Climate Change

- The science of climate change
  - Definitions
  - Facts, historical climate
  - Predicted future climate
  - Biological impacts
- Mechanisms – why does climate change?
- The politics of climate change

Climate Change

- What exactly is climate change?
  - “Global warming” is a misnomer
  - Models predict greater variability, more extremes and global mean increase in temperature

Natural vs. Anthropogenic Influence

- Isn’t climate change a natural process?
  - Yes
  - However, the question is whether human activities are accelerating the rate of change.
- What impact might accelerated climate change have on biological systems?
  - Alter physical environment (gradients)
  - Biodiversity
  - Ecosystem function

Science vs. Politics

- Political debate – what is the economic cost of doing something (now) vs. accepting the consequences (later)
  - Abuse of science
  - Selective presentation of facts by those with an agenda
  - Influence of lobbyist from energy companies
Evidence for climate change

• Long term trends
  – Snowball earth
  – Glacial periods and ice ages

• Short term trends
  – Obvious warming trend
  – 11 of the warmest years ever recorded were in the last 12 years
  – Rate of change is unprecedented

Sea Ice Changes

• Decrease in area covered in ice, decrease in ice thickness.

Sea Level Changes

• Melting glaciers → less water tied up in glaciers → sea levels rise
Increase in variability in precipitation

What is not evidence of climate change?

- “It’s really hot today…global warming!”
- “We had a record low yesterday…global warming!”

- Climate change in your lifetime will be visible on the following scale
  - Greater daily variability in temperature
  - Change in annual mean temperature
  - More extreme precipitation patterns (more droughts and floods)
  - More extreme storm events
  - Change in sea levels

Greenhouse effect, how are humans contributing?

- **Greenhouse gasses** – absorb infrared radiation, trap heat in the atmosphere

  - CO₂
  - H₂O
  - CH₄
  - NO₂

What are greenhouse gases?
Positive feedback loops
- Increased temperature → decrease in area covered in ice → lower surface albedo → more solar input

Historical Gas Levels
- At the poles: Climate too cold to melt snow, ice accumulates in annual layers
- Bubbles in ice preserve a record of atmospheric gases

Ice Core Gas Data
- Of the greenhouse gases, CO₂ is the most abundant
- All biologically produced, only CO₂ produced by fossil fuels
- Historic range from 150-290 ppm
Greenhouse Gas Emissions

- Sharp spike in levels seen after industrialization
- CO₂ is the major gas, note other gasses measure in parts per billion

Human Greenhouse Gas Emissions

- Greenhouse gas emissions are anticipated to rise by 32% between 1990 and 2020
- Projections for warming suggest a global increase of 2.5°F - 10.4°F by 2100

CO₂ emissions and the carbon cycle

Projected future CO₂ levels

- Based on
  - Population growth
  - Industrialization of developing countries
  - Continued economic growth
- Limiting factors
  - Peak oil
  - Technological advances
  - Source/sink dynamics
Decreasing atmospheric CO$_2$

- CO$_2$ scrubbers
- More efficient combustion engines
- Increase primary productivity
- Carbon sinks

Carbon Neutral Fuel

- Carbon is recycled, no fossil fuels burned
- Easy to adapt current vehicles
- Problems
  - Not enough farm area to feed us and fuel cars
  - Fossil fuels burned to produce ethanol (farming, ethanol plant, etc).

Where does our electricity come from?

- Electric cars may ultimately be coal powered.
- Non-fossil fuel sources – solar, nuclear, wind, hydroelectric

Climate Change Impacts
Biological impacts of climate change

• Health
  – Air quality, increased weather extremes
• Agriculture
  – Crop yield, irrigation demand
• Forests
  – Change in forest composition, production, range
• Water Resources
  – Drought and floods, water quality issues
• Coastal Areas
  – Beach erosion, inundation of coastal areas
• Ecosystem Function
  – Loss of habitat, extinctions, change in production

Likelihood of Impacts

<table>
<thead>
<tr>
<th>Change in Phenomenon</th>
<th>Confidence in projected change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher maximum temperatures, more hot days</td>
<td>Very likely</td>
</tr>
<tr>
<td>Higher minimum temperatures, fewer cold days and frost days</td>
<td>Very likely</td>
</tr>
<tr>
<td>Increase of heat index</td>
<td>Very likely, over most areas</td>
</tr>
<tr>
<td>More intense precipitation events</td>
<td>Very likely, over many areas</td>
</tr>
<tr>
<td>Increased summer continental drying &amp; associated risk of drought</td>
<td>Likely, over most mid latitude continental interiors</td>
</tr>
<tr>
<td>Increase in tropical cyclone peak wind and precipitation intensities</td>
<td>Likely, over some areas</td>
</tr>
</tbody>
</table>

Change in species distribution

POLEWARD SHIFTS IN WINTER RANGES OF NORTH AMERICAN BIRDS

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Abstract: Climate change is thought to promote the poleward movement of geographic ranges; however, the spatial dynamics, mechanisms, and regional anthropogenic drivers associated with these trends have not been fully explored. We estimated changes in latitude of northern range boundaries, center of occurrence, and center of abundance for 264 species of wintering North American birds (1980–2004). After accounting for the effect of range center changes, we found that geographic range changes were associated with significant poleward shifts (p < 0.001) in the latitudes of northern boundaries, center of occurrence, and center of abundance. However, these poleward shifts were associated with distribution changes within ranges, primarily abundance, producing patterns that mirrored projected movements. We conclude that these distributional shifts represent the interaction between climate change and regional factors whose outcome is determined by the role of the analysis and the birds and plant foraminifers in the region, and how anthropogenic activities have impacted these systems.

Keywords: abundance, Christmas Bird Count, common species, distribution of endemic geophysical range, global climate change, North American temperate latitudes, winter range.
Extinctions due to habitat loss

- Loss of Polar bear habitat
- Similar affects expected in most systems

The politics of climate change

IPCC
- The Intergovernmental Panel on Climate Change (IPCC)
- Established in 1988
- 190 government members
- Role of the IPCC: “The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation. Review by experts and governments is an essential part of the IPCC process. The Panel does not conduct new research, monitor climate related data or recommend policies. It is open to all member countries of WMO and UNEP.”

Latest IPCC Report
- “Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.”
- “Eleven of the last twelve years (1995–2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850).”
- “At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones.”
Kyoto Protocol

- International treaty (169 countries) on greenhouse emissions. Goal was to stabilize greenhouse gas concentrations.
- Emission targets — went into effect on February 16, 2005
- US
  - single largest greenhouse gas producing country (China is 2nd)
  - Signed agreement, but was not ratified
- European Union
  - Produce 31% of greenhouse gasses, committed to 8% reduction by 2012
Political Summary

• There is known climate change (IPCC)
• Human influence is known (IPCC)
• Extent of damage is not precisely known (IPCC)
• Political choices:
  – Mandate change now to reduce climate change (Kyoto etc.)
  – Deal with climate change later when it happens
• Easy choice on the 2, 4 or 6 year political cycle

Political Summary

• First mandated increase in mpg standards in over 20 years
• Cost incurred now vs. cost later due to climate change

Habitat Fragmentation

• Habitat fragmentation – turning one large continuous habitat into multiple smaller ones.

Forest Fragmentation

• How widespread is habitat fragmentation?

• Most of the US original forest land has been cut.

• Over 90% of all land in the US is within ½ mile of a road.

One of the most influential biodiversity works of the century.

Question – How do you explain species diversity on islands?

Why is this a scientifically important question?

Used to be continuous forest, grassland - Now have isolated “islands” of habitat.

If we can understand islands, we can understand what affect fragmenting landscapes will have on species and ecosystems.

“Island” Processes and Properties
- Recall: $N_{t+1} = N_t + B + I - D - E$
- Immigration
- Emigration
- Colonization
- Extinction
- Species diversity
- Population size
- Turnover rate

Species Area Relationship

Largest area
7 species

Small area
1 species

Medium area
3 species

Large area
6 species
Species Area Relationship

- Applies to:
  - Sampling area
  - Habitat area
  - Continental area

Species Area Relationship on Islands

- Immigration/Extinction and habitat size
- Larger habitats support:
  - more species
  - larger populations
- Larger populations are less likely to go extinct
- Larger area habitats are more likely to receive immigrants (bigger target for dispersers)
Species Diversity and Habitat Diversity

- Areas with more diverse habitats (more types of habitat) will support more species.
- Wider variety of niches available.

Island Proximity and Species Diversity

- Islands of the same area that are close to the mainland have more species.
- Colonization rate is higher, extinction rate the same.
Dispersal ability of individual species needs to be considered.

MacArthur and Wilson Model

- Island species diversity should be at an equilibrium where immigration rate is equal to extinction rate.
- Island with few species (eg. recently disturbed) – high immigration and low extinction

\[ \hat{S} = \text{equilibrium number of species} \]

Experimentally Defaunated Islands

The number of species on the near island soon equaled predefaunation levels, while the number of species on the far island was still below the original level.
Immigration and Extinction by Island Size

- Small population sizes
- Fewer Species
- Fast extinction rate
- Low immigration rate

Large Island

- Large population sizes
- More species
- Slow extinction rate
- High immigration rate

Interaction between size and proximity

\[ S_{sf} = \# \text{species on a small, far island} \]

\[ S_n = \# \text{species on a large, near island} \]

\[ T_{sf} = \text{turnover rate, small and far etc...} \]

Island Archipelago

Allows for a test of immigration and extinction rate hypotheses.

If rates are at equilibrium (unlikely) then number of species (\( S \)) is predictable.
Edge Effects

- Islands = fragmented habitat!
- Remember that habitats are not distinct, but consist of gradients of environmental variables.
- The edge of an island (habitat) is going to feature conditions intermediate to the core and outside.
- Shape and size of habitat determines proportion of edge vs core (interior) habitat.

Fragmentation and the loss of core habitat

- Interior species tend to be k-selected specialists
- Edge species tend to be generalists

Size and shape both affect the relative proportions of edge and core habitat.
Source-Sink Dynamics

- Large population – single group of interbreeding individuals
- Smaller populations – each a group of interbreed individuals. Extinction, immigration and emmigration occur. **Metapopulation.**

**Rescue effect** – population on an island is not sustainable (sink), population is sustainable due to immigration from other islands (source)

**Application**

- Given
  - Desire to conserve biodiversity and ecosystem function
  - The need for economic development
- How do you balance these?
  - Park or Preserve Design
Advantages/disadvantages of each

- **Single Large**
  - Less edge (+)
  - More core (+)
  - Only one population, single disturbance dangerous (-)
  - Fewer habitat types possible (-)
  - Large population (+)
  - No rescue effect (-)

- **Several Small**
  - More edge (-)
  - Less core (-)
  - Multiple populations, single disturbance less dangerous (+)
  - Multiple habitat types possible (+)
  - Small populations (-)
  - Rescue effect (+)

The best approach may be to have several small, provided they are linked. Equal or less area designated to preserve compared to single large. Linkages increases dispersal rate, increase rescue effect, decrease extinction.

Island Isolation, Preserve Connectivity

Application – Best use of conservation effort

- If you are able to purchase 10,000 acres for conservation purposes, what do you buy?
  - One large piece of land or several small pieces

- Considerations
  - What are you trying to preserve?
    - Large or small? Mobile or sessile? Migratory?
  - Where is the maximum diversity?
Application – Best use of conservation effort

- Other Considerations
  - Shape and configuration
    • Edge, core and connectivity of preserve
  - Is the goal to conserve species or an ecosystem?
    • How important are individual species?