Ecology and ecosystems: the here and now

Polar bears: *Ursus maritimus*

- Federally listed endangered

What’s the problem with rapid climate change for living organisms?

- They cannot always adapt fast enough
- They may survive but be relegated to ‘refugia’
- Many will suffer genetic bottlenecks as a result
- Biomes will shift and organisms will have to shift with them (or not)

Refugia and habitat fragmentation

Some organisms CAN survive in these refugia, but may never get out, or may emerge quite changed

Wolves-the unexpected impacts

- Elk were eating riparian (river) trees and shrubs
- Birds and steelhead had declined - ecosystem change
- Wolves drove Elk up into higher ground
- Riparian systems are recovering, ecosystem is shifting back

Attempting to maintain health populations is also about ecological stability, especially for top predators. This of course is about human stability too.
Ecosystem change: an example

Killer whales and their appetite for sea otters

Dead zones in the oceans

- Eutrophication
- Stratification and oxygen depletion on the bottom
- Can affect all trophic levels, but it takes time

The large region of low oxygen water often referred to as the ‘Gulf Dead Zone,’ shown here, crosses nearly 5,800 square miles of the Gulf of Mexico again in what appears to be an annual even

Nature & Science: The World’s Top Science Journals

- Both agree:
  - global warming is real
  - not normal cycle
  - its cause is OUR CO$_2$

Climate Scientists Are 90% Certain That Global Warming Is Driven By Humans: IPCC

Life on Earth

- Living things cause change
- Living things respond to change
- Living things change their environments
- Living (biotic) and non-living (abiotic) components of our Earth interact
- Processes like global warming/climate change follow large-scale patterns, but it is the composition of life on earth that can affect those patterns
- Ecological systems exist in balance - that balance can be disturbed, and its evolution from there can be difficult to predict.

Life - as we know it

- Organized internal structure - share a similar chemical composition
  - Composed of a common organization of atoms, molecules, cells... with emergent properties.
- DNA/RNA
- Respond to stimuli, coordinated growth and development
- Capture and transform energy from their environment
- Maintain internal conditions separate from external
  - Composed of cells
- Arise through reproduction
- Can adapt through mutations and adaptations
- Effect change on their environment
Two Main Classes of Cells

- **Prokaryotic** (Bacteria and Archaea)
  - Pro = “Before”; Karyon = “Kernel”
  - No nucleus, DNA coiled up inside cell

- **Eukaryotic** (Everything else)
  - Eu = “True”
  - DNA inside membrane bound organelle inside cell, the nucleus

How do we get these?

- Those Bio-geochemical cycles!!
- Don’t forget all the prokaryotes that drive so many of the cycles

Percentage of Elements found in things

<table>
<thead>
<tr>
<th>Elements</th>
<th>Human</th>
<th>Plant</th>
<th>Earth's crust</th>
<th>Ocean water</th>
<th>Air</th>
<th>Bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>18.0</td>
<td>11.3</td>
<td>0.10</td>
<td>1.27</td>
<td></td>
<td>0.08</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>1.10</td>
<td>0.4</td>
<td>0.10</td>
<td>0.26</td>
<td></td>
<td>0.82</td>
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<tr>
<td>Calcium</td>
<td>3.1</td>
<td>0.6</td>
<td>0.10</td>
<td>1.15</td>
<td></td>
<td>0.06</td>
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<tr>
<td>Phosphorus</td>
<td>1.10</td>
<td>0.7</td>
<td>0.10</td>
<td>0.9</td>
<td></td>
<td>0.37</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.25</td>
<td>0.01</td>
<td>-</td>
<td>0.04</td>
<td></td>
<td>-</td>
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<tr>
<td>Fluorine</td>
<td>0.10</td>
<td>0.0</td>
<td>0.010</td>
<td>0.004</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.10</td>
<td>0.0</td>
<td>0.004</td>
<td>0.004</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.05</td>
<td>0.0</td>
<td>0.004</td>
<td>0.004</td>
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<td>-</td>
</tr>
<tr>
<td>Silicon</td>
<td>-</td>
<td>0.0</td>
<td>0.004</td>
<td>0.004</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Aluminum</td>
<td>-</td>
<td>0.0</td>
<td>0.004</td>
<td>0.004</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Iron</td>
<td>0.004</td>
<td>0.0</td>
<td>0.004</td>
<td>0.004</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Iodine</td>
<td>-</td>
<td>-</td>
<td>0.004</td>
<td>0.004</td>
<td></td>
<td>0.99</td>
</tr>
<tr>
<td>Other elements</td>
<td>-</td>
<td>-</td>
<td>0.004</td>
<td>0.004</td>
<td>0.99</td>
<td>-</td>
</tr>
</tbody>
</table>
Trophic levels

1. Producers (photosynthetic plants, algae, bacteria)
2. Primary consumers (hard-bodied herbivores)
3. Secondary consumers (carnivores)
4. Tertiary consumers (usually a "top" carnivore)

Consumers that feed at all levels:
Parasites
Scavengers
Decompensers

Energy pyramid

- Producers 100%
- Herbivores 16.1%
- Primary carnivores 1.8%
- Top carnivores 0.1%


Antarctic food web

Biomagnification

DOT concentration: 0.01 ppb in 14 meter krill
DOT in krill feeding-bird: 75 ppb
DOT in whale: 150 ppb
DOT in killer whale: 1500 ppb
DOT in killer whale: 30,000 ppb

Taxonomy

| SPECIES: Panthera pardus | GENUS: Panthera | FAMILY: Felidae | ORDER: Carnivora |
| CLASS: Mammalia | PHYLUM: Chordata | KINGDOM: Animalia |

| Table 3.1: Taxonomy of Two Common Species |
| TAXONOMIC LEVEL | YOU | CORN |
| Kingdom | Animalia | Plantae |
| Phylum | Chordata | Anthophyta |
| Class | Mammalia | Monocotyledons |
| Order | Primates | Conomales |
| Family | Hominidae | Praceae |
| Genus | Homo | Zea |
| Species | Homo sapiens | Zea mays |
Five Kingdoms

Three Domains

Evolutionary Trees

What are the tools used by scientists to observe and understand evolutionary relationships?

- 1. Artificial selection
- 2. Fossil record
- 3. Comparative anatomy
- 4. Comparative embryology
- 5. Comparative biochemistry
- 6. Biogeography

Artificial Selection

The fossil record: A gallery of fossils
Homologous structures: anatomical signs of descent with modification

Function and design
- Co-evolution
- Convergent evolution

Comparative Embryology:
- "Ontogeny recapitulates phylogeny" - the appearance of ancestral structures in the embryos of modern descendants (Haeckel)

The Galapagos mockingbirds differ only slightly in size, shape, and coloration.

Nesomimus macdonaldi
Nesomimus melanotis
Nesomimus parvulus
Nesomimus trifasciatus

Darwin reasoned that they are similar because they share a common ancestor.

Geographic proximity of similar but distinct species

Natural selection: Facts and inferences

Fact 1. Natural populations have large excess reproductive capacities.
Fact 3. Resources are limiting.
Inference 1. A severe struggle for existence must occur.
Fact 4. An abundance of variation exists among individuals of a species.
Fact 5. Some of this variation is heritable.
Inference 2. Genetically superior individuals outsurvive and outreproduce others.
Inference 3. Over many generations, evolutionary change must occur in the population.

Experimental Evidence of Evolution by Natural Selection

• Case Study of Natural Selection by Pollinators of Alpine Skypilot Plants
In tundra habitats above timberline, the alpine skypilot is pollinated primarily by bumblebees.

In forested habitats below timberline, the alpine skypilot is pollinated primarily by flies.

**Below-timberline flower:** small and skunky-smelling

**Flower size (mm)**

<table>
<thead>
<tr>
<th>Number of individuals</th>
<th>Flower size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 12 14 16 18 20 22</td>
</tr>
</tbody>
</table>

**Tundra flower:** big and sweet-smelling

**Flower size (mm)**

<table>
<thead>
<tr>
<th>Number of individuals</th>
<th>Flower size (mm)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>10 12 14 16 18 20 22</td>
</tr>
</tbody>
</table>

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**The sickle cell allele**

*Overdominance* occurs when fitness of the heterozygote exceeds either homozygote.

**Alleles:**
- **HbA** = normal hemoglobin allele
- **HbS** = sickle cell allele

**Genotypes: Relative fitness**
- **HbA HbA**: susceptible to malaria 0.88
- **HbA HbS**: resistant to malaria, 1, experiences mild anemia
- **HbS HbS**: susceptible to severe anemia 0.12

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For example, very small and very large babies are most likely to die, leaving a narrower distribution of birthweights.

**Birthweight (pounds)**

<table>
<thead>
<tr>
<th>Percentage of population</th>
<th>Birthweight (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
</tbody>
</table>

**Mortality**

- Heavy mortality on extremes

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For example, only juvenile blackbelled seedcrackers with very long or very short beaks survived long enough to breed.

**Beak length (mm)**

<table>
<thead>
<tr>
<th>Number of individuals</th>
<th>Beak length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 6 7 8 9 10 11</td>
</tr>
</tbody>
</table>

---

**Adaptation, speciation, and the concept of the niche**

- Survival and differential reproductive success over a period of time
- Traits that increase ‘fitness’ are ‘selected for’, and are passed on through generations

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**Adaptation by the process of Natural Selection**
Mullerian Mimicry
- Two or more unpalatable species resemble each other

Batesian mimicry

Behavioral adaptations

Pitfalls
- Giraffes
- Polar Bears

The neck of the Giraffe
Most feeding is done below neck height.

“Sterling 1974”
- 1 “sneak and pounce”
- 54 “jump and crush”
- 233 “sit and wait”
Polar Bears

UV Hypothesis

Species Diversity

• What is species diversity: both
  – Species richness
  – Relative abundance
• What leads to high diversity?
  – Habitat heterogeneity
  – High levels of competition
  – Other...interspecific interactions, functional group diversity, abiotic factors?

Some important concepts

• What is a niche? -
  – The ‘role’ of an organism
  – Its use of abiotic and biotic resources, and its reaction to them (eg. Tolerance plays a role here)
• Competitive Exclusion Principle
  – No two species can occupy the same niche - it will always result in competition

Vultures: multiple niches or multiple species per niche?

• Generalists
• Specialists

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Warblers in tree
Figure 3.8

Source: Original observations by R. H. MacArthur
Effects of competition

- Competitive exclusion: One species dominates
- Resource partitioning
- Competition can lead to speciation
- Competition is an important factor in maintaining ecosystem function. When one species is removed, the structure of competition is changed too.
- Introduced species?

Species tolerance

- Law of tolerance: the existence, abundance and distribution of a species in an ecosystem are (largely) determined by whether the levels of one or more factors (abiotic) falls within the range of tolerance
- Tolerance to abiotic and biotic factors in part determines the range/distribution

Abiotic factors are important in determining ecosystem structure

- Living things have tolerance limits to abiotic factors such as...?

Tolerance Cont.

- Physiological responses
- Morphological responses
- Behavioral responses
- Community boundaries?
- Short term and long term

Reproductive strategies

SEX:
- Internal fertilization (few or many)
- Nest laying (brooding)
- Broadcast spawning (mass release)

This is mixing genes!

NO SEX (asexual)
- Fission - parent splits
- Budding - parent develops small growth

This is cloning!
Sex?

**Sexual reproduction**
- Introduce new genes
- Diversity in phenotype and genotype
- Resistance to disease
- Resistance to environmental change: *Adaptation*

**Asexual reproduction**
- Hard to find a mate
- Picking the right one
- Mutations/problems
- Parental investment?
- Don’t know exactly what you get

Sex?

**Asexual reproduction**
- Fast
- Know exactly what you get
- Can spread your exact genes
- Cover an area quickly
- No need to find a mate

Some can do both!

**Combination** of sexual and asexual reproduction can bring the best of both worlds

**Hermaphrodites:** no need to find the right sex! These are organisms that are both sexes at once, or can change from male to female or female to male.

Factors affecting organisms

**Abiotic:** non-living (temperature, water, sedimentation etc.) physical and chemical

**Biotic:** living interactions (between living organisms)
- Symbiosis
- Predation
- Herbivory
- Competition

Species Interactions (Biotic):
- *Interspecific* and *Intraspecific*
- Competition
- Predation
- Symbiosis

Zooxanthellae: the key to coral reef productivity
Ecosystem change: an example

Reduction of coral = increase in Algae. This shifts functional Groups of species, and affects Primary productivity

Cleaning symbiosis: mutualism

Predation

Herbivory has large effects on ecosystems

Ecosystem structure

- **Keystone species** - is there such a thing?
  - A species whose ‘role’ or niche has a major impact on the structure of an ecosystem
  - Some case studies?
Sea Otters and Sea Urchins: a kelp forest paradigm

Sea Urchins eat kelp, especially new recruits
If kept in check, they eat drift kelp
If populations expand, they will eat established kelp

Sea Otters eat urchins, especially exposed ones
They will keep sea urchin populations in check

The Aleutian Island studies

Sea Otters as a keystone predator

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Populations: what affects their size and growth?

- Density (#/area) - carrying capacity (K)
- Natality - birth rate
- Mortality - death rate
- Age distribution/sex ratio
- Spatial distribution
- Resource availability
- Species interactions
- Migration/emigration

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Reproductive strategies

<table>
<thead>
<tr>
<th>TABLE 3.2 Reproductive Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>&quot;Y&quot; ADAPTED SPECIES</strong></td>
</tr>
<tr>
<td>1. Short life</td>
</tr>
<tr>
<td>2. Rapid growth</td>
</tr>
<tr>
<td>3. Early maturity</td>
</tr>
<tr>
<td>4. Many small offspring</td>
</tr>
<tr>
<td>5. Little parental care or protection</td>
</tr>
<tr>
<td>6. Little investment in individual offspring</td>
</tr>
<tr>
<td>7. Adapted to unstable environment</td>
</tr>
<tr>
<td>8. Flowers, colonizers</td>
</tr>
<tr>
<td>11. Regulated mainly by extrinsic factors</td>
</tr>
<tr>
<td>12. Low trophic level</td>
</tr>
</tbody>
</table>
The role of ecosystem disturbance

- Equilibrium and stability: over what time scale do we measure this?
- ‘Natural’ and anthropogenic disturbance
- Short term and long-term disturbance
- Succession and disturbance: climax communities?
- What does ‘disturbance adapted’ mean?

Ecosystems and disturbance

- Size, frequency and severity of disturbance are important
- Intermediate disturbance model: moderate in frequency and severity - most stable, highest diversity
- Succession: what will the ecosystem ‘look like’ following a disturbance?
- Ecosystem disturbance affects community structure, composition, and diversity: RATE and SEVERITY are important