Climate Change

Effects on Biodiversity

The Earth’s Climate – past and present

- The Earth’s climate is changing
  - global mean surface temperature increased 0.6°C between 1861 and 2000
  - rainfall patterns have changed with more heavy precipitation events
  - the El-Nino phenomena has become more frequent, persistent and intense
  - sea level increased 10-20 cm between 1900 and 2000

Evidence for climate change

1. Mean surface temperature has increased
2. Melting glaciers and permafrost
3. Mountain peak air temperature records
4. Freezing elevations in the tropics have risen
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5) Atolls are disappearing under water (Carteret atolls evacuated)

Is change due to humans?

Link to greenhouse gases

1) increased CO₂ in atmosphere

Link to greenhouse gases

![CO₂ Concentration in Hawaii](image)
1) increased CO\textsubscript{2} in atmosphere

2) ice core records
   - CO\textsubscript{2} steady for 1700 years, then skyrocket

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A transition from oil is necessary

- Transportation accounts for 33% of U.S. CO\textsubscript{2} emissions
- Transportation is the fastest growing source of CO\textsubscript{2} emissions
A transition from oil is necessary

- For every gallon of gas burned, a car produces roughly 20 pounds of CO2.
- The average car (in terms of fuel economy) driven the average number of miles per year (15,000) produces approximately 13,000 pounds of CO2 annually.

Projected changes in climate by 2100

- Global mean surface temperatures are projected to increase by 1.4 to 5.8 °C relative to 1990
- Precipitation patterns will change, with more heavy precipitation events
- More El Nino-like conditions are projected
- Extreme events, e.g., heat waves, floods, droughts, are projected to increase – cold waves and frost days are projected to decrease
- Non-polar glaciers are projected to melt
- Sea level is projected to increase by 0.08 to 0.88 m relative to 1990

Environmental consequences

1) Weather
   - Warmer on average, but spatial variation
   - Global precipitation increase 10-15% and more variable (in space and time)
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2) More soil erosion
   - Rain more concentrated
   - More irrigation

Biological consequences

1) Change in patterns of net primary production (1982-1999)
   - 42% of this increase is in Amazon forests
   - Less cloud cover; increased solar radiation

2) Crop production
   - Growing season 11 days longer (Europe, 1959-93)
   - Predicted yields increase (but not everywhere)

3) Geographic range shifts
   - Move towards poles in many birds & butterflies
Biological consequences

4) Life-history changes
   - earlier egg laying in temperate birds


Tree Swallow

Black-billed magpie

USFWS

Climate change will exacerbate the loss of biodiversity

Estimated 10-15% of the world’s species will be committed to extinction over next 30 years

Impacts of climate change on biodiversity

- Observed regional changes in temperature have been associated with observed changes in ecological systems world-wide:
  - earlier plant flowering and longer growing season in Europe
  - poleward and upward in elevation migration of plants, insects and animals
  - earlier bird arrival and egg laying
  - increased incidence of coral bleaching

Climate change is projected to affect all aspects of biodiversity

- i.e., individuals, populations, species distributions and ecosystem composition and function
  - directly, through increases in temperature, changes in precipitation (and in the case of marine systems changes in sea level etc)
  - and
  - indirectly, through climate change and associated increases in the intensity and frequency of disturbances such as wildfires

Climate change and coral reefs

*Abrupt Changes in many ecosystems are possible with adverse effects*
- Coral bleaching is increasing in frequency and extent with recent bleaching appearing to be strongly associated with the most stressful periods in the ENSO cycle
  - Sustained increases in water temperature as little as 1°C can lead to corals ejecting their algae (coral bleaching) and the eventual death of the corals

The peak of Mt Kilimanjaro as it has not been seen for 11,000 years
Case studies…
Red squirrels are evolving to take advantage of an earlier spring and are breeding sooner, which allows them to hoard more pinecones for winter survival and next year’s reproduction. Squirrels with genes for earlier breeding are more successful than squirrels with genes for later breeding.

Another European bird, the blackcap, has been evolving due to changes in its migration patterns. Some blackcaps have begun to overwinter in the now slightly warmer Britain instead of in Spain, Portugal, and North Africa, as they historically did. The British sub-population has evolved genetic differences from the other birds and is more successful at reproducing since its members arrive at the nesting grounds earlier and have first choice of territories and mates.

One North American mosquito species has evolved to take advantage of longer summers to gather resources while the weather is good.
Turtles and global warming

Painted Turtles - From Janzen
PNAS (1994)

Response?
- Projected temperature changes ~ 2-3 degrees C
- Slow generation times
- Remote possibility that turtles can evolve quickly enough to track such environmental change and maintain balanced sex ratios in the wild.

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The issue

- The fate of many species in a rapidly warming world will likely depend on:
  - their ability to permanently migrate away from increasingly less favorable climatic conditions to new areas that meet their physical, biological and climatic needs.

Likely scenarios

- Required migration rates for plant species due to global warming appear to be 10X greater than those recorded from the last glacial retreat.

Areas at Risk

- Russia, Sweden, Finland, Estonia, Latvia, Iceland, Kyrgyzstan, Tajikistan, and Georgia all have more than half of their existing habitat at risk from global warming.
- In the USA, more than a third of existing habitat in Maine, New Hampshire, Oregon, Colorado, Wyoming, Idaho, Utah, Arizona, Kansas, Oklahoma, is at risk.
- Despite their large land areas, an average of 38.3 and 33.1% of the land surface of Russia and Canada, respectively, exhibited high required migration rates.

http://assets.panda.org/downloads/habitatsatriskfull.pdf
**Polar Bears**
- Long-term studies in Canada's Western Hudson Bay
- Sea-ice season is 2 ½ weeks shorter than a few decades ago
- Polar bears less time to hunt seals on the sea ice
- Decline in body condition and cub survival now evident

**Highly Sensitive Ecosystems**
- Non-glaciated regions where previous selection for high mobility has not occurred among species may suffer disproportionately.
- Therefore, even though high Required Migrations Rates are not as common in the tropics, there may still be a strong impact in terms of species loss.
- Some species have evolved *in situ* and may fail to migrate at all.

**The View from Delaware**

see: [http://www.epa.gov/globalwarming/](http://www.epa.gov/globalwarming/)
Future Climate

- By 2100 temperatures in Delaware could increase about 4°F in winter and spring, and slightly more in summer and fall (with a range of 2-8°F).
- Precipitation is projected to increase by 10-20% (with a range of 0-40%), with slightly less change in spring and slightly more in winter.
- Similar temperature changes have occurred, but took place over centuries instead of decades.

Ecosystem Effects

- The ecosystems of Delaware are diverse
- Sea level rise could alter food availability for wading birds and other animals in the coastal areas because of loss of wetlands.
**Methods**

- Estimated the distribution and abundance of seaside sparrow populations in Connecticut.
- Determined the relationship between seaside sparrow patch occupancy and marsh area.
- Estimated the viability of seaside sparrow populations in response to three scenarios of sea-level rise (0-, 50-, and 100-cm).

**Seaside Sparrow Range and Biology**

Seaside Sparrows sub-populations

Seaside Sparrows and Patch Size

Modeled Salt Marsh Loss

Salt Marsh Patch Size Distribution

Probability of Decline

Probability of Quasi-extinction
Interactions with fragmentation

- Increased connectivity among natural habitats within developed landscapes critical
- May help organisms to attain their maximum intrinsic rates of migration and help reduce species loss.
- Thus, habitat fragmentation plays a role in species response to climate change

Climate Change, Stress, and Disease

- All major classes of pesticides affect the immune system.
- Die-offs may be directly attributed to viruses and other pathogens.
- Often a link suspected that the animals' immune systems may have been compromised by high levels of one or more contaminants, making them abnormally susceptible to disease.

Chytridiomycosis

- Frogs may be suffocating because of the fungal growth.
- In reaction to chyrid infections, they lay down extra layers of keratin in their skin.
- Another possibility is that the fungus is releasing a toxin.

Chytrid Fungi

- Chytrid fungi is at least a proximate cause of current die-offs in Central and North America.
- New chytrids moving in waves around world.
- Compromised by fact that there are approximately 4 experts in the world who can identify species of chytrid fungi associated with anurans!
- Direct cause? Stress-induced? New pathogen?

Sequence of infections...
Why?

- In the 1930s, discovered that a female Xenopus would ovulate if injected with the urine from a pregnant woman.
- Hormone chorionic gonadotropin was the active ingredient.
- In the 1940s and 50s, the only available pregnancy test.
- Many hospitals kept Xenopus but many releases: California, Chile, England etc.

Connection to climate change?

- Earth's rising temperatures enhance cloud cover on tropical mountains.
- Results in cooler days and warmer nights.
- Both favor the chytrid fungus which operates best at temperatures between 63 to 77 degrees Fahrenheit (17 to 25 degrees centigrade).
- "We propose that temperatures at many highland localities are shifting towards the growth optimum of Batrachochytrium, thus encouraging outbreaks."


Conservation and Climate Change

Effects of climate change on distribution, life histories, and survival of species already documented.

- The notion of conserving biodiversity as it presently exists is fast becoming obsolete.
- Conservation strategies must be responsive to inevitable changes.
- One key element is to model responses to climate change.

"... climate change is the most severe problem that we are facing today - more serious even than the threat of terrorism ..."

-Sir David King
chief scientific adviser to Her Majesty’s government.
End climate change