Community

- A biological community refers to all the species that occur together at any particular locality.

Biological communities

Gleason & Clements

Individualistic

Holistic

Individualistic

Holistic

Environmental gradient (such as temperature or moisture)

Population densities of species

Environmental gradient (such as temperature or moisture)

Population densities of species
Individual species in a community respond independently to changing environmental conditions.

A synchronous change of species in communities exist only when sharp changes of environmental conditions occur.

Attributes of ecological communities
- Biodiversity —
  - The number and evenness of species.
- The niche concept—
  - The role of interspecific interactions
- Food web structure —
  - The feeding relationships among species.
- Succession—
  - The change of communities through time.

Biodiversity measures the number of species and their evenness
- Species richness may be equal, but relative abundance may be different.

Biodiversity: number & evenness

Most species in a community are rare

Number of species

Number of individuals represented in sample
Biodiversity: community 1 > 2

Exercise: What factors determine the occurrence of a species in a community?

First, a species needs to be able to tolerate the local physical-chemical environment.

Second, the environment must provide required resources, such as food.

~ the fundamental “niche”
The distribution patterns of Chthamalus & Semibalanus

Exercise: Is this range the fundamental niche of Chthamalus? How do you know?

Let's do a removal experiment

Results: What does the removal experiment tell you?
Realized Niches

- Actual niche utilized by an organism is influenced by competition, predation, parasitism, mutualism, etc.

- Biological interactions change niche space, thus contribute to the structure of a community.

Predation often reduces “niche” space

\[ \text{Fundamental niches} \quad \text{Realized niches} \]

\[ \begin{align*}
\text{High tide} & \quad \text{Low tide} \\
\text{Chthamalus} & \quad \text{Semibalanus} \\
\text{Fundamental niches} & \quad \text{Realized niches}
\end{align*} \]

~ the realized “niche”

Biotic interactions limiting

required resources

Adequate range for survival and reproduction

Exercise: What’d happen if 2 species had overlap niches, e.g. steelhead & roach?

Ghost of competition past …
Ghost of predation past …

The fundamental niche of a species may shift due to consistent biological interactions over evolutionary time scale. Thus, the effects of competition or predation are no longer exist in the present day.

Species as we see them today are products of biological interactions over evolutionary times.
Outcomes of interspecific competition
- If niche overlap extensively, then, to coexist, the shared resources must not be limiting. Otherwise, ..... 
- One species may be driven to extinction (competitive exclusion).
- Or, one or both species has to shift their niches by changing their behavior (resource partitioning).
- Sometimes, morphology change as well (character displacement) to enhance resource partitioning.

Principle of Competitive Exclusion
- When resources are limiting, no two species utilizing the same niche can coexist indefinitely.
- one will eventually eliminate the other

Georgyi F. Gause (Moscow Univ.)

Competitive Exclusion Among Paramecium

If competitive exclusion did not occur, resource partitioning must exist.

Either way, competition reduce population sizes, thus, change relative abundance and community structure.
Consequences of long-term competition

- The fundamental niche of a species may shift under long-term interspecific competition through 2 processes:
  - Resource partitioning
  - Character displacement

Resource Partitioning

- Species living in the same area (sympatric species), over time, evolve behavioral mechanisms that partition available resources to avoid direct competition.

Resource Partitioning – the sympatric species have subdivided the niche

Resource partitioning of insect-eating lizards

- Sympatric species tend to exhibit greater differences in morphology than allopatric species (species that live apart from each other) to avoid direct competition.
Does the diversification of Darwin’s finches involve resource partitioning & character displacement?

Character Displacement

<table>
<thead>
<tr>
<th>Individuals in each size class (%)</th>
<th>Finch beak depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Hermanos Islets</td>
<td>G. fuliginosa Alone</td>
</tr>
<tr>
<td>Daphne Major Island</td>
<td>G. fortis Alone</td>
</tr>
<tr>
<td>San Cristobal and Floreana Islands</td>
<td>G. fuliginosa and G. fortis Sympatric</td>
</tr>
</tbody>
</table>

Exercise: Use an analogy to describe “niche” to your friend.

Mode of interspecific competition

- Exploitative competition
  - e.g. Paramecium compete for food
  - the 2 species consume shared resources
  - The 2 species don’t need to see each other

- Interference competition
  - e.g. barnacles compete for space
  - the 2 species fight over resources (space)
  - there are face-to-face confrontations

Exploitative competition – Hey, don’t drink too fast!

Interference competition – Hey, you pinch my straw!
Kangaroo rats and other desert rodents

Removal experiments are the strongest tests of the existence of interspecific competition

Detecting Interspecific Competition
- Negative effects of one species on another do not automatically indicate competition.
- Presence of one species may attract a predator that consumes both, causing one species to have a lower population size than the other. (apparent competition)

Exercise: So, how does competition affect community structure?

Predation also affects community structure.

Exercise: What’d happen to the community when heron reduce roach?
Predators reduce the population size of prey, and often induce top-down trophic cascades.

Trophic cascades are a key feature in community dynamics.
We will talk about it in ecosystem ecology.

Coevolution
The interdependent evolution of two or more species.
Particularly, "arms races" between predators and prey drive evolutionary changes and remarkable adaptations in both predator and prey species, and promote species diversity.

Plant defenses against herbivores -- Morphological defenses

Plant defenses against herbivores -- secondary compounds
Some herbivores can breakdown secondary compounds

Mustard oils – cabbages – cabbage butterfly
Herbivores make use of secondary compounds

Cardiac glycoside – milkweed – Monarch butterfly

Herbivores make use of secondary compounds

Prey defenses against predators
- Chemical defenses
- Morphological defenses
  - Cryptic (camouflage) coloration.
  - Warning (aposematic) coloration.
  - Mimicry

Chemical defenses

Camouflage! Can you see them?

Warning! Dare you eat them!
Batesian mimicry is where a harmless species mimics a harmful one.

Müllerian mimicry is where two or more unpalatable species resemble each other.

Müllerian mimicry & Batesian mimicry

In addition to competition, predation & herbivory, there are other types of species interactions

Cannibalism

Commensalism

Epiphytes Barnacles on whales
Mutualism

Parasitism -- ectoparasites

Parasitism -- endoparasites

Insect Parasitoid

Parasites with complex life cycles often manipulate host behavior

Mutualism turns parasitism
Interactions Among Ecological Processes

- Predation may reduce competition
- Parasitism may alter competition
- Indirect effects
  - Presence of one species may affect a second species through interactions with a third species.

What’d happen to ants if you removed rodents?

Complex indirect interaction

Keystone species

- A species whose absence would bring about a significant change in the community.
- Top predators in a community are often keystone species (e.g. sea stars affect the diversity of tidal pool communities).

A tidal pool community
After sea star removal

Sea stars as a keystone species

Ecosystem engineering
Some keystone species modify their habitats to produce a particularly strong effect on community structure, e.g. beavers.

Exercise: Who do you think is the keystone species in this community?

Succession
- Biological communities change with time, usually, but not necessarily, from a simple to a more complex structure.
  - primary succession
  - secondary succession
Primary succession - occurs on bare substrates

- Glacial retreat

![Year 1](image1)

- Year 100

![Year 200](image2)

Soil nutrients change as succession progress

![Year 1](image3)

- Nitrogen in mineral soil

- Nitrogen in forest floor

![Year 200](image4)

Year 1

Year 100

Year 200

- Pioneer moses

- Invading alders

- Alder thickets

- Spruce forest

Secondary succession occurs where an existing community has been cleared, but the soil is left intact.

![Secondary succession](image5)

Why succession occurs?

- Pioneer species are able to tolerate harsh conditions during early succession.

- Settled species alter the habitat which facilitate the invasion of subsequent colonizers.

- The habitat may be further altered that inhibit the growth of original colonizers.

Why succession occurs?

- Seed dispersers also aid the succession process
Most communities are in a state of nonequilibrium owing to frequent disturbances.

Marine and island communities are subject to disturbance by tropical storms.

We often think that disturbances have a negative impact on communities, but some communities are maintained by disturbance.

Exercise: Do disturbances increase or decrease species diversity in a community? How?

<table>
<thead>
<tr>
<th>Species number</th>
<th>?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disturbance</td>
<td></td>
</tr>
</tbody>
</table>

Intermediate disturbance theory

- Communities experiencing moderate levels of disturbance will have greater species richness than communities experiencing either smaller or larger levels of disturbance.
  - simultaneous successional stages
  - dominant competitors kept at bay

Exercise: What factors influence the biodiversity of this community?
Causes of biodiversity, so far

- Physical-chemical environment
- Biological interaction
- Disturbance
- Others?

Dynamics of Ecosystems

Chapter 55

Ecosystem ecology

- An ecosystem includes all the organisms living in a particular place, and the abiotic environment in which they interact.

- Ecosystem ecology is about …
  - Biogeochemical cycles of chemical elements through ecosystems.
  - Energy flows through ecosystems (a one-way process).

Eugene Odum (Univ. of Georgia)

Biogeochemical Cycles

- The water cycle
- The carbon cycle
- The nitrogen cycle
- The phosphorus cycle
Physical processes move elements around

Biological processes move elements around

**Biogeochemical Cycles**

- The water cycle
  - The carbon cycle
  - The nitrogen cycle
  - The phosphorus cycle

**The water cycle**

- By area, oceans receive ¾ and lands ¼ of precipitation. Both lands and oceans evaporate much of water back to the atmosphere.
- On lands, transpiration from plants account for 90% of water back to the atmosphere.
Groundwater

- Groundwater (stored in aquifer) is the largest reservoir of water on lands.

- It is recharged via percolation of rainfall and water seeps down from lakes and streams through soil, very slowly. The flow is also very slow.

Mining and pollution of groundwater

- Human mine groundwater, thus many underground aquifers have much higher withdraw rates than recharge rates. Agriculture will be in trouble.

- Pesticides, herbicides, and fertilizers accumulate in groundwater are virtually impossible to be removed (b/c slow turnover rate). Yet, groundwater supplies about 50% of drinking water (in U.S.).

Deforestation breaks the local water cycle

- In forest ecosystems, plants take up much moisture and transpire it back into the atmosphere, forming clouds. When forests are cut down, water drains from the local area instead of forming clouds.

- The lack of rains further prevents reforestation, and may create semi arid desert (positive feedback).

Deforestation also causes erosions

Biogeochemical Cycles

- The water cycle
- The carbon cycle
- The nitrogen cycle
- The phosphorus cycle
The carbon cycle

Carbon Cycle

- Carbon cycle is based on CO₂ which makes up 0.03% of the atmosphere, dissolved in water, and those C locked up in organic compounds (live or dead organisms) and sediment (carbonates).

- Most organic compounds formed as a result of CO₂ fixation (photosynthesis). About 70% of CO₂ in the atmosphere is fixed by photosynthesis annually.

Reservoirs of Carbon

Carbon Cycle

- Carbon in the ecosystems cycles through photosynthesis and respiration processes. Most organic compounds are ultimately broken down, and C is released back into the atmosphere.

- Under natural condition, photosynthesis and respiration are proximately balanced. But we have been tipping the balance.

Carbon cycling processes

Tipping the balance

- Increasing fuel consumption, and deforestation by burning are liberating carbon at an increasing rate.
Biogeochemical Cycles

- The water cycle
- The carbon cycle
- The nitrogen cycle
- The phosphorus cycle

The Nitrogen Cycle I

- Only a few kinds of prokaryotes can fix atmospheric nitrogen into forms that can be used for biological processes. Only symbiotic bacteria fix enough nitrogen to be of major significance
- Nitrogen fixation: $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$
Reservoirs of nitrogen

The Nitrogen Cycle II
- After organisms die, nitrogen in organisms become soil nitrates through 2 processes carried out by decomposers.
  - Ammonification – NH₄⁺ (ammonium) are released during the metabolic processes of decomposers.
  - Nitrification – NH₄⁺ are converted by bacteria into NO₂⁻ (nitrite) and NO₃⁻ (nitrate) which can be taken up by regular plants.

The Nitrogen Cycle III
- Nitrogen fixed in soil (NO₃⁻, nitrate) may return to atmosphere through Denitrification, carried out by bacteria under anaerobic condition.
  - Denitrification: Bacteria get O₂ from NO₃⁻ and release N₂ or N₂O back to the atmosphere.

Nitrogen cycling processes

Tipping the balance
- The use of fertilizers, thus large amount of nitrogen, in agriculture alter the natural cycles of nitrogen.

Eutrophication
Biogeochemical Cycles

- The water cycle
- The carbon cycle
- The nitrogen cycle
- The phosphorus cycle

Phosphorus Cycle

The largest reservoir of phosphates exist in rocks.
Phosphates weather from rocks and soils into water. They may enter plants and animals, or are transported to oceans and accumulate in sediments.

Reservoirs of phosphate

Sediments & up-welling

- The nitrates and phosphates locked up in sediments, particularly those in the deep ocean floor, can be brought back only by up-welling.
Tipping the balance

- Three times more phosphates than crops required are added to agricultural lands each year.

Eutrophication

Exercise: What would happen to nutrient cycles after deforestation?

When the watershed is intact …

- The amounts of nutrient inputs from rains and snows are about equal to the amounts that flow out.

When the forest is cut down …

- The nutrient inputs from rains drain from the local area.

Consequences of deforestation

Nutrients cycle, but energy doesn’t
Energy flows through ecosystems

Different types of producers
- Photo-autotrophs –
  \[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 \]  
  (Energy provided by solar energy)
- Chemo-autotrophs –
  \[ \text{CO}_2 \text{ or CH}_4 \rightarrow \text{C(H}_2\text{O)}_n \]  
  (Energy provided by \( \text{H}_2\text{S} + \text{O}_2 \rightarrow \text{Energy} \))

Different types of consumers
- Primary consumers – herbivores, grainivores, frugivores,
- "Higher" consumers – carnivores, insectivores, parasites,
- Detritivores -- break down dead organic material
  - Scavengers – Vultures and crabs
  - Decomposers – Bacteria and fungi

Trophic level refers to the feeding level of an organism

Primary Productivity
- Green plants capture about 1% of the solar energy that falls on their leaves.
- In a given area during a given period of time ...
  - Gross primary productivity (GPP) is the total organic matter produced by producers.
  - Net primary productivity (NPP) is the amount of organic matter produced that is available to consumers.
  - Biomass is the total mass of all organisms.

Primary productivity of various ecosystems.
Primary productivity of various ecosystems.

Exercise:
Why do they have different NPP?

We did not talk about the material covered in the following 20 slides. But they will show up in the final exam.

Primary Productivity
- The productivity in a given area is ultimately determined by the amount of energy it receives. Thus, NPP often increases as the growing season lengthens.
- In aquatic ecosystems, light and nutrients limit primary production.
- In terrestrial ecosystems, temperature, moisture, and nutrients limit primary production.

On a local scale, nutrients in the soil can play key roles in limiting primary production.

Not all NPP is consumed
- NPP not consumed will eventually become available to decomposers.
- And, not 100% of the NPP consumed by herbivores is assimilated
  - Herbivores assimilate about 20% of consumed biomass; carnivores 5%. On average, 10% of consumed biomass is assimilate by consumers.
The assimilation by consumers is only ~10%

17% Growth = assimilation
33% Cellular respiration = heat loss
50% Feces

~10% assimilation from one level to the next

Exercise: Why most food chains contain less than 4 trophic levels?

Diminishing energy due to heat loss

Energy availability (NPP) affects

No. of species
No. of trophic links

High (control) Medium Low

Productivity

One-way energy flow
Exercise: Why are top predators rarer than lower consumers?

Ecological Pyramids
Moving up a food chain, you generally find fewer individuals, lower total biomass, and lower total energy at each successive trophic level.

Pyramid of numbers

Pyramid of biomass

Pyramid of energy

Here is a good reason to be a vegetarian
### Trophic cascade

- The effect of one trophic level flows up or down to other levels.
  - Top-down effects
  - Bottom-up effects

### Three-level top-down cascade

**Trout – Invertebrate → Algae**

<table>
<thead>
<tr>
<th>Invertebrates (number/m²)</th>
<th>Algae (mg chlorophyll a/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Trout</td>
<td>0</td>
</tr>
<tr>
<td>Trout</td>
<td>2.0</td>
</tr>
</tbody>
</table>

### Four-level top-down cascade

- Predatory fish
- Damsel Fly nymph
- Algae-eating insect
- Algae

### Exercise:

In a imaginary state, people love to hunt – deer hunting. They hate the wolves that take “their” deer. Wolves are bad. So they do everything to get rid of wolves.

What would happen if wolves disappeared?

### Sand County Almanac

**By Aldo Leopold**

I have lived to see state after state extirpate its wolves. I have watched the face of many wolfless mountain, and seen the south-facing slopes wrinkle with a maze of new deer trails.

I have seen every demise, and then to death. I have seen every edible tree defoliated to the height of a saddle horn.
**Bottom-up effects**

Four levels

Increase productivity, increase food-chain length

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**Exercise:** Why are there portions of the curves where vegetation biomass does not increase as productivity increases?