Ecology 8310
Population (and Community) Ecology

Coexistence in a competitive guild

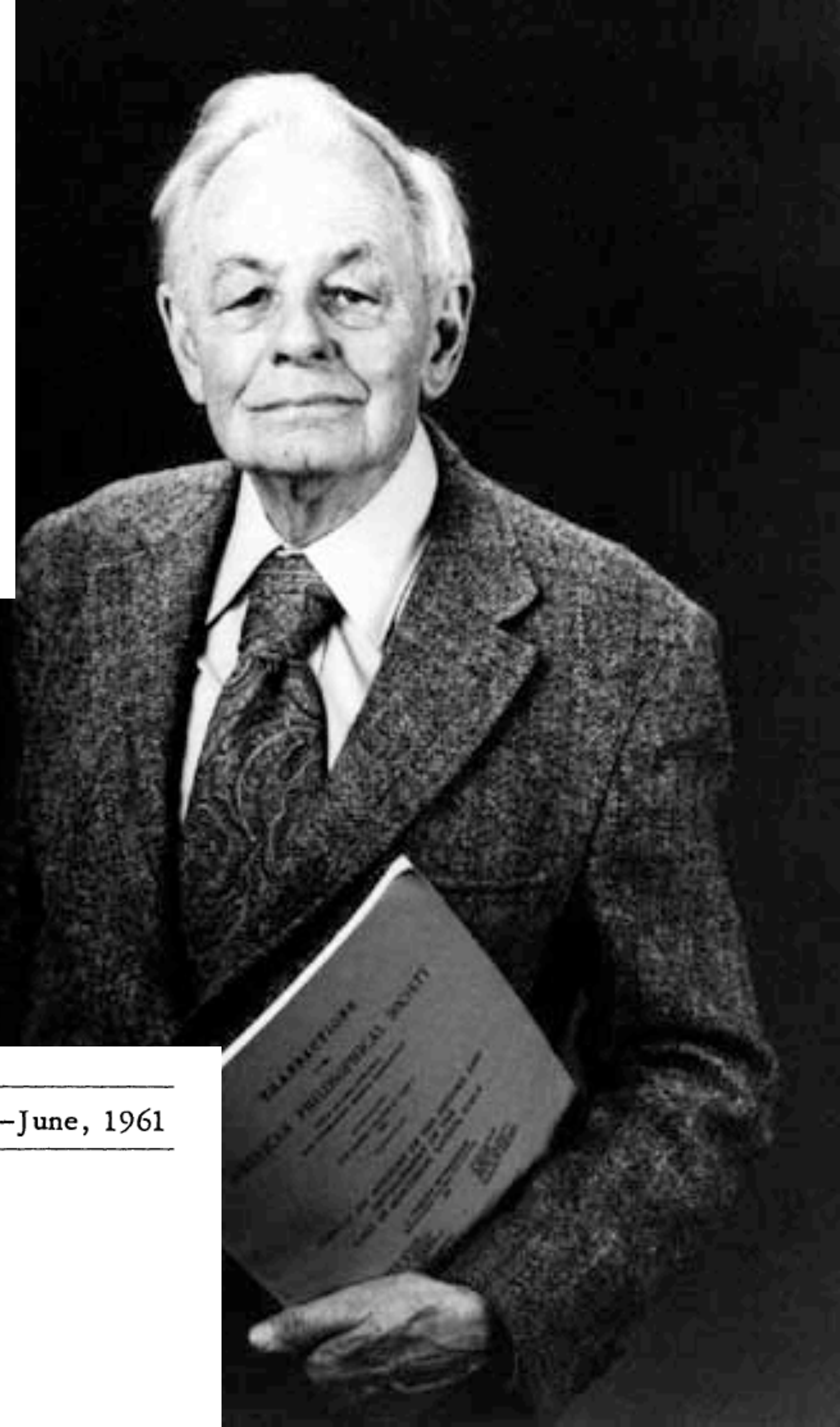
- Hutchinson
- Resource heterogeneity
- Patch dynamics / IDH
- Predation
- Resource fluctuations
- Neutral Theory
- Interference competition
- Chesson: stabilizing and equalizing mechanisms

THE
AMERICAN NATURALIST

Vol. XCIII | May–June, 1959 | No. 870

HOMAGE TO SANTA ROSALIA
or
WHY ARE THERE SO MANY KINDS OF ANIMALS?*

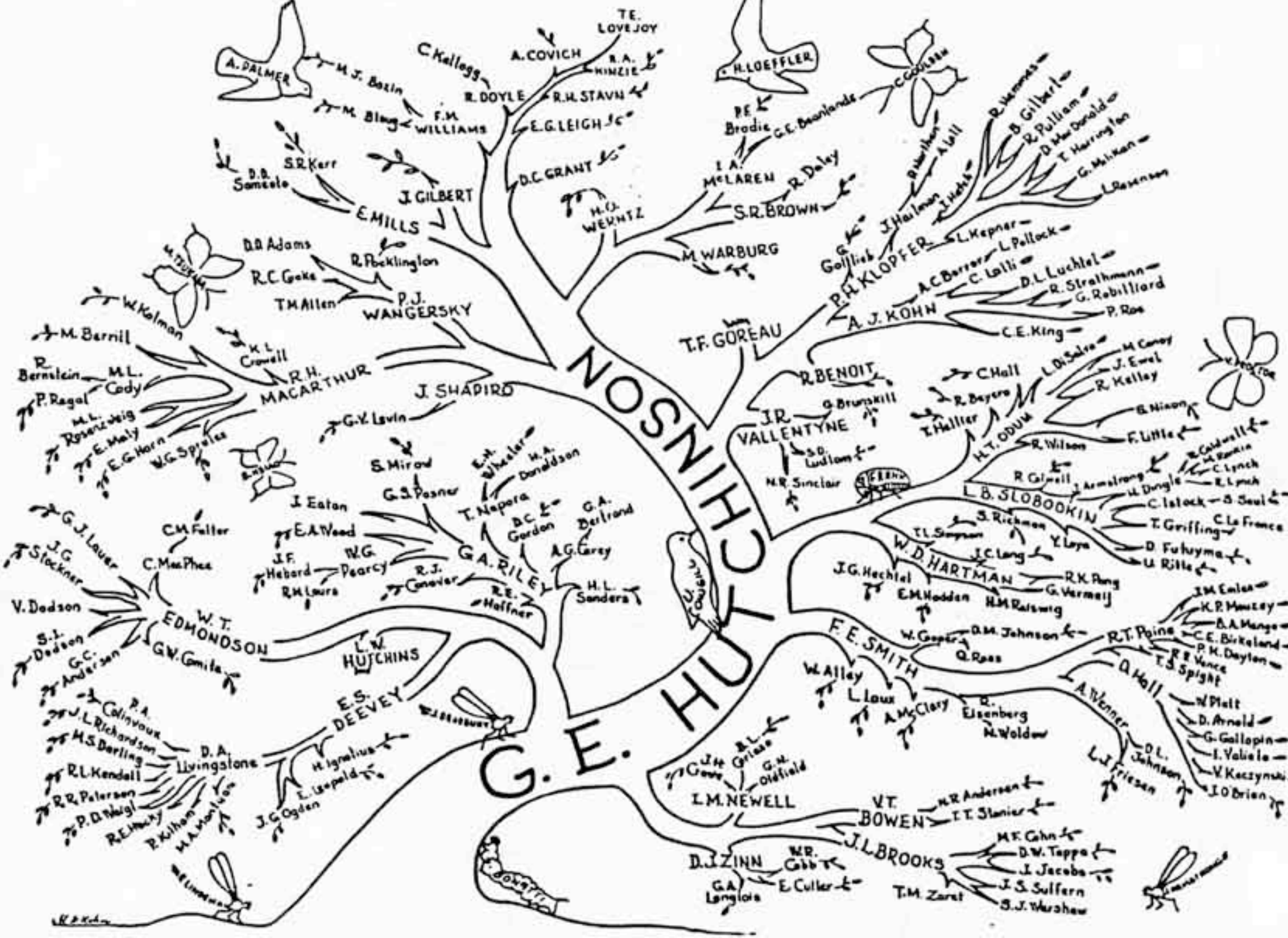
G. E. HUTCHINSON
Department of Zoology, Yale University, New Haven, Connecticut



Vol. XCV, No. 882 | The American Naturalist | May–June, 1961

THE PARADOX OF THE PLANKTON*

G. E. HUTCHINSON
Osborn Zoological Laboratory, New Haven, Connecticut



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G.A. Langlois

"Vast numbers of Corixide were living in the water .... These ideas finally prompted the very general question as to why there are such an enormous number of animal species."

Let's explore a few of those issues for a guild of competitors…

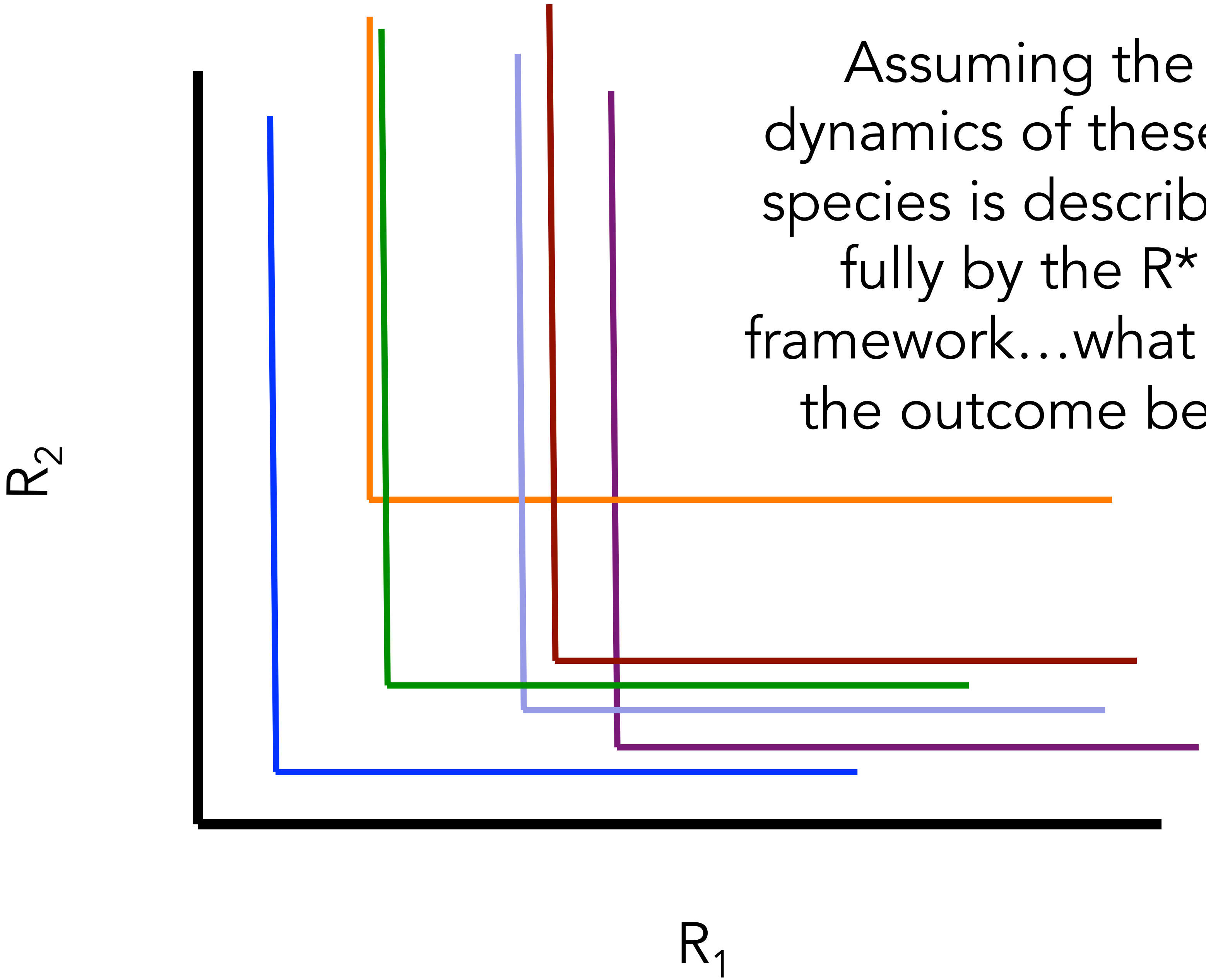
1) Resource partitioning (niche divergence): "intra>inter"

2) Environmental heterogeneity

3) Disturbance

4) Interference competition

Many competitors:

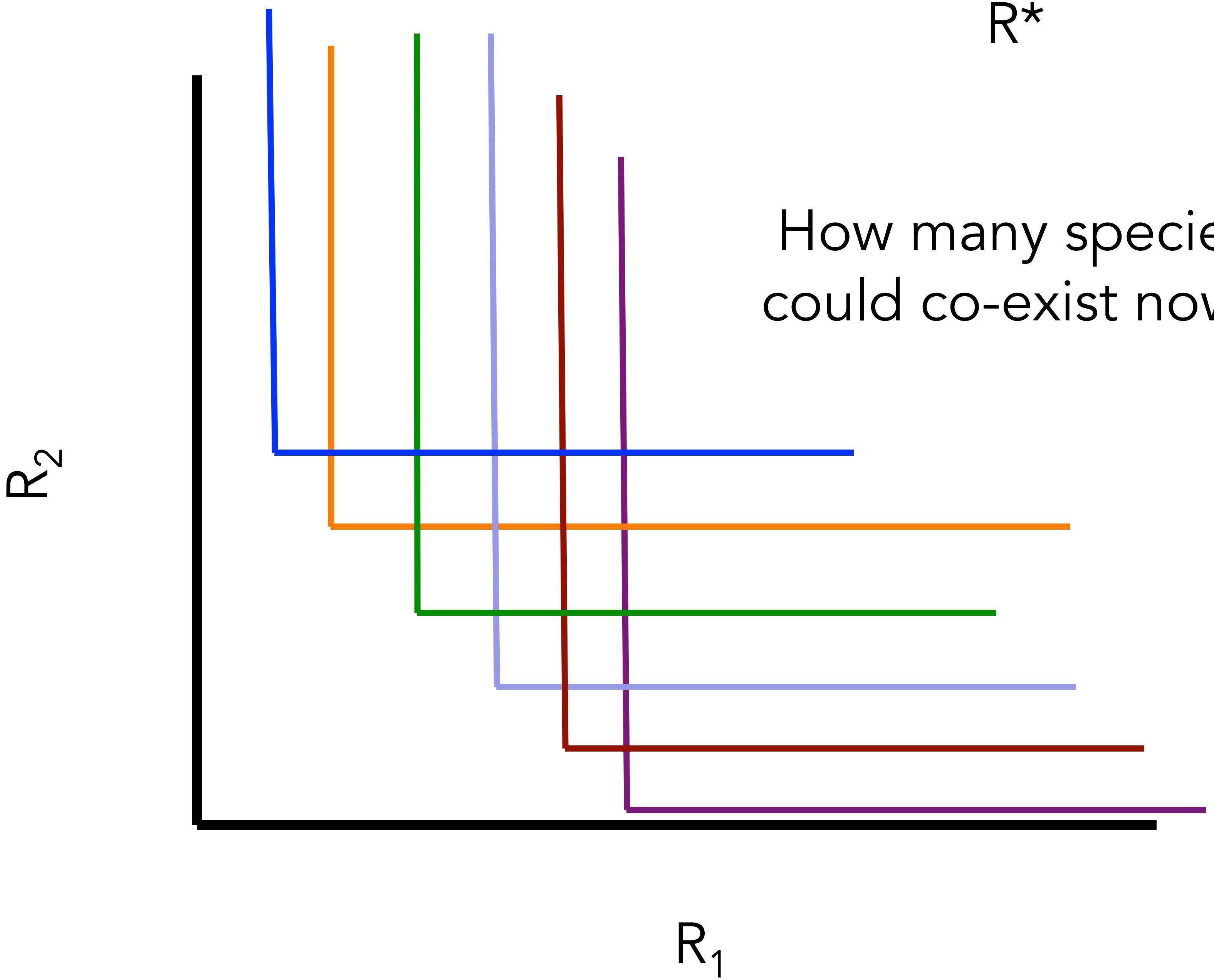


Assuming the dynamics of these 6 species is described fully by the R* framework…what will the outcome be?

How can we modify this picture to facilitate coexistence?

Many competitors:

Assume a trade-off in R^*



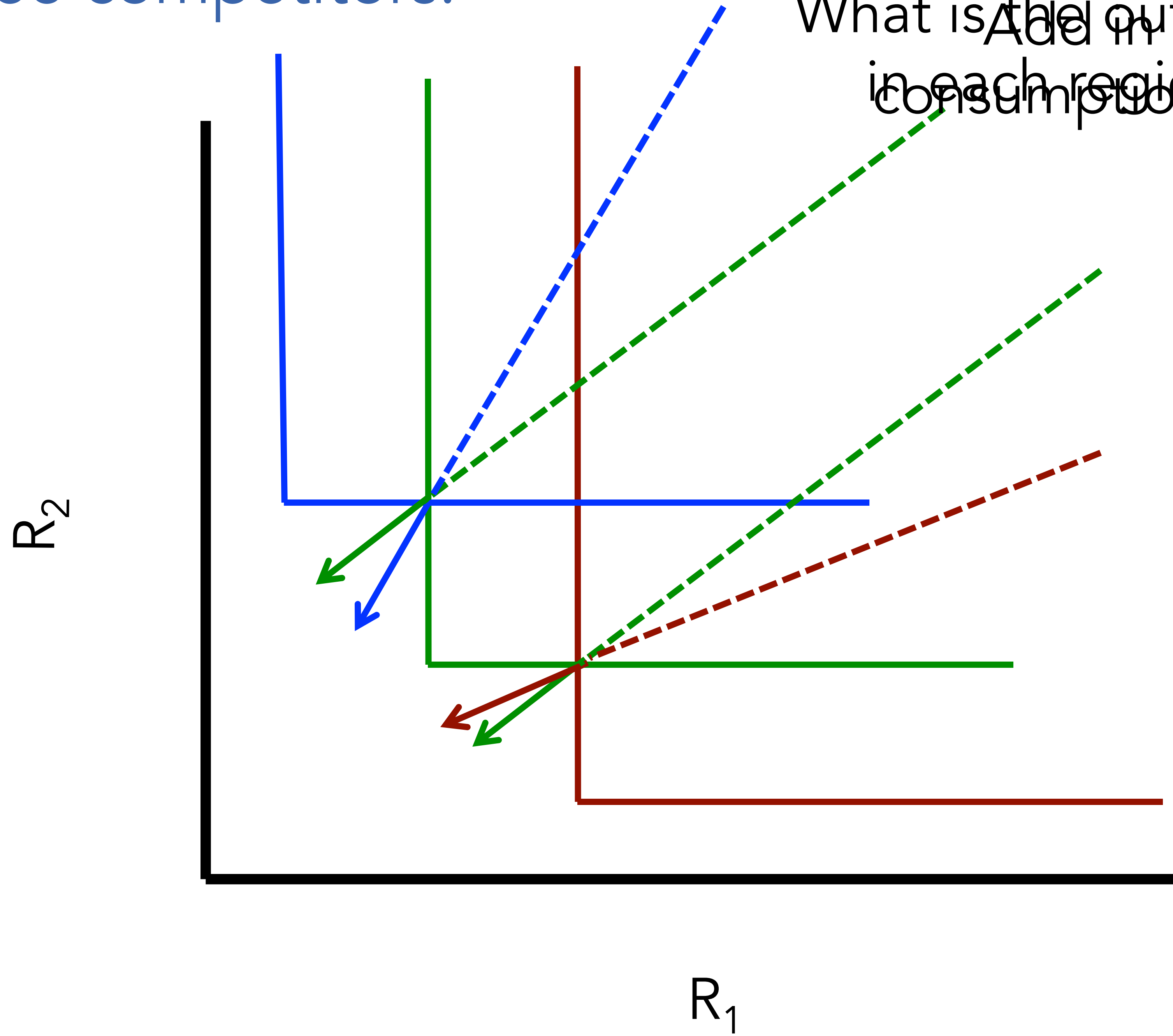
How many species could co-exist now?

We need to specify consumption (and supply)

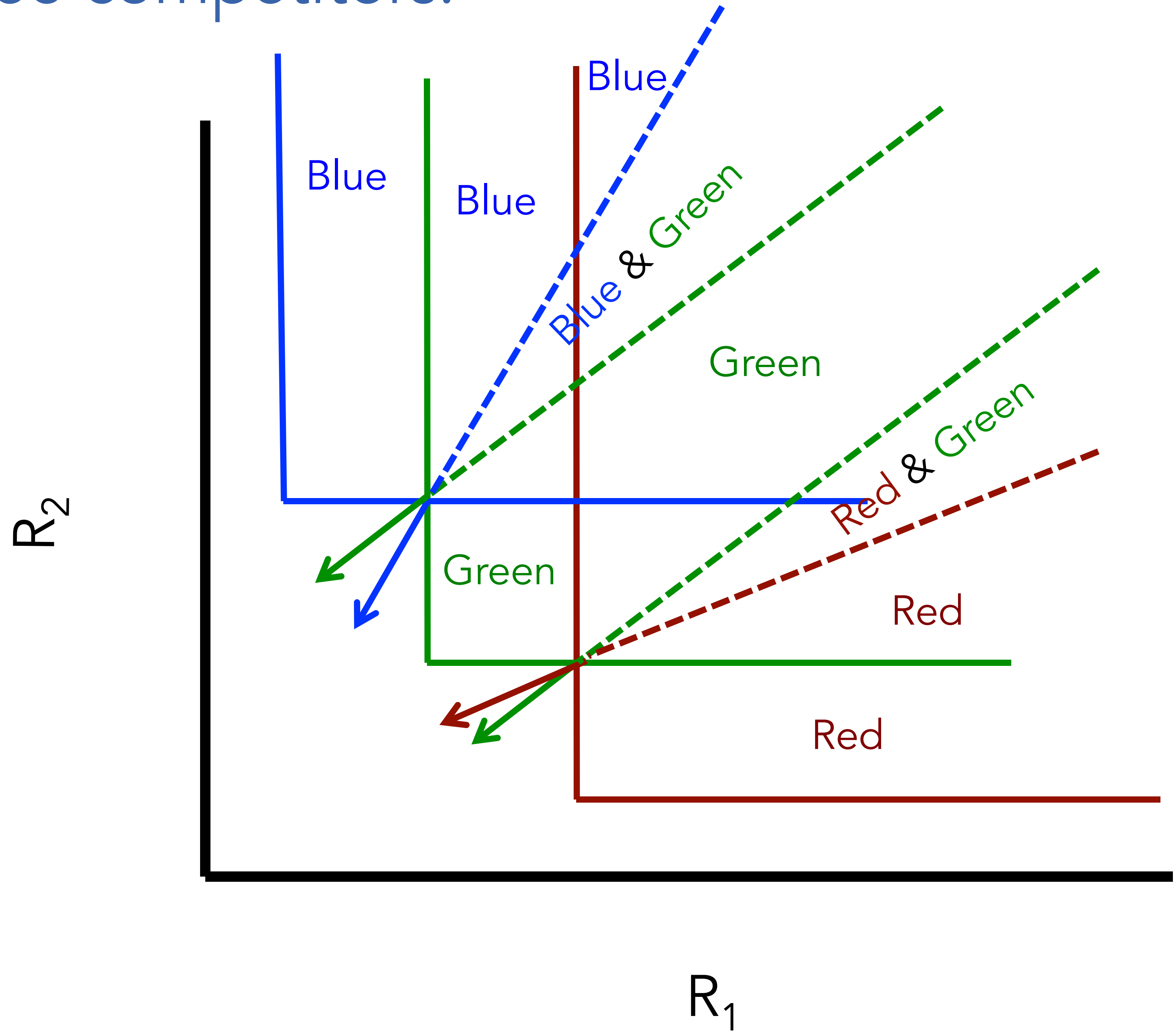
Three competitors:

What is the outcome in each region?

Add in consumption...



Three competitors:

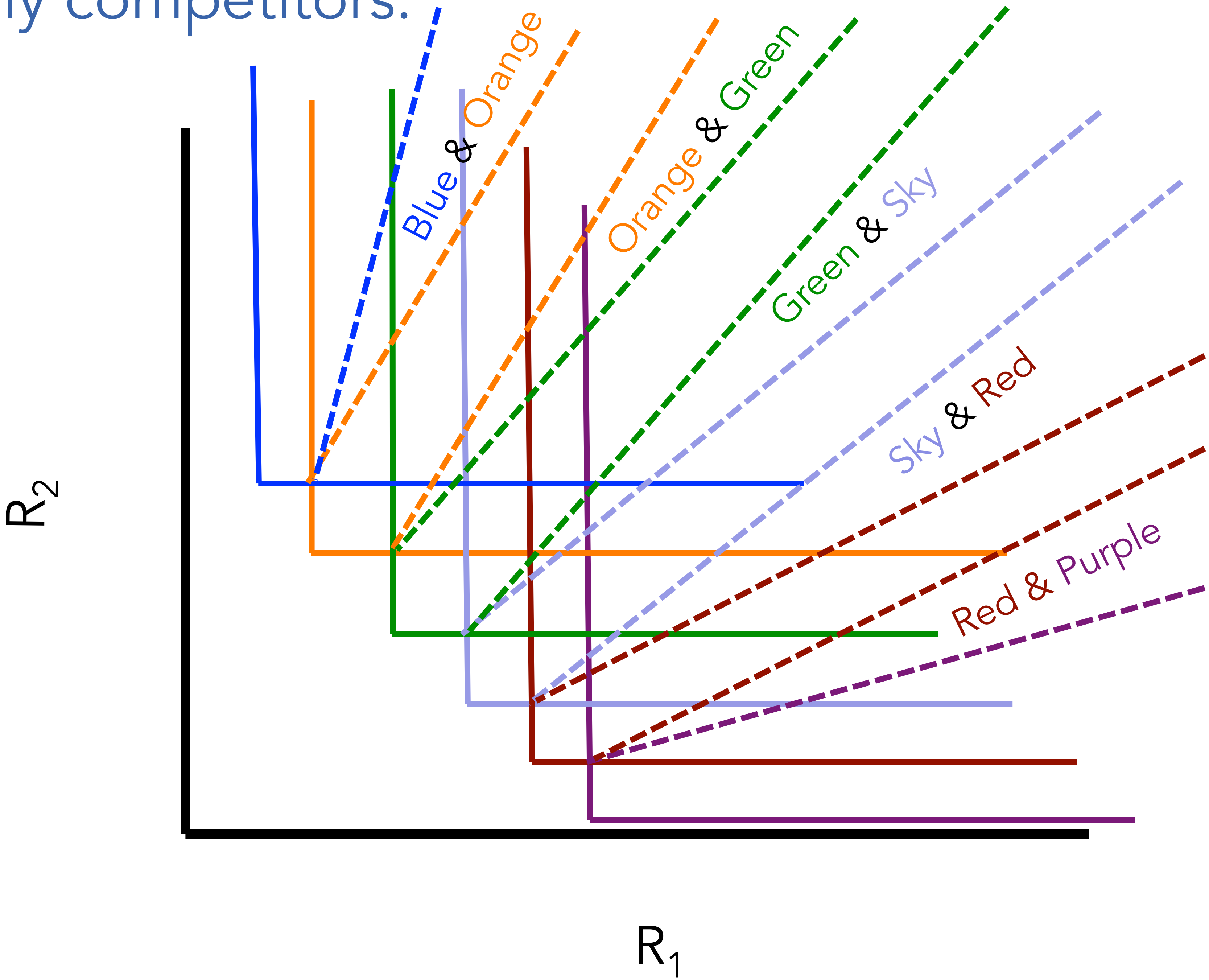


- Trade-off in R*s
- Correlation between R*s and consumption

(i.e., better competitor for a resource, consumes relatively less of that resource)

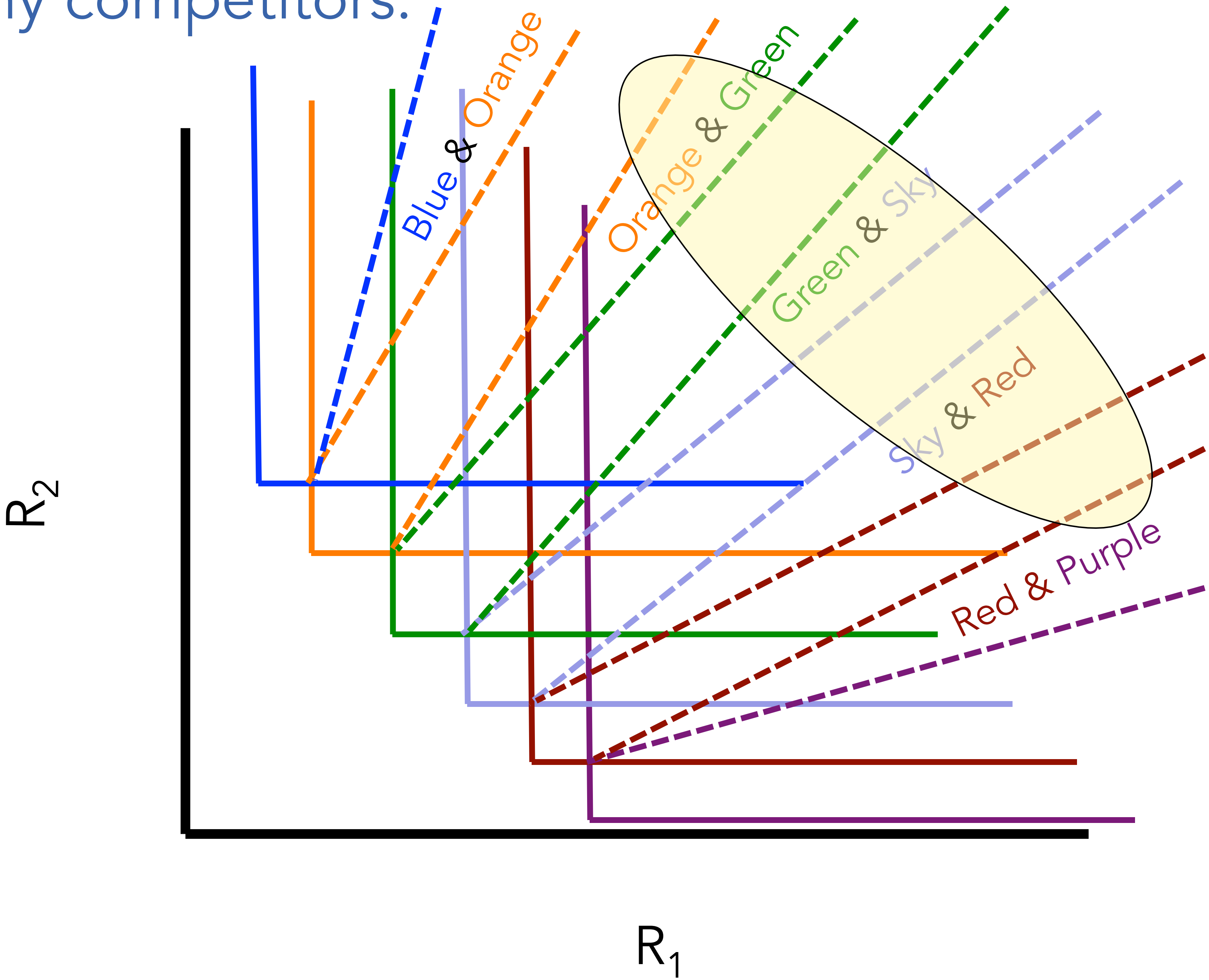
- But, still only get (at most) 2 coexisting consumers

Many competitors:



What if a region is heterogeneous in S?

Many competitors:



What if patches don’t come to a competitive equilibrium?

Paradox:

1 limiting resource (Nitrogen)

Many species of plants (persisting together)

How is this possible?

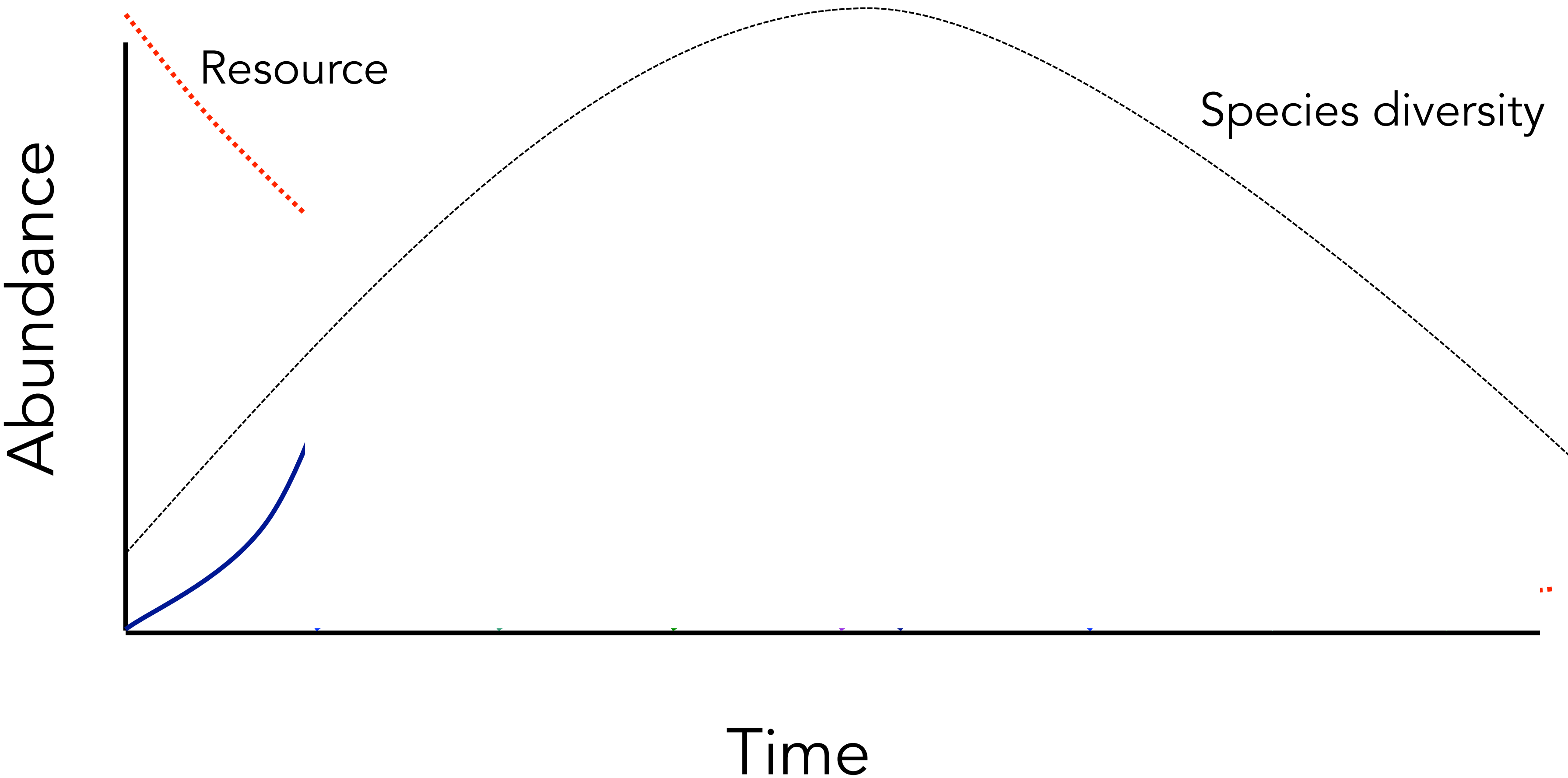
Patch dynamics:

1. Disturbances open up space.
2. Good colonizers arrive first.
3. Competition occurs as others colonize.
4. One species wins (within that patch).
5. "Losers" persist by colonizing recently disturbed sites.

→Trade-off b/w 'R*' and colonizing ability

With-in Patch:

Let's look at one patch in detail:

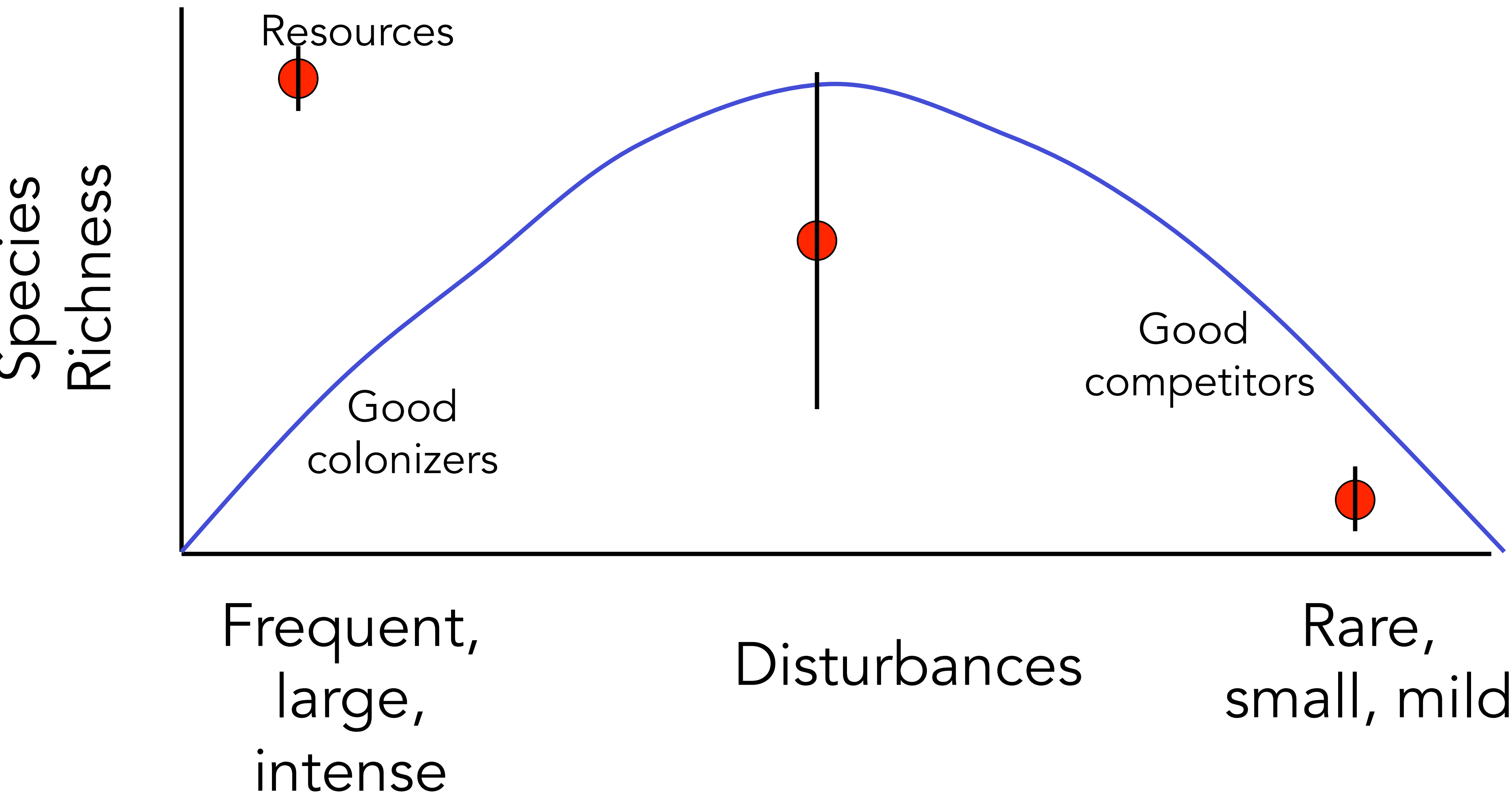


Note: Richness increases then decreases with time

Among-Patch:

Intermediate Disturbance Hypothesis

Now look at a collection of patches (and vary disturbances) → mosaic:



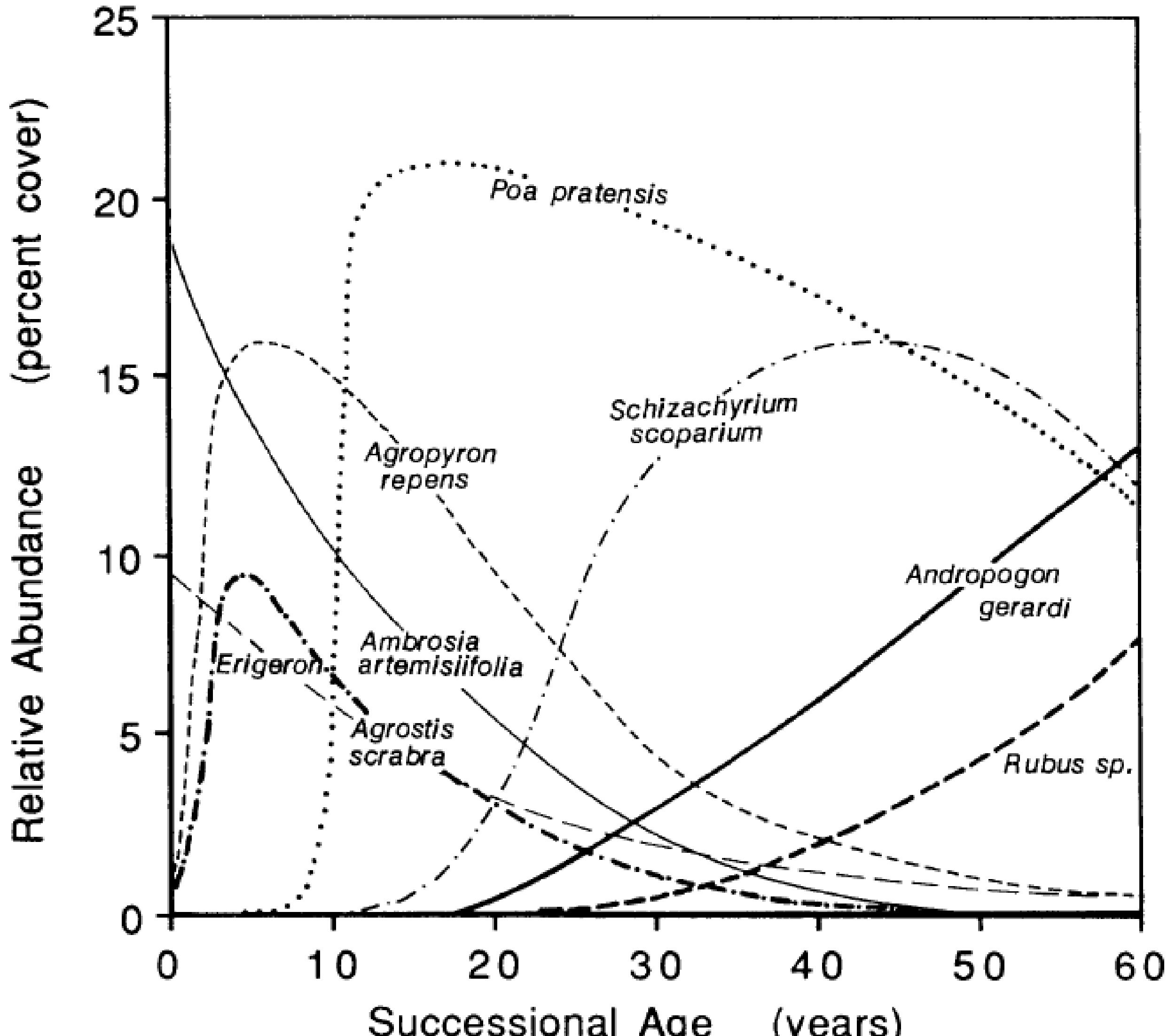
Let's review Tilman's classic paper:

Ecology, 75(1), 1994, pp. 2–16

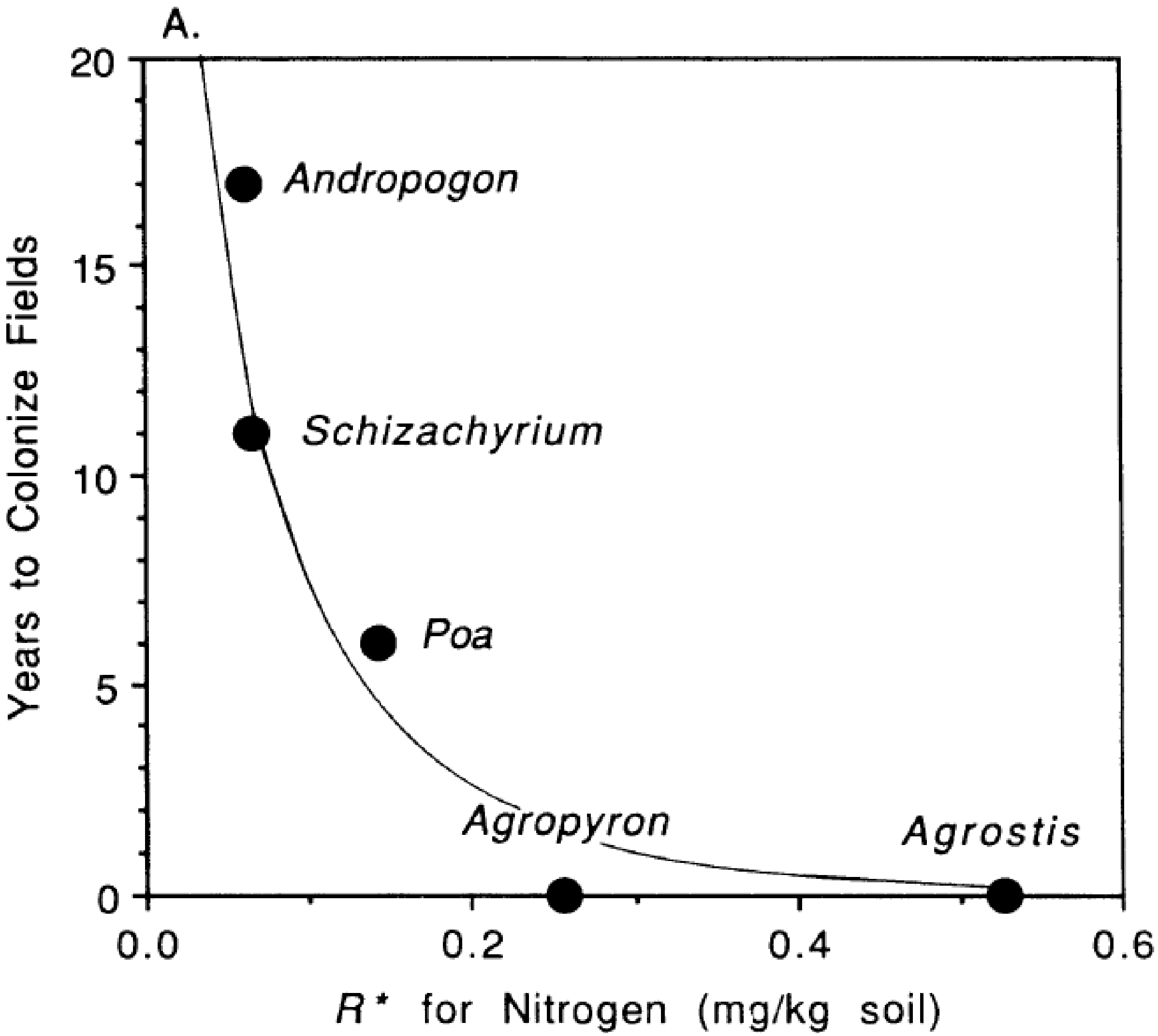
COMPETITION AND BIODIVERSITY IN SPATIALLY STRUCTURED HABITATS[1]

DAVID TILMAN
Department of Ecology, Evolution, and Behavior, 1987 Upper Buford Circle, University of Minnesota, St. Paul, Minnesota 55108 USA

Successional patterns:



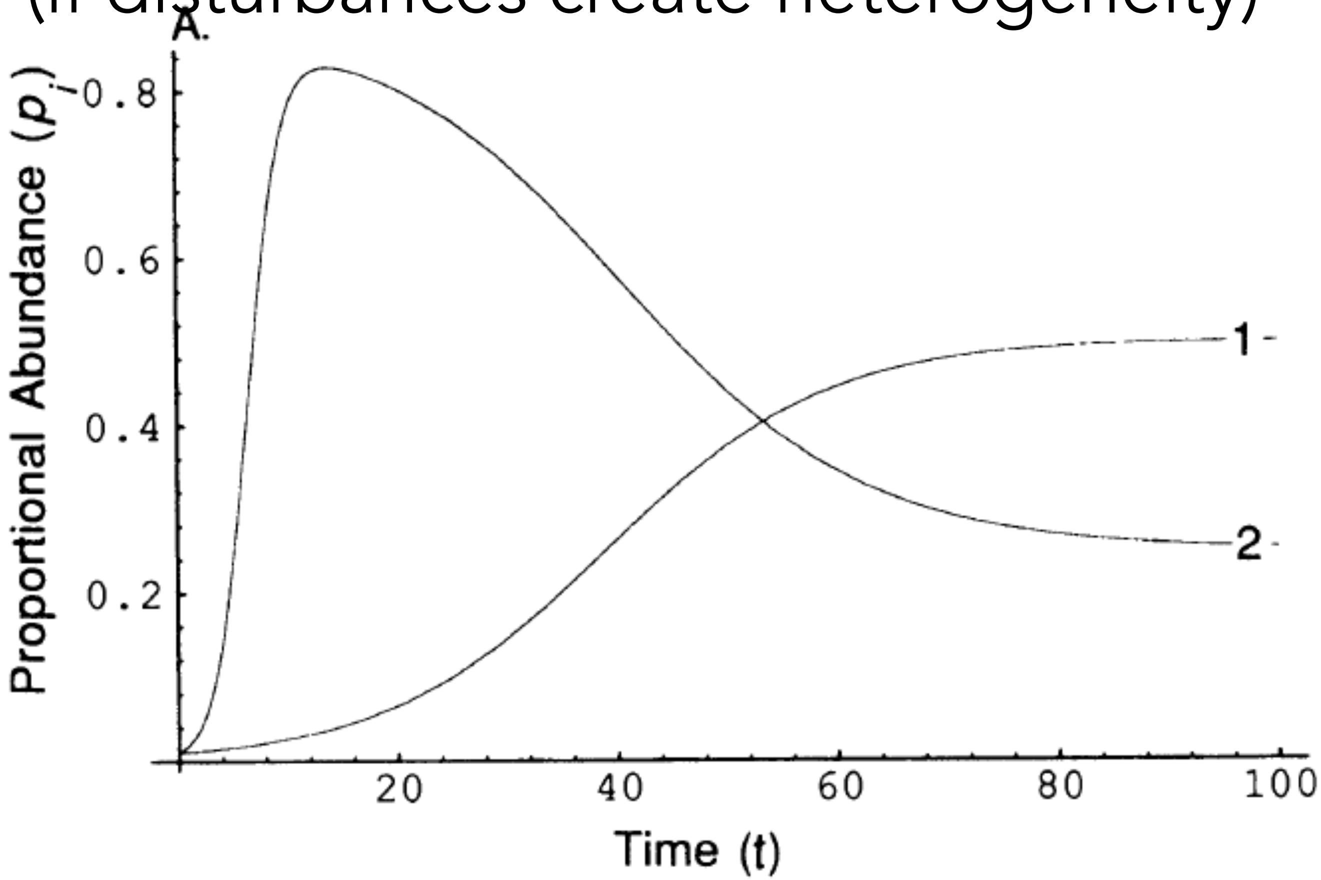
Trade-off:



A.
Years to Colonize Fields
R* for Nitrogen (mg/kg soil)
20
15
10
5
0
0.0
0.2
0.4
0.6
Andropogon
Schizachyrium
Poa
Agropyron
Agrostis

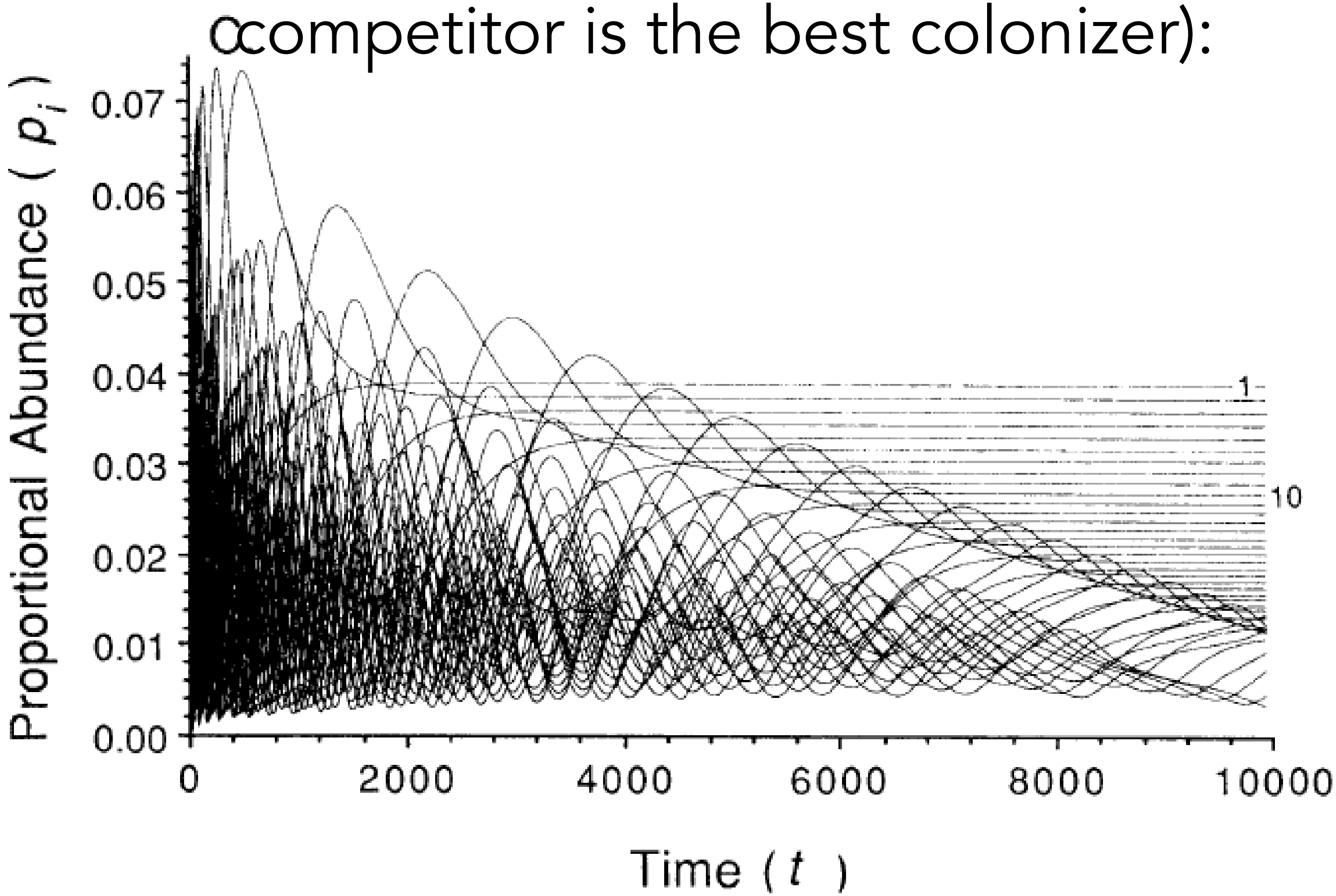
Trade-off:

Two species can persist…on one resource,
even when one species is best competitor
(if disturbances create heterogeneity)



Trade-off:

Many species can persist…on one resource (so long as the poorest competitor is the best colonizer):



Trade-offs

Possible trade-offs with competitive ability (that promote persistence of competitors):

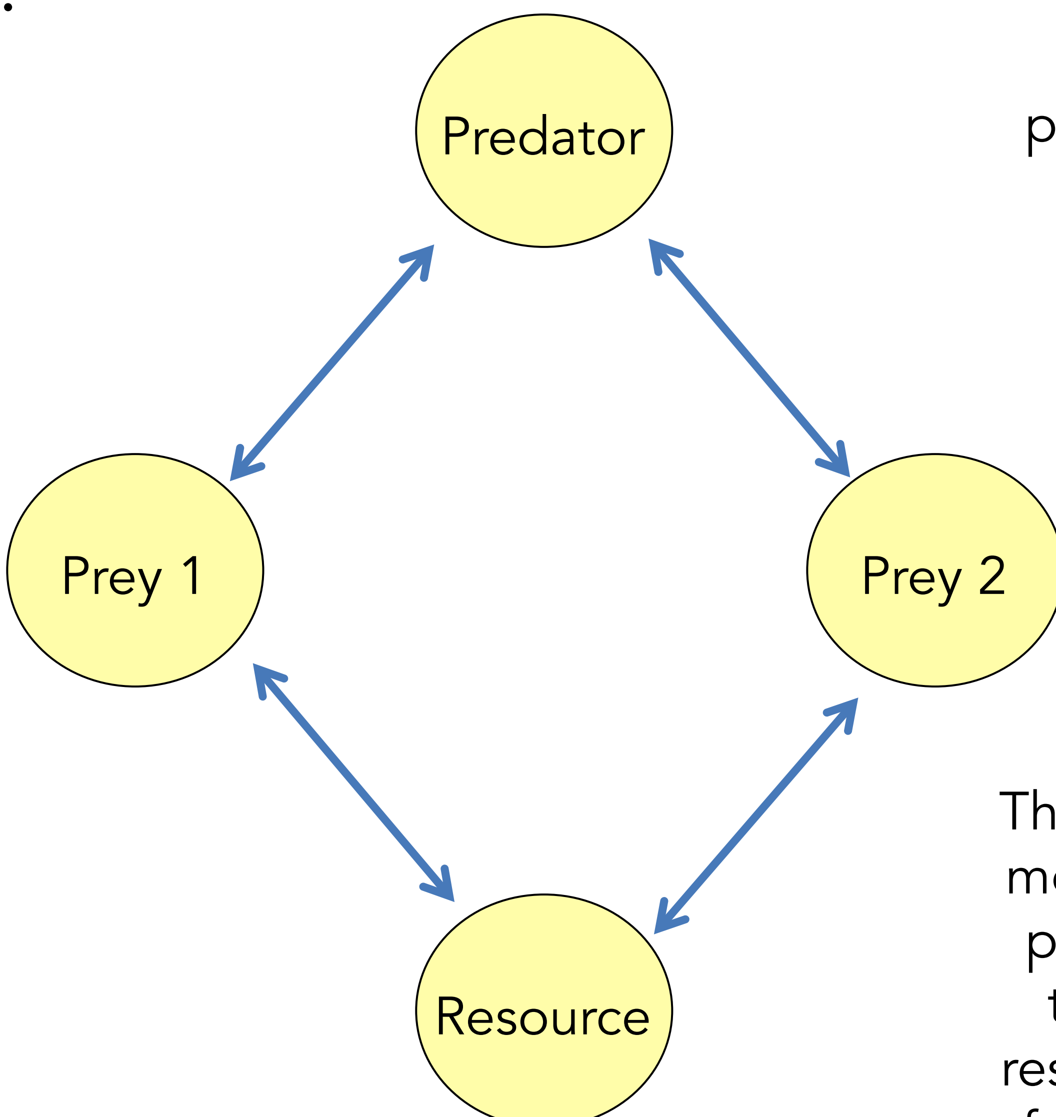
Colonizing ability

Vulnerability to disturbance

Vulnerability to predators

Predators

Diamond food web:



Coexistence possible if better competitor is preferred by predator

Thus one prey is more limited by predation and the other by resource (a form of "partitioning")

Vol. 112, No. 983 The American Naturalist January–February 1978

PLANT SPECIES DIVERSITY IN A MARINE INTERTIDAL COMMUNITY: IMPORTANCE OF HERBIVORE FOOD PREFERENCE AND ALGAL COMPETITIVE ABILITIES

JANE LUBCHENCO*

Biological Laboratories, Harvard University, Cambridge, Massachusetts 02138

Damselfish as Keystone Species in Reverse: Intermediate Disturbance and Diversity of Reef Algae

SCIENCE, VOL. 220

29 APRIL 1983

MARK A. HIXON

Department of Ecology and Evolutionary Biology, University of California, Irvine 92717

WILLIAM N. BROSTOFF

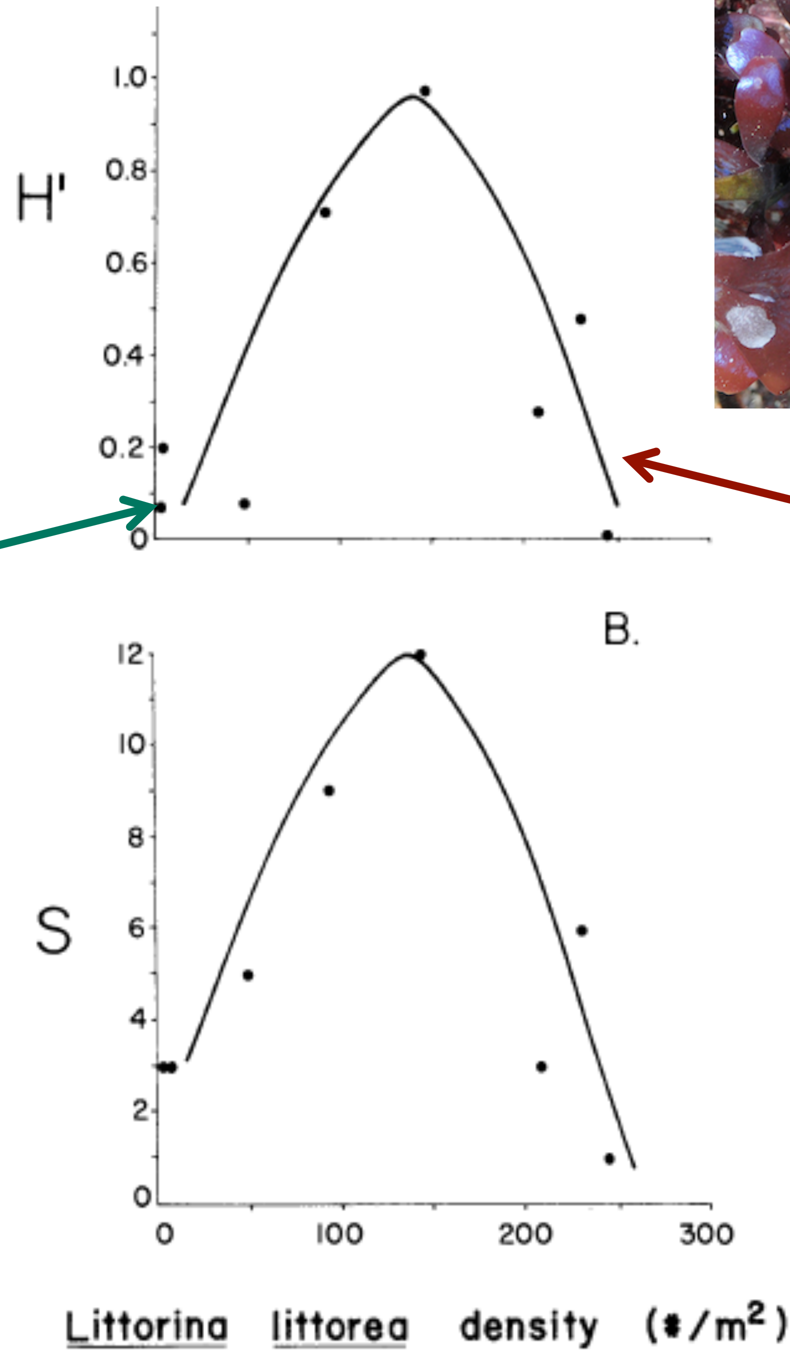
Department of Botany, University of Hawaii, Honolulu 96822

Avoided:
Chondrus

The grazer:
Littorina littorea

Preferred:
Enteromorpha

Competitive dominant wins (Enteromorpha)



Inedible species dominates (Chondrus)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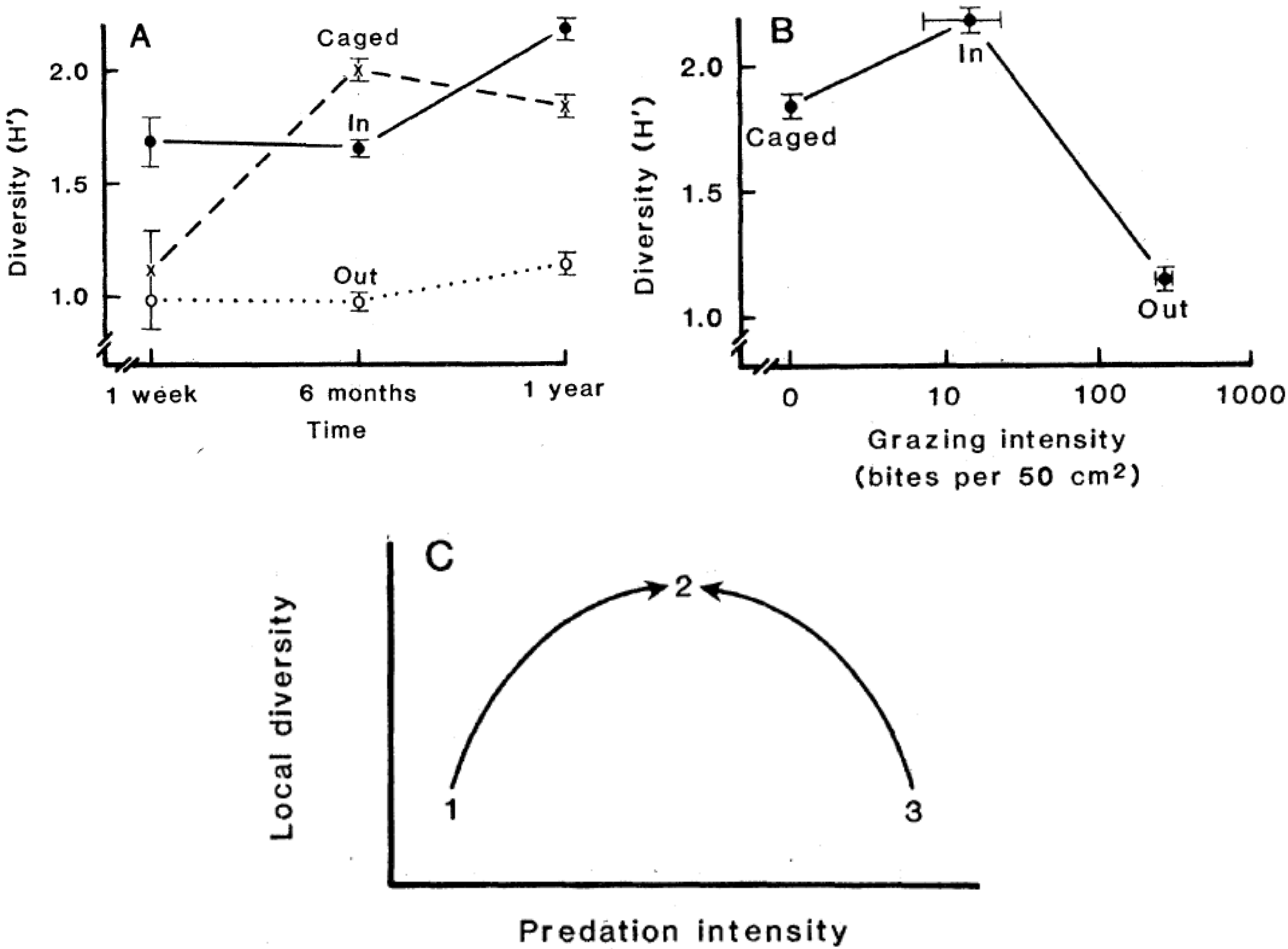


A
Caged
In
Out
Diversity (H')
2.0
1.5
1.0
1 week
6 months
1 year
Time
B
In
Caged
Out
Diversity (H')
2.0
1.5
1.0
0
10
100
1000
Grazing intensity
(bites per 50 cm2)
C
2
1
3
Local diversity
Predation intensity

Resource fluctuations

Vol. 114, No. 6 The American Naturalist December 1979

COEXISTENCE IN A VARIABLE ENVIRONMENT

RICHARD LEVINS

Exogenous:

Mean vs. variance specialists

Endogenous:

Limit cycles

Vol. 115, No. 2 The American Naturalist February 1980

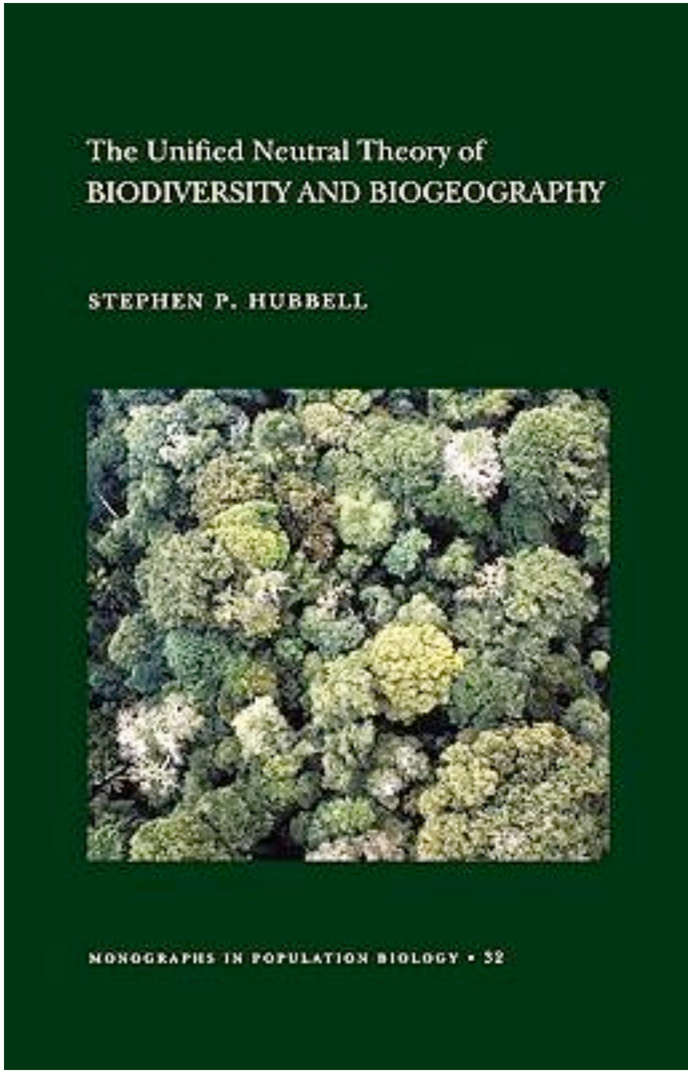
COMPETITIVE EXCLUSION

ROBERT A. ARMSTRONG* AND RICHARD MCGEHEE

Hubbell's Neutral theory:

A different perspective (analogous to Kimura's model neutral theory in evolution):

1. Species are identical: cf. niche theory
2. Systems are saturated
3. Random walk to extinction
4. Extinction balanced by speciation
5. Can achieve persistence of diverse communities (dynamic, no “winner”)



What if competitors compete via exploitation AND interference?

Ecology, 93(12), 2012, pp. 2728–2735

Intraspecific density dependence and a guild of consumers coexisting on one resource

Mark A. McPeek[1]

Department of Biological Sciences, Dartmouth College, Hanover, New Hampshire 03755 USA

Logistic growth

Type II functional responses

$$\frac{dR}{dt} = R\left(c - dR - \sum_{i=1}^{n} \frac{a_i N_i}{1 + a_i h_i R} \right)$$

Resource

$$\frac{dN_i}{dt} = N_i\left(\frac{b_i a_i R}{1 + a_i h_i R} - (f_i + g_i N_i) \right)$$

Consumer

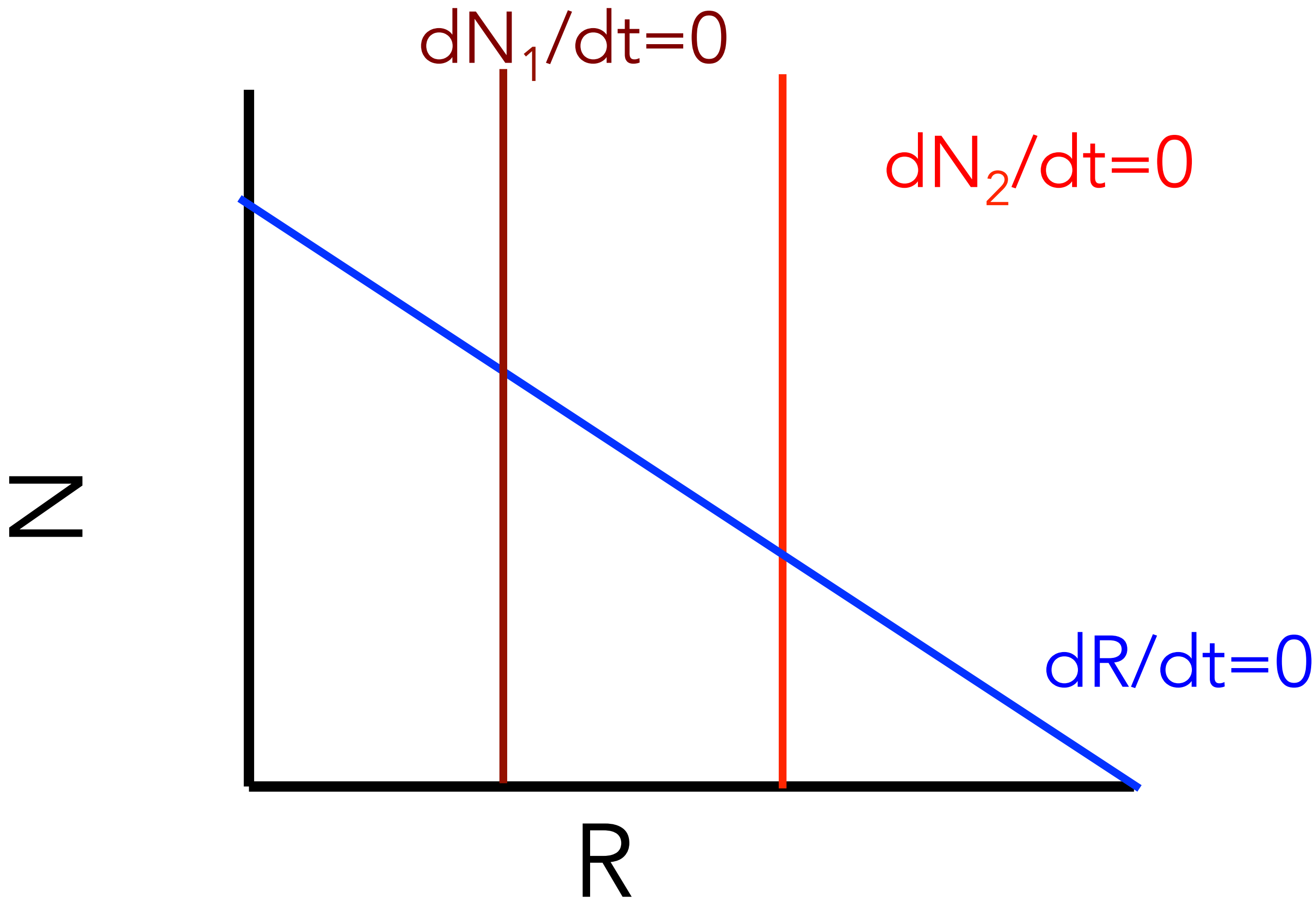
Mortality

Interference-mediated mortality

How does this change our basic 2-consumer model?

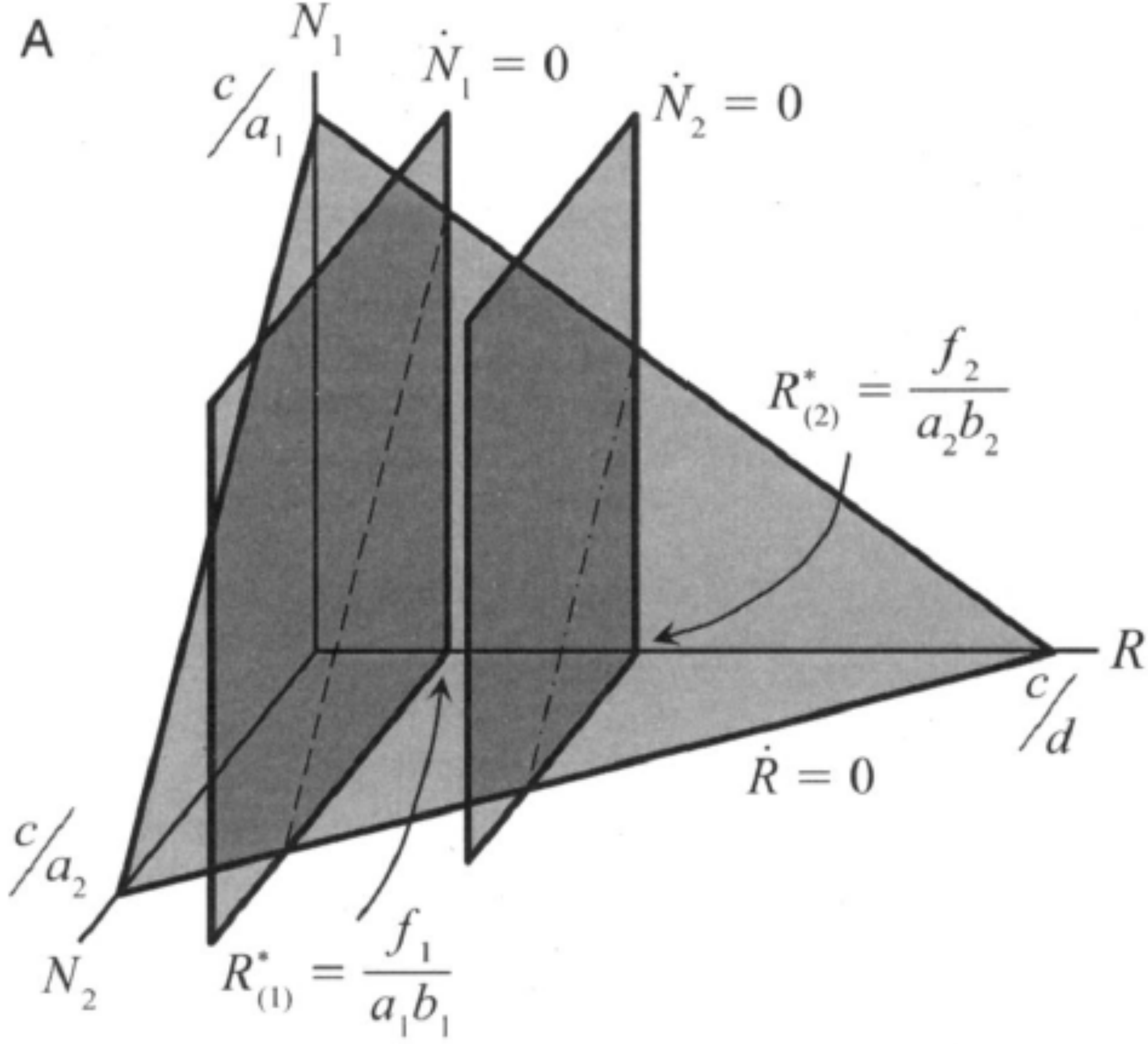
Consumer-resource phase plane:

Without interference (g=0) or handling costs (h=0)



Who will "win"?

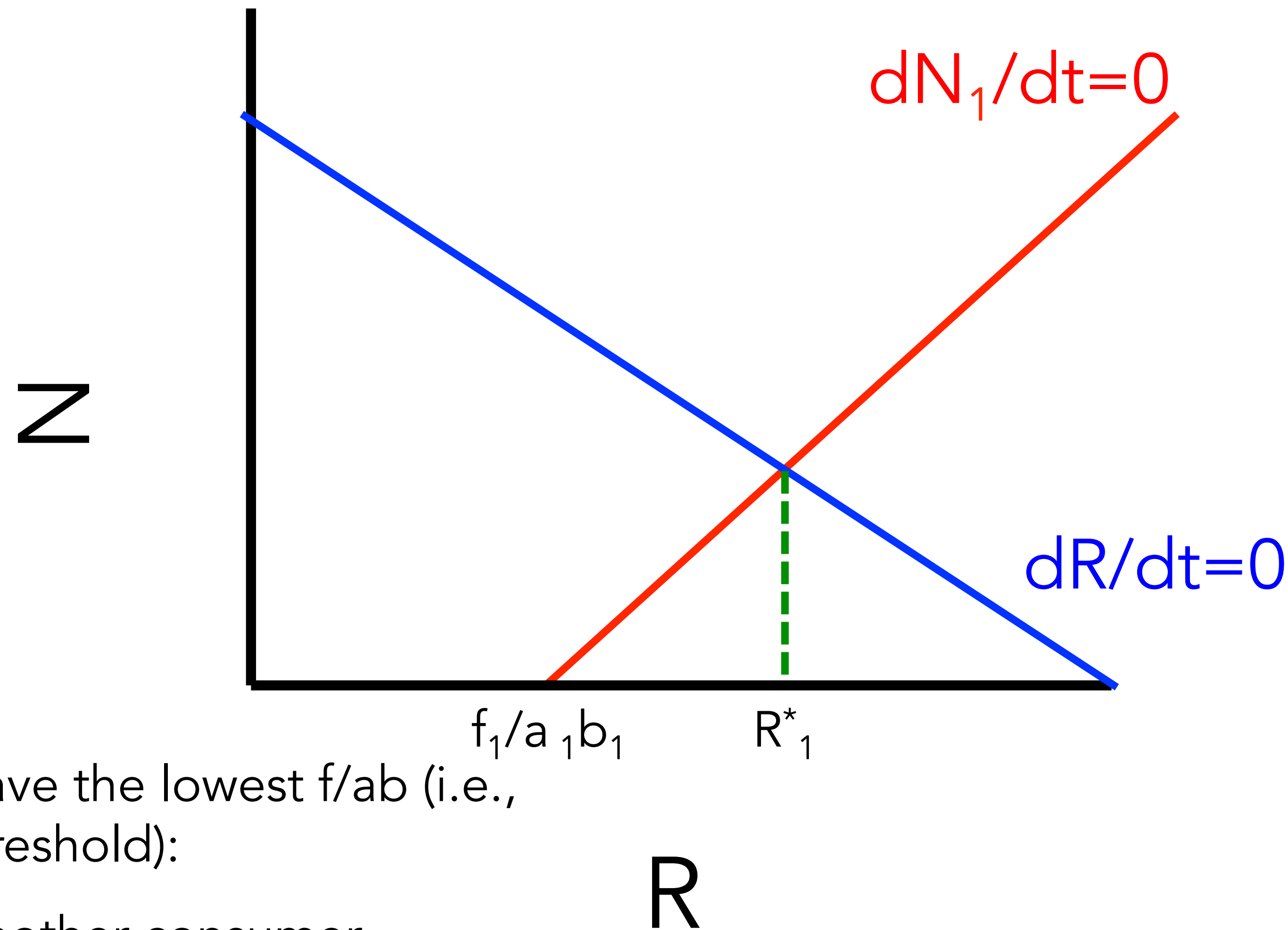
Our picture isn't sufficient – we really need a 3-d phase plane…


A
N_1
$\dot{N}_1 = 0$
$\dot{N}_2 = 0$
c/a_1
$R^*_{(2)} = \frac{f_2}{a_2 b_2}$
R
c/d
$\dot{R} = 0$
c/a_2
N_2
$R^*_{(1)} = \frac{f_1}{a_1 b_1}$

Now let there be INTRAspecific interference…

Consumer-resource phase plane:

With interference ($g>0$) but still no handling costs ($h=0$).

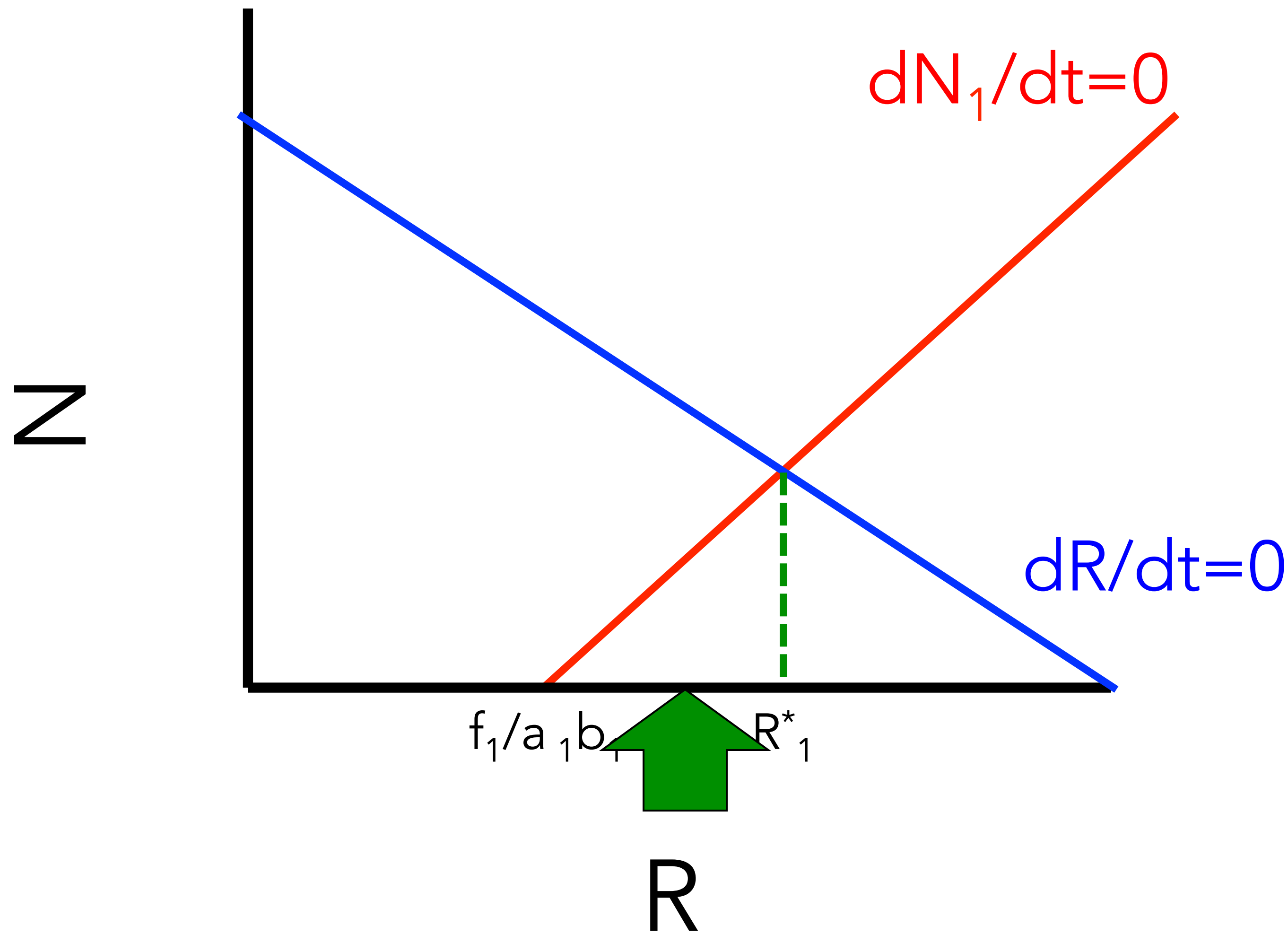


Let sp. 1 have the lowest f/ab (i.e., invasion threshold):

How can another consumer invade?

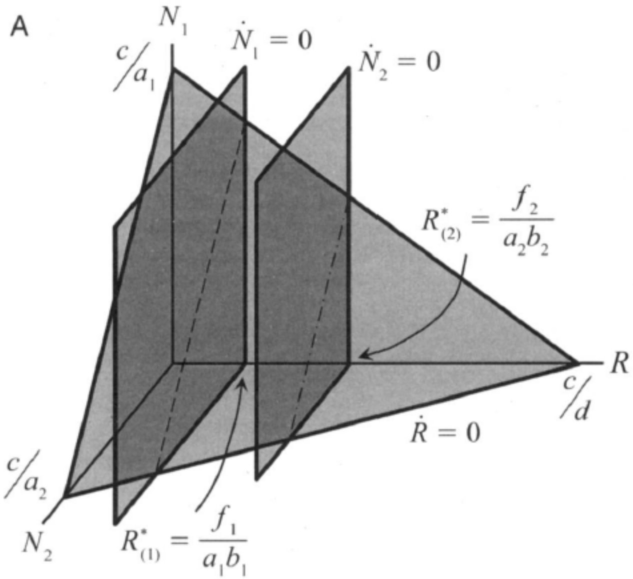
Consumer-resource phase plane:

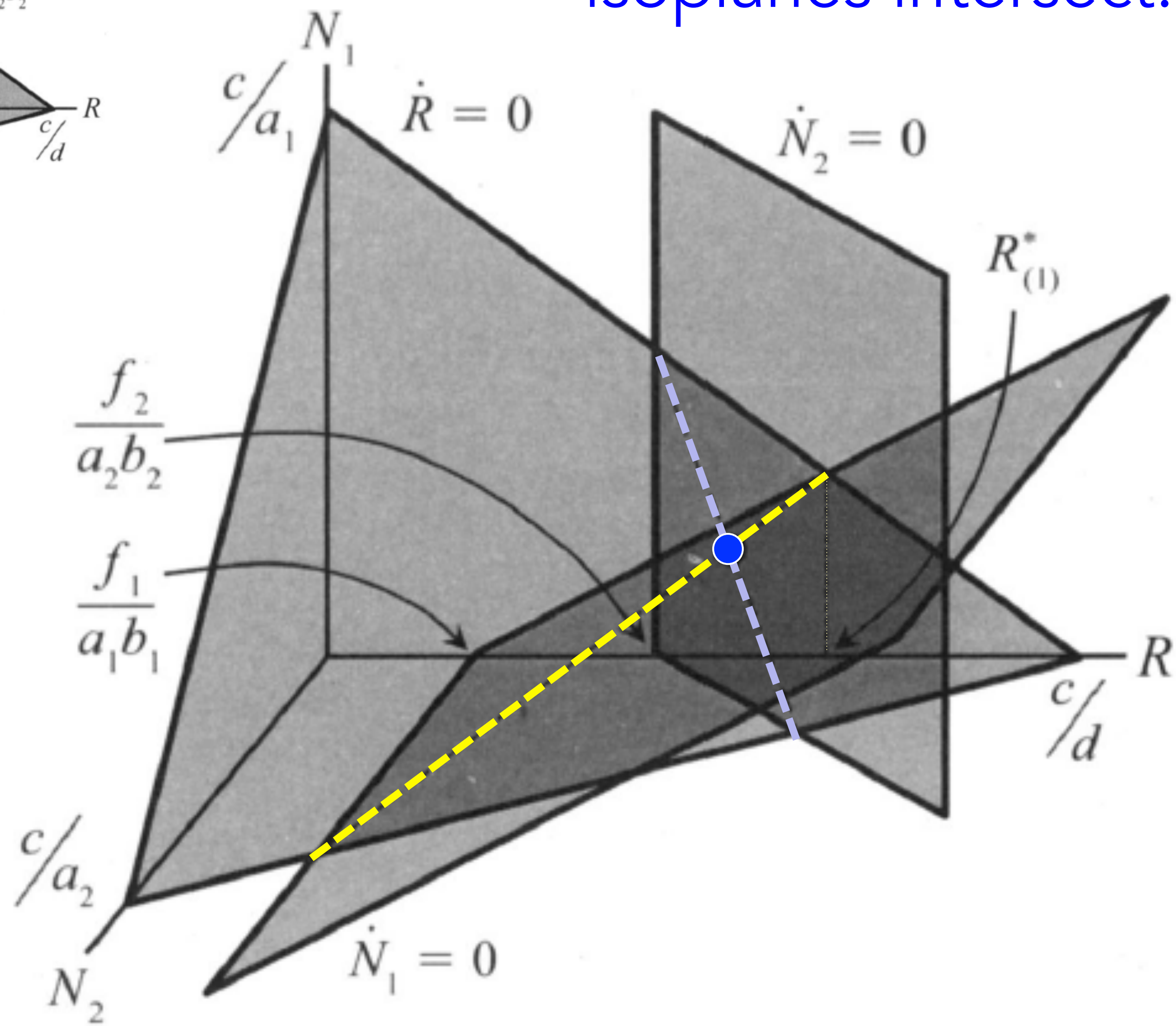
For species 2 to invade: $f_2/a_2b_2 < R^*_1$



Let's look at this in 3-d…

Three species equilibria where the isoplanes intersect:





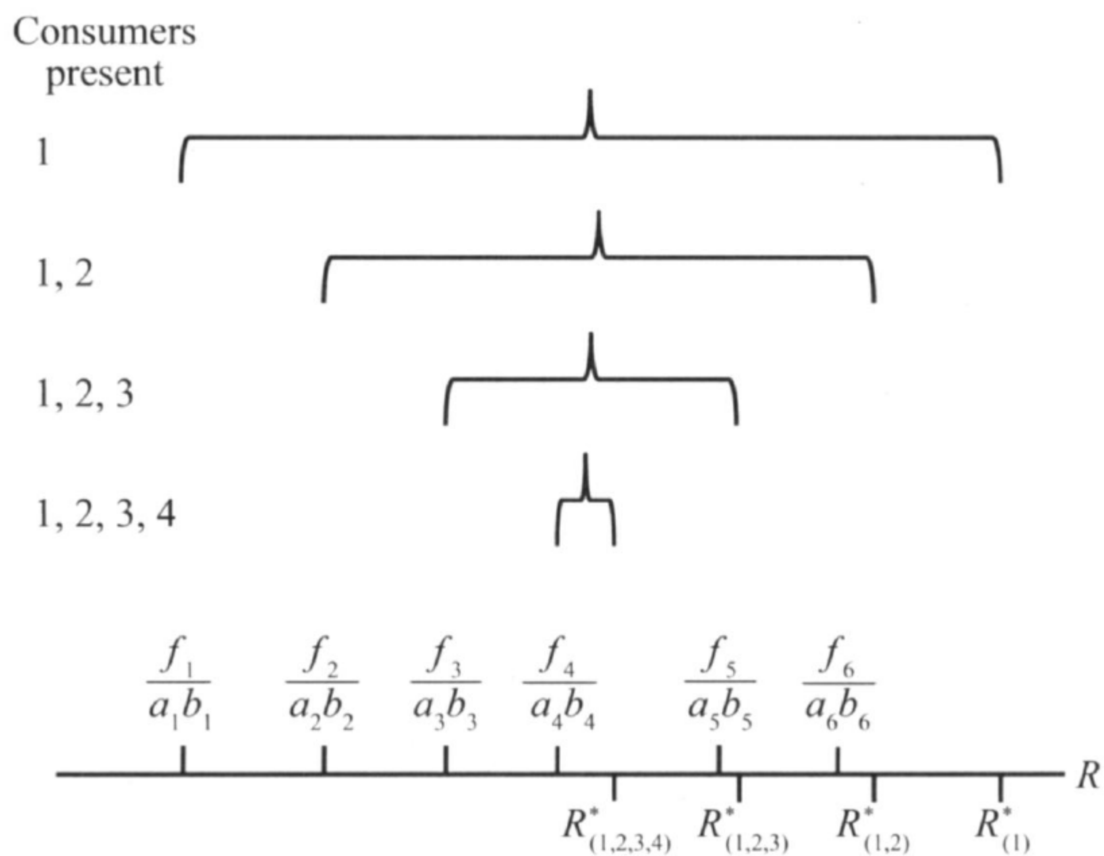


FIG. 2. An illustration focusing on the resource axis from Fig. 1 to show how adding additional species causes the window of critical ratios to become smaller as more consumers invade the system. With only consumer 1 (the species that can maintain a positive population growth rate at the lowest resource abundance) in the system, any species with $f_1/(a_1b_1) < f_i/(a_ib_i) < R^*_{(1)}$ can invade the system and coexist with consumer 1; with both consumer 1 and 2 (the two species that can maintain positive population growth rates at the lowest resource abundances) in the system, any species with $f_2/(a_2b_2) < f_i/(a_ib_i) < R^*_{(1,2)}$ can invade and coexist with them; and so on. In this specific case, consumers 1–4 could coexist with one another, but consumers 5 and 6 would be excluded. Note that consumer 5 could coexist in a community that contained consumers 1, 2, and 3 but lacked consumer 4, and that consumer 6 could coexist in a community that contained consumers 1 and 2 but lacked consumers 3 and 4.

Therefore, interference enables multiple consumers to coexist on a single resource

(creates "intra>inter"; analogous to each species having it's own unique resource (partitioning) or specialized predator (apparent competition))