BIOL 410 Population and Community Ecology

Community composition

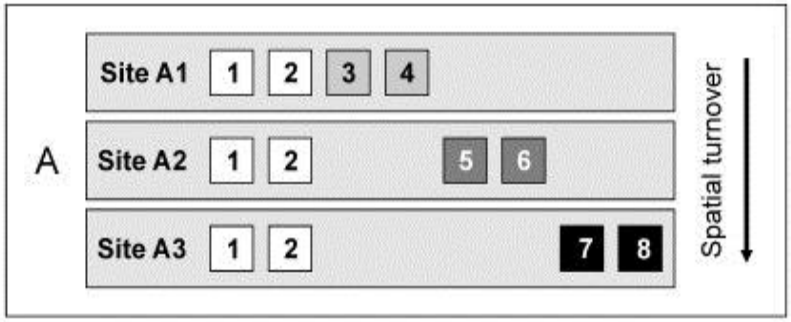
Species and community diversity

- Alpha diversity
  - Within patch diversity
- Beta diversity
  - Between patch diversity
  - Rate of species change between two areas
- Gama diversity
  - Landscape level diversity

Beta diversity

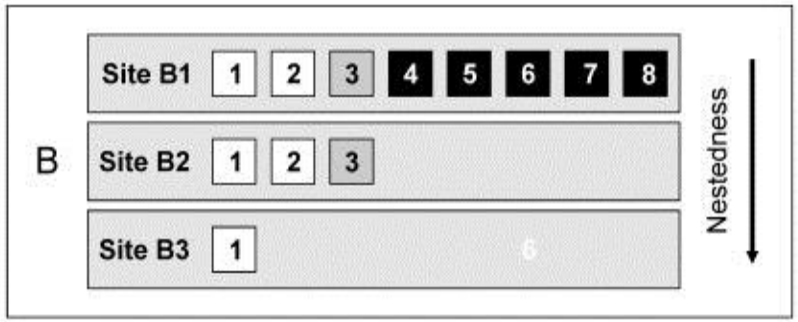
$$D_s = 1 - \frac{2a}{(2a + b + c)}$$

$$D_j = 1 - \frac{a}{a + b + c}$$



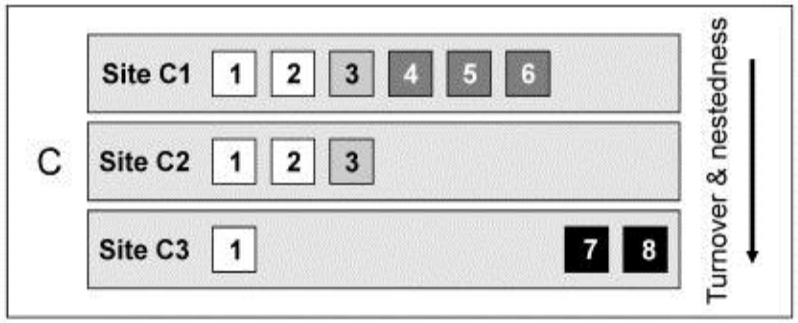
β=8/4=2

	a	b	c	Sorenson	Jacard
A1-A2	2.00	2.00	2.00	0.50	0.33
A1-A3	2.00	2.00	2.00	0.50	0.33
A2-A3	2.00	2.00	2.00	0.50	0.33
				0.50	0.33



β=8/4=2

	a	b	c	Sorenson	Jacard
A1-A2	3.00	5.00	0.00	0.55	0.38
A1-A3	1.00	7.00	0.00	0.22	0.13
A2-A3	1.00	2.00	0.00	0.50	0.33
				0.42	0.28



β=8/4=2

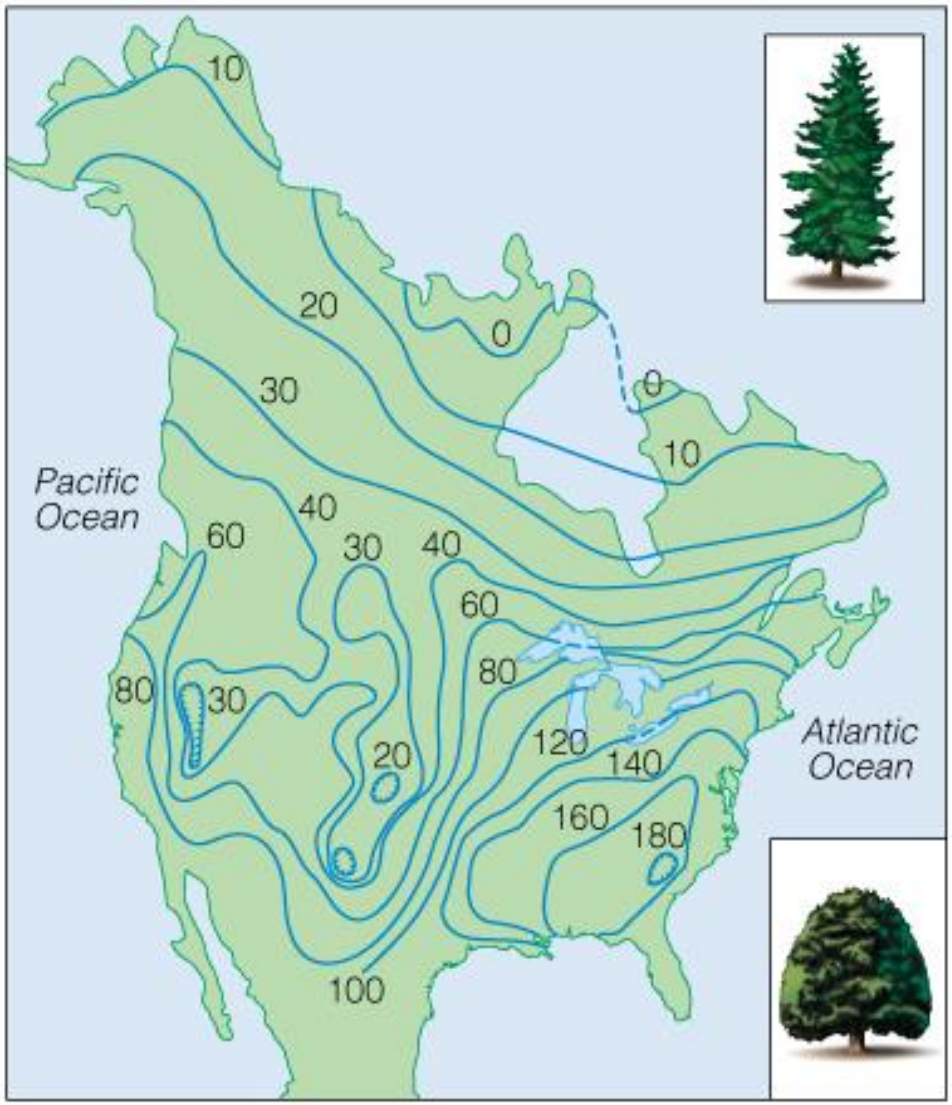
	a	b	c	Sorenson	Jacard
A1-A2	3.00	3.00	0.00	0.67	0.50
A1-A3	1.00	5.00	2.00	0.22	0.13
A2-A3	1.00	1.00	1.00	0.50	0.33
				0.46	0.32

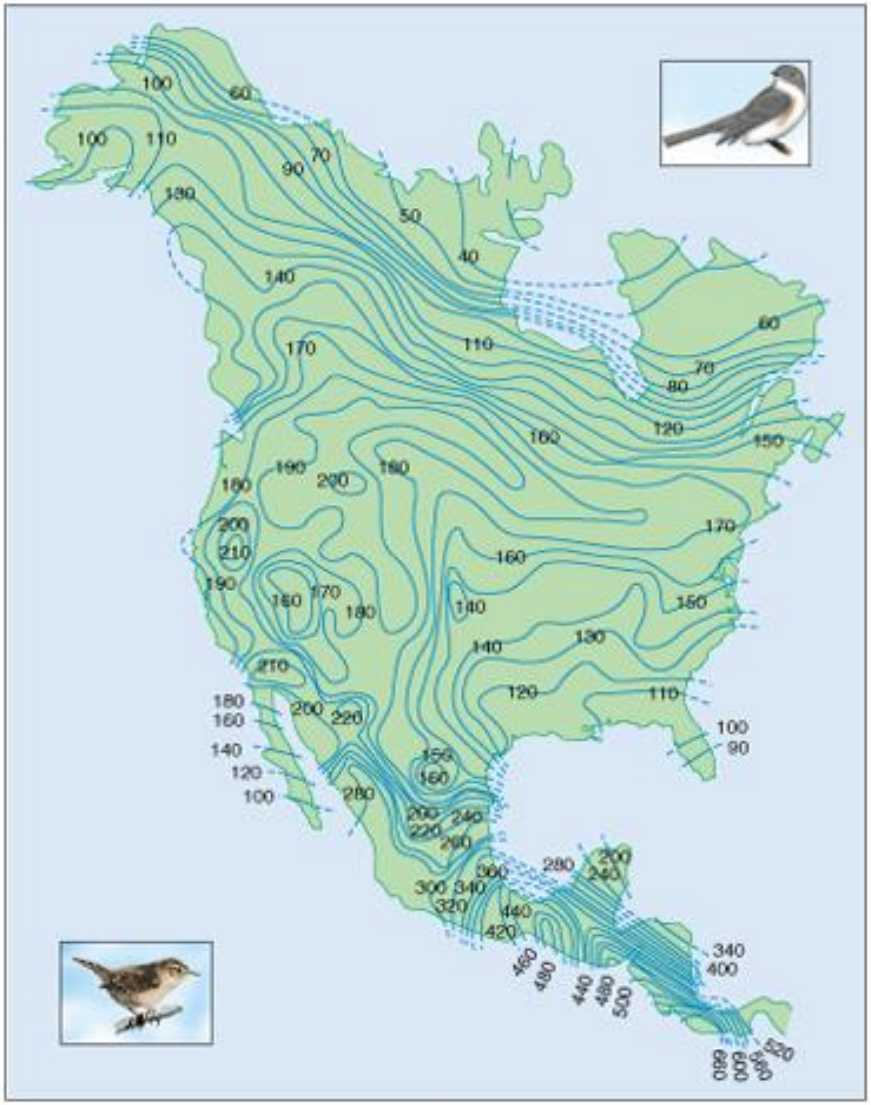
Beta diversity and diversity gradients

- Are landscape or regional patterns of diversity observed?

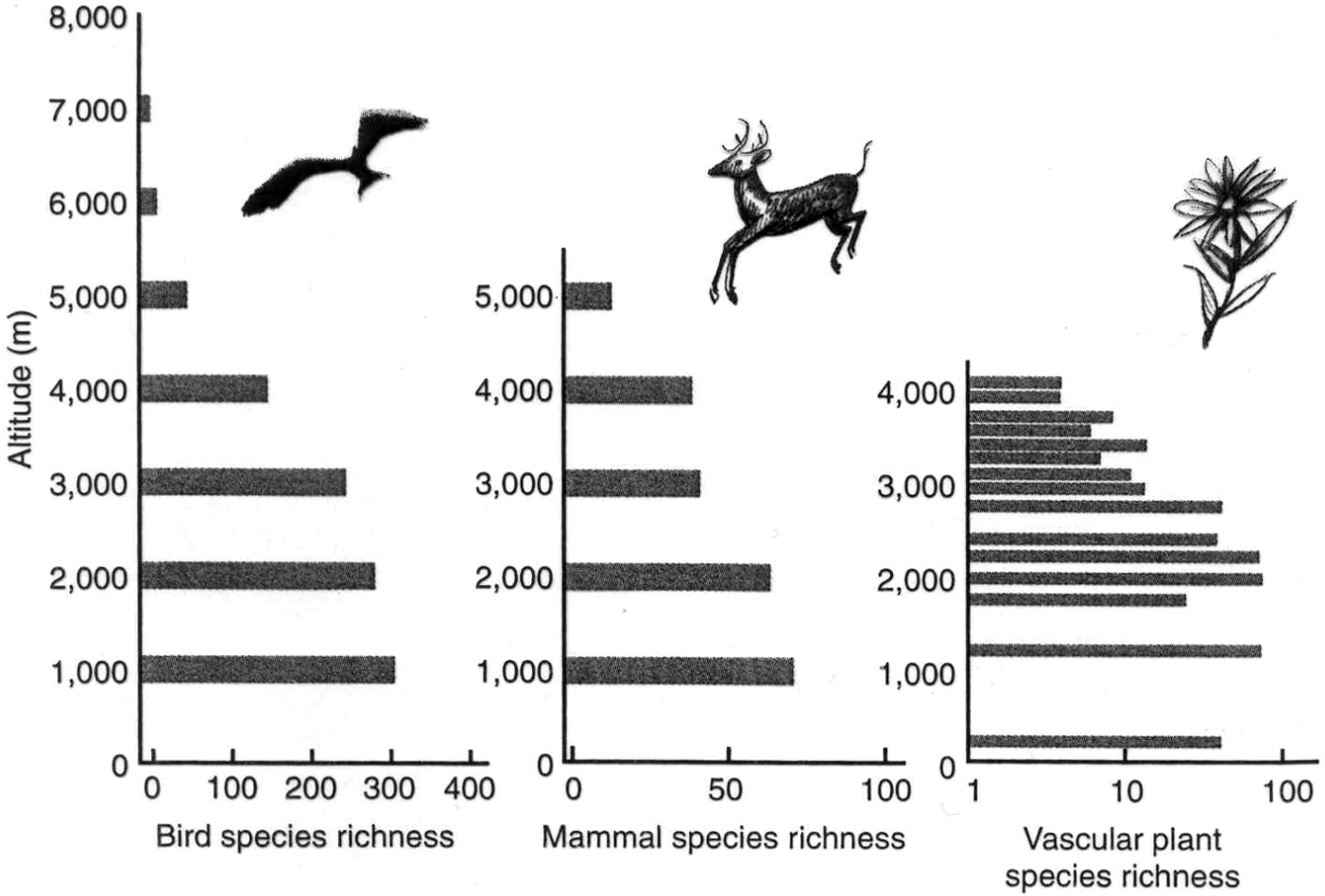
- Gradients
  - Latitudinal gradients
  - Elevation gradients
  - Precipitation gradients
  - Peninsulas

Latitudinal gradients



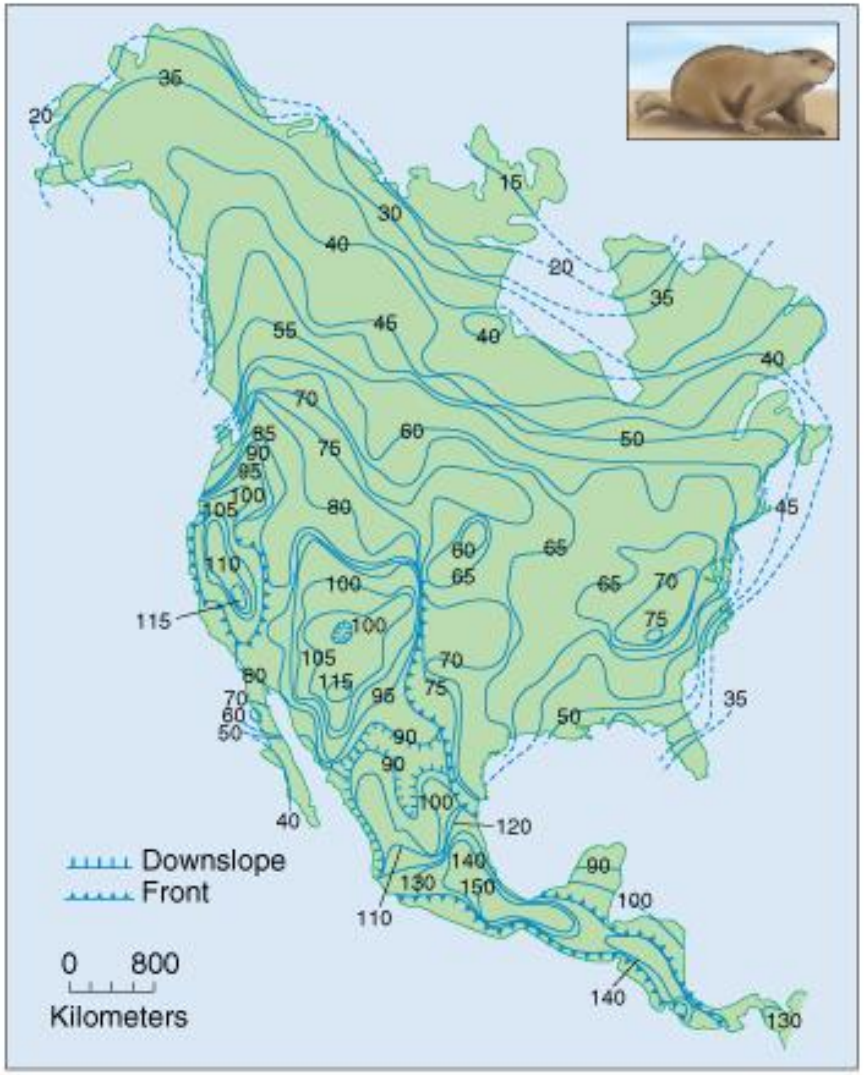


Altitudinal gradient



Begnn et al 1996

Diversity gradients



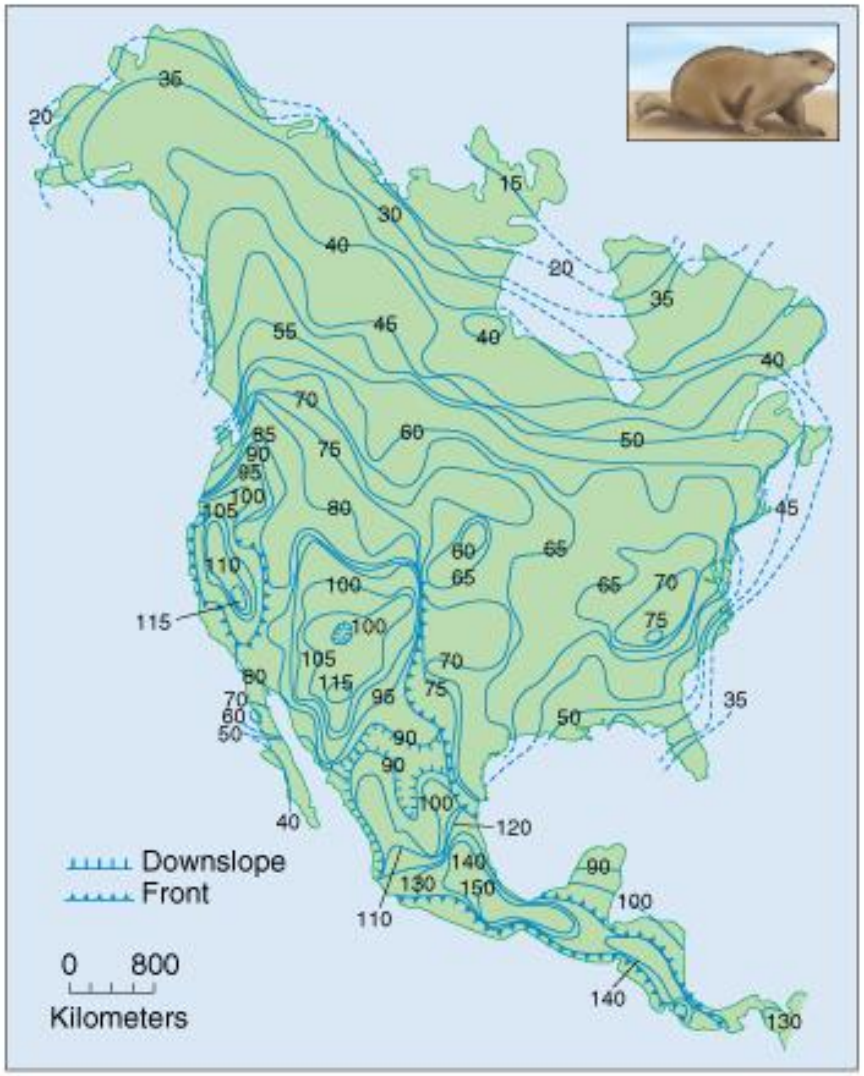
Mammal latitudinal gradient

Precipitation gradients

Peninsulas

What produces diversity gradients?

Diversity gradients



Mammal latitudinal gradient

Drivers of diversity gradients

- History (time)
  - Increased age, increased diversity
- Spatial heterogeneity
  - Environmental complexing increases available niche space
- Competition
  - In areas were K is not weather dependent, competition drives niche differentiation
- Predation
  - Predation increases diversity by reducing competition
- Productivity
  - More resources available promotes more diversity
- Environmental stability
  - Stable environments promote species niche partitioning
- Disturbance
  - Disturbances promote habitat heterogeneity which increases diversity

Community structure

- We can measure community diversity
- How can we characterize community structure?

- What determines the number and kinds of species that occur in a particular place?
- Why do number and kinds of species vary from place to place?

Not all species are equal

- Dominant species
  - Few common species with high population density or relative abundance
  - Dominance often the converse of diversity
  - Dominance may not be numerical abundance but may be biomass or functional importance

Community structure

- Guilds
  - Multiple species with “similar” niches may exist together
  - Collection of species in space
  - Guild represents a group of species having similar resource requirements and foraging strategies
  - No canonical definition of guild
  - E.g. MacArthur’s warblers

Interactions between guilds

Predator

Primary producer

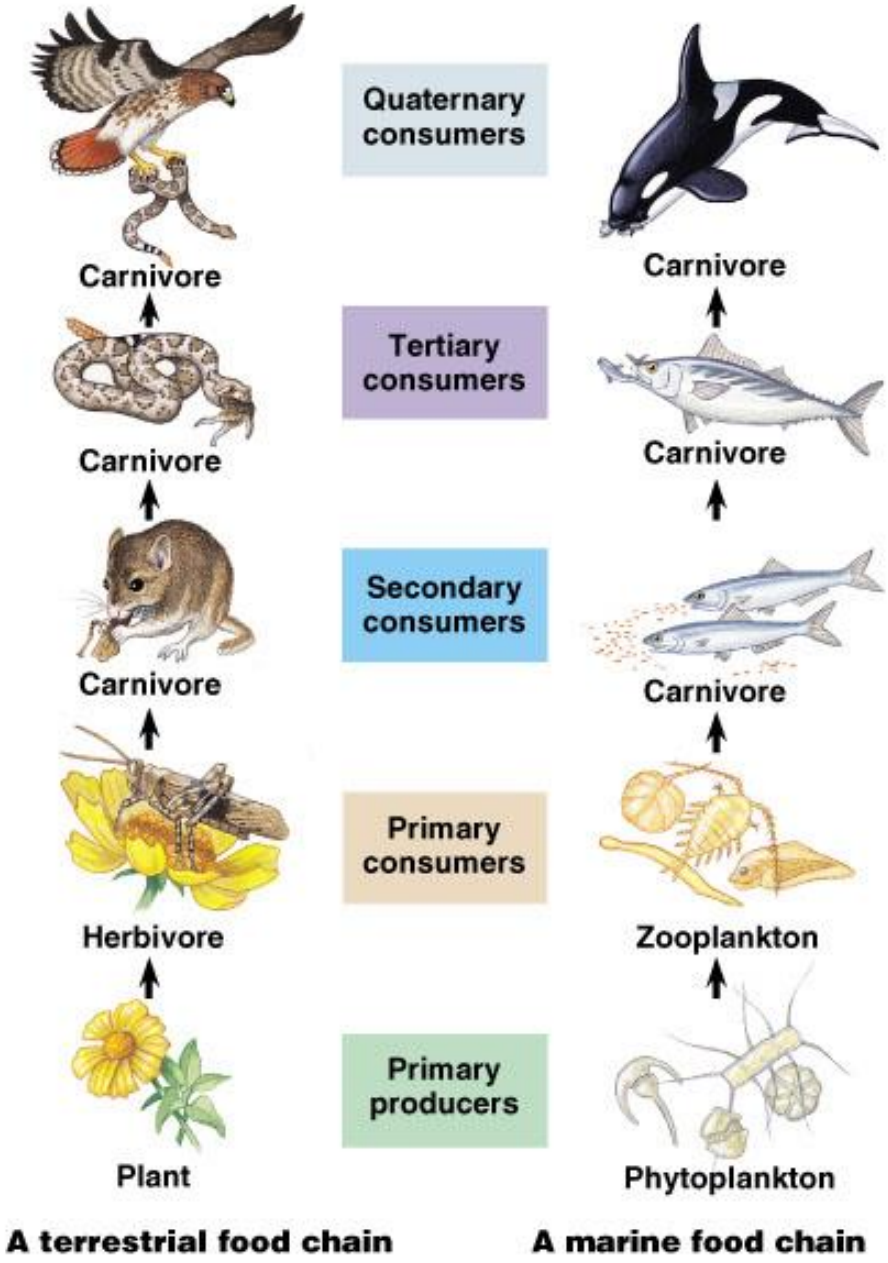
Trophic structure

- Trophic structure of a community
  - Determined by the feeding relationships between organisms
  - Transfer of food energy from its source in photosynthetic organisms through herbivores and carnivores is the food chain

- Trophic structure is a key determinant of community dynamics

Food chains

- Charles Elton
  - English zoologist
  - Trophic interactions
  - Noted that food chains are usually for or five links (trophic levels)
  - Noted that food chains are not isolated units but are often hooked together into webs



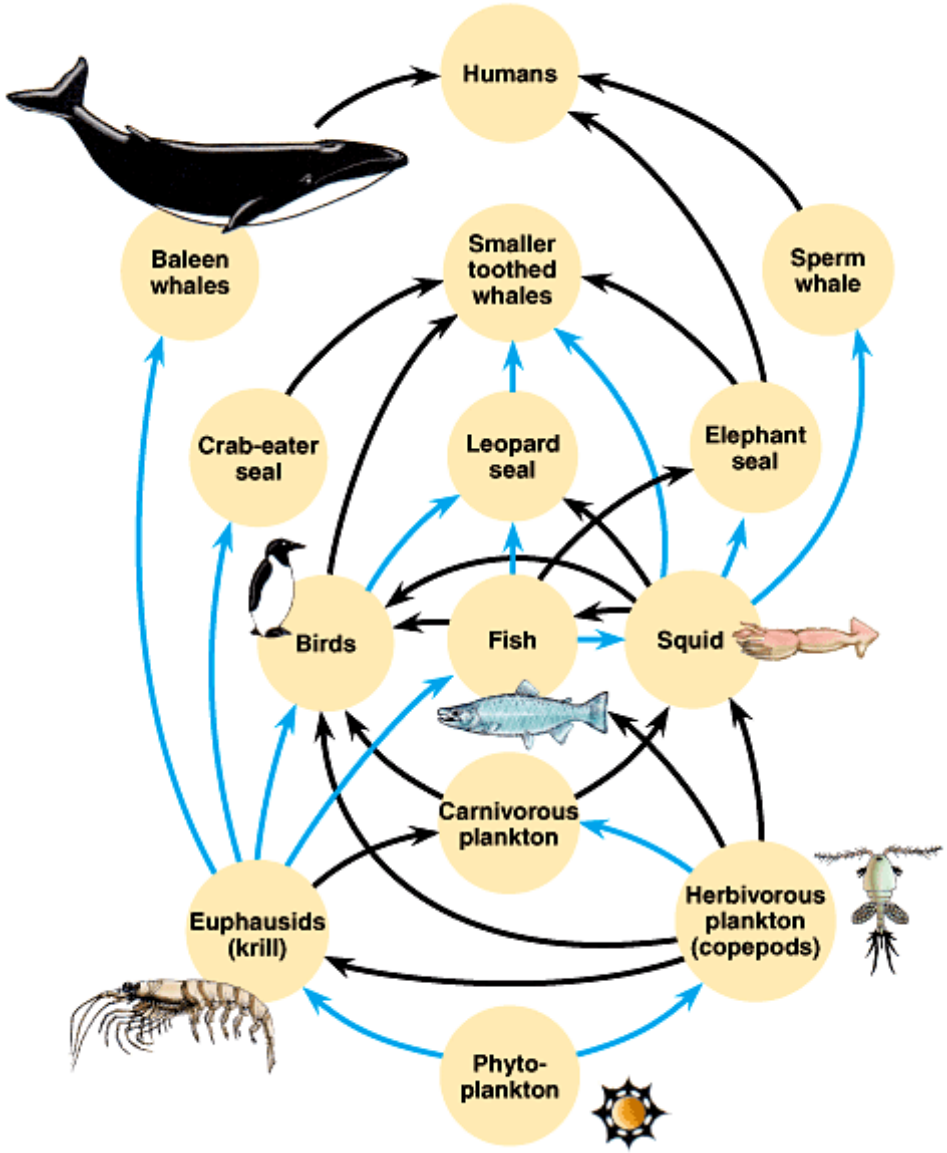
Food web

- Another type of collection of species in space

- Food web
  - Defined by feeding relations among organisms in all or part of the community
  - Describes the flow of energy and nutrients through a community
  - Defined by nodes (species or guilds) and links/paths that connect nodes
  - Nodes distinguished by position:
    - Basal species (bottom), intermediate species, predators (top)

Food webs

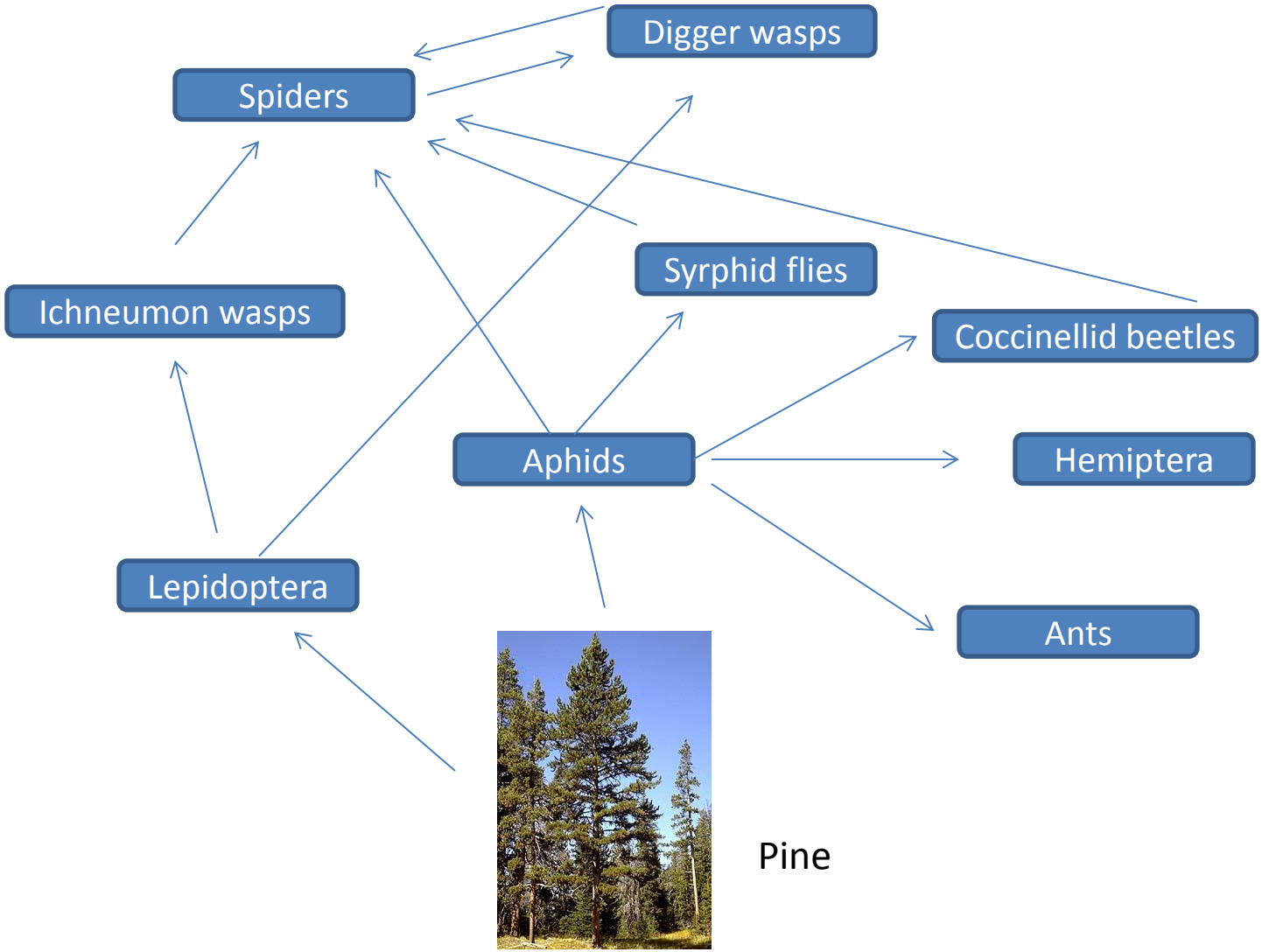
- Who eats who in a community?
- Diagram of trophic relationships within community
- Trophic relationships defined by flow of energy (food)
- Community structure (simple but)
  - Top predators, basal species
  - Cycles
  - Interactions
  - Connectance (number of potential interactions realized)
  - Linkage density (connections per species)
  - Compartments



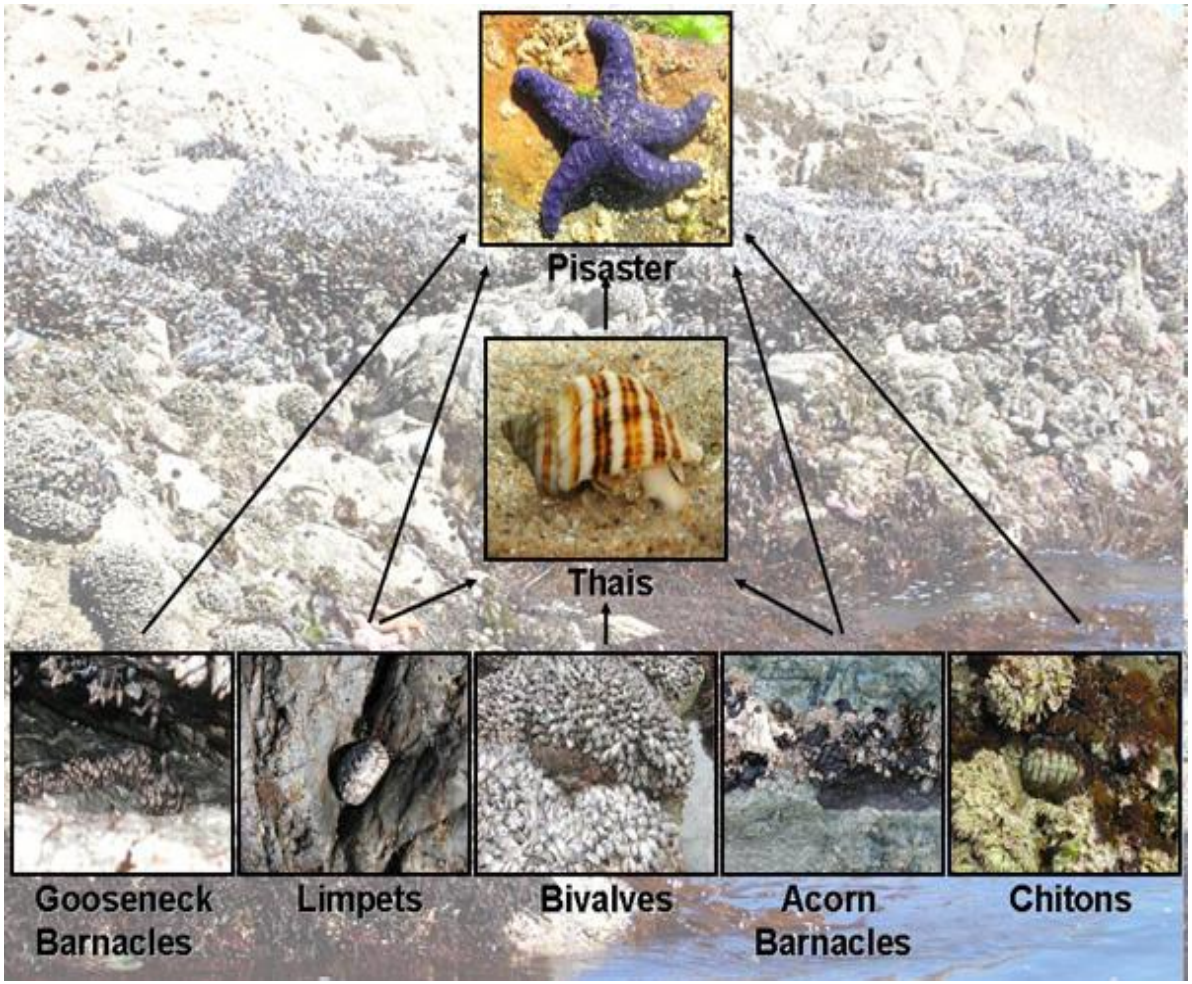
Types of food webs

- Source webs
  - Describe feeding relationships that start at a single "source", with focus on how energy moves away from this source
  - Start at the energy entry point (primary production)
- Sink
  - Describe relationship among species from the perspective of the consumer
  - Start at the end point (top predator)
- Community web
  - Describe the entire set of feeding relationships
  - complex

Source web


Digger wasps
Spiders
Syrphid flies
Ichneumon wasps
Coccinellid beetles
Aphids
Hemiptera
Lepidoptera
Ants
Pine

Sink web



Predator

Predator/grazer

Herbivores

General patterns in food/community webs

1. Primary producers (small organisms) generally more divers and abundant than their predators

2. Species diversity and abundance decreases as food web progress through trophic levels

3. Scale is important in understanding food web dynamics: greater taxonomic resolution results in larger chains

4. Chains are longer in more productive environments

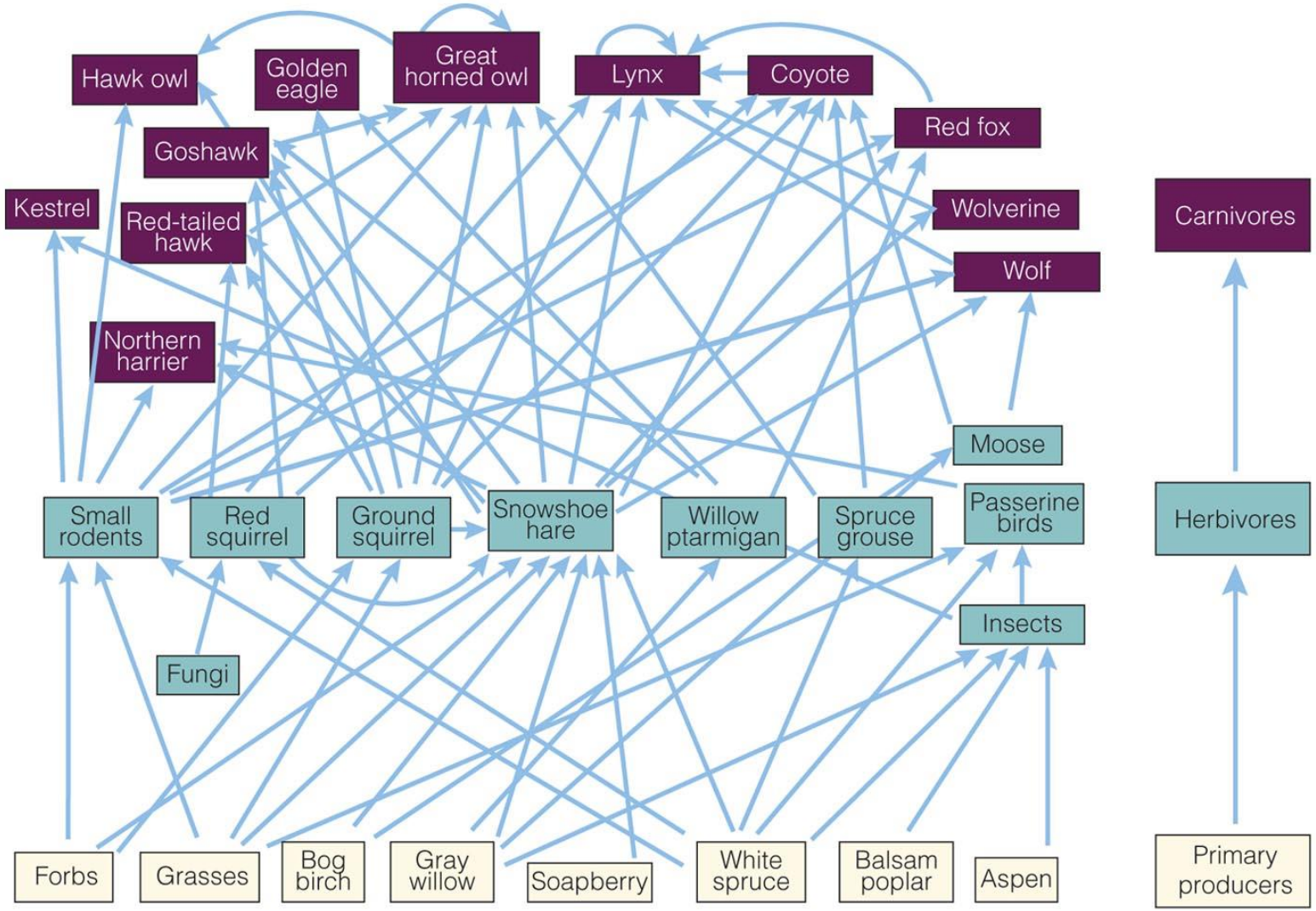
5. Complexity can decrease or increase food web stability
   a) Strength of interactions varies: evidence suggest that many interactions are weak (i.e. little dependence)
   b) Food web patterns vary through time: most webs are collages of many possible interactions (communities are dynamic)
   c) Omnivores are different: less dependent on stasis, less variable population dynamics, can stabilize communities

Community web

- Top-down effects:
  - Predators dictate composition and abundance of species in lower trophic levels
    1. Increase in predators
    2. Reduces herbivores
    3. Increase plant population
    4. Reduce nutrient in soil

- Bottom-up
  - Primary productivity dictates abundance and diversity of species in community
    1. Increase in nutrients
    2. Increased plant growth
    3. Increase in herbivores
    4. Increase in predators

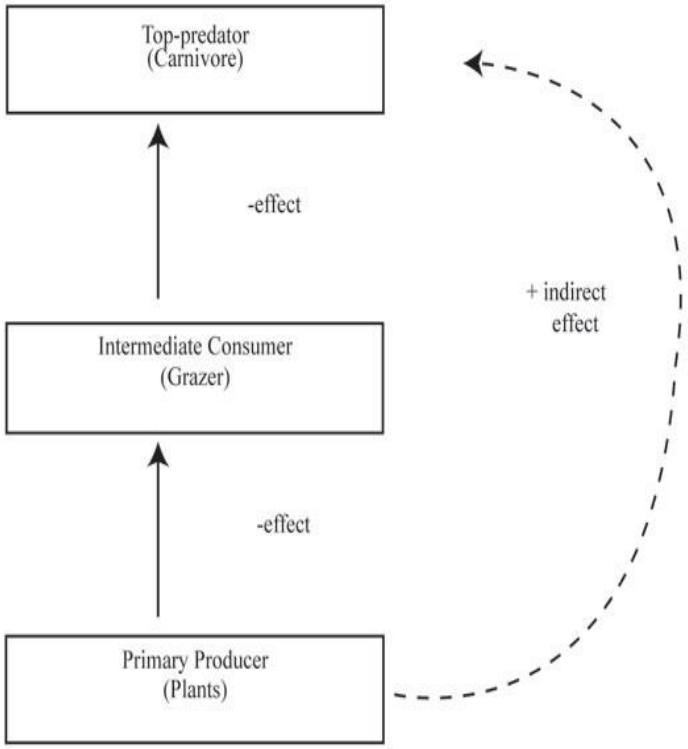
Community/food web
How can organisms be grouped?

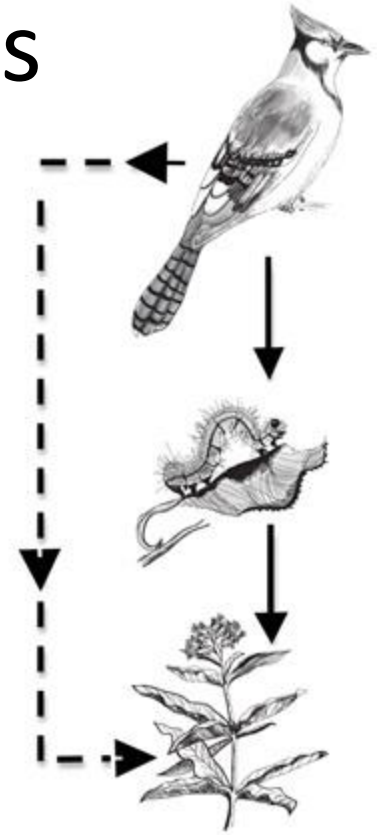


Trophic cascades

- Top-down or bottom-up cascades
  - Cascade are indirect changes in composition and abundance of species in lower trophic levels
  - Trophic cascade:
    - Top-down effects of predators on lower levels
    - Initiated by loss of apex predator
  - Tri-trophic effects:
    - Indirect effects that propagate from the bottom-up through multiple trophic levels
    - Results from change in the primary productivity of an ecosystem

Trophic cascades and indirect interactions





- Trophic cascade
- Keystone predation, exploitation competition, habitat facilitation, apparent competition

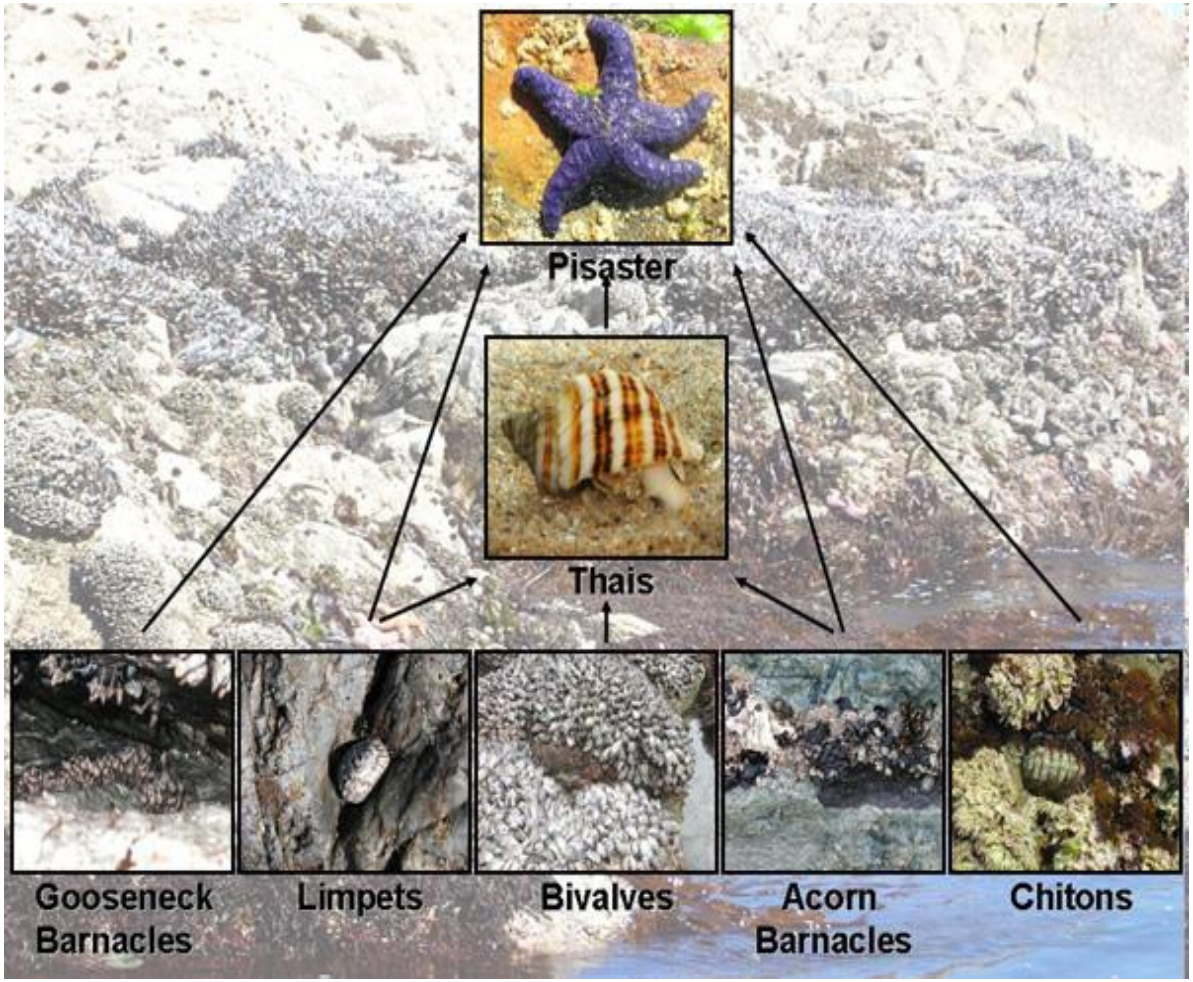
Trophic cascades and apex predators

- Bow Valley, Alberta
  - Banff town site provides natural treatments of wolf exclusion: low/high wolf areas
  - Low-wolf, high elk areas
    - In vicinity of town
      - Elk densities 10X than in high wolf areas
      - Aspen and willow replace by grassland meadows
      - Few beavers, few deciduous dependent birds (warblers)
  - Keystone species/predator

Keystone species

- Not always dominant species
  - May be less abundant but play a crucial role in the functioning of the community
  - Have a unique and significant role through their overall effect on the community
  - If removed
    - Major changes in community structure are expected
    - Potentially a loss of diversity
  - Keystone species may occupy the role due to:
    - Modification of habitat
    - Large influence on the interactions between other species.

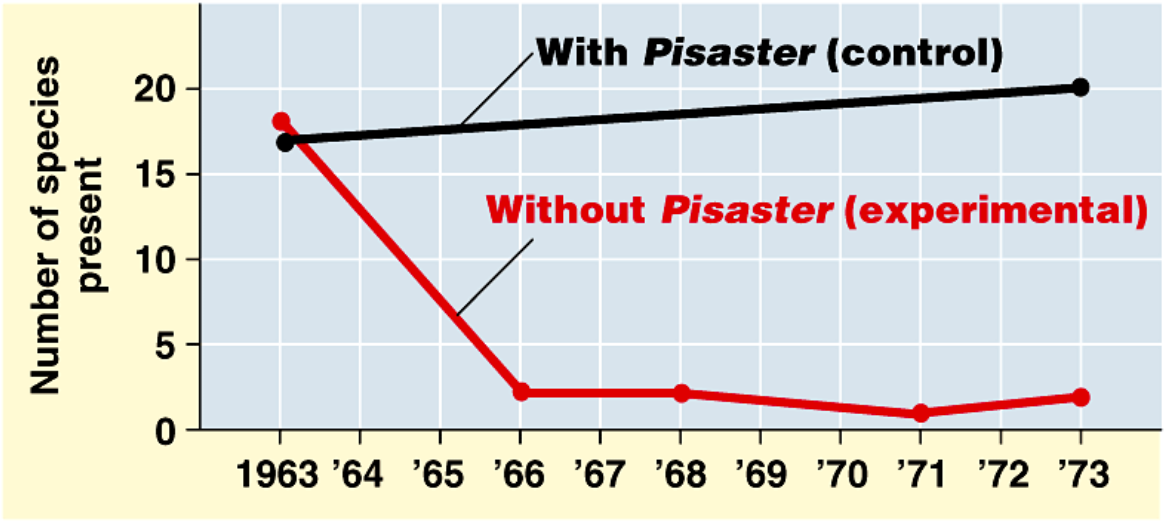
Keystone species



- Robert Paine 1966
- Impact of starfish (*Pisaster*, top predator) on rocky intertidal ecosystems

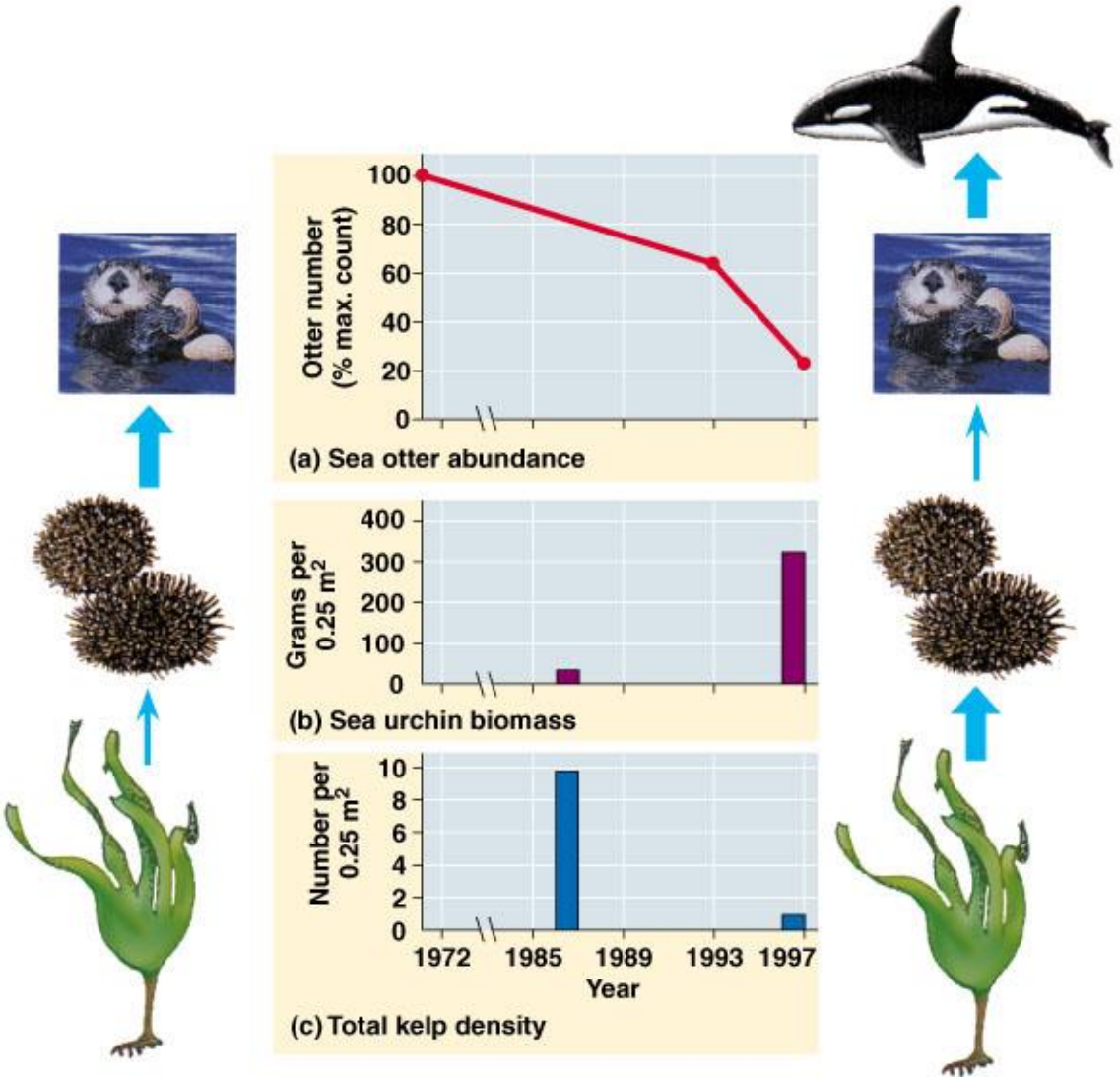
- What happens to the system when the starfish is removed?

Keystone species



- Keystone species (predators)
  - Paine (1969)
    - Exerts top-down influence on lower trophic levels
    - Prevents species at lower trophic levels from monopolizing critical resources (food, space)

Keystone species: Sea otters



Keystone species

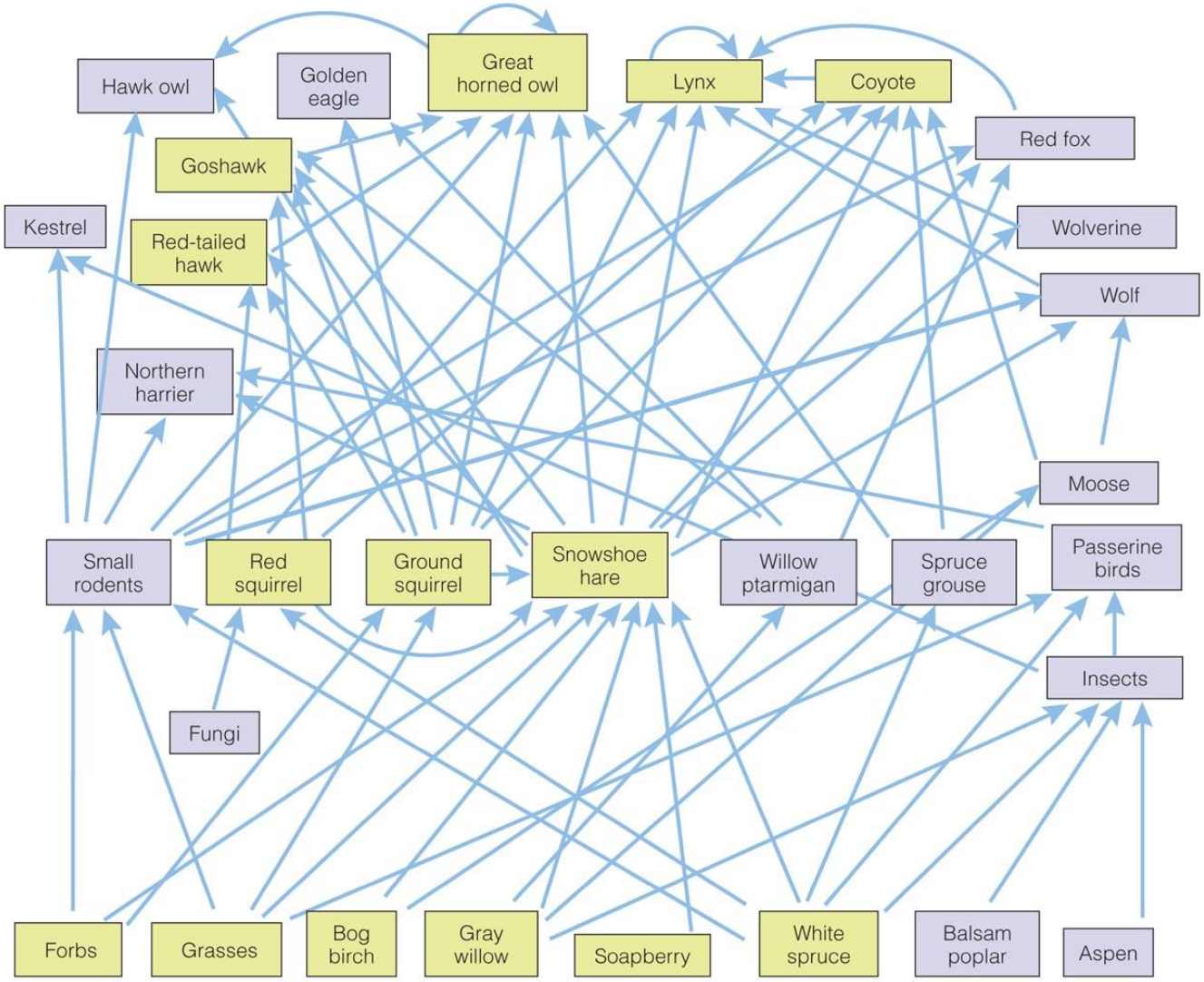
Keystone modifiers

Saguaro cactus

Keystone hosts
(habitat providers)

Keystone mutualists
(pollination)

Species interactions, community dynamics and **stability**



Stability and the diversity of ecosystems

- Are diverse ecosystems more productive?
- Are diverse ecosystem less likely to be invaded by non-native species?
- Are divers ecosystems more resistant to environmental change?
- Are diverse ecosystems more resilient to environmental change?

Ecosystem function

- Ecosystem functioning can encompass a variety of phenomena
  - Ecosystem properties
    - Size of compartments
      - Pools of materials such as carbon and organic matter
      - Rates of processes: fluxes of materials and energy among compartments
  - Ecosystem goods
    - Ecosystem properties that have direct market values
      - Food, construction materials, tourism, recreation
  - Ecosystem services
    - Properties of ecosystems that directly or indirectly benefit human endeavours
      - Maintaining hydrological cycles, regulating climate, cleansing air and water, pollination, soil genesis, storage of nutrients
- Ecosystem function of interest, and appropriate metrics, need to be defined prior to evaluating how species diversity, community structure, functional diversity, etc. affect it

Ecosystem functioning

- Traits that characterize the ecological function of a species are termed functional traits

  - Species that share similar suits of traits are often categorized together into functional groups (similar to guild)

  - E.g Brussard et al (1997) identified four main functions of soil biota
    - Decomposition of organic matter
    - Nutrient cycling
    - Bioturbation
    - Suppression of soil borne diseases and pests

  - Not all soil species perform each of these functions
  - Therefore, categorized them into functional groups
    - Microsymbionts
    - Decomposers
    - Elemental transformers
    - Soil ecosystem engineers
    - Soil-borne pests and pathogens
    - microregulators

Functional traits, functional types, and functional diversity

- Functional traits
  - Traits that influence ecosystem properties or species responses to environmental conditions
  - Species often grouped together according to functional traits to understand general mechanism or to make studies of complex systems more tractable
- Functional group
  - Set of species that have similar effects on a specific ecosystem process or similar response to environmental conditions
  - Similar to guild concept (animal community ecology), and niche concept.
  - Defining functional types can be difficult

Defining functional types

1. Organism effects on ecosystem properties generally fall along a continuous gradient, not into discreet groups

2. Traits that determine how species respond to environmental change will often differ from those that determine how the species affects ecosystem properties.

3. Functional types identified for a specific ecosystem property are not necessarily relevant to other properties

Functional groups

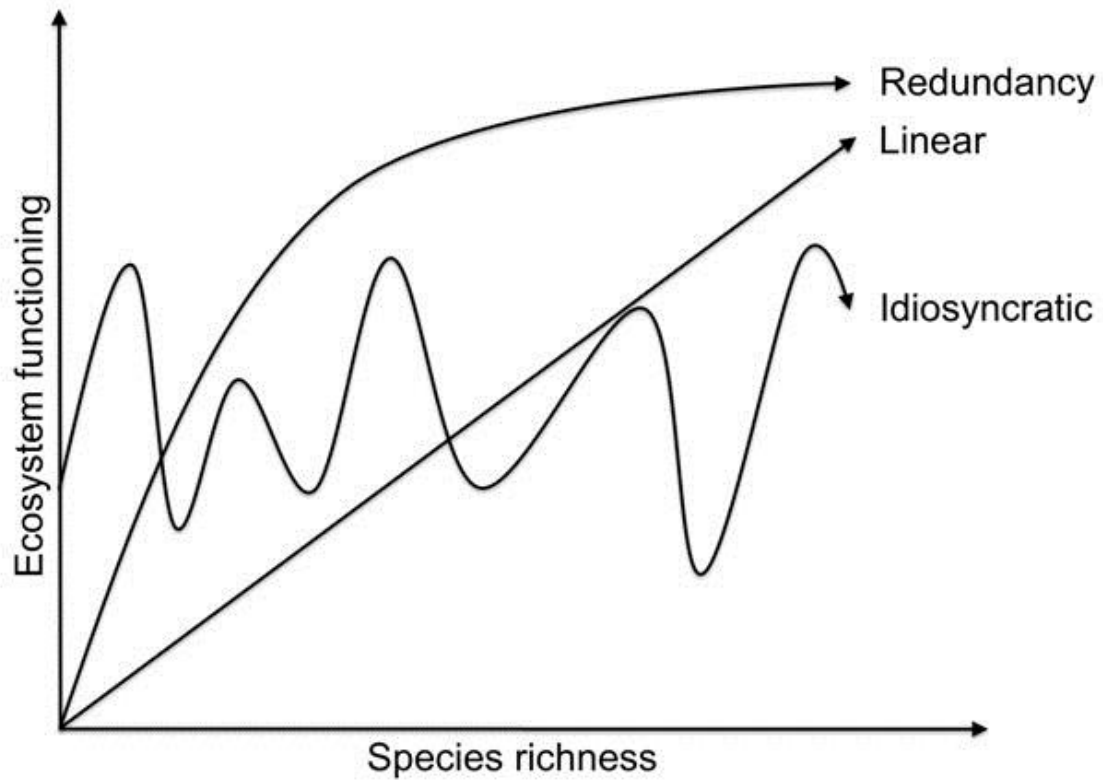
- Examples of functional groups
  - Feeding level
  - Exploitation of common resources (guilds)
  - Photosynthetic pathway
  - Shade tolerance
  - Life history

- Groups of functionally equivalent species
- With “functionally equivalent” being operationally defined by the ecosystem property being measured

- Multitrophic systems
  - E.g. containing autotrophs, herbivores and/or predators
  - Functional groups may be operationally defined as trophic groups

How does species diversity and functional group diversity impact ecosystem functioning?

Potential positive relationships between species diversity and ecosystem functioning

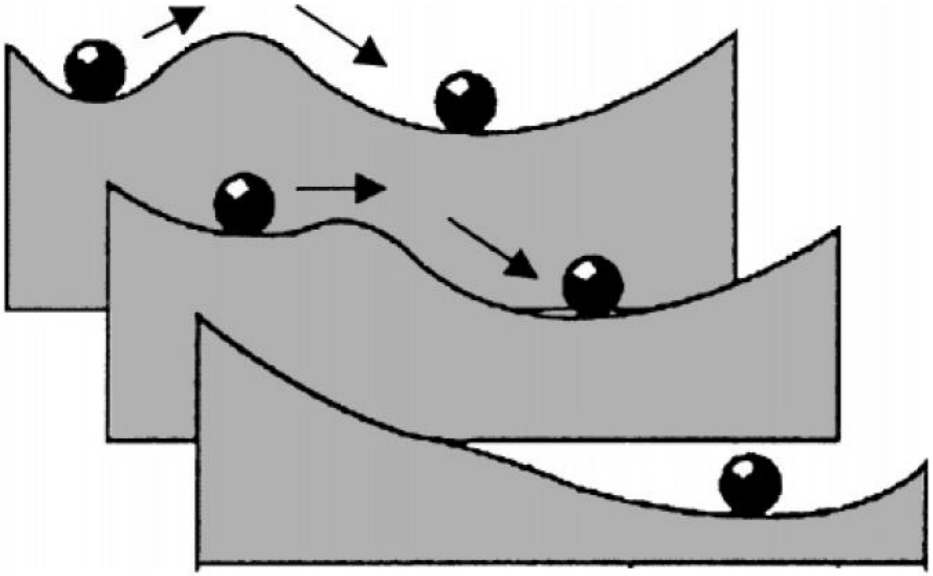


- Redundancy
  - New species only have a positive effect if function is not already found in community
- Linear
  - Addition of any new species increases functioning
- Idiosyncratic
  - Species differ in their ability to increase functioning

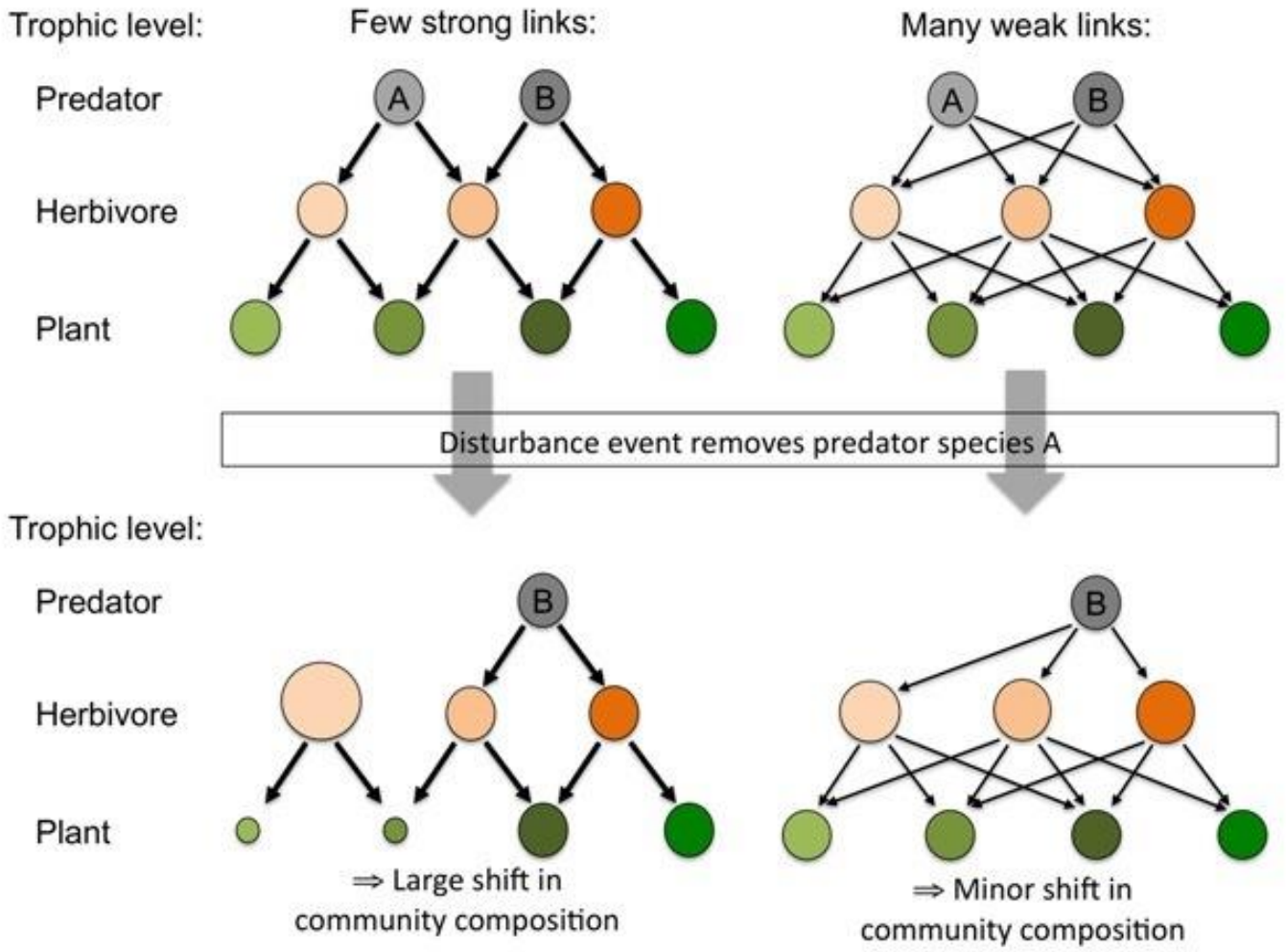
Increased functioning ~ increased stability

Ecosystem stability

- Heuristic of ecosystem stability
  - Stable ecological states (stability domain)
    - Alternate stable states may exist
      - Grass-dominated to woody-dominated semi-arid rangelands
  - Resistance
  - Resilience
    - Engineering resilience (slope surrounding stability domain)
    - Ecological resilience (width of stability domain)



Interaction number, strength and community stability



Ecosystem reliability

- Does biodiversity represent a form of biological insurance against the loss of selected species?

- Ecosystem resistance and resilience can be hard to measure
- “Ecosystem reliability”
  - Will a system provide a consistent level of performance over a given time unit?

Ecosystem reliability

Biodiversity enhances ecosystem reliability

Shahid Naeem & Shibin Li

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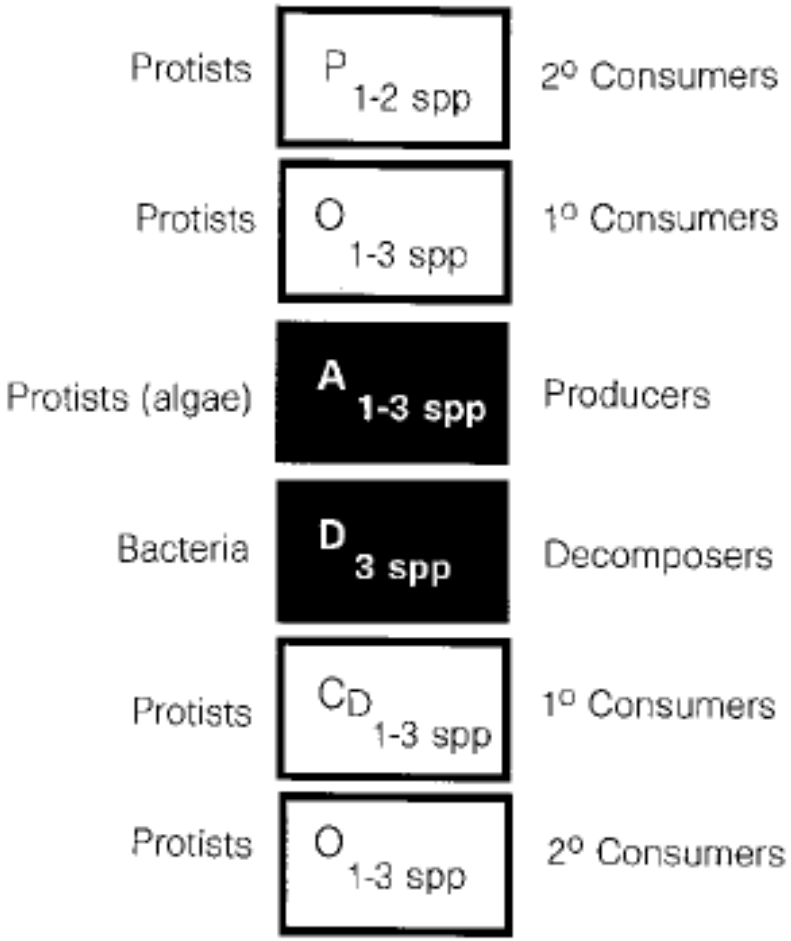
- Empirical evidence that biological diversity increases ecosystem reliability is rare
- Experiment where number of species per functional group is varied
  - Microcosm experiment using protists and bacteria
- Ask question: are communities with more species per functional group more “reliable”
  - Consistent in biomass and density
  - Ecosystem property



Ecosystem reliability

Biodiversity enhances ecosystem reliability

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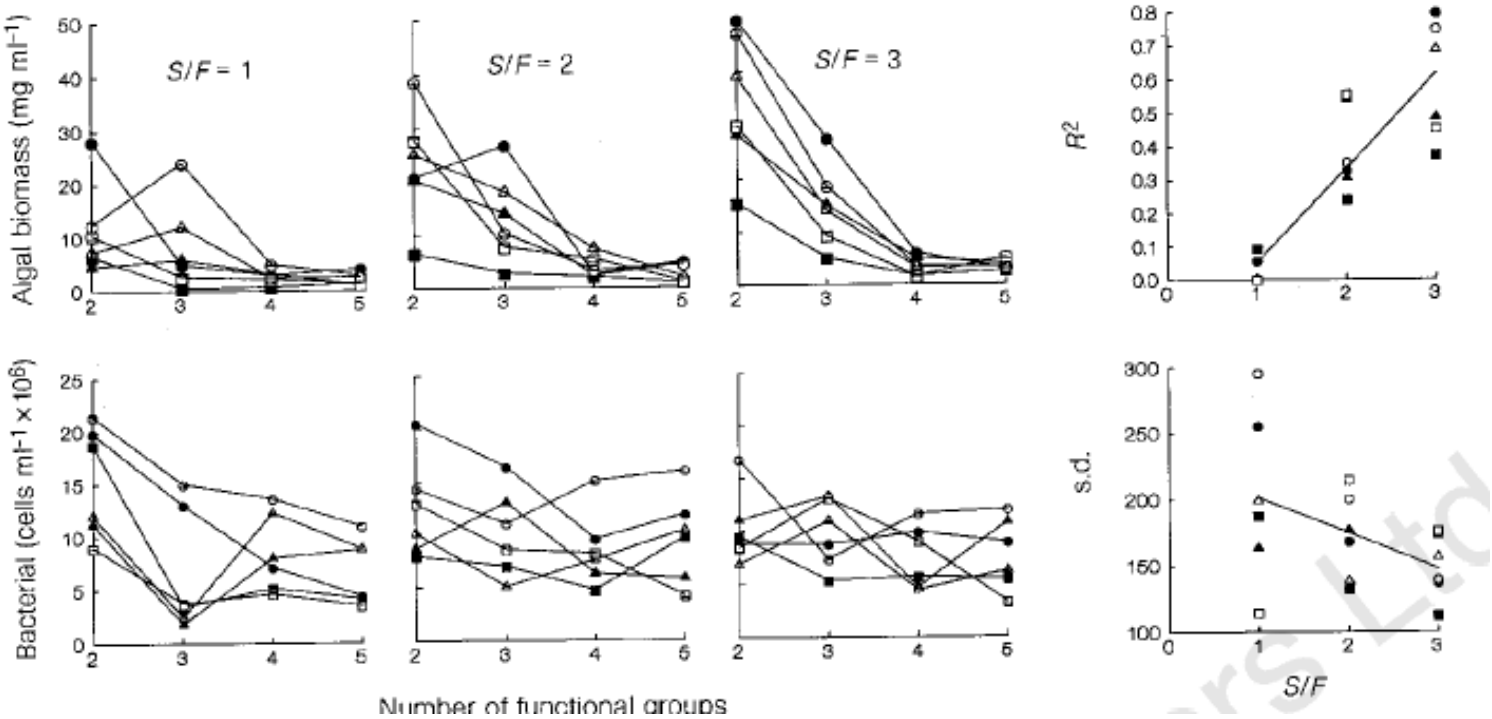

Autotroph biomass becomes increasingly predictable as S/F increases

Variation in bacteria density declines with increasing S/F

- Support for the biological insurance hypothesis for biodiversity
- Ecological basis for biological insurance is compensatory growth

Diversity and invasion resistance

Species Diversity and Invasion Resistance in a Marine Ecosystem

John J. Stachowicz,[1]* Robert B. Whitlatch,[1] Richard W. Osman[2]

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