Robert Paine
1933 – 2016
An Introduction to Ecology and the Biosphere
• Ecology
  – is the scientific study of the interactions between organisms and the environment
    • these interactions determine distribution and abundance
  – oikos (from Gr.) meaning *household, home or place to live*
Producers

Dead organic matter

Consumers

Decomposers

Inorganic nutrient pool

Ecosystem boundary

LIGH

HEAT

Nutrient import and export
Ecology
– has a long history as a descriptive science

Aristotle’s climate classification

Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
Antarctic Circle

Frigid Zone
Temperate Zone
Torrid Zone
Temperate Zone

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Aristotle (384-322 BC)

Painted by S. Uchii, 2003
Ecology
– today is also a rigorous experimental science

Predator exclusion cage  Sham  No cage
Ecology – is a highly quantitative science
Ecology and Evolutionary Biology

• events that occur in ecological time
  – affect life on the scale of evolutionary time
excerpted from
Organisms and the Environment

The environment of any organism includes:
- abiotic, or nonliving components
- biotic, or living components

General zonations determined by relative lengths of exposure to the air and to the action of waves.
Subfields of Ecology

• organismal ecology
  – how do individuals interact with each other and the physical environment?

Are Catalina bison suffering from malnutrition?
Population ecology
– how and why does population size change over time?

What fraction of potential kelp bass parents successfully reproduce each year?
Community ecology
– how do species interact and with what consequences?

Will hunting pigs on Santa Cruz I. save the foxes?
Ecosystem ecology
– emphasizes energy flow and chemical cycling among the various biotic and abiotic components

Will seeding the ocean with iron increase algal growth, absorb greenhouse gases and cool the planet?
Landscape ecology
– deals with arrays of ecosystems and how they are arranged in a geographic region

To what extent do trees lining drainage channels serve as dispersal corridors?
Ecology ≠ Environmentalism

• Ecologists
  – provides the scientific understanding underlying environmental issues

• Environmentalists
  – advocate for environmental protection

Rachel Carson
Why do species live where they do?
Biogeography
– provides a good starting point for understanding what limits the geographic distribution of species

Species absent because

Dispersal limits distribution?

Yes

Behavior limits distribution?

No

Area inaccessible or insufficient time

Yes

Habitat selection

No

Biotic factors (other species) limit distribution?

Yes

Predation, parasitism, competition, disease

No

Abiotic factors limit distribution?

Yes

Water, Oxygen

Salinity

pH

Soil nutrients, etc.

No

Physical factors

Temperature

Light

Soil structure

Fire

Moisture, etc.
Dispersal may explain why pigmy mammoths lived on N. Channel Islands but not S. Channel Islands
Biogeography
– provides a good starting point for understanding what limits the geographic distribution of species

Figure 50.6, 1084
Sea otters could disperse to San Nicolas Is., but they don’t want to stay there.
Biogeography
– provides a good starting point for understanding what limits the geographic distribution of species

Species absent because

Dispersal limits distribution?
  Yes
  No

Behavior limits distribution?
  Yes
  No

Area inaccessible or insufficient time

Habitat selection
  Yes
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Biotic factors (other species) limit distribution?
  Yes
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Predation, parasitism, competition, disease

Abiotic factors limit distribution?
  Yes
  No

Chemical factors
  Water
  Oxygen
  Salinity
  pH
  Soil nutrients, etc.

Physical factors
  Temperature
  Light
  Soil structure
  Fire
  Moisture, etc.
Biotic Factors

• biotic factors limiting distribution include:
  – presence of predators, parasites, competitor(s), disease
  – absence of prey, pollinators, symbionts
A specific case of an herbivore limiting distribution of a food species

**EXPERIMENT**

W. J. Fletcher tested the effects of two algae-eating animals, sea urchins and limpets, on seaweed abundance near Sydney, Australia. In areas adjacent to a control site, either the urchins, the limpets, or both were removed.

**RESULTS**

Fletcher observed a large difference in seaweed growth between areas with and without sea urchins.

Removing both limpets and urchins or removing only urchins increased seaweed cover dramatically.

Almost no seaweed grew in areas where both urchins and limpets were present, or where only limpets were removed.

Removing both limpets and urchins resulted in the greatest increase of seaweed cover, indicating that both species have some influence on seaweed distribution. But since removing only urchins greatly increased seaweed growth while removing only limpets had little effect, Fletcher concluded that sea urchins have a much greater effect than limpets in limiting seaweed distribution.

**CONCLUSION**

Figure 50.8, 1086
Biogeography
– provides a good starting point for understanding what limits the geographic distribution of species
Trophic Structure

terrestrial & marine food chains

A terrestrial food chain

A marine food chain
Food Webs

Antarctic marine food web
Trophic structure is a key factor in community

• Detritivores derive their energy from detritus, the dead material produced at all the trophic levels.

• Decomposers
  – are mainly prokaryotes and fungi and
  – secrete enzymes that digest molecules in organic materials and convert them into inorganic forms in the process called decomposition.
Producers provide the chemical energy and nutrients used by all other members of the food web.
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- **Producers (plants)**: Mesquite, Prickly pear cactus, Saguaro cactus
- **Primary consumers**: Grasshopper mouse, Desert kangaroo rat, Harvester ants
- **Secondary consumers**: Grasshopper, Collared lizard, Western diamondback, Praying mantis, Gila woodpecker, Elf owl, Western diamondback, Harris’s antelope squirrel
- **Primary and secondary consumers**: Red-tailed hawk

**Nutrient Transfer**

- From Producers to Primary consumers
- From Primary consumers to Secondary consumers
Producers provide the chemical energy and nutrients used by all other members of the food web.
Species with large impact

dominant species
  - biomass
  - invasive species

keystone species - not necessarily abundant

foundation species - or ecosystems engineers
Dominant species
Dominant species

- biomass
- invasive species
Keystone species

keystone species - not necessarily abundant
Ecosystem engineers
(foundation species)

e.g., beavers
Abiotic Factors

- temperature
- water
- sunlight, UV exposure
- waves
- wind
- rocks & soil, pH
Light penetration affects distribution of algae with different photosynthetic pigments.
Soil type can drive parapatric speciation in plants
Abiotic Factors Determine Climate

• major determinants of climate
  – temperature
  – water
  – sunlight
  – wind
  – rocks and soil

• macroclimate: global, regional, local
• microclimate: very fine scale
Global Patterns
Sunlight intensity

– plays a major part in determining the Earth’s climate patterns

**LALITUDINAL VARIATION IN SUNLIGHT INTENSITY**

- Low angle of incoming sunlight
- Sunlight directly overhead
- Low angle of incoming sunlight

North Pole 60°N
30°N
Tropic of Cancer
0° (equator)
Tropic of Capricorn
30°S
60°S South pole

Atmosphere

Figure 50.10, pg. 1088
**June solstice:** Northern Hemisphere tilts toward sun; summer begins in Northern Hemisphere; winter begins in Southern Hemisphere.

**March equinox:** Equator faces sun directly; neither pole tilts toward sun; all regions on Earth experience 12 hours of daylight and 12 hours of darkness.

**Constant tilt of 23.5°**

**September equinox:** Equator faces sun directly; neither pole tilts toward sun; all regions on Earth experience 12 hours of daylight and 12 hours of darkness.

**December solstice:** Northern Hemisphere tilts away from sun; winter begins in Northern Hemisphere; summer begins in Southern Hemisphere.
Air circulation cells affect rainfall

GLOBAL AIR CIRCULATION AND PRECIPITATION PATTERNS

Descending dry air absorbs moisture

Ascending moist air releases moisture

Descending dry air absorbs moisture

Arid zone

30° 23.5° 0° 23.5° 30°

Tropics

0° (equator) 30° 60°N 30°N 60°S 30°S 60°S
Air circulation cells drive windbelts.
Global belts of low and high atmospheric pressure
Earth’s rotation causes Coriolis

- little deflection at equator
- deflected right in northern hemisphere
- deflected left in southern hemisphere
Regional Patterns
Oceans and large lakes moderate climate

1. Warm air over land rises.
2. Air cools at high elevation.
3. Cooler air sinks over water.
4. Cool air over water moves inland, replacing rising warm air over land.
Mountains produce “rain shadow”

1. As moist air moves in off the Pacific Ocean and encounters the westernmost mountains, it flows upward, cools at higher altitudes, and drops a large amount of water. The world’s tallest trees, the coastal redwoods, thrive here.

2. Farther inland, precipitation increases again as the air moves up and over higher mountains. Some of the world’s deepest snow packs occur here.

3. On the eastern side of the Sierra Nevada, there is little precipitation. As a result of this rain shadow, much of central Nevada is desert.
Long Term Climate Change
Temperature has risen ~1°C over past century.
Can organisms adapt to changing conditions?

- coral bleaching attributed to thermal stress
- major diebacks already attributed to global warming
- must move, adapt or go extinct