Community Ecology

I. Basic Patterns and Elementary Processes

Population ecology focuses on patterns and processes of single species groups of individuals

But…

Any individual or population does not exist in isolation but exists as an integrated component within a complex ecological whole.

A. Community Ecology Defined

One level in the hierarchical **levels of organization** in Ecology.

A. Community Ecology Defined

Most definitions include idea of collection of species found in a particular place.

Whitaker (1975) – Assemblage of populations that live in environment and interact, forming a distinctive living system with its own composition, structure, environmental relations, development and function.

A. Community Ecology Defined

Ricklefs (1990) associations of animals and plants that are spatially delimited and that are dominated by one or more prominent species or by physical characteristics.

Does not emphasize interactions

A. Community Ecology Defined

Elton (1927) closely knit society or community similar to our own.

Emphasizes roles of species

A. Community Ecology Defined

Community: the all inclusive entirety of the biotic elements of an ecosystem: an interactive assemblage of species occurring together within a particular geographic area, a set of species whose ecological function and dynamics are in some way interdependent.

A. Community Ecology Defined

Not a flat mosaic of co-occurring species but as a dynamic interactive system of interdependent populations

A. Community Ecology Defined

Parameters that define it

- Composition – the spp present and their relative abundance
- Nature and Form of Relationship – direction, relative strength, and impact of those relationships
- Dynamics – its flux in both time and space

A. Community Ecology Defined

Community Classification

1. Physically defined community – defined by discrete habitat boundaries

Includes assemblages of species in particular habitat or place

Lakes, ponds, rotting fruit etc.

Biomes also example

A. Community Ecology Defined

Community Classification

2. Taxonomically defined (Taxocene) - Organisms of a particular taxon occurring together in one place (e.g., "plant community")

A. Community Ecology Defined

Examples would include the Beech and Maple forests of the northeastern United States, or the Tallgrass prairie of the Great Plains.

In both cases the predominance of one or two species defines the community. In some cases the species that defines the community may also play an important role in defining its physical structure.

A. Community Ecology Defined

3. **Statistically defined communities**. A set of species whose abundances are significantly correlated, positively or negatively over space or time.

The approach makes use of overall patterns in the identity and abundance of species to quantify similarities and differences among communities.

A. Community Ecology Defined

Provides a unbiased interpretation of a community. Method is called ordination. Outside the scope of this class.

A. Community Ecology Defined

4. Interactively defined community – consists of those subsets of species in a particular place or habitat whose interactions significantly influence their abundances.

Only some, and perhaps none of the species in a physically defined community may constitute an interactively defined community.

A. Community Ecology Defined

Hairston (1981) used this approach to point out that only a small subset of species of salamanders found in the Mts of North Carolina could be shown to interact and affect one another’s abundances.

7 spp found there but only 2 most abundant affected each other’s abundances.

A. Community Ecology Defined

So…

Key point is that the assignment of membership in a community, whether based on taxonomy or physical definition does not guarantee that species will really interact.

A. Community Ecology Defined

Most communities are extraordinarily complex.

- difficult to assemble a complete list of species for a given area.
- often focus attention on conspicuous and readily identifiable sets of species (ecologically or taxonomically similar)

A. Community Ecology Defined

- Guild- a collection of species that use resources in similar ways.
  - Granivore guilds in deserts of SW consists of birds, rodents and insects that consume seeds as their primary source of food.

A. Community Ecology Defined

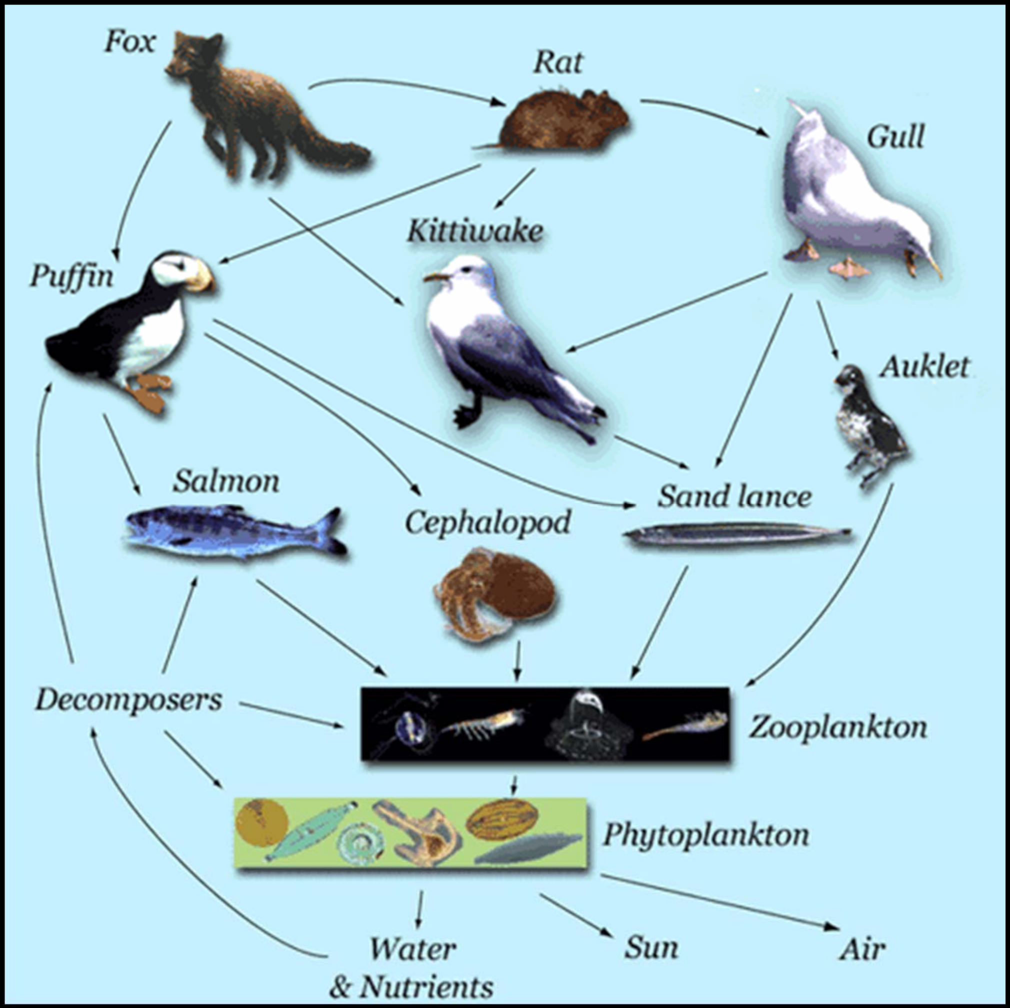
- Trophic Level – provides a way to recognize subsets of spp within a community that acquire energy in similar ways.

1° producers-----1°consumers (herbivores) -----2° consumers (carnivores).

At the ends of chains are decomposers (detritivores).

A. Community Ecology Defined

Depicted in a linear path the actual trophic relations are more complex and called a food web.



B. Community Properties

- How does one describe a community?
- How can you compare two different communities?

Ecologists have various descriptors to condense and summarize information about the #, identity, and relative abundance of a species, but no single # or index exists that can provide a complete description of a community.

B. Community Properties

1. **Species richness**

Robert May – 1 single number that goes a long way toward characterizing a biological community is simply the total # of spp present.

B. Community Properties

Species richness = the number of species per unit area of ground (difficult number to obtain)

a. don’t have complete taxonomic information about many of the groups of organisms found in even the most studied communities

b. still problem of deciding whether we had searched long and hard enough to say that all spp in that place had been found.

B. Community Properties

One way to determine if enough sampling has been done is to plot cumulative # of species by sampling effort.

Beyond a certain amount of spp vs. effort curve should reach asymptote. Reasonable estimate of the # species present.

B. Community Properties

There is increasing evidence that species richness is not just merely a nice way to compare and contrast communities.

Spp richness is related to the important functional attributes of communities.

Tilman and Downing 1994. Nature 367:363-365

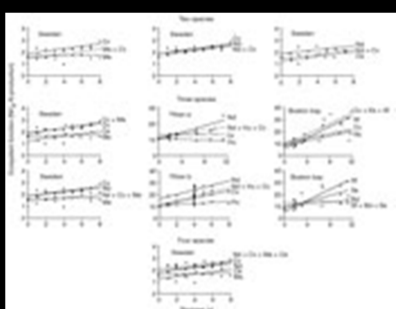
McGrady-Steed et al. 1997. Nature 390:162-165

B. Community Properties

Recent experimental work indicates

- primary production
- resistance to natural disturbance
- resistance to invasion

all increase as species richness increases



B. Community Properties

2. Diversity

a. Definition

Diversity = Informal definition = variety;

Formal definition = the way in which the number of organisms (or their biomass) is allocated among the species present,

incorporates species richness and evenness

B. Community Properties

wrote about diversity in amazon rainforest.

Intuitively that region has high diversity.

There are few individuals and many species =

High spp diversity

B. Community Properties

B. Community Properties

Probability of intraspecific encounter

Cattail Marsh =
High

Rainforest =
Low

B. Community Properties

Probability of interspecific encounter

Cattail Marsh =
Low

Rainforest =
High

B. Community Properties

So…

the number of species and relative abundance of those species are components of diversity

B. Community Properties

b. Kinds of Diversity

Point = the diversity of micro-habitat or a sample taken or from within a homogenous habitat

α = Diversity within a single community or habitat; 1- single place

B. Community Properties

β = The degree of change in diversity along a transect or between habitats; measure of the turnover of spp between two places

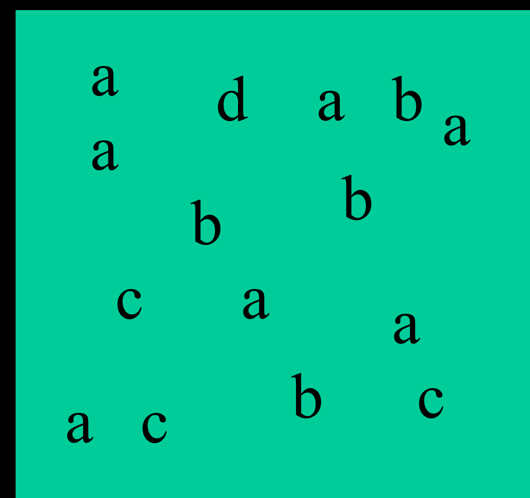
δ = Diversity of a larger unit such as an island or landscape

ε = Diversity of large biogeographic areas

B. Community Properties

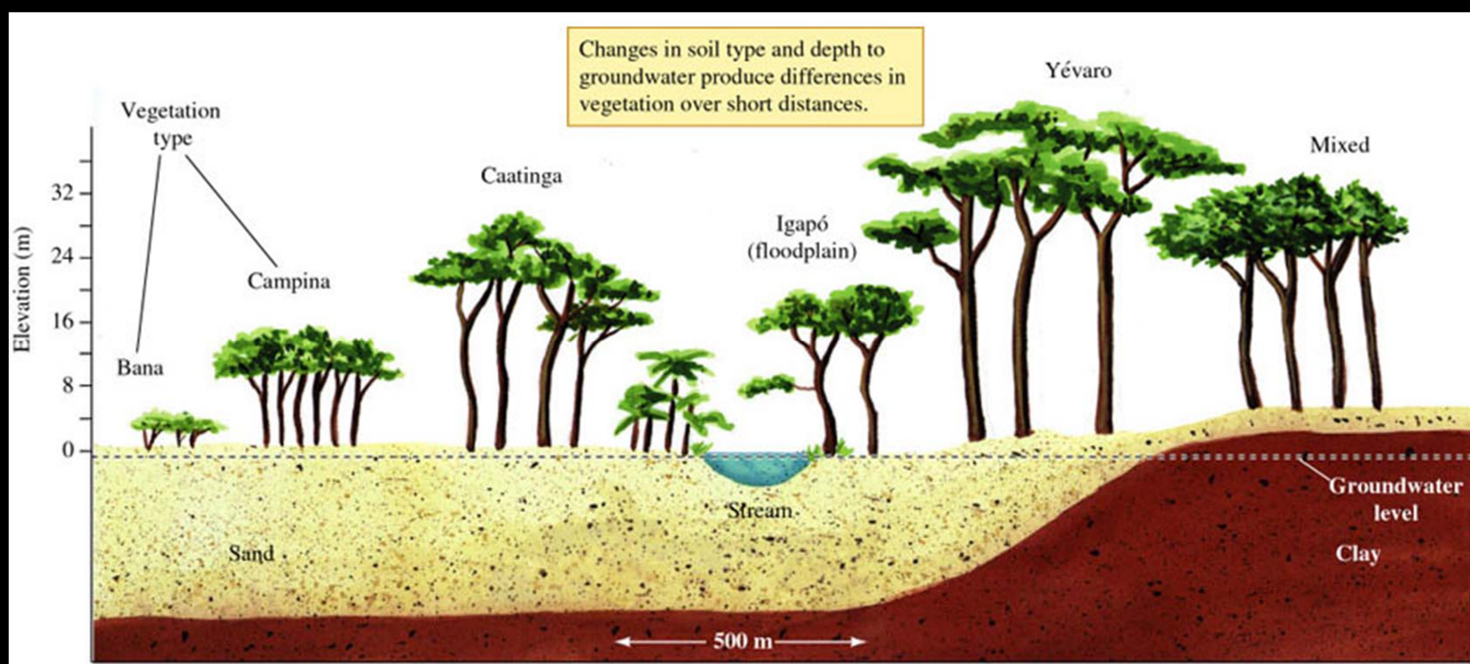
Scales of diversity

- Alpha – number of species in a given plot or area



B. Community Properties

- Beta – species turnover across an environmental gradient



B. Community Properties

- Gamma – regional species richness
- Global – total number of species of different taxa in the whole world. About 1.65 million identified. Estimates range up to about 30 million species.

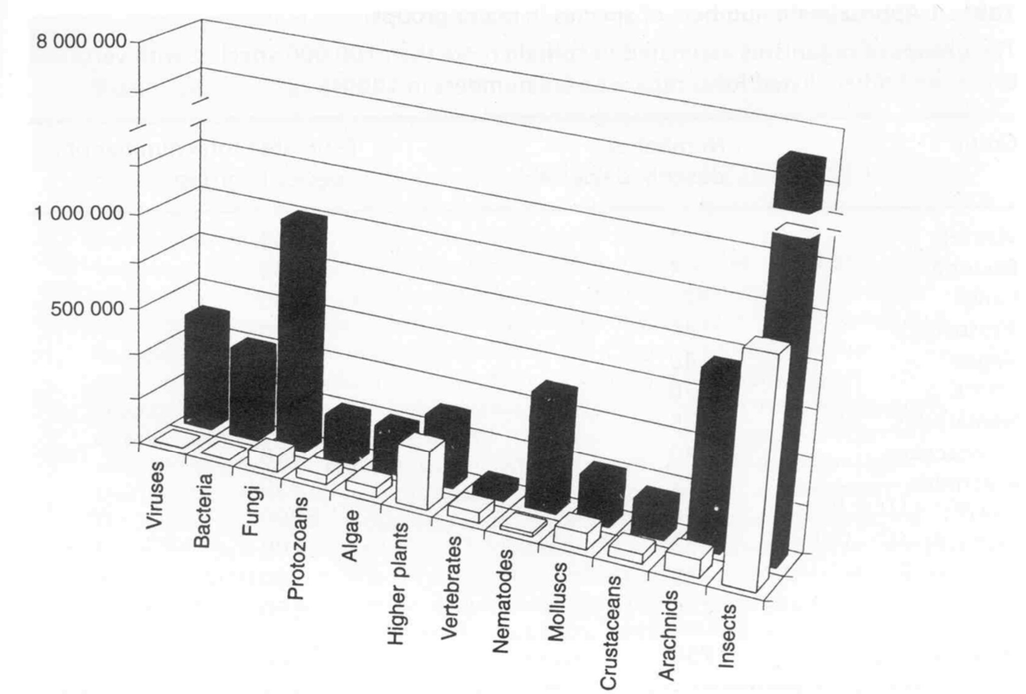


Fig. 6 Numbers of described species (open columns) and possibly existing species (dark columns) for those major groups of organisms expected to contain in excess of 100 000, with vertebrates for comparison (from Hammond, P.M. 1992. Species inventory. In: WCMC, *Global Biodiversity, Status of the Earth's Living Resources*, 17–39. Chapman and Hall, London).

Biodiversity
(≠Species diversity)

Biodiversity

- Species level: sp diversity
- < Sp level: genetic diversity
- > Sp level: community diversity,
  ecosystem diversity,……etc.

B. Community Properties

How to Measure Species Diversity

c. Diversity Indices

Many ways to measure diversity (incorporating evenness and species number). At least 60 formulas have been published.

B. Community Properties

Species Diversity

Two factors define species diversity:

- **Species Richness (S)**:
  - Number of species in the community.
- **Species Evenness**:
  - Relative abundance of species.

B. Community Properties

S = species richness, number of species

n_i = number of individuals of sp_i

N = total number of individuals

P_i = relative abundance = n_i/N

i. ***Shannon-Weiner*** – this formula gives weight to both species richness and evenness

$$\sum P_i \ln P_i = H'$$

Index for Species diversity -- Shannon-Wiener Index

- Shannon-Wiener Index =Shannon-Weaver diversity index (=Shannon diversity index), (H)

$$H' = -\sum_{i=l}^{s} p_i \log_e p_i$$

H' = Value of Shannon-Wiener diversity index.

P_i = proportion of the i^{th} species.

Log_e= natural logarithm of $p_{i.}$

S = number of species in the community.

Shannon-Wiener

- Gives weight to both species richness and evenness

B. Community Properties

ii. Simpson's – this formula gives most weight to evenness and little weight to species richness.

$$1-\sum P_i^2 = D$$

Index for Species diversity -- Simpson index

- Origin: $D=\Sigma P_i^2$
- Modifications:

$$D=\frac{1}{\sum_{i=1}^{S} P_i^2}$$

$$D=1-\Sigma Pi^2$$

Simpson's Index

- Expressed as – probability that 2 species chosen at random from community will be different species.
- Gives most of the weight to evenness and little to species richness

Evenness

- Defined as – the extent to which a group of species is uniform in number
- Most communities consist of a few species that are rare and most species are moderately abundant.

B. Community Properties

- Measurements have been devised to quantify the unequal representation of the community against a hypothetical community (where all species are equally common).

B. Community Properties

Sp evenness/ Equitability index
--from Shannon

$$J = \frac{H}{H_{max}} = \frac{\sum_{i=1}^{S} P_i \ln P_i}{\ln S}$$

Similarity Index

- How similar are 2 different communities?
- Jaccard’s Coefficient

B. Community Properties

- 1959, G. Evelyn Hutchingson’s paper, “Homage to Santa Rosalia or Why are there so many kinds of animals?”

→ what controls the no. & abundance of species?

Factors affecting diversity

Equilibrium

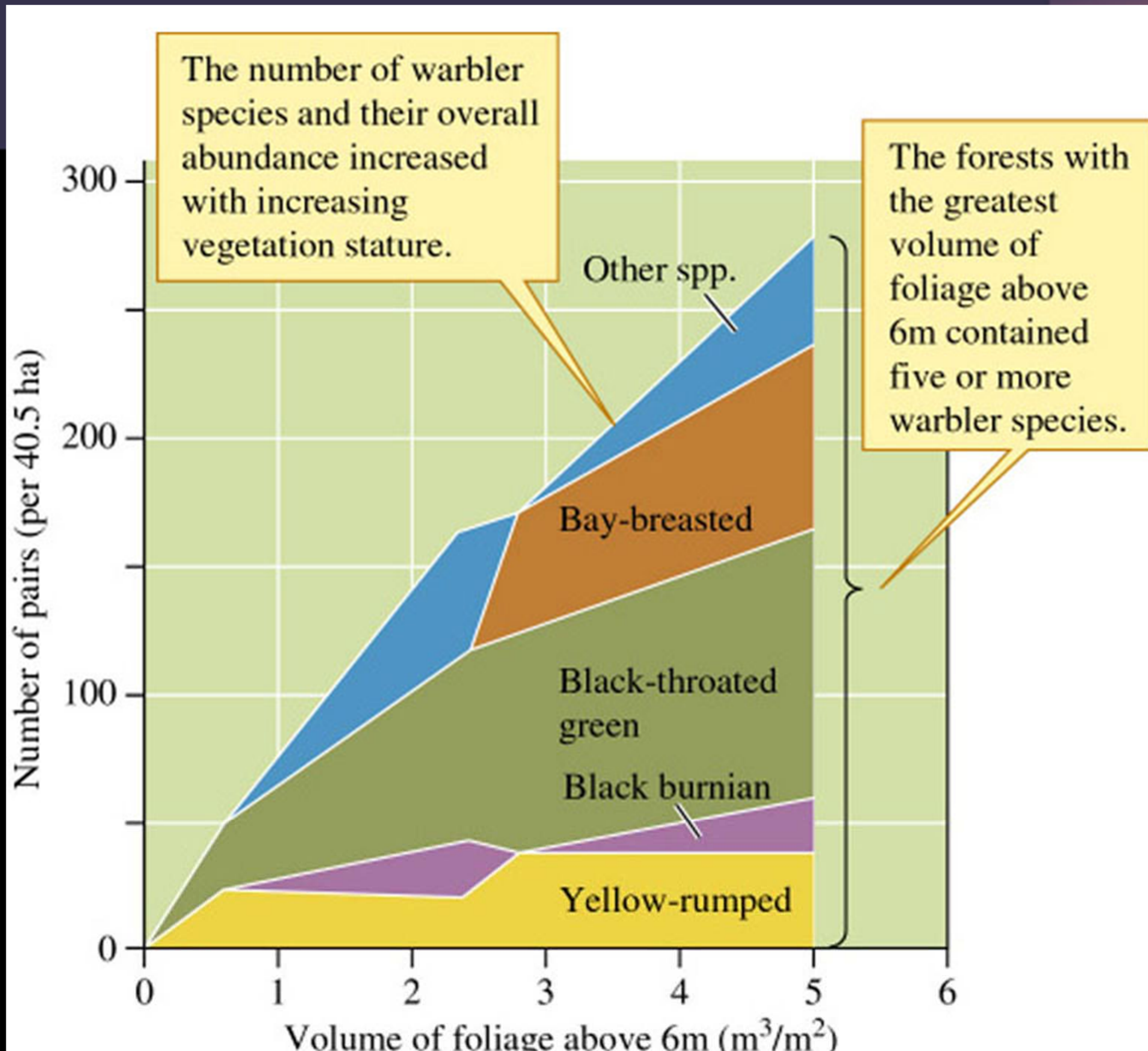
1. Environmental complexity (habitat heterogeneity)
2. Trophic interactions

Non-equilibrium

1. Intermediate disturbance

1. Environmental Complexity

- In general, species diversity increases with environmental complexity or heterogeneity.
- *MacArthur* found warbler diversity increased as vegetation stature increased.
  - Measured env. complexity as foliage height.
- Many studies have shown positive relationship between env. complexity and species diversity.



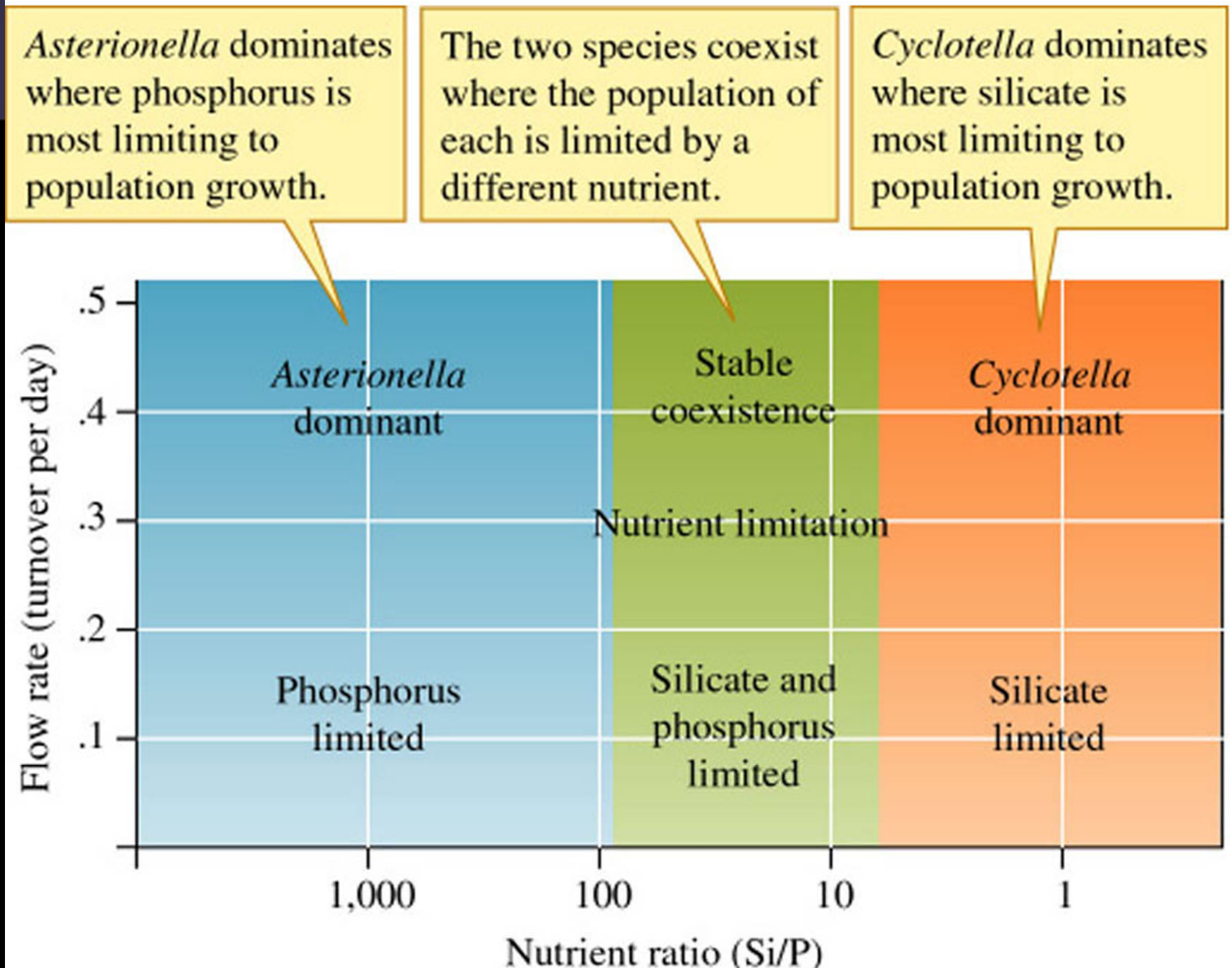
The number of warbler species and their overall abundance increased with increasing vegetation stature.
The forests with the greatest volume of foliage above 6m contained five or more warbler species.
Other spp.
Bay-breasted
Black-throated green
Black burnian
Yellow-rumped
Number of pairs (per 40.5 ha)
300
200
100
0
0
1
2
3
4
5
6
Volume of foliage above 6m (m3/m2)

Diversity of Algae and Plants

- ***Hutchinson***: *"The paradox of the plankton"*
  - Phytoplankton communities present an apparent paradox because they live in relatively simple environments and compete for the same nutrients, yet many species coexist without competitive exclusion.
    - Env. Complexity in the time domain may account for significant portion of the species diversity. Temperature, oxygen and nutrient availability vary considerably over the year.

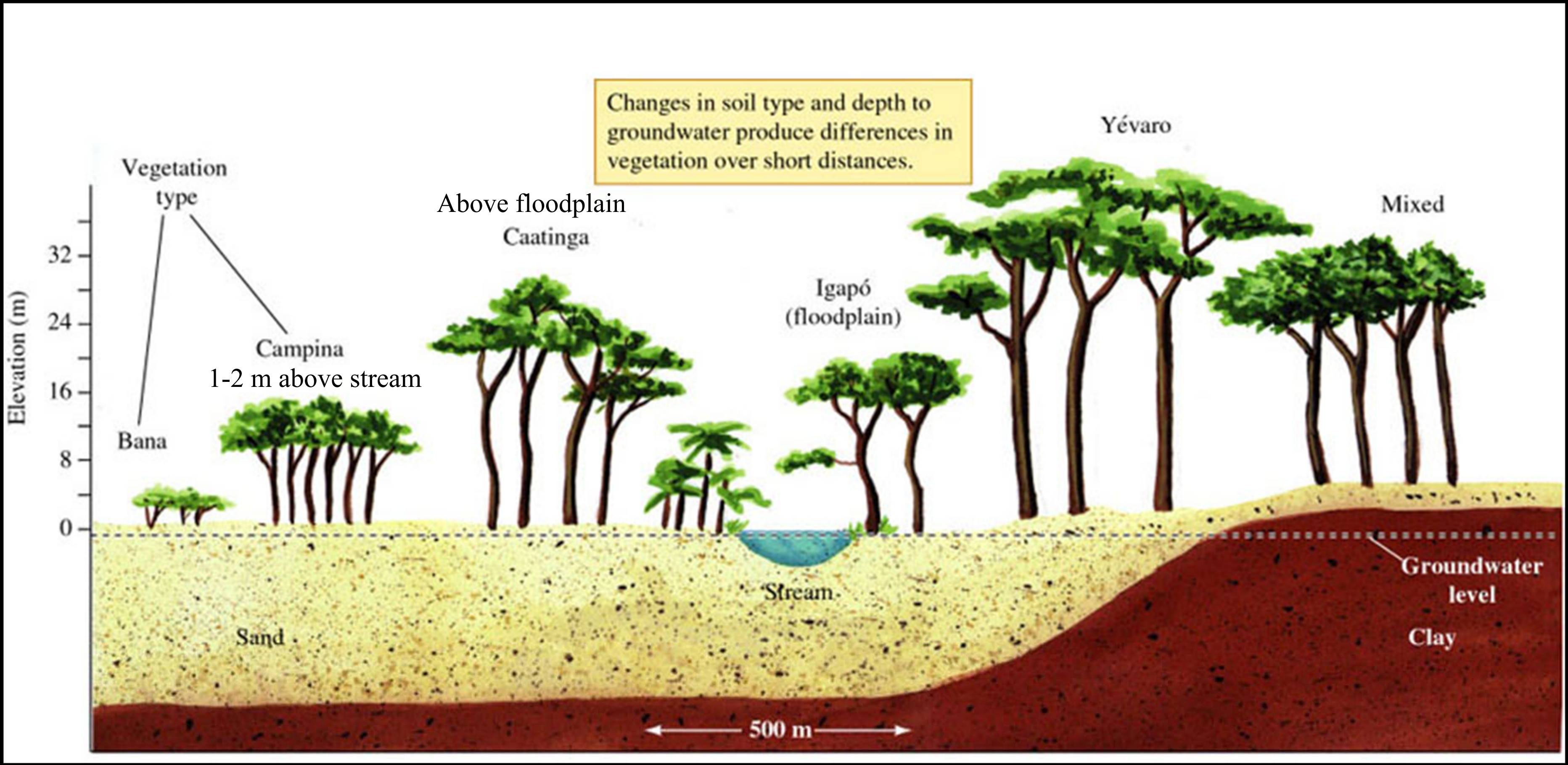
Diversity of Algae and Plants

- Algal niches appear to be defined by their nutrient requirements.
  - *Tilman* found coexistence of freshwater diatoms depended upon ratio of silicate and phosphate.
    - Found conditions allowing coexistence.
      - Diatoms held different trophic niches.
        - » Thus different diatoms would dominate different areas.


Asterionella dominates where phosphorus is most limiting to population growth.
The two species coexist where the population of each is limited by a different nutrient.
Cyclotella dominates where silicate is most limiting to population growth.
Asterionella dominant
Stable coexistence
Cyclotella dominant
Nutrient limitation
Phosphorus limited
Silicate and phosphorus limited
Silicate limited
Flow rate (turnover per day)
.5
.4
.3
.2
.1
1,000
100
10
1
Nutrient ratio (Si/P)

Niches, Heterogeneity and Diversity of Tropical Forests

- *Jordan* concluded tropical forest diversity organized in two ways:
  - Large number of species live within most tropical forest communities.
  - Large number of plant communities in a given area, each with a distinctive species composition.



Changes in soil type and depth to groundwater produce differences in vegetation over short distances.
Vegetation type
Elevation (m)
32
24
16
8
0
Bana
Campina
1-2 m above stream
Above floodplain
Caatinga
Igapó
(floodplain)
Yévaro
Mixed
Stream
Sand
Groundwater level
Clay
500 m

Non-equilibrium - Intermediate disturbance hypothesis

What is a disturbance?

Disturbance – any relatively discrete event in time that disrupts an ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment.

IMPORTANT – Consider spatial and temporal scale

Non-equilibrium - Intermediate disturbance hypothesis

Connell proposed that disturbance is a prevalent feature of nature and significantly influences the diversity of communities.

High diversity consequence of continually changing conditions, not of competitive accomodation at equilibrium.

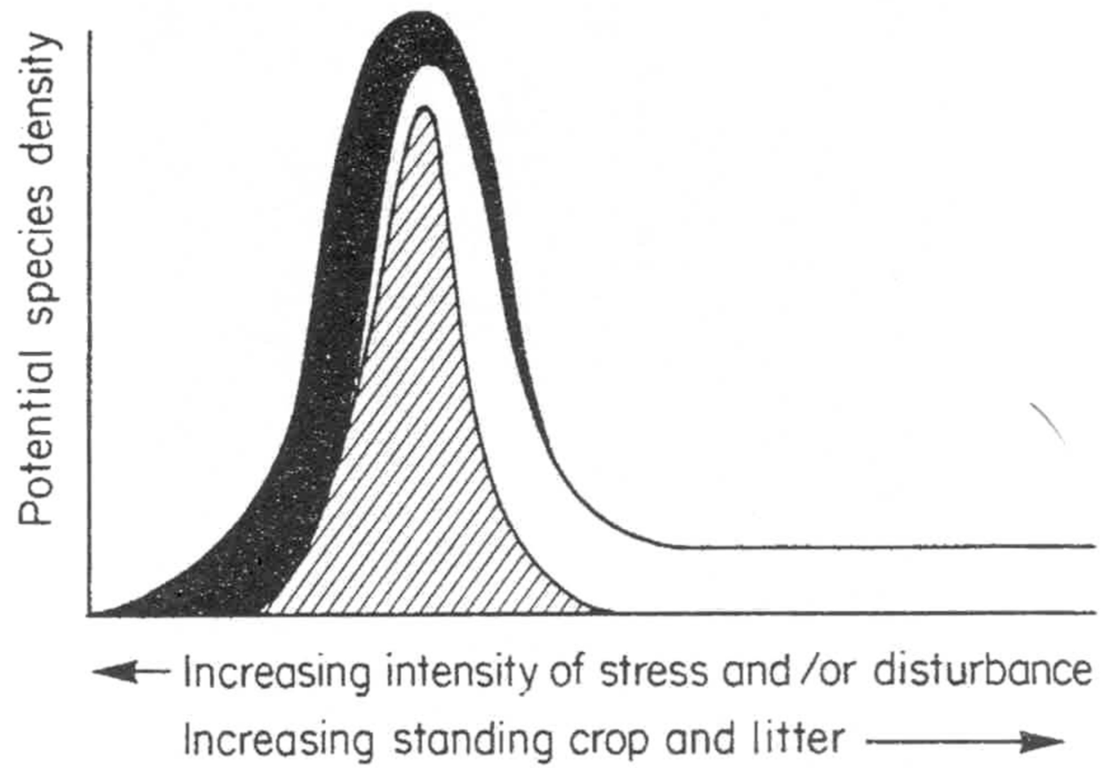


Figure 88. Model describing the impact of a gradient of increasing stress and/or disturbance upon the potential species richness in herbaceous vegetation. □ potential dominants; ■ species or ecotypes, highly adapted to the prevailing form(s) of stress or disturbance; shaded area species which are neither potential dominants, nor highly adapted to stress or disturbance. (Reproduced from Grime 1973a by permission of Macmillan (Journals) Ltd.)

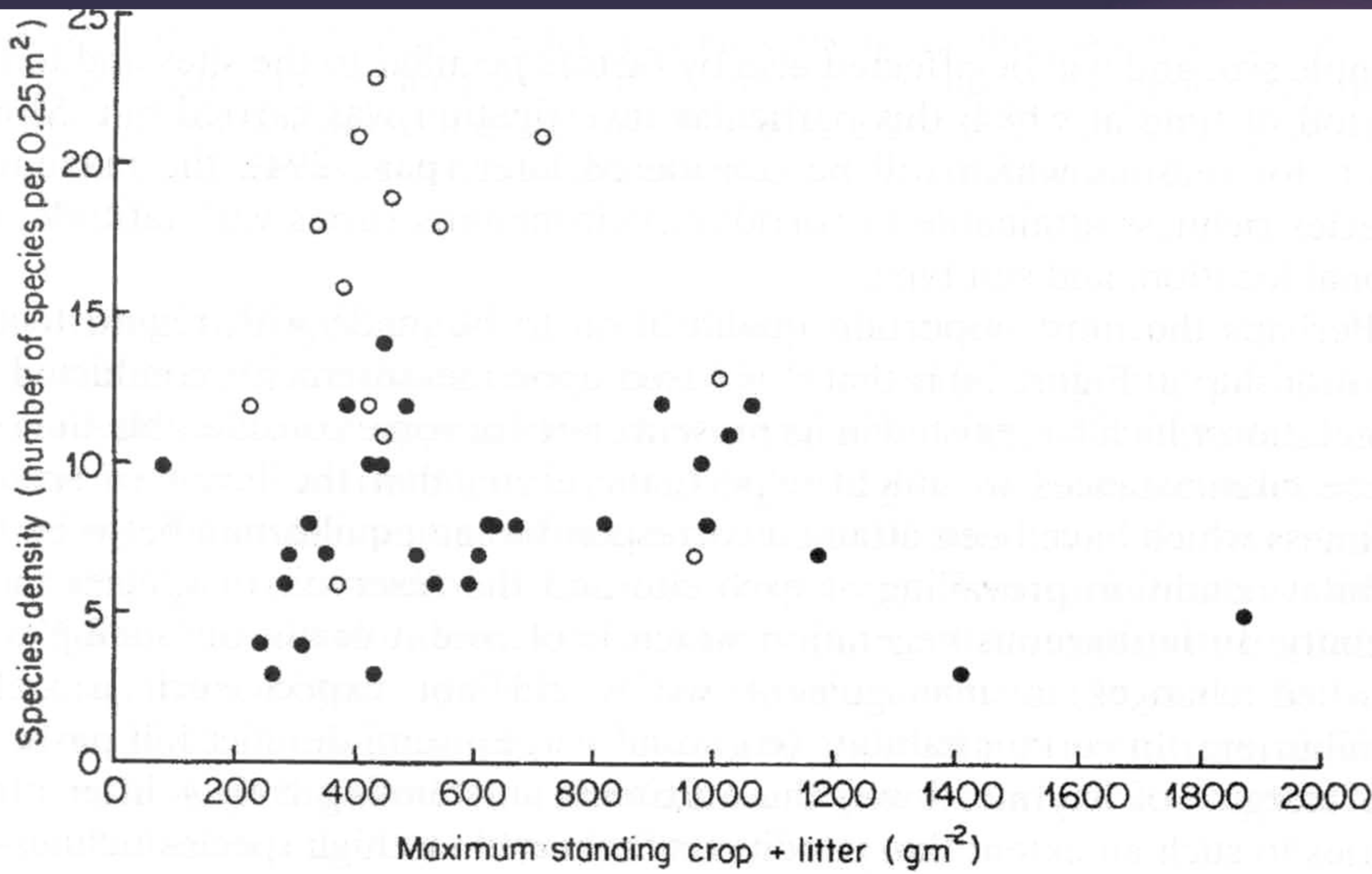
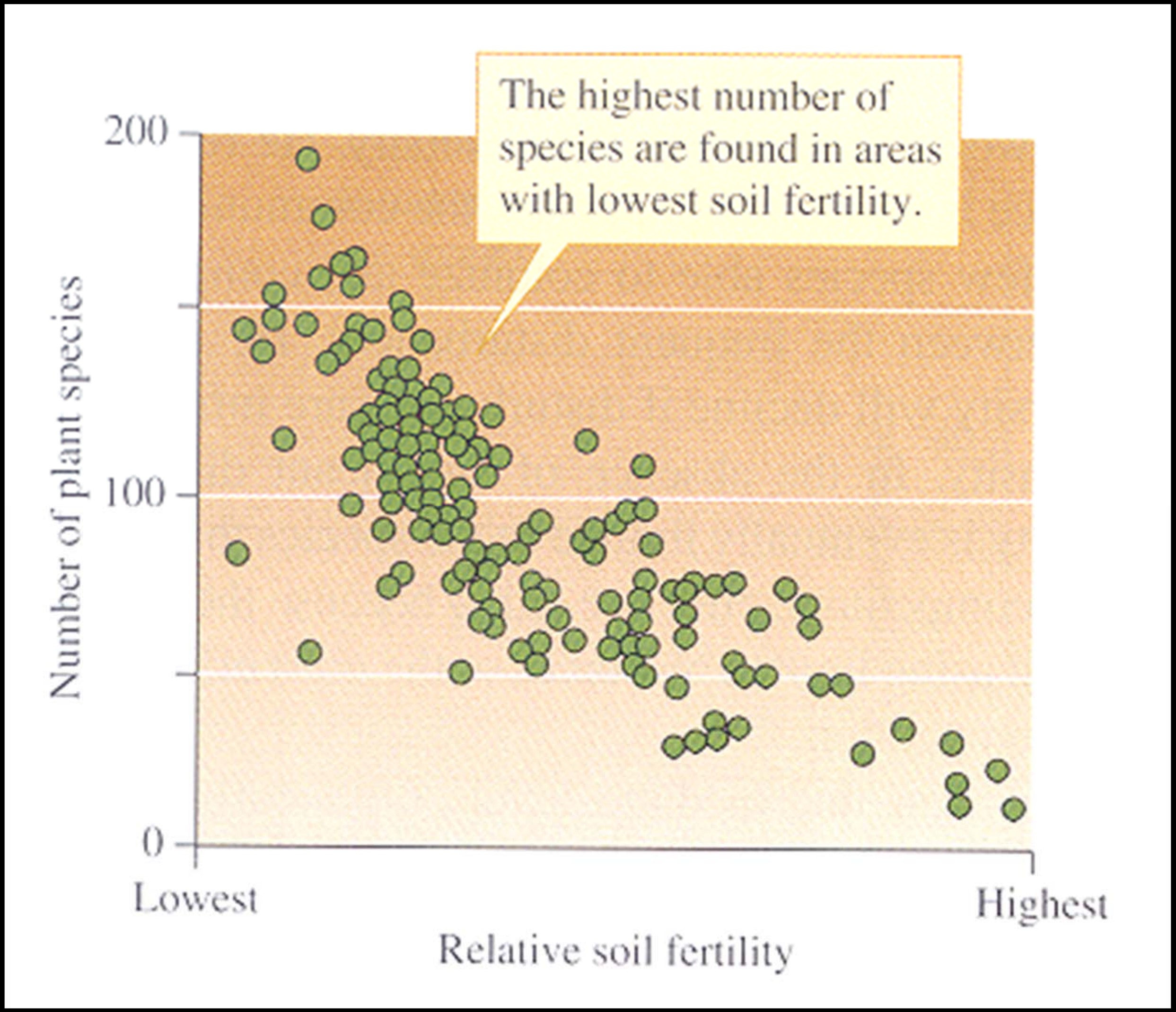


Figure 91. The relationship between estimates of the maximum standing crop plus litter and species richness of herbs in environments experiencing fluctuating patterns of vegetation management in northern England. ● road verges, subject to occasional mowing; ○ semi-derelict limestone pastures. (Reproduced by permission of Grime, Sydes, and Rodman)

Highest species richness generally found in areas with low nutrient availability

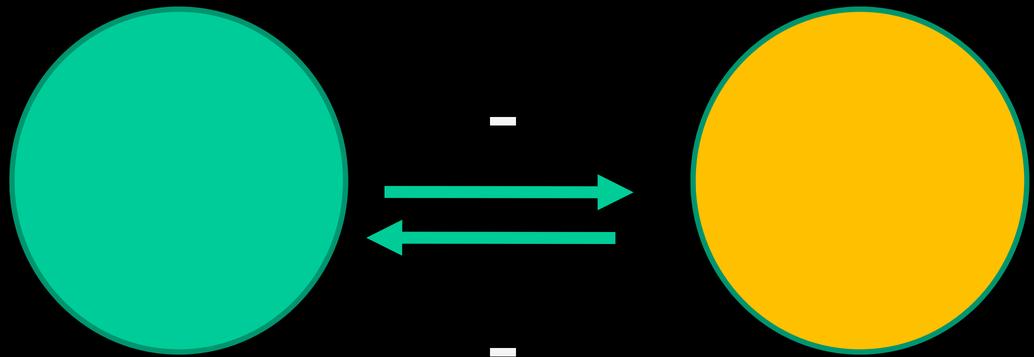


C. Interspecific Interactions

Interactions between pairs of spp can be categorized by assessing the net effect of populations on each other

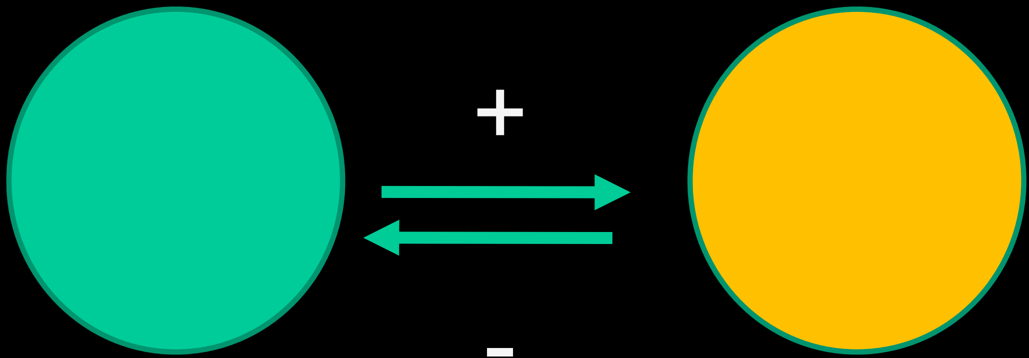
C. Interspecific Interactions

1. Competition



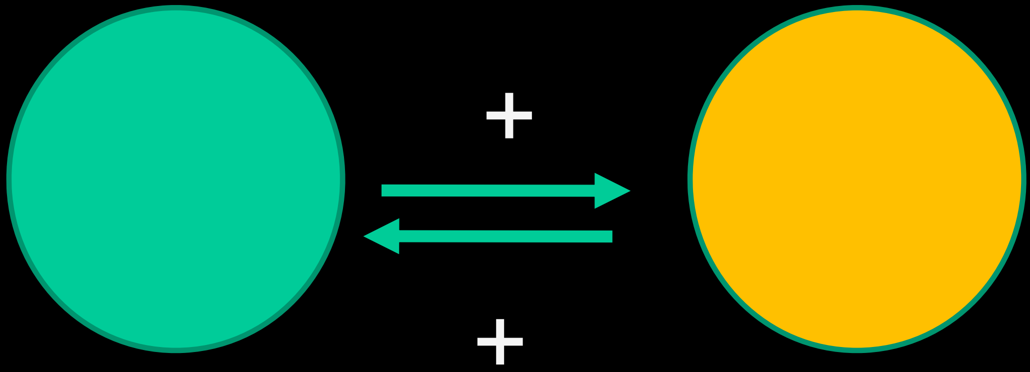
C. Interspecific Interactions

2. Predation



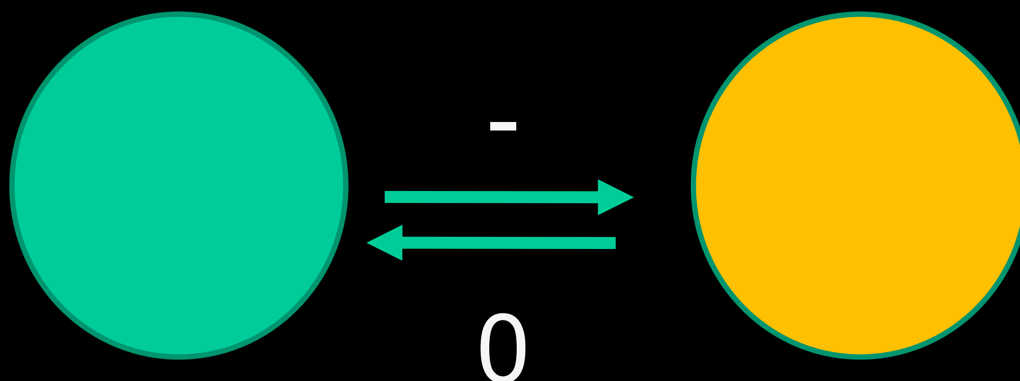
C. Interspecific Interactions

3. Mutualism



C. Interspecific Interactions

4. Amensalism



C. Interspecific Interactions

4. Amensalism

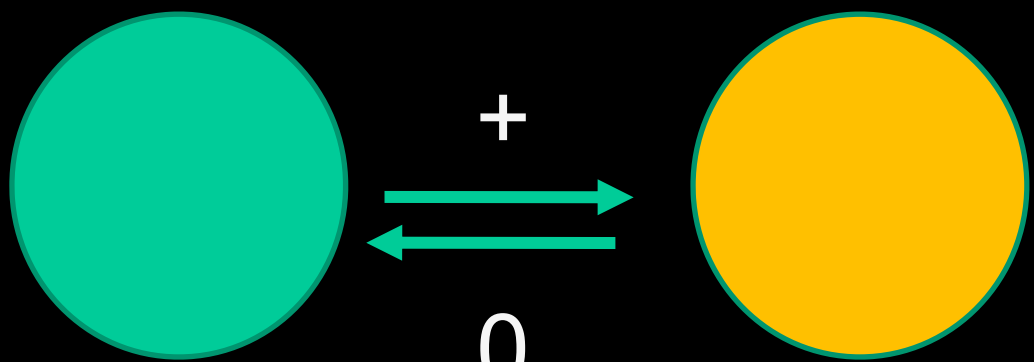
can be considered one-sided competition.

1 species has a negative effect on another but other has no detectable effect on the 1st

In most experimental settings it is unclear whether absence of reciprocal effect is real or just not observed

C. Interspecific Interactions

5. Commensalism



C. Interspecific Interactions

5. Commensalism

can be considered one-sided mutualism.

1 species has a positive effect on another but other has no detectable effect on the 1st

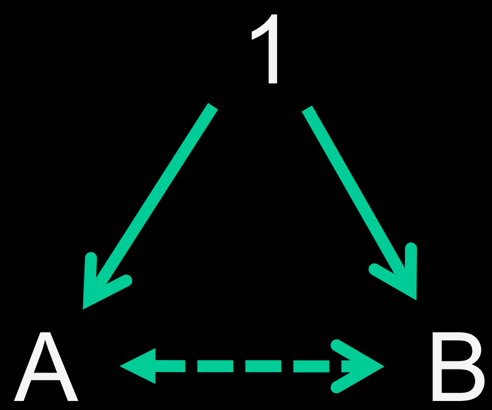
C. Interspecific Interactions

- Communities are more complex than pairs of interactions;

For example, the idea of apparent competition involves three interacting species giving the appearance that competition is occurring.

- 2 prey species – A and B
- 1 predator – 1

C. Interspecific Interactions



Neither prey species competes, but more predators will persist when both are present.

Net result = predation more intense on both prey when they co-occur (each prey has an indirect negative affect on the other)

Community Ecology

I. Basic Patterns and Elementary Processes

D. Community Patterns

Goals of Community Ecology

- Finding patterns, laws and generalizations
  - applicable to diverse systems
  - convey understanding about those systems

- Ability to predict community properties and processes under certain conditions

Communities

- Properties and Patterns
  - # species
  - relative abundance
  - morphology
  - trophic links
  - succession
- Processes
  - disturbances
  - trophic interactions
  - competition
  - mutualism
  - indirect effects

D. Community Patterns

Community patterns arise from a hierarchy of processes.

Many factors determine the composition of species within a given area with no single factor providing the explanation.

D. Community Patterns

Composition of a regional species pool of potential community members sets the upper limit on the species composition of a new community developing in a new place.

D. Community Patterns

Membership in a regional pool is constrained by

- -physiological tolerances
- -historical factors
- -evolutionary processes

D. Community Patterns

Habitat selection and dispersal abilities then sift and filter the species from a regional pool

set the identity of those species available to colonize a given community.

These factors make community nonrandom subsets of the regional pool of species.

D. Community Patterns

- Interspecific interactions (or there of) influence the subsequent success or failure of a species that actually arrives at the community.

II. Competition

Is it omnipresent and omnipotent?

II. Competition

A. Definition – mutually negative interaction between two or more species

- reduced abundance
- decreased fitness
- component of fitness
    - body mass
    - growth rate
    - fecundity
    - survivorship

B. Experimental vs. Observational Data

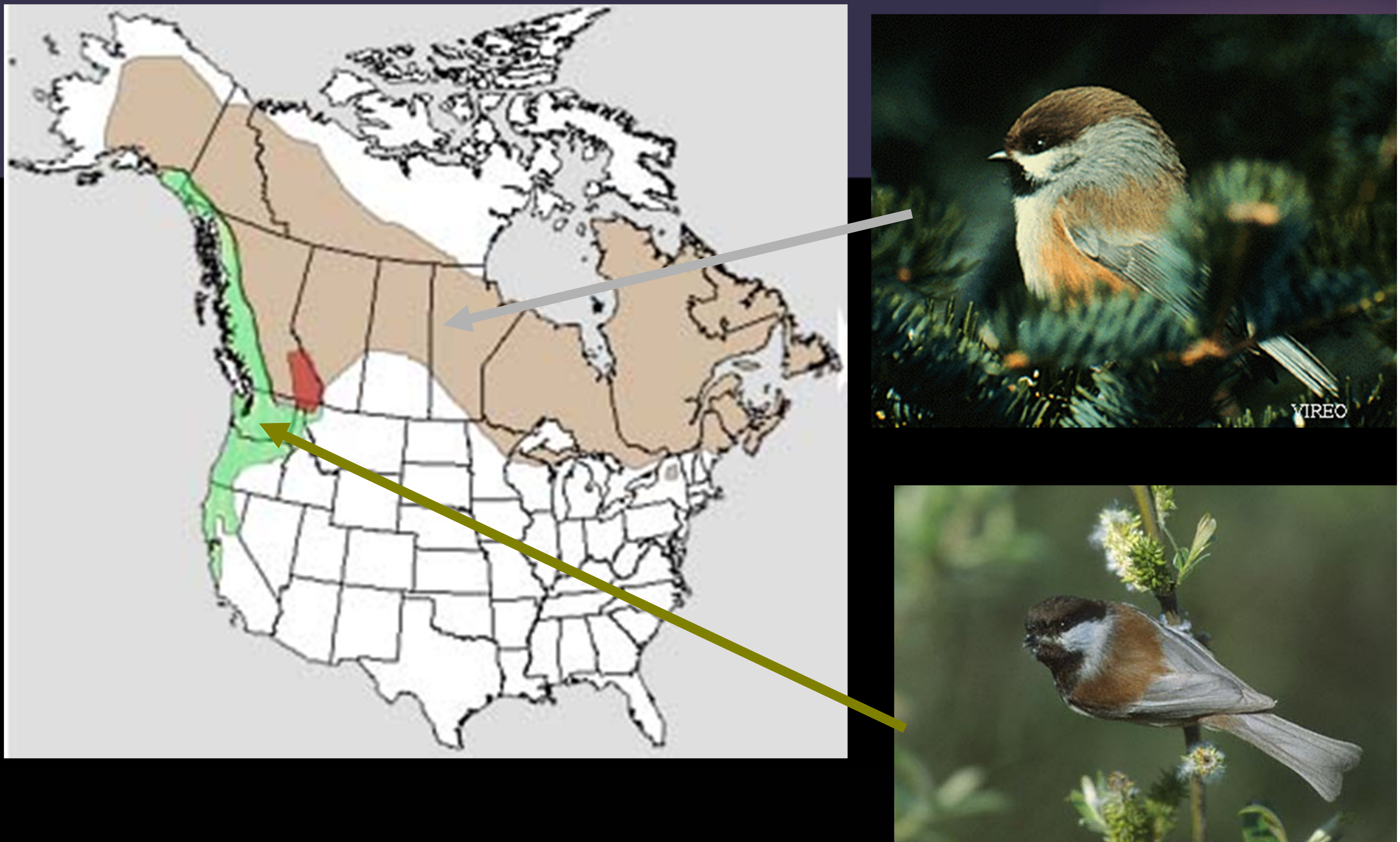
Observational Studies – search for patterns produced by interspecific competition in natural communities without manipulating the abundances of competitors

Experimental – observe how species respond to direct manipulation of potential competitors

Debate as to value of experiments vs. observational studies.

Experimental manipulations are more direct, provides very strong inference

Observational studies have definite value, many questions can’t be answered via experiments.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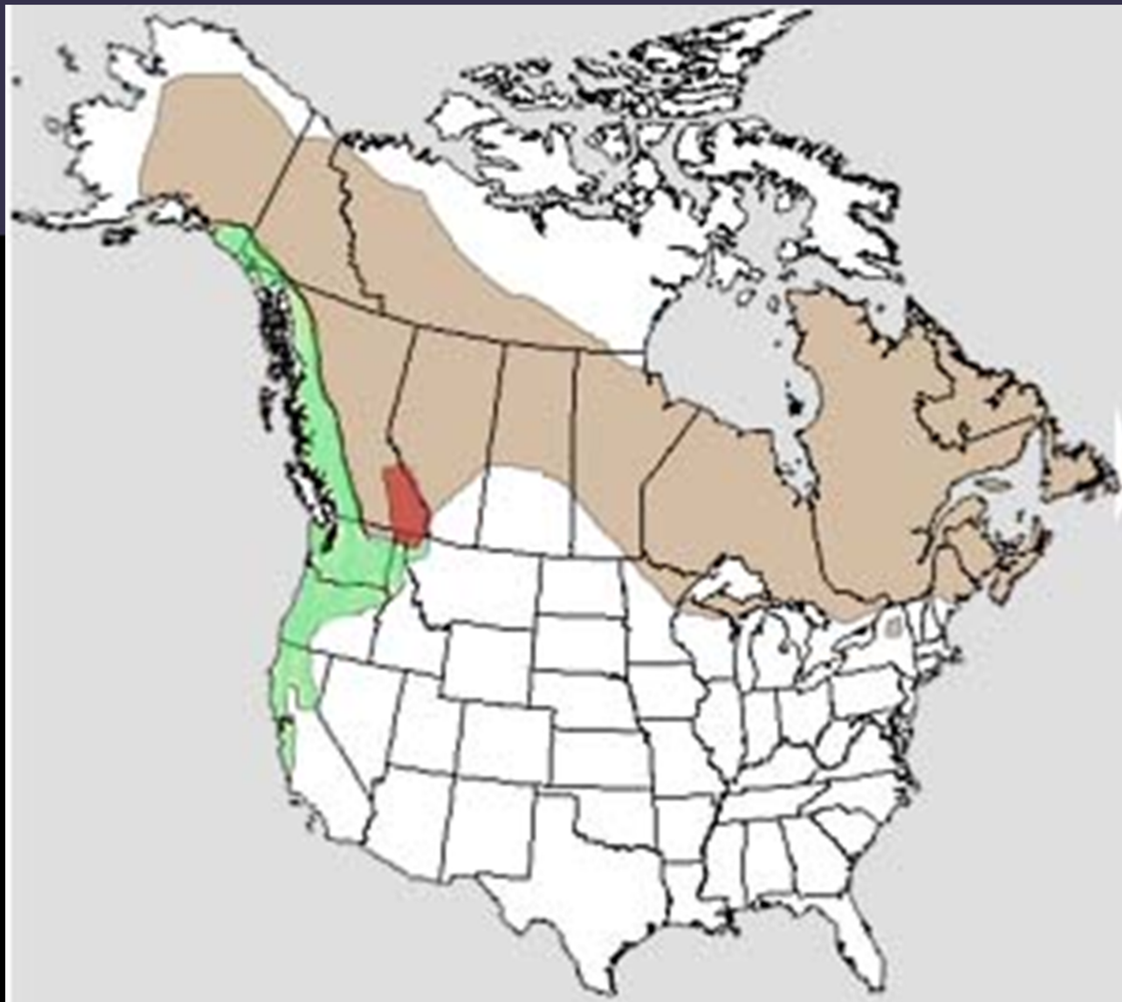


Where the species overlap –

Boreal Chickadee at higher elevations

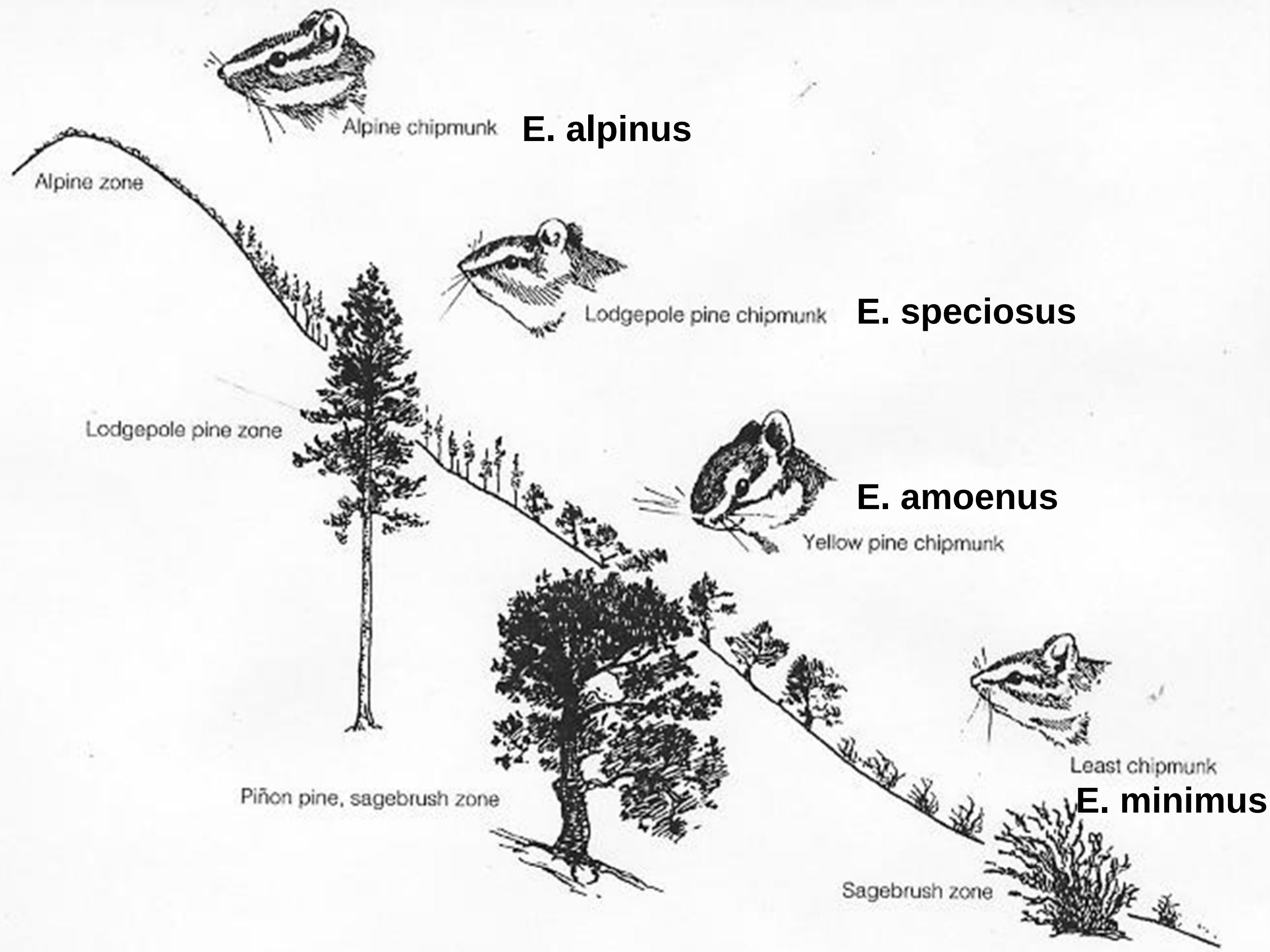
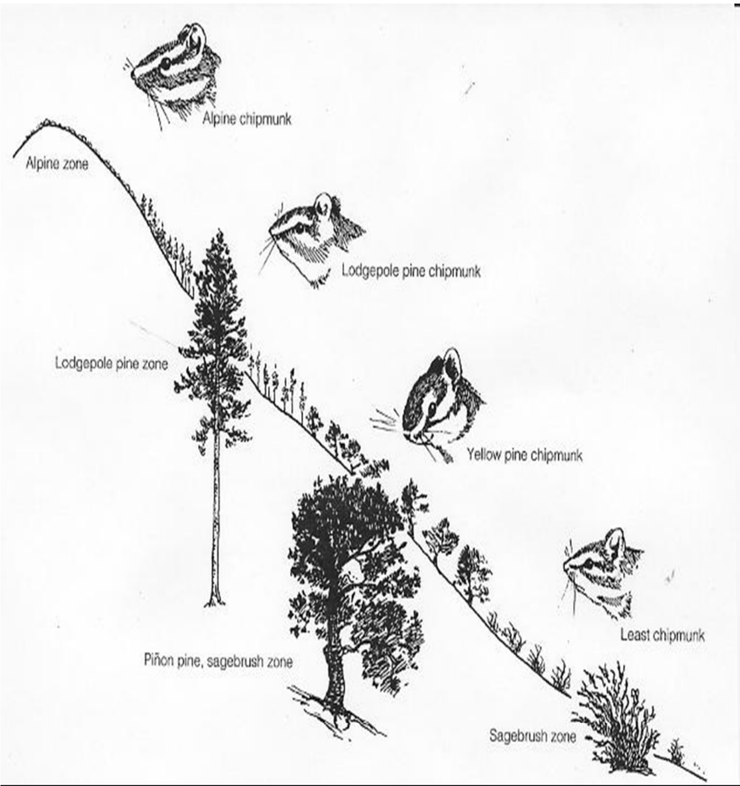


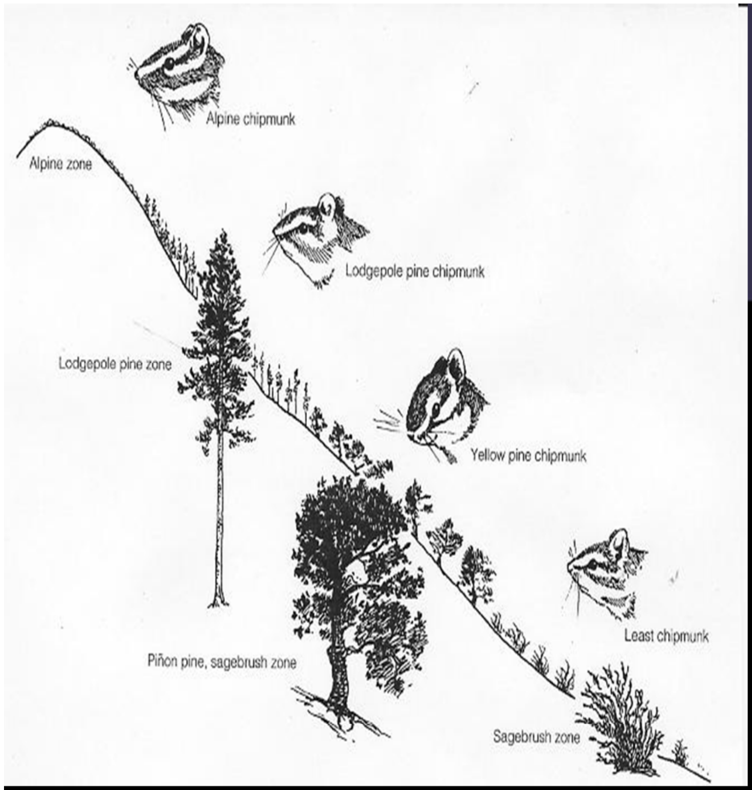
Figure 15.4 A transect of the Sierra Nevada Mountains in California, 38° north latitude, showing vegetation zonation and the altitudinal ranges of four species of chipmunks *(Eutamias)* on the east slope.



Have overlapping food requirements

Least Chipmunk can occupy full range of habitats

If Yellow pine absent Least moves into vacated open pine woods



If Least is absent, Yellow pine doesn't invade into sagebrush zone.

Least can tolerate, hot dry conditions of the lower elevations (others can't)

These studies have established a correlation but not a cause.

To establish causation need manipulation

- Replication
- Randomization
- Independence
- Control

Observational studies can be made more compelling by determining if patterns differ from those expected by chance –

Null Models

C. Ecological vs. Evolutionary Time Scale

Ecological:

- Question is how a community functions now
- How do contemporary processes act to maintain the observed community structure?

Evolutionary:

- Question is the history of how a community came to its present state over evolutionary time
- How do species evolve in response to selection due to community processes?

Ecological vs. Evolutionary Questions

- Ecological studies more easily conducted
- Evolutionary studies rely less on direct experiment and more on comparative, observational, and theoretical models
- Evolutionary questions imply ecological questions
- Ecological questions do not necessarily imply evolutionary questions.

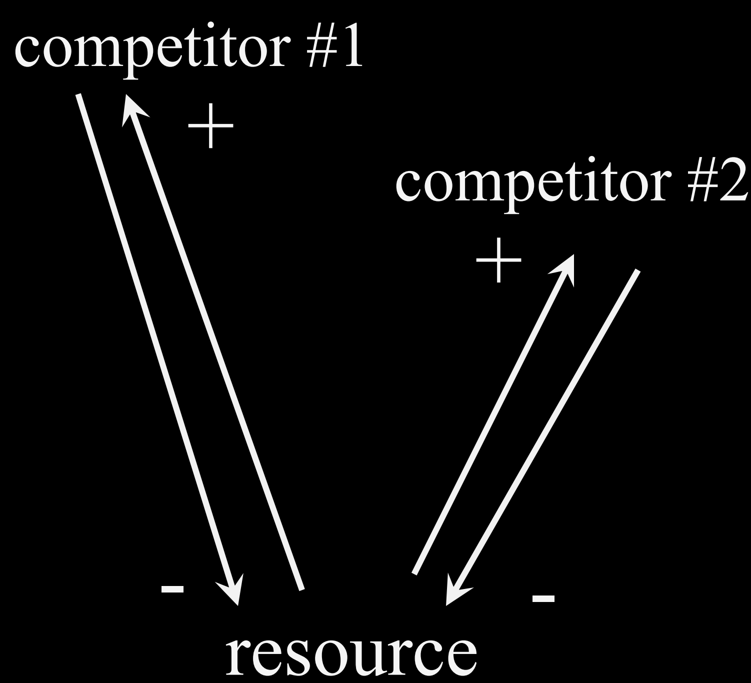
D. Mechanisms of Interspecific Competition

1. Traditional Classification

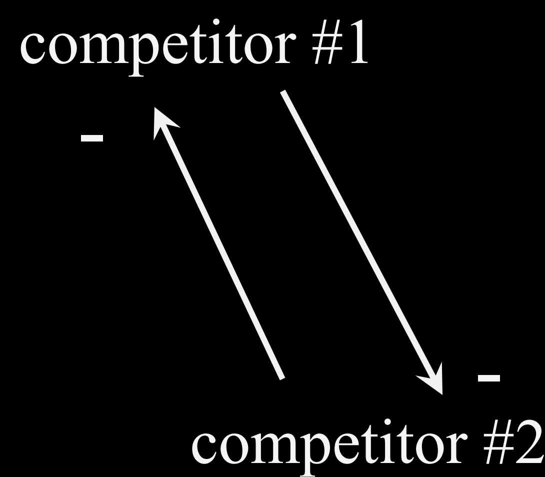
Exploitation – competition in which 2 or more organisms consume the same limited resource

Interference – competition in which one species prevents resource use by another, active inhibition

Resource competition



Interference competition



2. Schoener's Classification

Difficulty in fitting all types of competition into either exploitation or interference

a. Consumption – one species inhibits another by consuming shared resource

b. Preemptive – sessile organisms, results when a physical resource is occupied and thus made unavailable

c. Overgrowth – one organism grows over another, with or without physical contact

d. Chemical – chemical growth inhibitors or toxins produced by some species, kill or inhibit others growth (Black Walnut, antibiotics, tadpoles).

e. Territorial – results from aggressive behavioral exclusion of organisms from specific units of space

f. Encounter – results when nonterritorial encounters between foraging individuals result in negative effects on one or both of the interacting individuals.

E. Models of competition

- yield important predictions about conditions promoting coexistence or exclusion
- useful when lab or field studies are impractical
- used to generate new hypotheses

1. Classical Model

Lotka-Volterra Competition Model

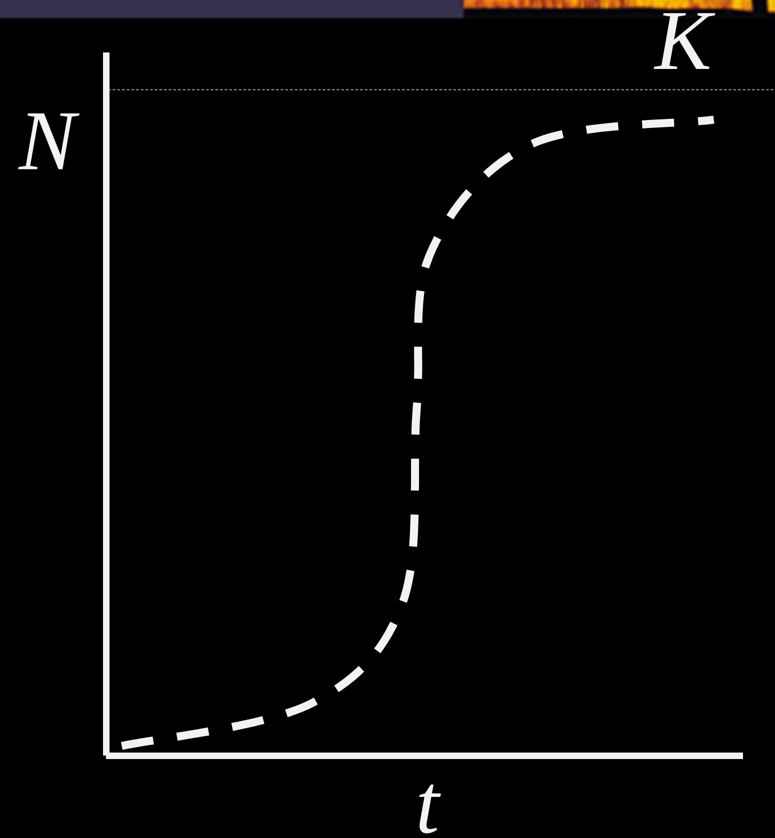
Derived independently

Model describes competition between organisms for food or space

Based on logistic growth curve

Logistic growth:

$$dN / dt = r N [K - N /K]$$



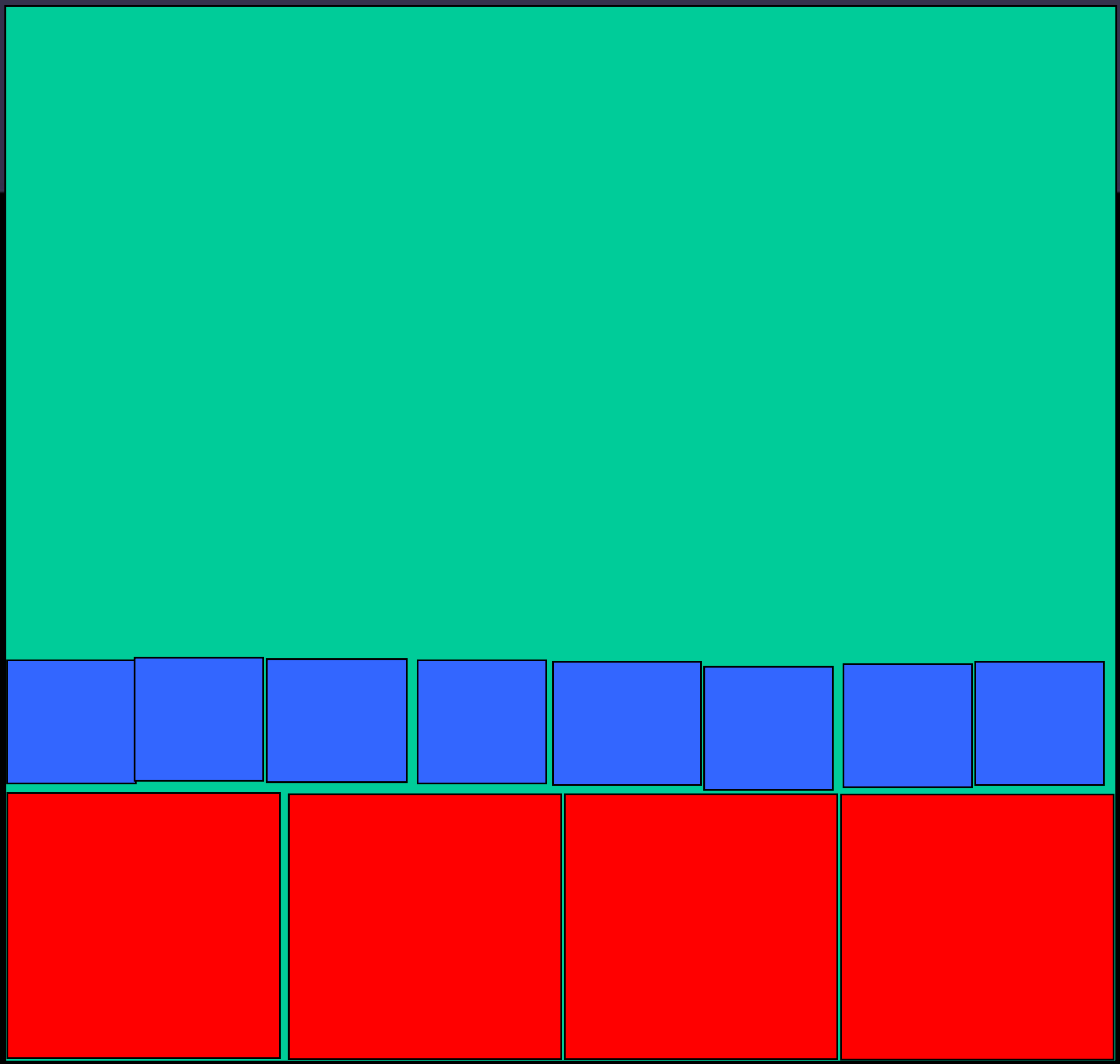
r = intrinsic rate of increase

K = carrying capacity

2 species interact, each is affecting population growth of the other

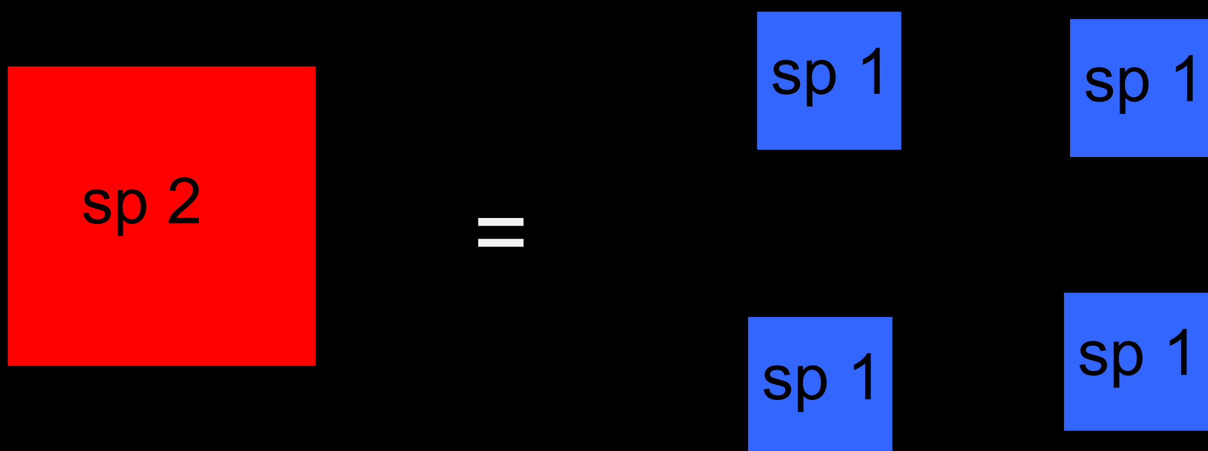
sp 1

sp 2



Species are not equivalent

Need a term to express species 2 in terms of species 1 and vice versa



α , β = competition factors

This can be defined by $N1 = \alpha * N2$

Lotka-Volterra Competition

- α = competition coefficient
  - effect of species 1 on species 2
- β = competition coefficient
  - effect of species 2 on species 1
- equivalence of N_1 and N_2

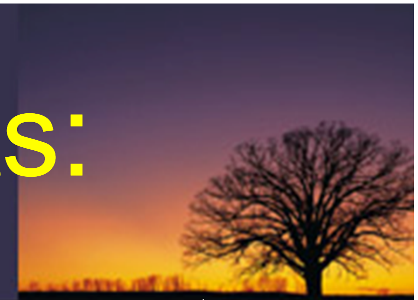
Lotka-Volterra Competition

$N_1 \; N_2 \qquad r_1 \; r_2 \qquad K_1 \; K_2$

$$dN_1 / dt = r_1 N_1 \frac{[\, K_1 - N_1 - \alpha N_2 \,]}{K_1}$$

$$dN_2 / dt = r_2 N_2 \frac{[\, K_2 - N_2 - \beta N_1 \,]}{K_2}$$

Competition coefficients:



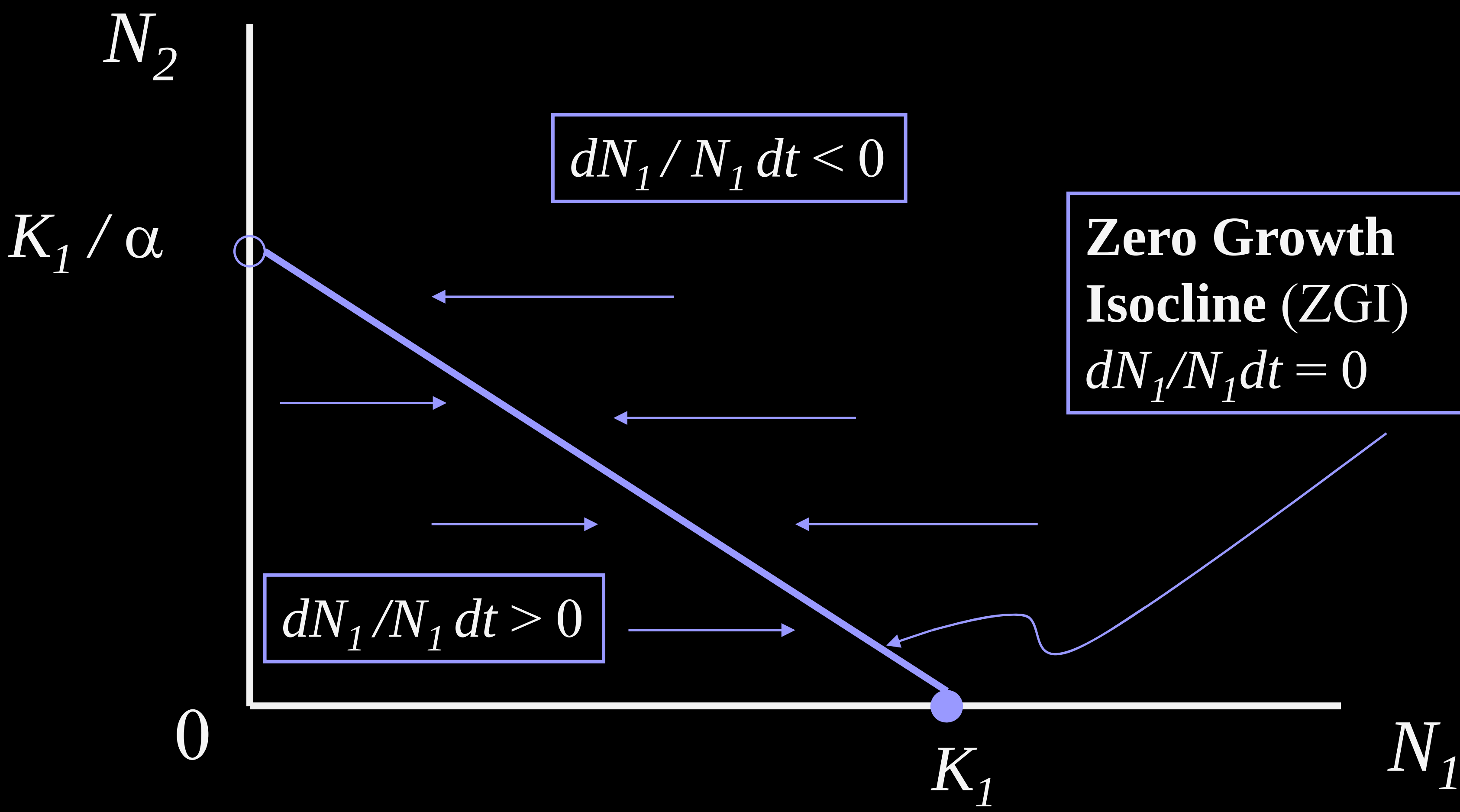
- $\beta > 1 \rightarrow$ impact of sp. 2 on sp. 1 greater than the impact of sp. 1 on itself
- $\beta < 1 \rightarrow$ impact of sp. 2 on sp. 1 less than the impact of sp. 1 on itself
- $\beta = 1 \rightarrow$ impact of sp. 2 on sp. 1 equals the impact of sp. 1 on itself

NOTE: Impact of a species on itself =1.0

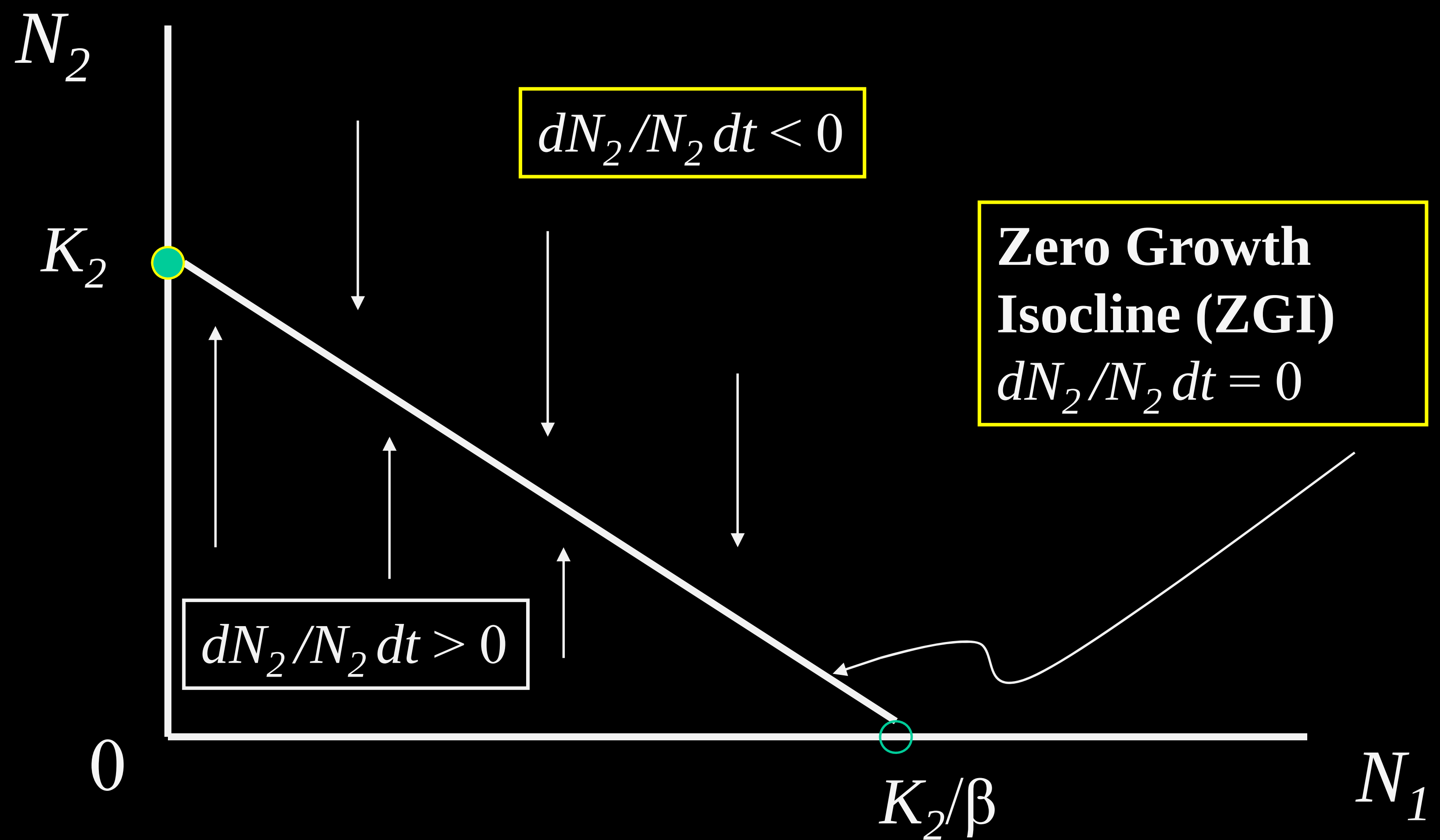
K1/ α = carrying capacity of species 1 expressed in species 2 equivalents

K2/β = carrying capacity of species 2 expressed in species 1 equivalents

Zero growth isocline for sp. 1



Zero growth isocline for sp. 2



Two Isoclines on same graph

May or may not cross

Indicates whether two competitors can coexist

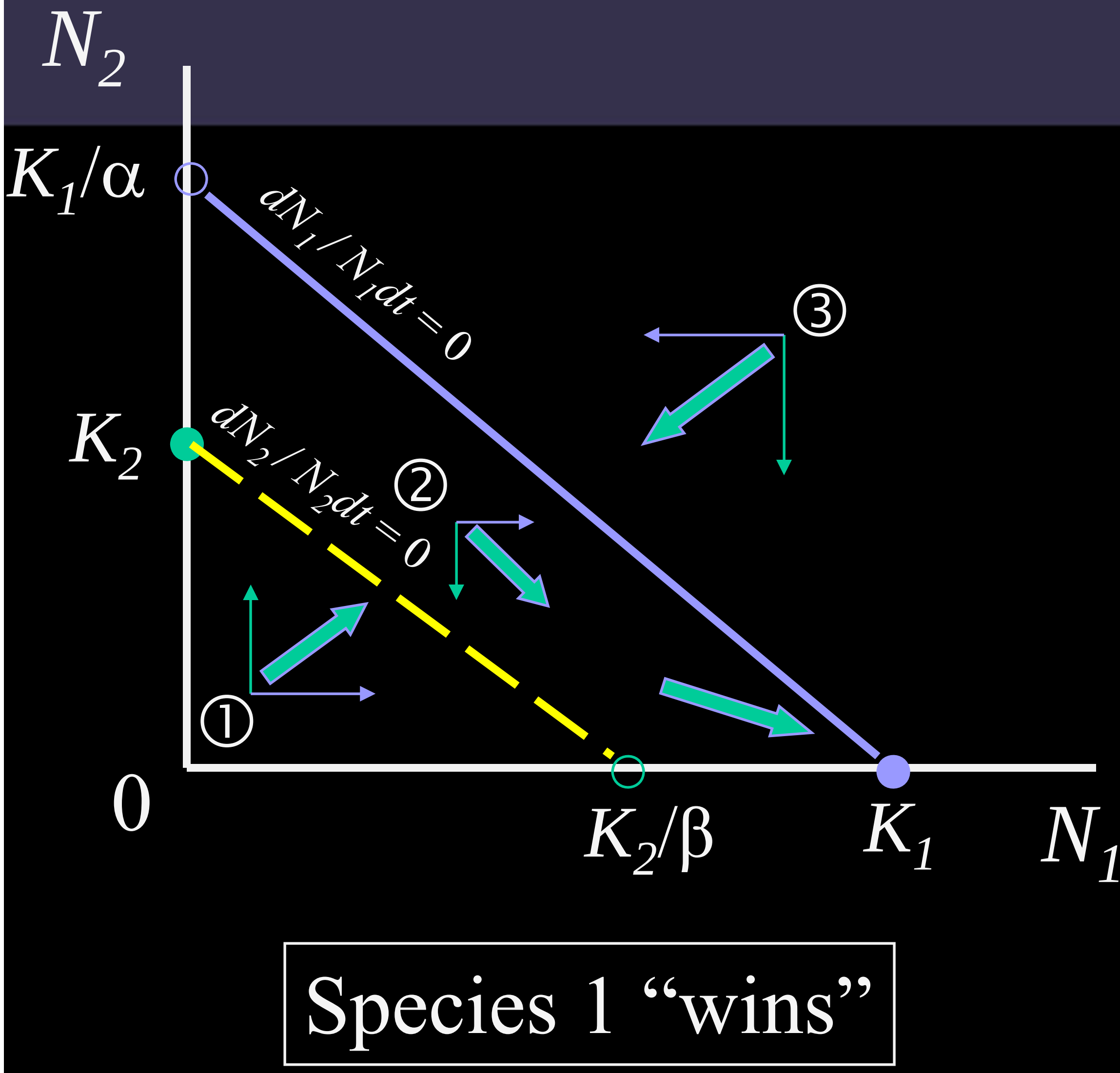
For equilibrium coexistence, both must have

- $N_i > 0$
- $dN_i \,/\, N_i dt = 0$

4 Possible Outcomes

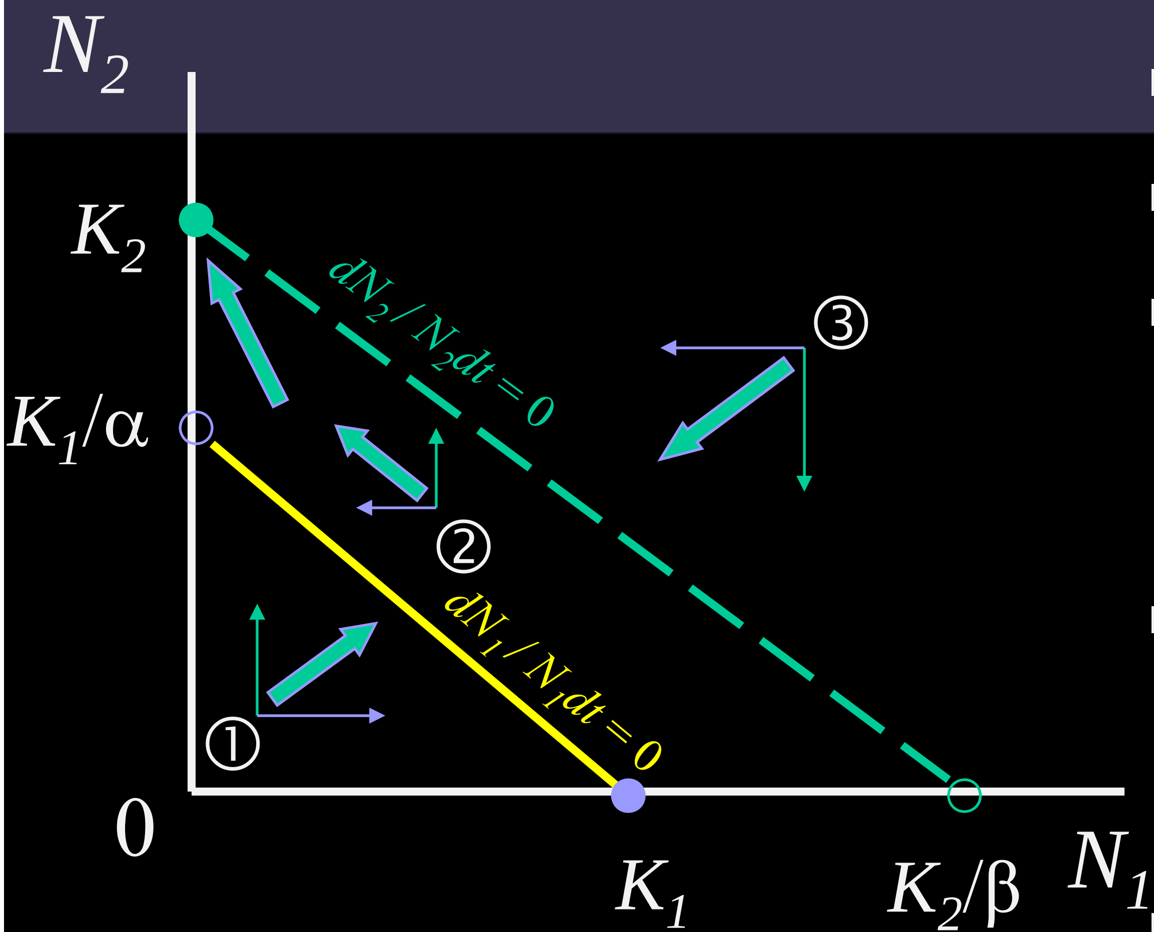
- species 1 wins
- species 2 wins
- stable coexistence
- unstable coexistence

Lotka-Volterra Zero Growth Isoclines



- $K_1 / \alpha > K_2$
- $K_1 > K_2 / \beta$
- Region ①
  $dN_1/N_1dt>0$ &
  $dN_2/N_2dt>0$
- Region ②
  $dN_1/N_1dt>0$ &
  $dN_2/N_2dt<0$
- Region ③
  $dN_1/N_1dt<0$ &
  $dN_2/N_2dt<0$

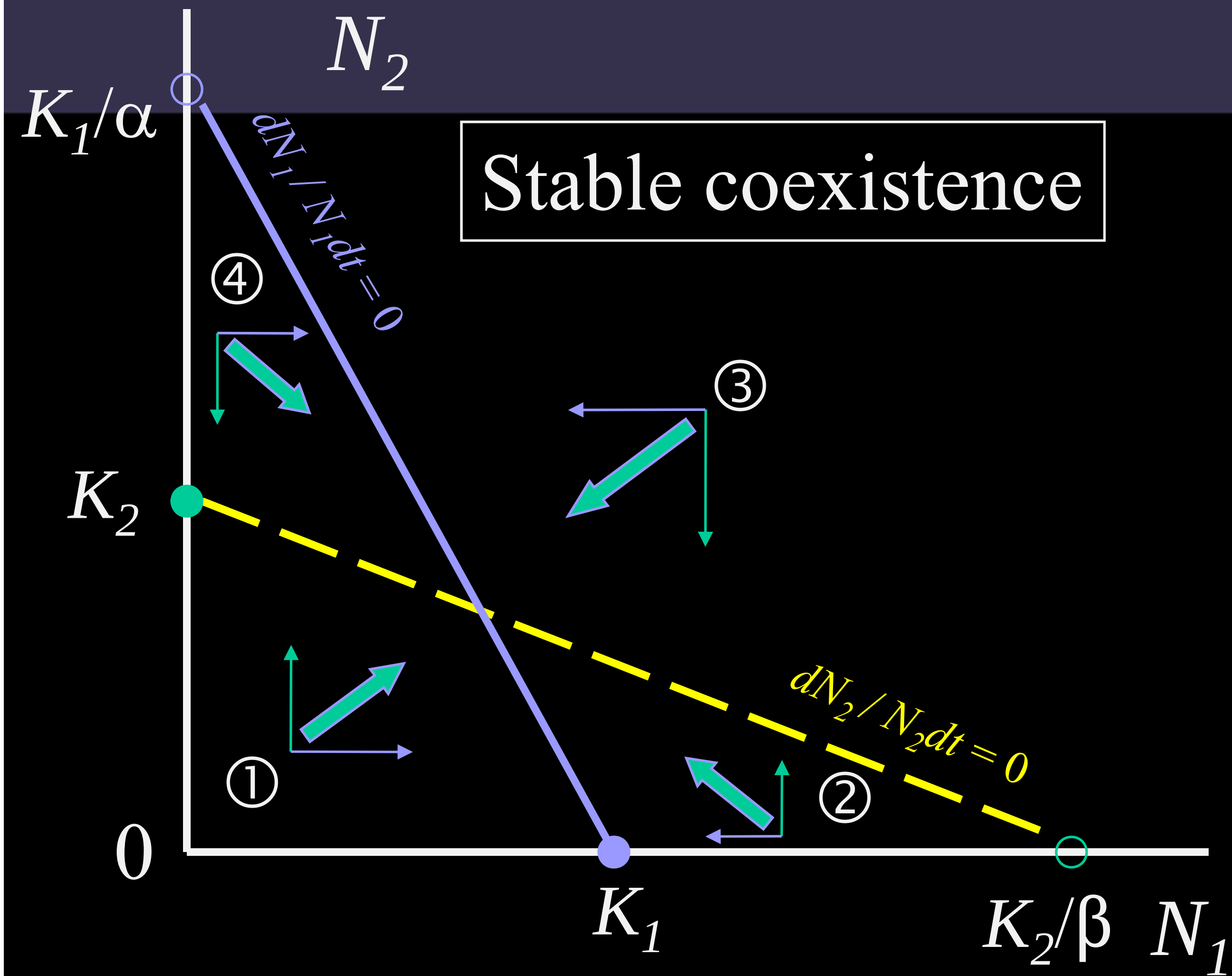
Lotka-Volterra Zero Growth Isoclines



Species 2 “wins”

- $K_2 > K_1 / \alpha$
- $K_2 / \beta > K_1$
- Region ① $dN_1/N_1dt>0$ & $dN_2/N_2dt>0$
- Region ② $dN_1/N_1dt<0$ & $dN_2/N_2dt>0$
- Region ③ $dN_1/N_1dt<0$ & $dN_2/N_2dt<0$

Lotka-Volterra Zero Growth Isoclines



- $K_1 / \alpha > K_2$
- $K_2 / \beta > K_1$
- Region ① both species increase
- Regions ② & ④ one species decreases & one species increases
- Region ③ both species decrease

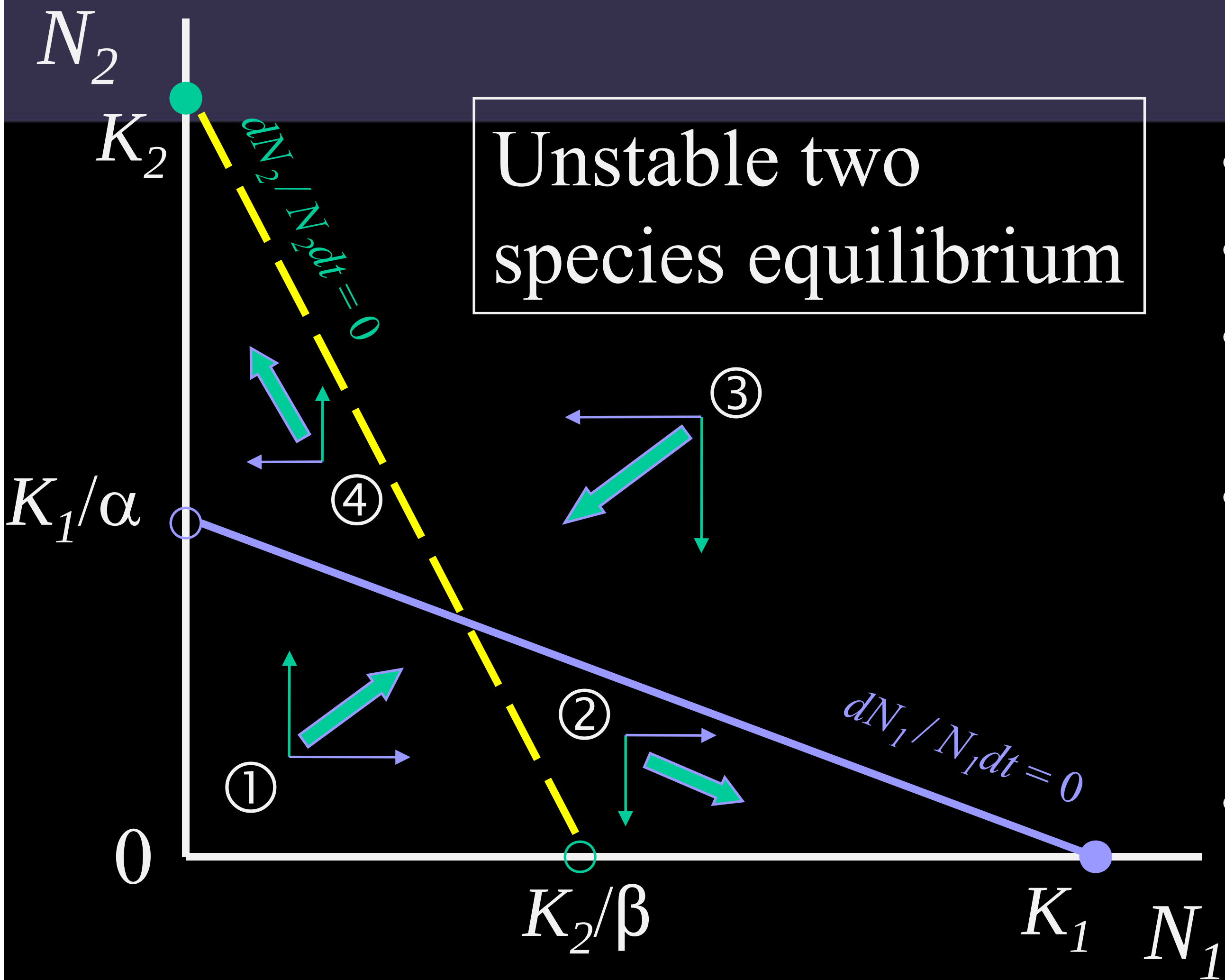
Stable Competitive Equilibrium

- **Competitive Coexistence**
- Suppose $K_1 \cong K_2$. What values of α and β lead to coexistence?

$\alpha < 1.0$ (small) and $\beta < 1.0$ (small)

- effect of each species on *dN/Ndt* of the other is less than effect of each species on its own *dN/Ndt*
- **Intraspecific competition more intense than interspecific competition**

Lotka-Volterra Zero Growth Isoclines



- $K_2 > K_1 / \alpha_2$
- $K_1 > K_2 / \alpha_1$
- Region ① both species increase
- Regions ② & ④ one species decreases & one species increases
- Region ③ both species decrease

Unstable Competitive Equilibrium

- **Exactly** at equilibrium point, both species survive
- Anywhere else, either one or the other “wins”
- Stable equilibria at:
  - ($N_1 = K_1$ & $N_2 = 0$)
  - ($N_2 = K_2$ & $N_1 = 0$)
- Which equilibrium **depends on initial numbers**
  - Relatively more N_1 and species 1 “wins”
  - Relatively more N_2 and species 2 “wins”