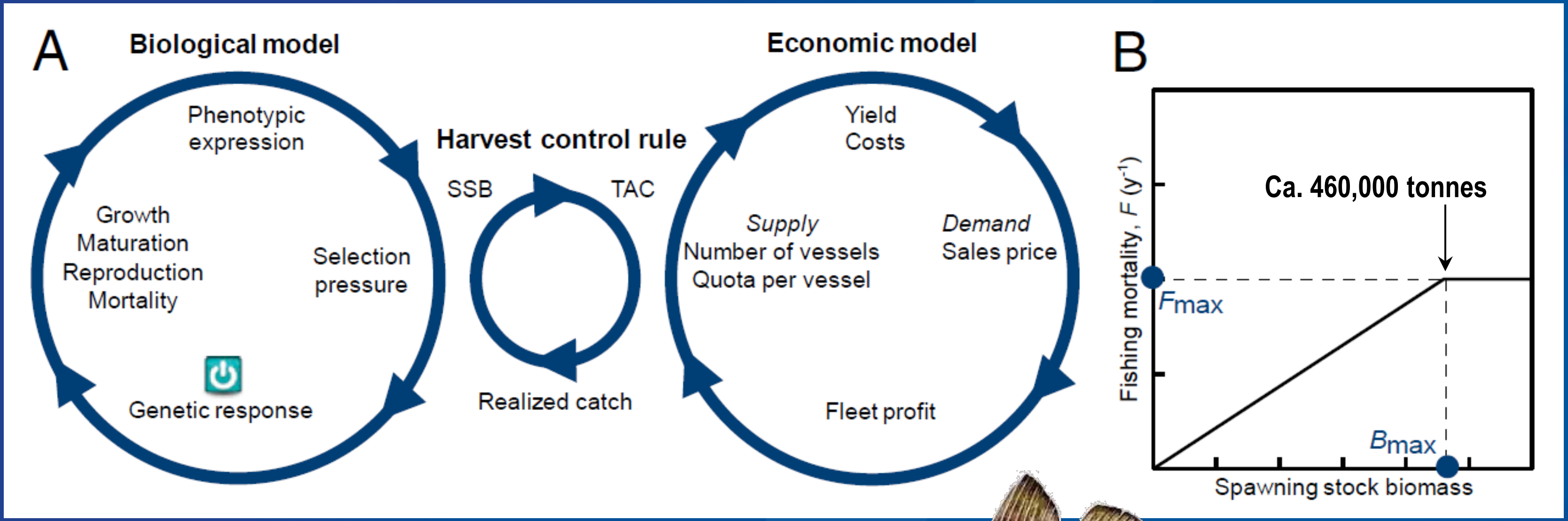
Article history:
Received 13 October 2011
Received in revised form
21 May 2012
Accepted 14 October 2012
Available online 12 December 2012

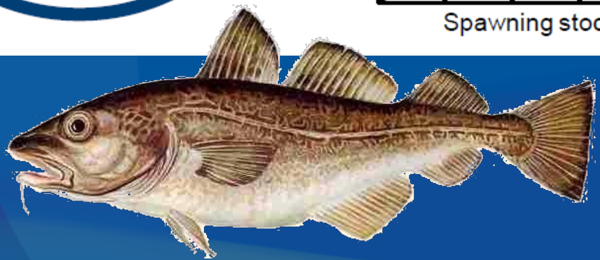
Keywords:
Fisheries
Spawning stock biomass
Profit
Harvest control rule
Optimal management
Feedback control

ABSTRACT

Harvest control rules (HCRs) have been implemented for many fisheries worldwide. However, in most instances, those HCRs are not based on the explicit feedbacks between stock properties and economic considerations. This paper develops a bio-economic model that evaluates the HCR adopted in 2004 by the Joint Norwegian–Russian Fishery Commission to manage the world's largest cod stock, Northeast Arctic cod (NEA). The model considered here is biologically and economically detailed, and is the first to compare the performance of the stock's current HCR with that of alternative HCRs derived with optimality criteria. In particular, HCRs are optimized for economic objectives including fleet profits, economic welfare, and total yield and the emerging properties are analyzed. The performance of these optimal HCRs was compared with the currently used HCR. This paper show that the current HCR does in fact comes very close to maximizing profits. Furthermore, the results reveal that the HCR that maximizes profits is the most precautionary one among the considered HCRs. Finally, the HCR that maximizes yield leads to un-precautionary low levels of biomass. In these ways, the implementation of the HCR for NEA cod can be viewed as a success story that may provide valuable lessons for other fisheries.

Integrated Bioeconomic Model

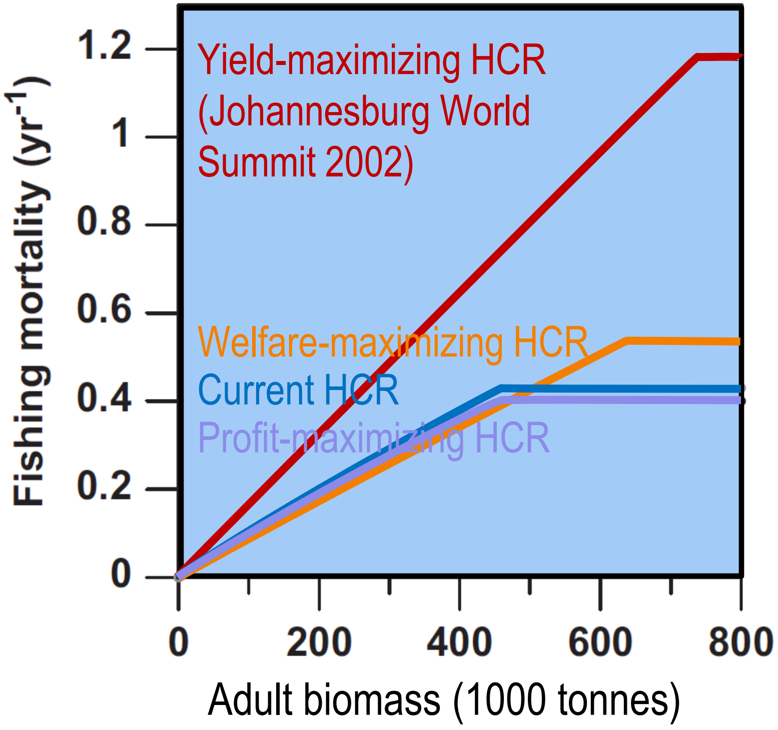




Northeast Arctic cod

Derived Harvest Control Rules

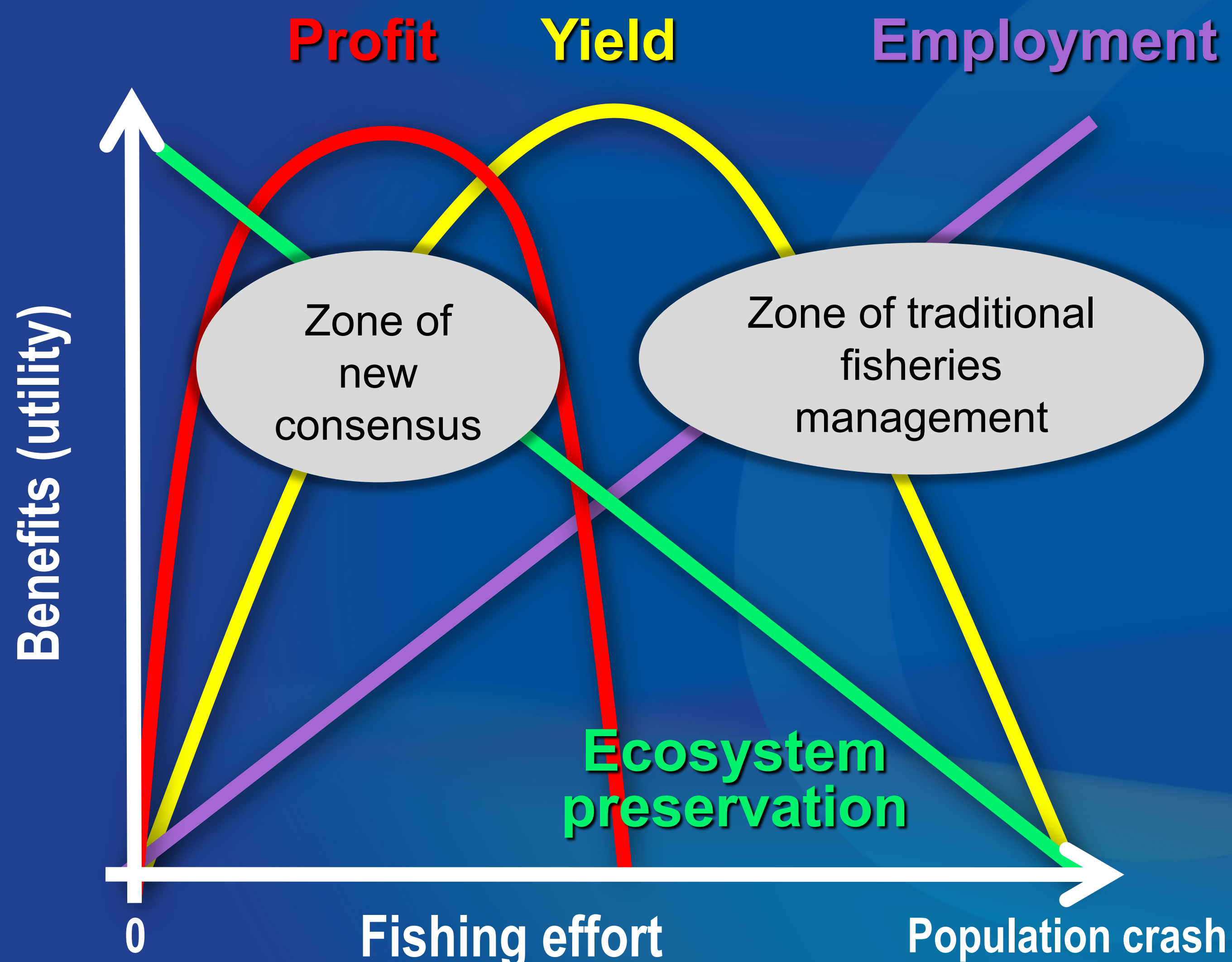
- Harvest-control rules are politically negotiated without support from quantitative modeling
- Our assessment is process-based, couples an individual-based biological model with an economic model, and accounts for three alternative objectives
- Current rule maximizes profit, while alternative objectives lead to more aggressive exploitation



Results Summary

- Current HCR comes very close to profit-maximizing HCR
- Yield-maximizing HCR leads to un-precautionary low biomasses
- Profit-maximizing HCR is more precautionary than current HCR, yield-maximizing HCR, and welfare-maximizing HCR
- Optimal HCR implies taking 50% less fish: making this cut and waiting for the stock to rebuild could lead to sustainable yields over 30% greater than today

Hilborn 2007: “Zone of New Consensus”



Integrated Assessment

1. Biological model

Northeast Arctic cod,
Barents Sea capelin

2. Socio-economic model

Fleet costs, revenues, and effort-employment relationships estimated from profitability surveys by the Norwegian Fisheries Directorate

3. Stakeholder model

Heterogenous preferences

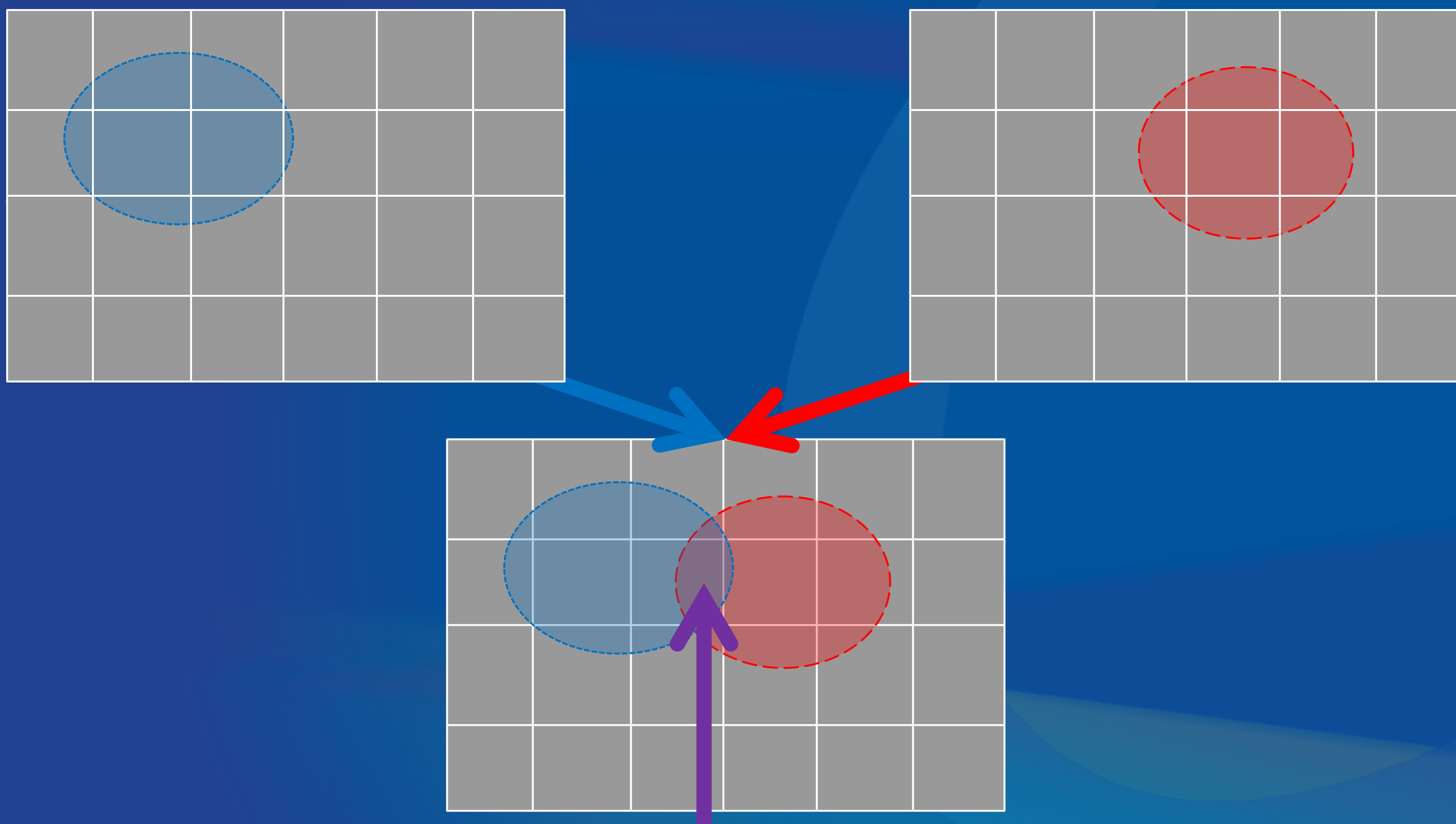
Stakeholder Preferences

	Yield	Employ-ment	Profit	Preser-vation
Industrial fishers	30%		70%	
Artisanal fishers	50%	10%	10%	30%
Employment-oriented community	20%	50%		30%
Profit-oriented community	20%		60%	20%
Conservationists	10%	20%	20%	50%

Mapping the Zone of Consensus

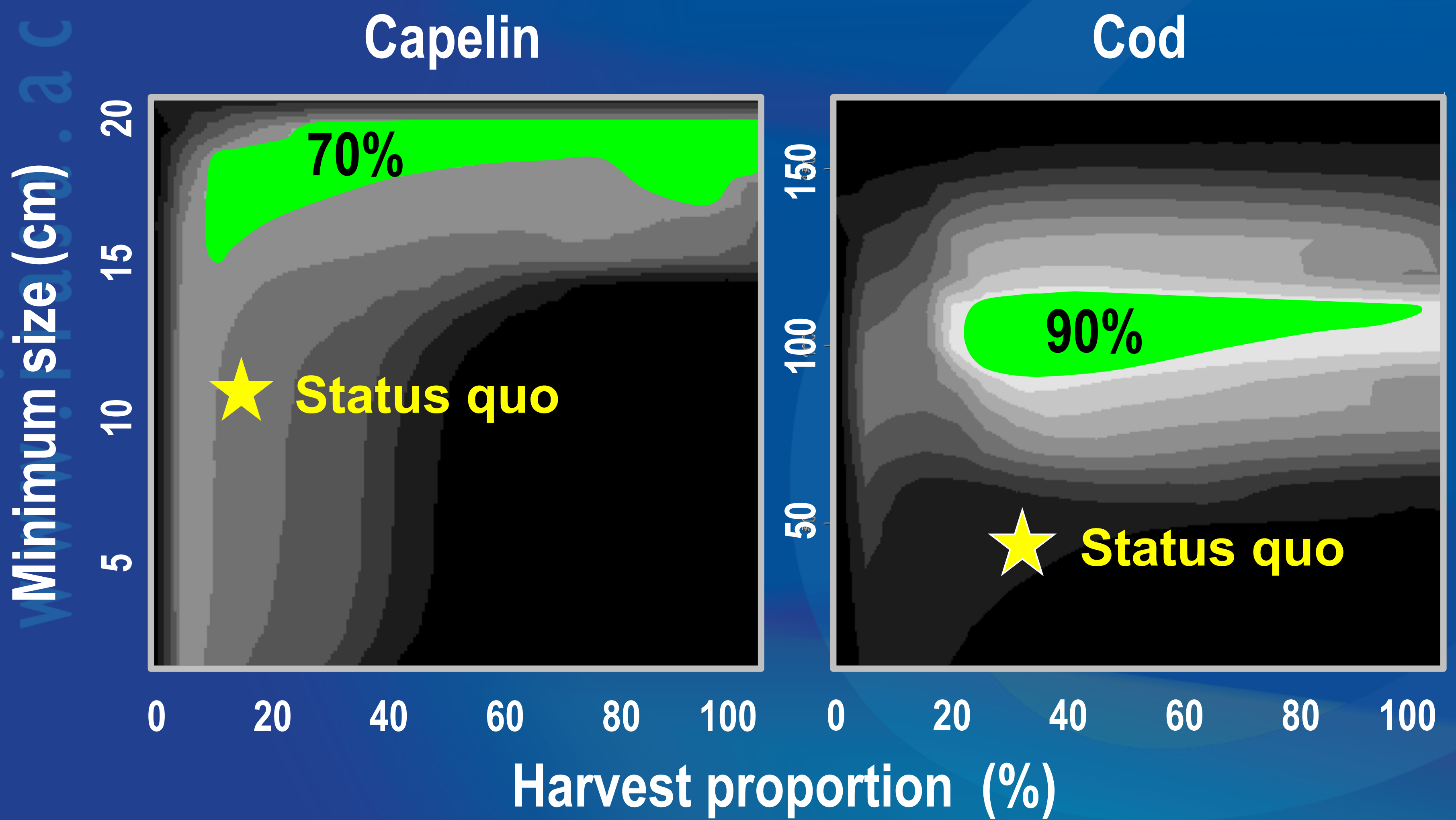
Stakeholder A

Stakeholder B



Area of joint satisfaction: Consensus most likely

Mapping the Zone of Consensus



Conclusions

- Complex adaptive systems are ubiquitous
- Conceptual and methodological commonalities can facilitate their understanding
- Recognition of these commonalties can help avoid pitfalls in managing complex adaptive systems
- Systems thinking is key for addressing most contemporary global or universal challenges

Modeling Complex Adaptive Systems at the Interface of Ecology and Evolution

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Director, Evolution and Ecology Program

International Institute for Applied Systems Analysis

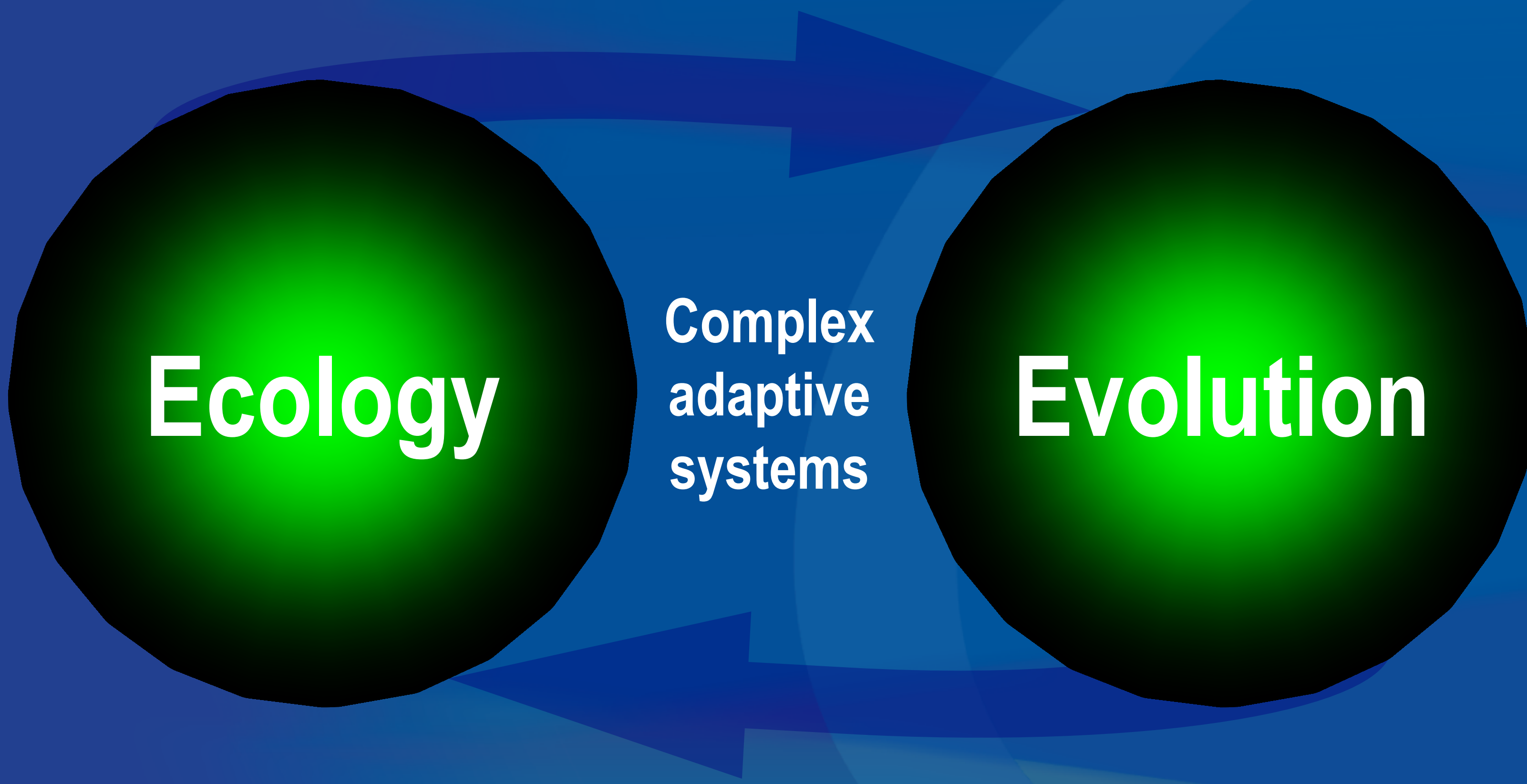
Laxenburg, Austria

Managing Living Systems

In many contexts, we need to understand and manage living systems, including their interactions with anthropogenic environmental changes:

- Conservation ecology
- Biodiversity management
- Sustainable exploitation
- Disease and pest control
- Landscape planning
- Design of regulations and incentives
- And several other areas…

Dynamics of Living Systems



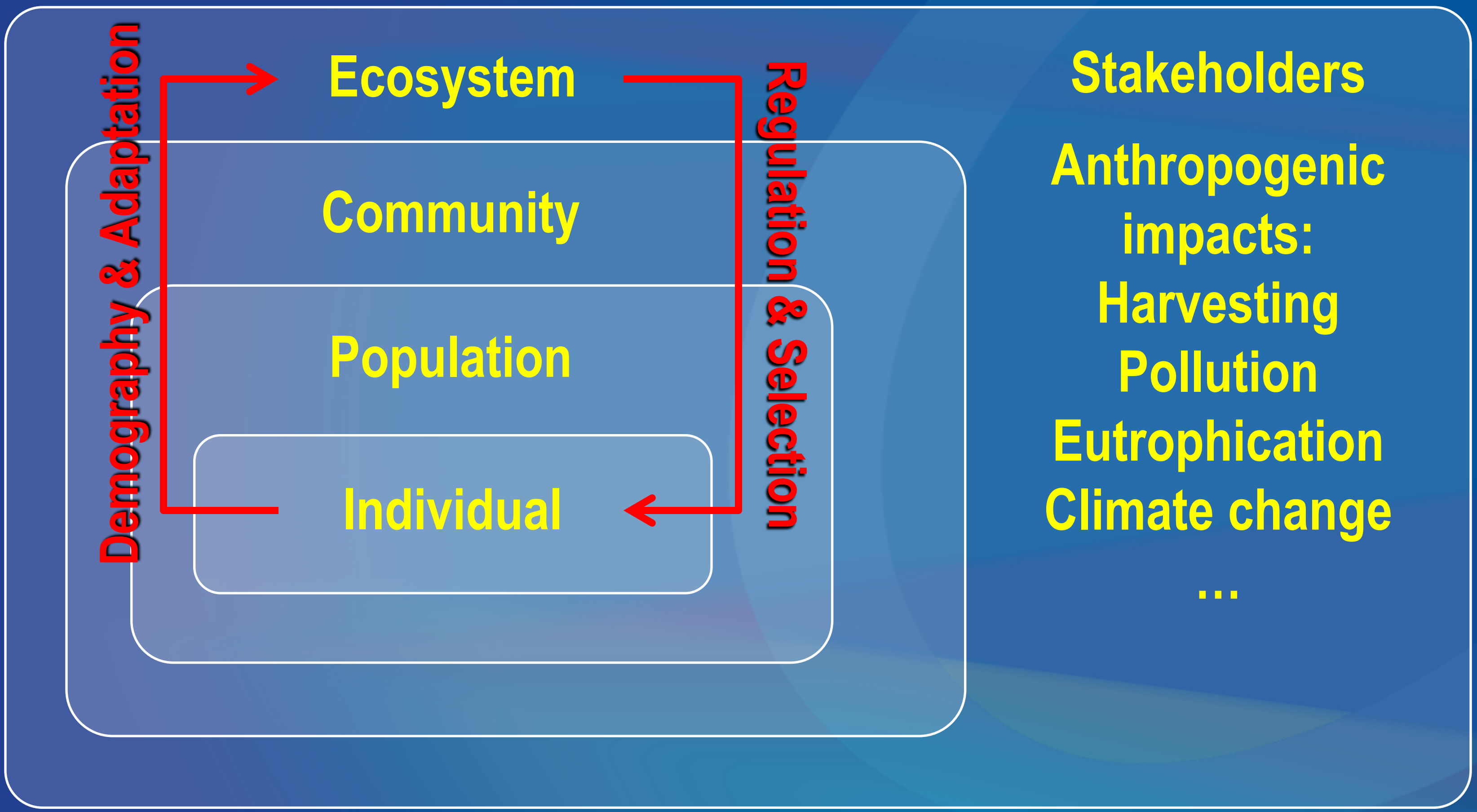
Changes in numbers

Changes in heritable features

An Inexorable Link

- “The ecological theatre and the evolutionary play” (Hutchinson 1965)
- “Evolution is ecology in action” (Krebs 1985)
- Ecological dynamics determine all natural selection pressures
- Evolutionary dynamics shape all natural ecological settings

Levels of Complexity



Need for Eco-Evolutionary Models

- **Derive** species- or ecosystem-level predictions from individual-level processes
- **Explain** ecological structures
- **Identify** evolutionary mechanisms
- **Understand** eco-evolutionary feedbacks
- **Forecast** rapid evolution

Overview

Eco-Evolutionary Dynamics

Modelling Frameworks

Biodiversity Dynamics

Mathematical Connections

Adaptive Speciation

Niche Theory

1 Eco-Evolutionary Dynamics

Three Common Misperceptions

- **Biological evolution is always slow**

  On the contrary, rapid contemporary evolution is widespread, in particular in response to anthropogenic environmental change

- **Biological evolution is always optimizing**

  On the contrary, selection operates at the individual level, implying that population-level features will rarely get optimized by evolution

- **Biological evolution is always leading to stable outcomes**

  On the contrary, feedbacks between adaptations and selection pressures can cause cyclic evolution, or other types of persistent adaptations

1a

Evolution can be rapid

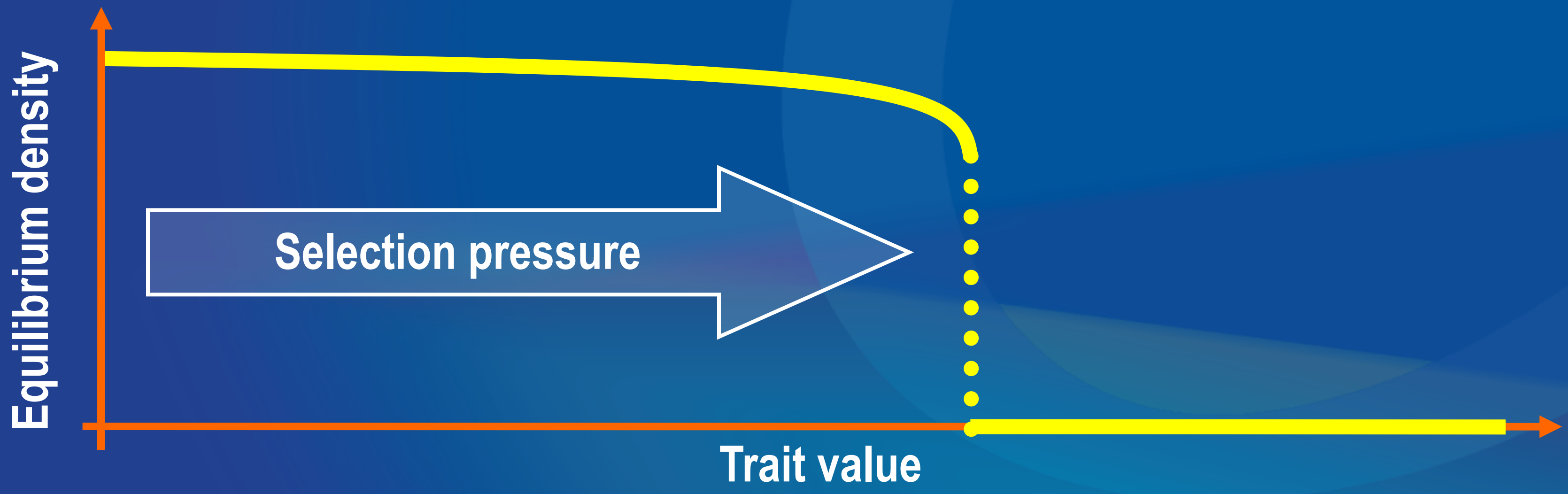
1b

Evolution can be non-optimizing

Selection-driven Extinction

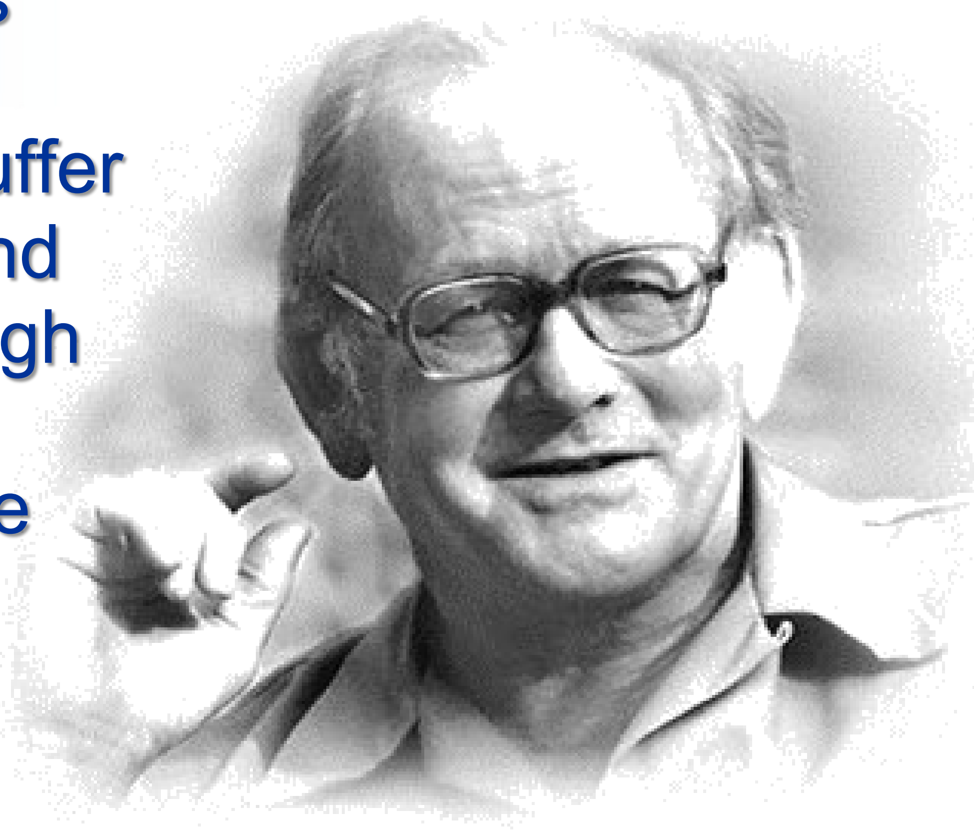
Ferrière (2000)

Selection-driven extinction (aka "evolutionary suicide") occurs when the evolution of an adaptive trait induces a bifurcation in the underlying population dynamics that involves a discontinuous transition to extinction:



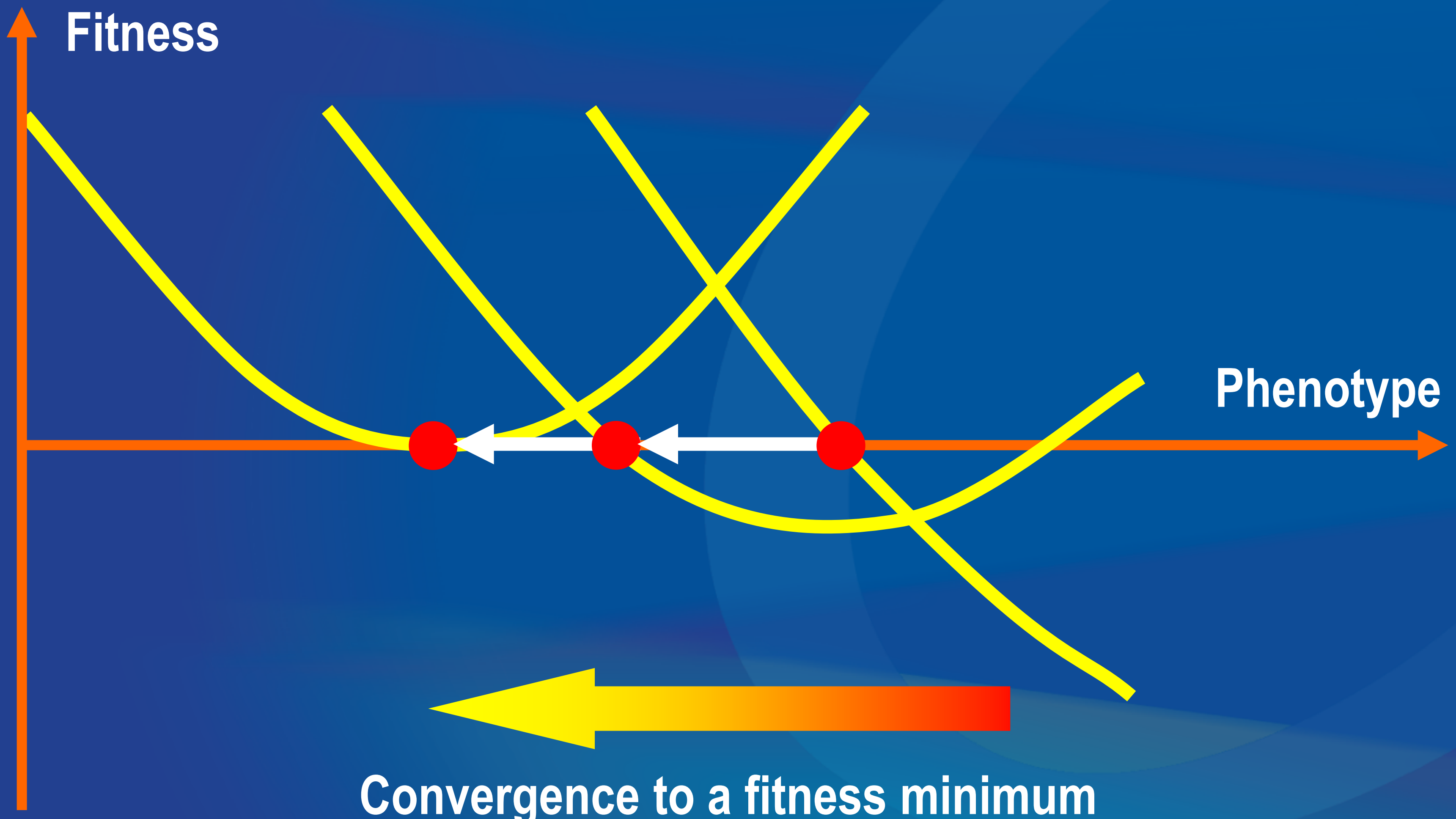
Garrett Hardin

Open-access resources that are utilized unrestrictedly tend to suffer from overexploitation and will often collapse through a **'tragedy of the commons'**, in which the selfish actions of individuals jeopardize a common good



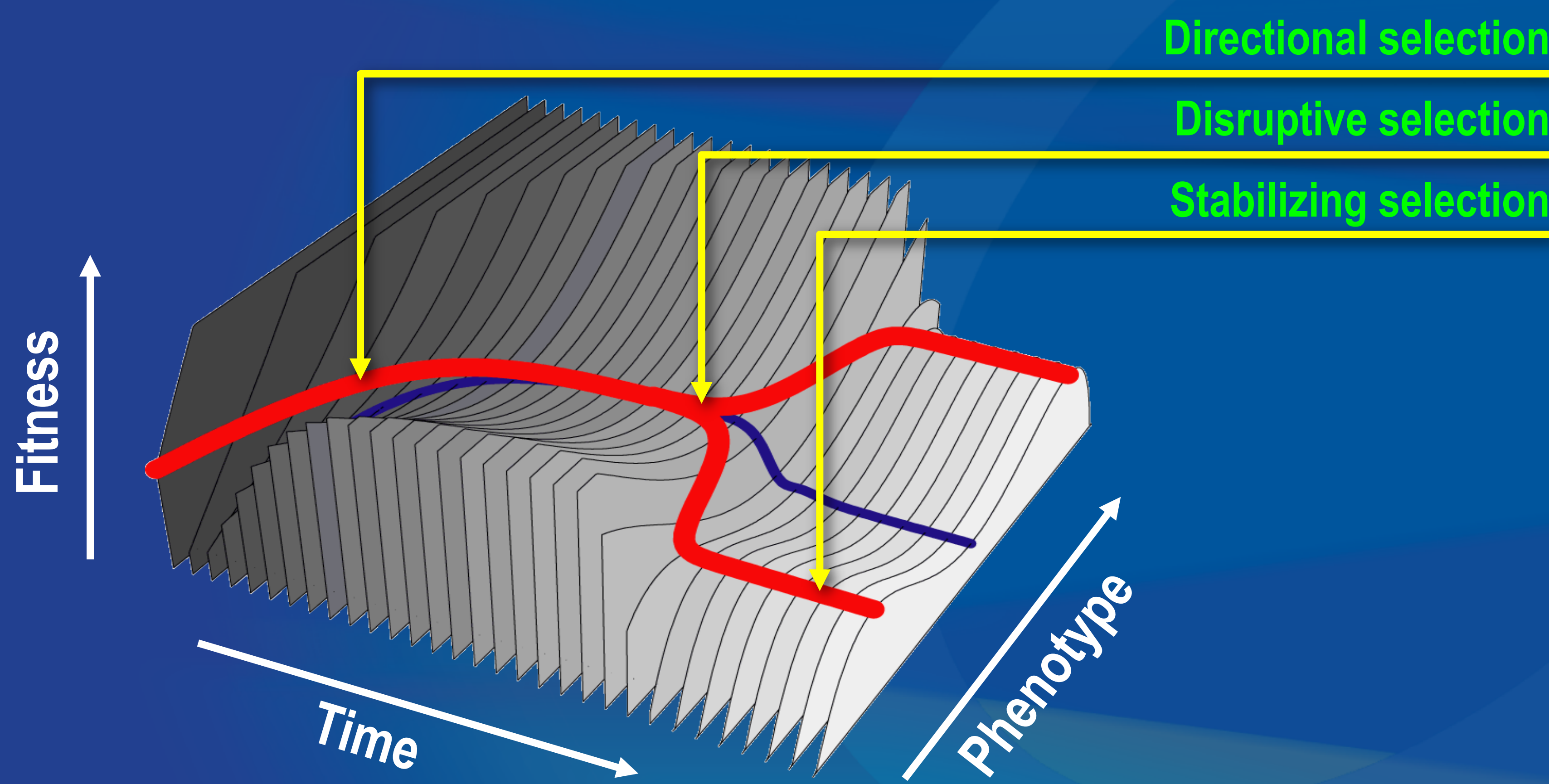
Evolutionary Branching

Metz et al. (1992)



Evolutionary Branching

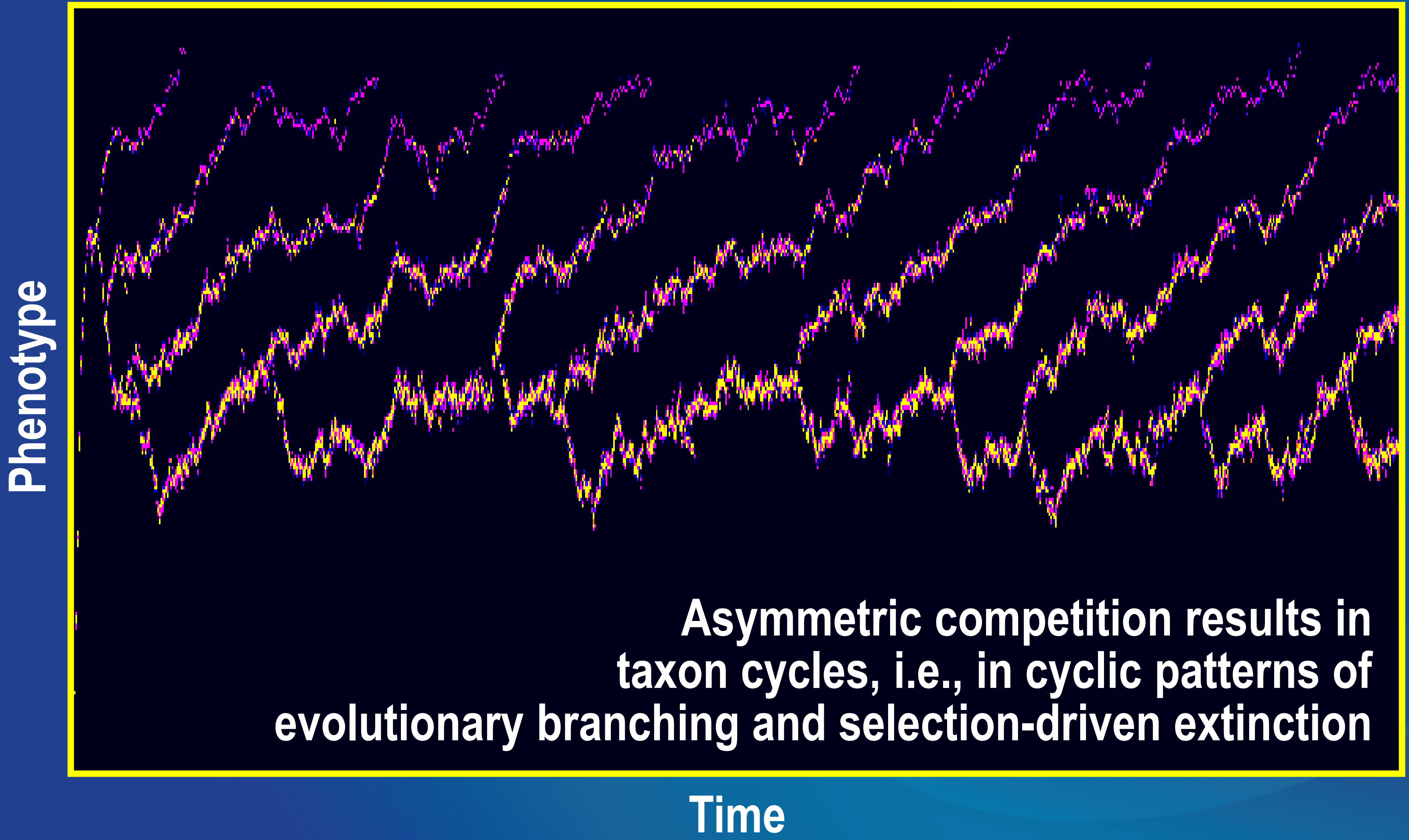
Dieckmann et al. (2004)



1c Evolution can be persistent

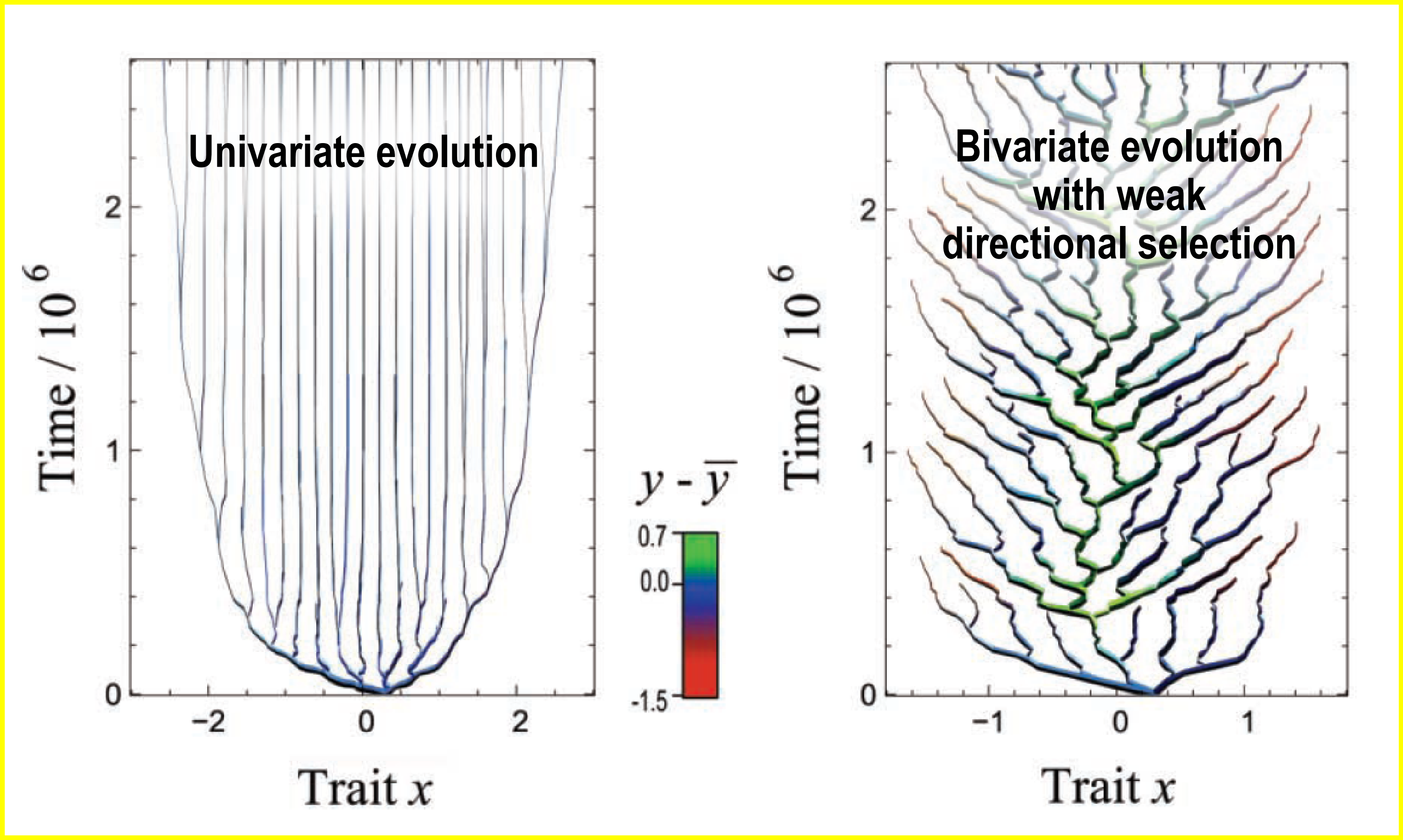
Asymmetric Competition: Taxon Cycles

Dieckmann et al. (2007)



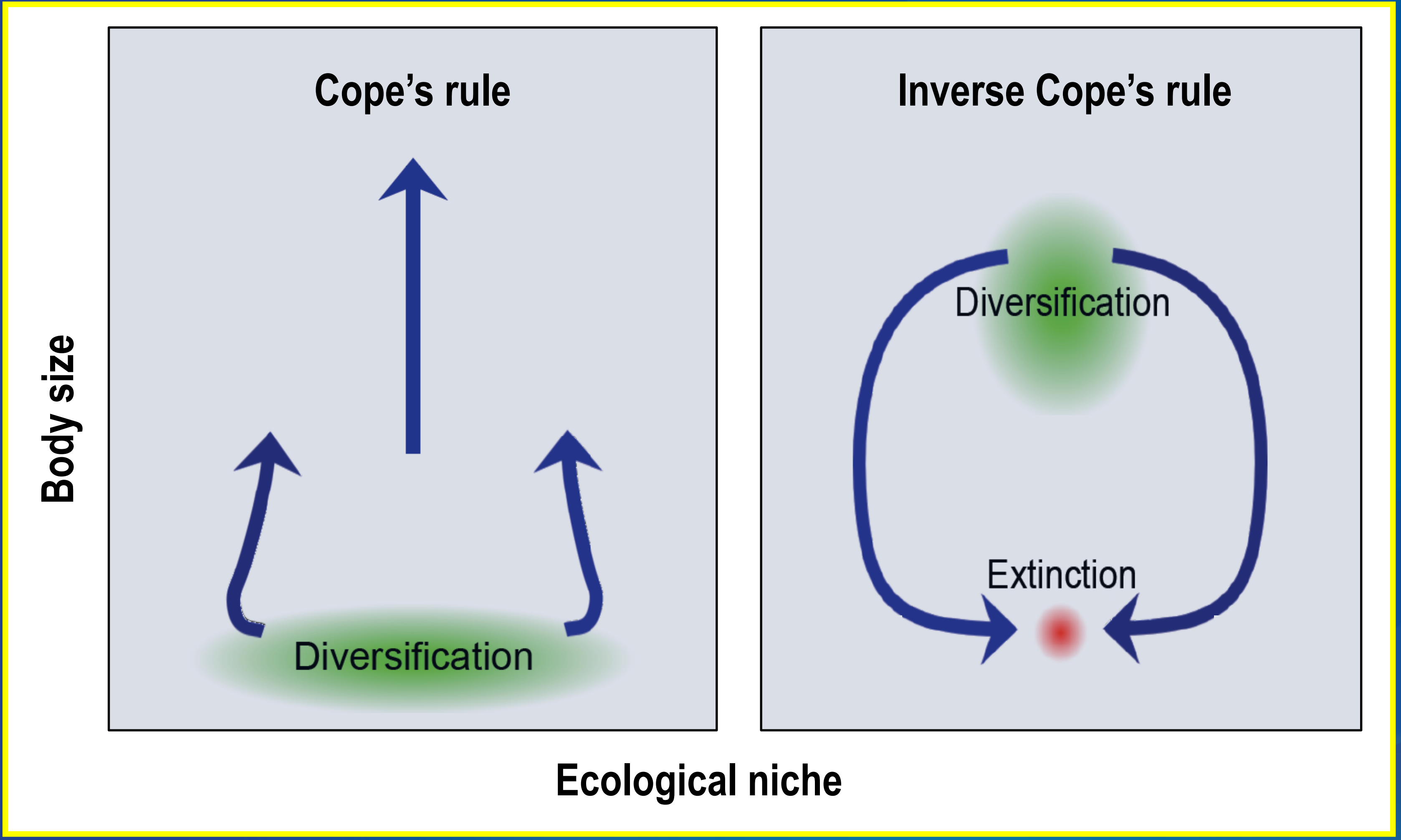
Second Trait under Weak Selection: Recurrent Radiations

Ito & Dieckmann (2007)



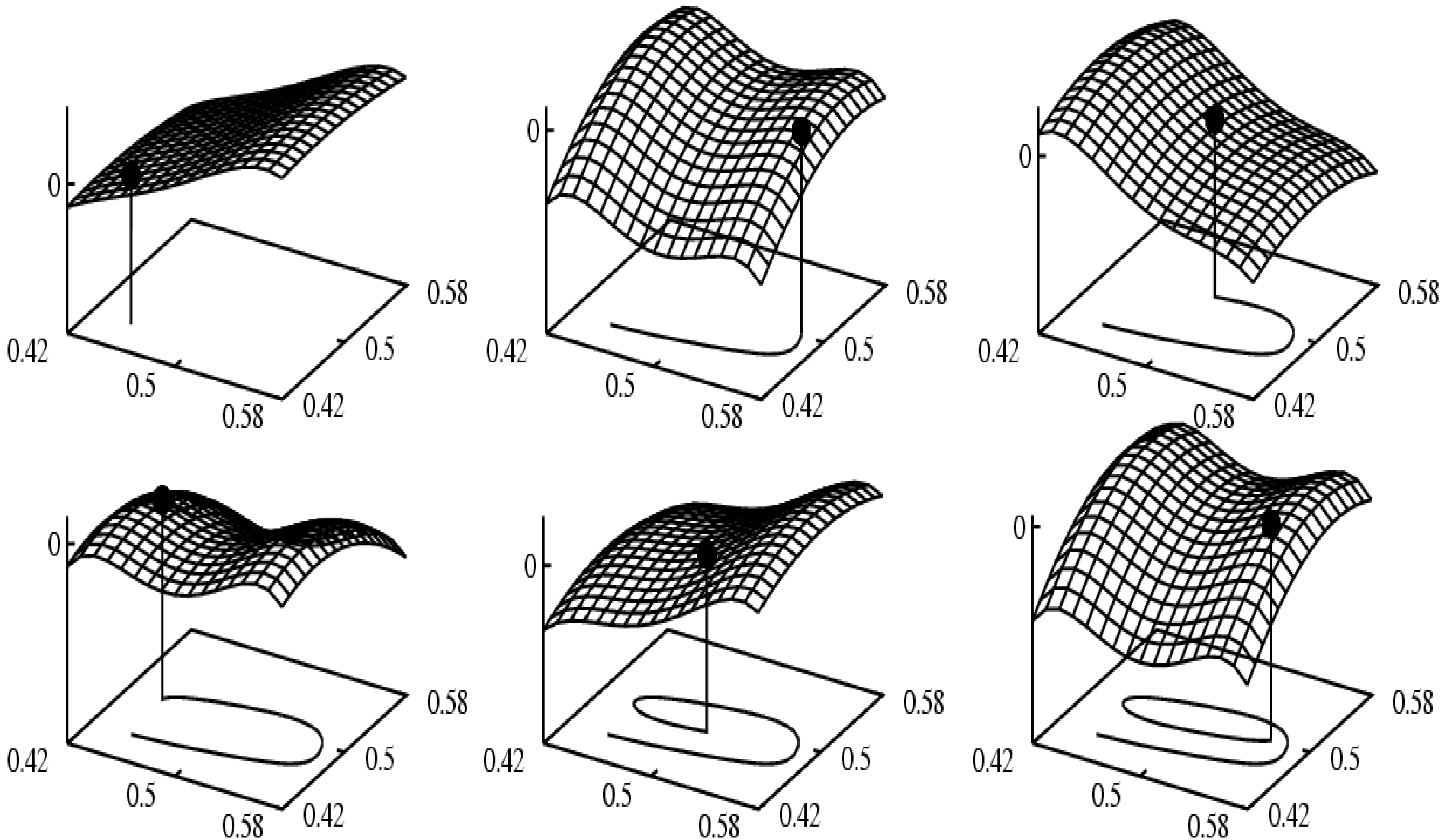
Second Trait Determining Body Size: Cope's Rule

Roy et al. (unpublished)

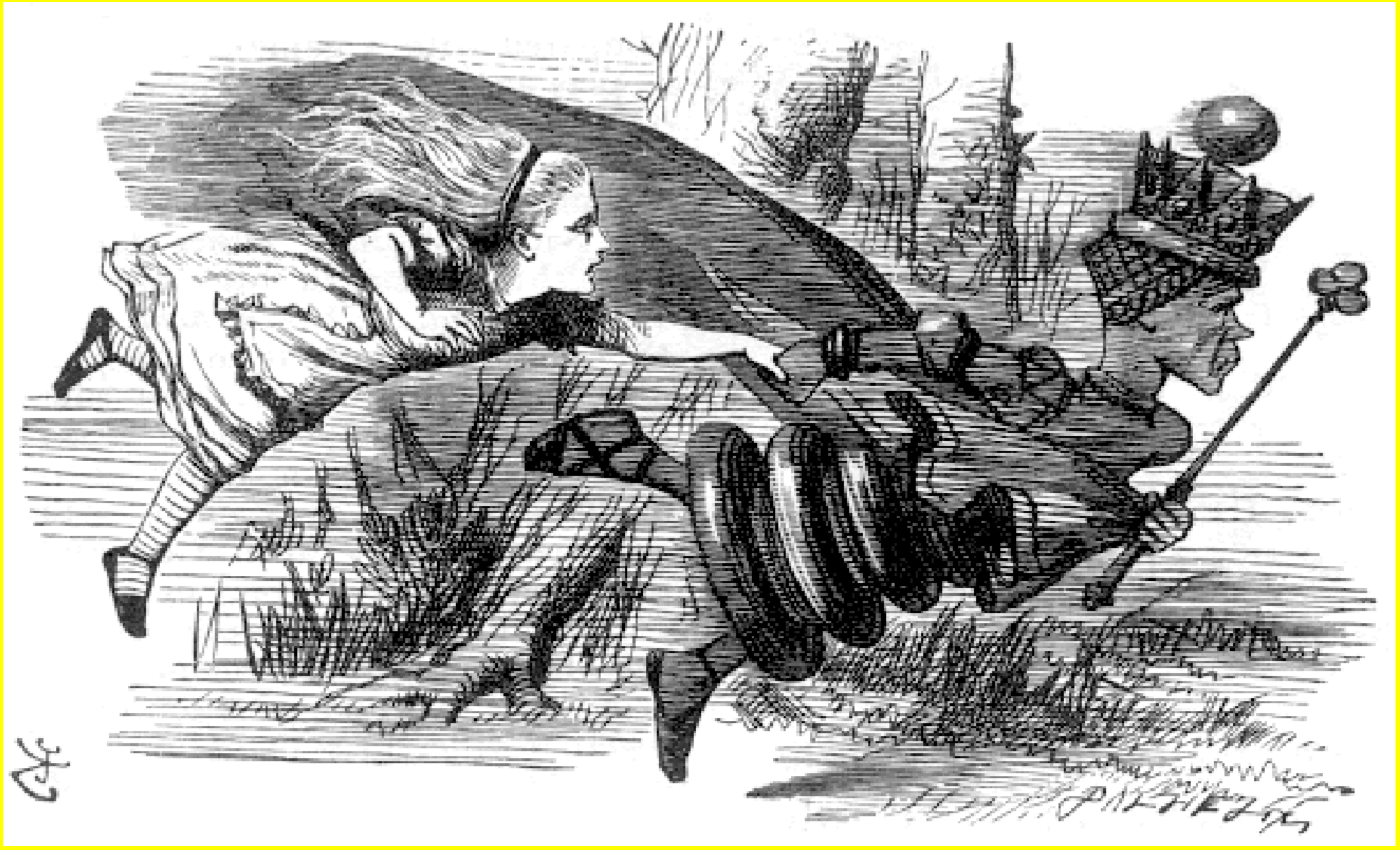


Second Trait under Coevolution: Evolutionary Cycling

Dieckmann et al. (1995)



Red Queen Dynamics



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