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

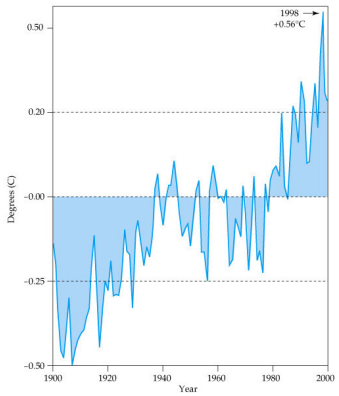
- Isn't climate change is a natural process?
  - Yes
  - However, the question is whether human activities are accelerating the rate of change.
- What impact might accelerated climate change have on biological systems?
  - Alter physical environment (gradients)
  - Biodiversity
  - Ecosystem function

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

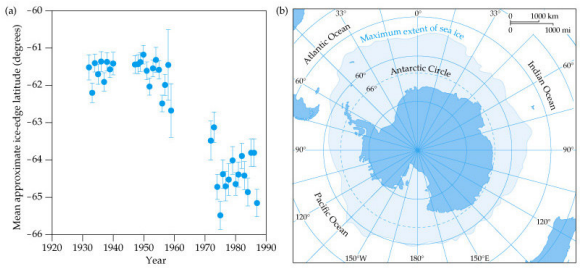
Evidence for climate change

- 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



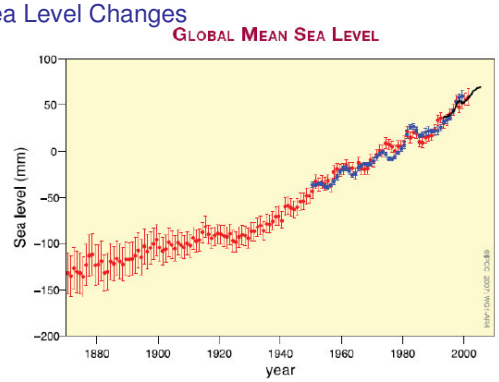
Sea Ice Changes

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



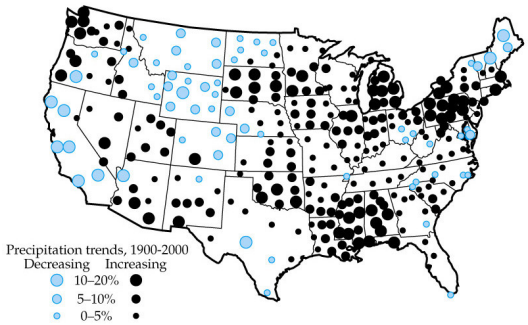
Impacts –

Sea Level Changes



- Melting glaciers → less water tied up in glaciers → sea levels rise

Increase in variability in precipitation



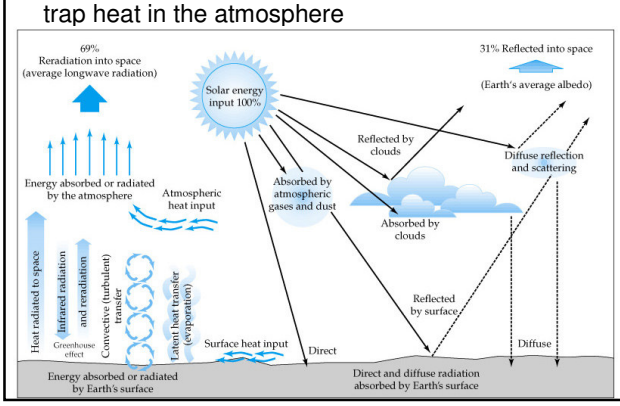
What is ***not*** evidence of climate change?

- "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

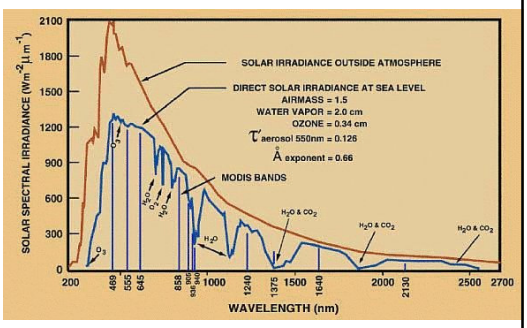
Greenhouse effect, how are humans contributing?

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



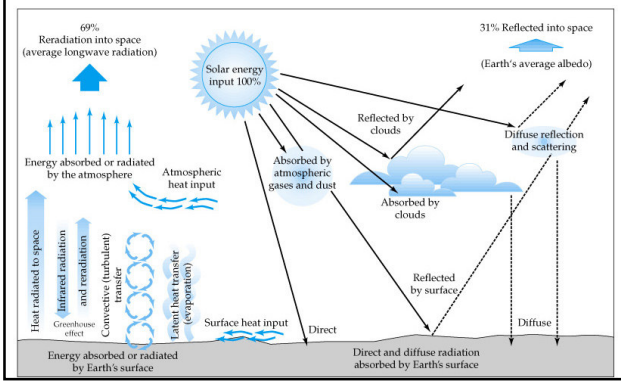
What are greenhouse gases?

- CO_2
- H_2O
- CH_4
- NO_2

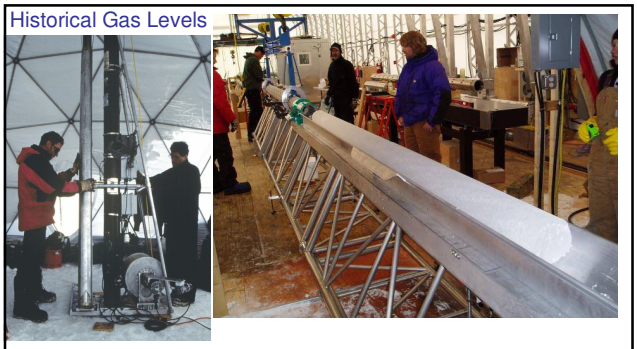


Positive feedbacks loops

- Increased temperature → decrease in area covered in ice → lower surface albedo → more solar input

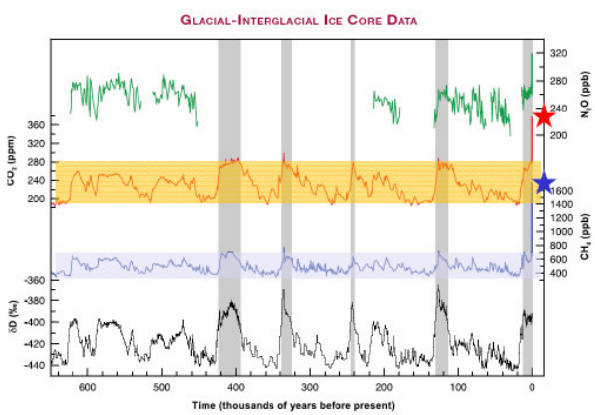


Historical Gas Levels



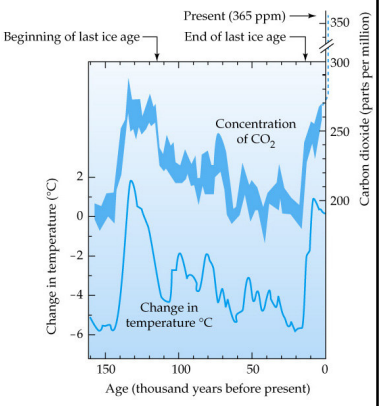
- At the poles: Climate too cold to melt snow, ice accumulates in annual layers
- Bubbles in ice preserve a record of atmospheric gases

Ice Core Gas Data



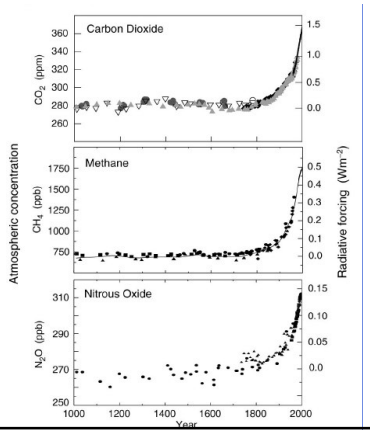
Historical relationship between temp and CO_2

- Of the greenhouse gasses, CO_2 is the most abundant
- All biologically produced, only CO_2 produced by fossil fuels
- Historic range from **150-290 ppm**



Greenhouse Gas Emissions

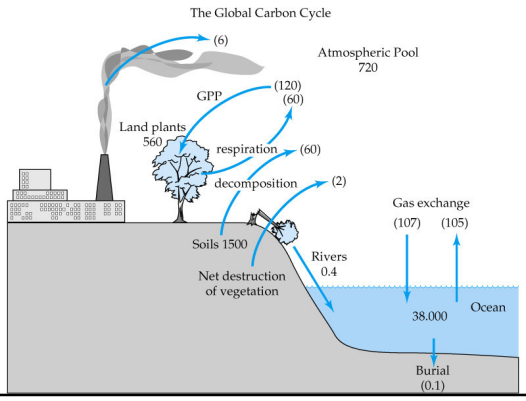
- Sharp spike in levels seen after industrialization
- CO_2 is the major gas, note other gasses measure in parts per **billion**



Human Greenhouse Gas Emissions

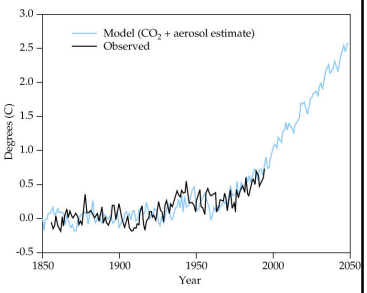
- Greenhouse gas emissions are anticipated to rise by 32% between 1990 and 2020
- Projections for warming suggest a global increase of 2.5ºF - 10.4ºF by 2100

CO_2 emissions and the carbon cycle



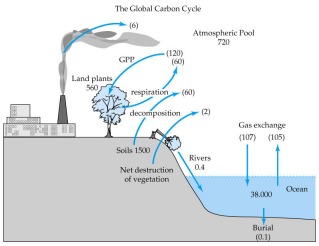
Projected future CO_2 levels

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

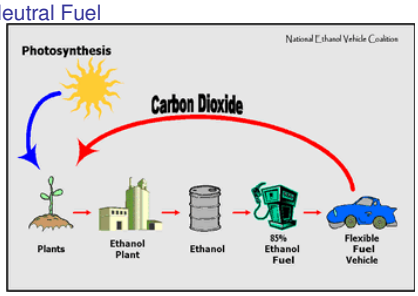


Decreasing atmospheric CO_2

- CO_2 scrubbers
- More efficient combustion engines
- Increase primary productivity
- Carbon sinks

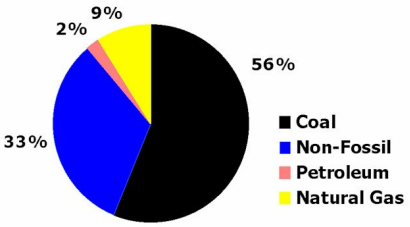


Carbon Neutral Fuel



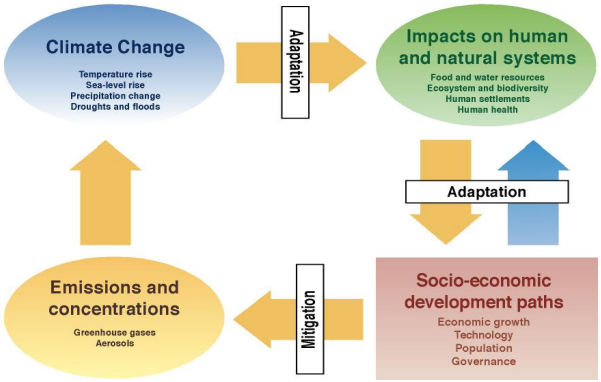
- Carbon is recycled, no fossil fuels burned
- Easy to adapt current vehicles
- Problems
  - Not enough farm area to feed us and fuel cars
  - Fossil fuels burned to produce ethanol (farming, ethanol plant, etc).

Where does our electricity come from?



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

Climate Change Impacts



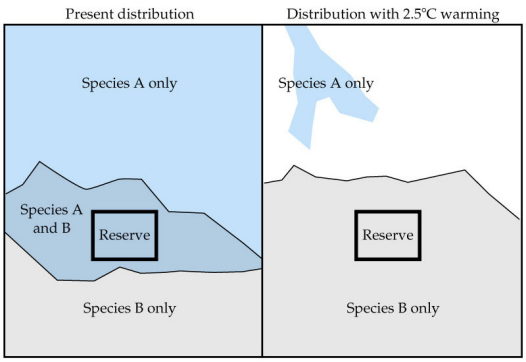
Biological impacts of climate change

- **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

Change in Phenomenon	Confidence in projected change*
Higher maximum temperatures, more hot days	Very likely
Higher minimum temperatures, fewer cold days and frost days	Very likely
Increase of heat index	Very likely, over most areas
More intense precipitation events	Very likely, over many areas
Increased summer continental drying & associated risk of drought	Likely, over most mid-latitude continental interiors
Increase in tropical cyclone peak wind and precipitation intensities	Likely, over some areas

Change in species distribution



Ecology, 88(7), 2007, pp. 1803–1812

POLEWARD SHIFTS IN WINTER RANGES OF NORTH AMERICAN BIRDS

Frank A. La Sorte[1,3] and Frank R. Thompson III[2]

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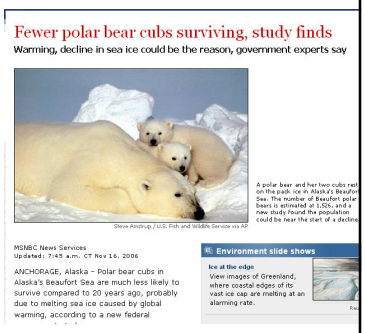
[2]*USDA Forest Service, Northern Research Station, University of Missouri, Columbia, Missouri 65211 USA*

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 254 species of winter avifauna in North America from 1975 to 2004. After accounting for the effect of range size and the location of the northern boundary, positive latitudinal trends were evident for the northern boundary (1.48 km/yr), center of occurrence (0.45 km/yr), and center of abundance (1.03 km/yr). The northern boundary, when examined across individual species, had the most variable trends (SD = 7.46 km/yr) relative to the center of occurrence (SD = 2.36 km/yr) and center of abundance (SD = 5.57 km/yr). Trends did not differ based on migratory status, but there was evidence that trends differed for species with ranges centered in the southern vs. northern portion of the study area. Species occurred more sporadically over time at northern range boundaries, and northern boundaries were associated with a concentration of colonization and extirpation events, with a greater prevalence of colonization events likely promoting poleward trends. Regional anthropogenic drivers explained ~8% of the trend for the northern boundary, 14% for the center of occurrence, and 18% for the center of abundance; however, these effects were localized in the northern portion of species' ranges and were associated with distributional changes within ranges, primarily abundance, producing patterns that mimicked poleward movements. We conclude that poleward distributional shifts represent the interaction between climate change and regional factors whose outcome is determined by the scale of the analysis and the biotic and abiotic features in the region, and how anthropogenic activities have impacted these features.

Key words: abundance; Christmas Bird Count; common species; distribution of avifauna; geographical range; global climate change; North America; temporal turnover; winter range.

Extinctions due to habitat loss

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



Fewer polar bear cubs surviving, study finds

Warming, decline in sea ice could be the reason, government experts say

A polar bear and her two cubs rest on the pack ice in Alaska's Beaufort Sea. The number of Beaufort polar bears is estimated at 1,526, and a new study found the population could be near the start of a decline.

Steve Amstrup / U.S. Fish and Wildlife Service via AP

MSNBC News Services
Updated: 7:45 a.m. CT Nov 16, 2006

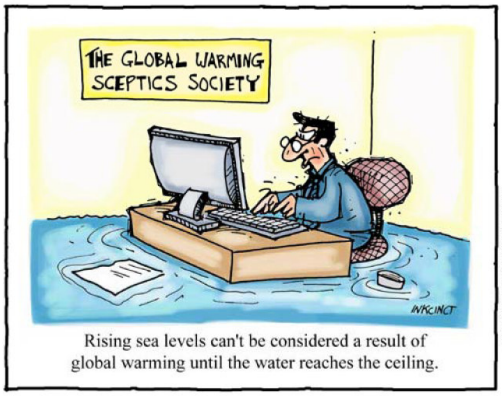
ANCHORAGE, Alaska – Polar bear cubs in Alaska's Beaufort Sea are much less likely to survive compared to 20 years ago, probably due to melting sea ice caused by global warming, according to a new federal

Environment slide shows

Ice at the edge

View images of Greenland, where coastal edges of its vast ice cap are melting at an alarming rate.

The politics of climate change



Rising sea levels can't be considered a result of global warming until the water reaches the ceiling.

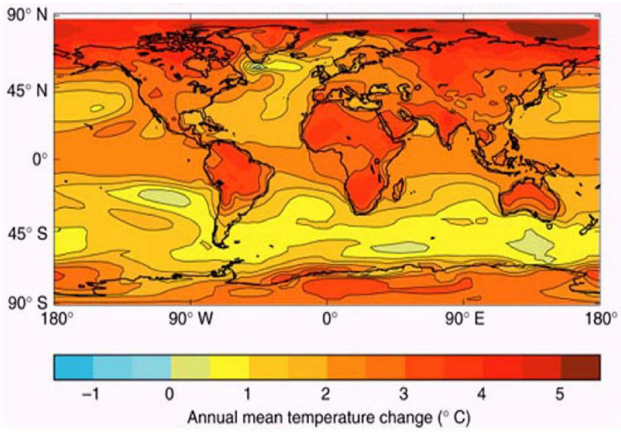
IPCC

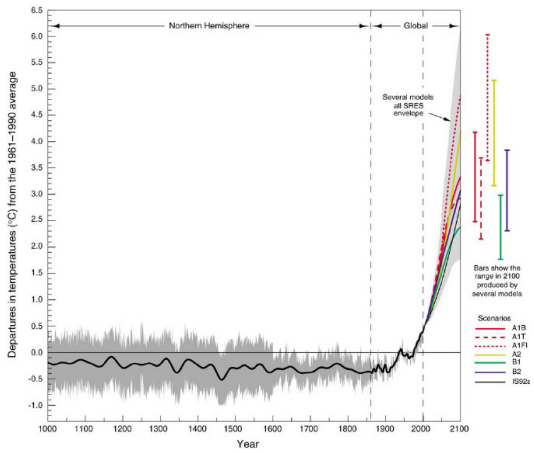
- The Intergovernmental Panel on Climate Change (IPCC)
- Established in 1988
- 190 government members
- **Role of the IPCC:** *"The role of the IPCC is to **assess** on a **comprehensive**, **objective**, **open and Transparent** basis the **scientific, technical and socio-economic** information relevant 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."*

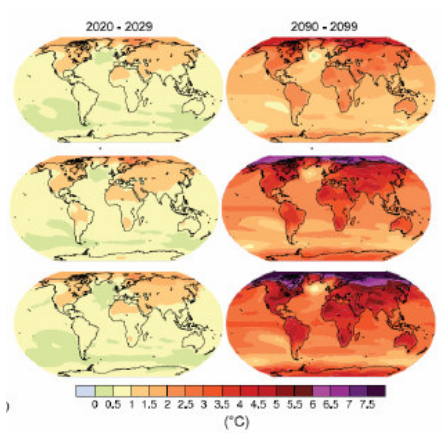
Latest IPCC Report

- *"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."*

Climate Change Projections







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

U.S. Senate votes to raise mileage standards to 35 mpg for cars, SUVs

The Associated Press — Published: June 21, 2007

WASHINGTON: The U.S. Senate voted to require average fuel economy of 35 miles per gallon for new cars, pickup trucks and SUVs by 2020, raising efficiency standards that have not changed significantly for nearly two decades.

The fuel economy measure was added to a broad energy bill without a roll call vote even as senators were holding a news conference announcing the compromise.

Republicans earlier blocked Democratic efforts to raise oil taxes by $29 billion (€21.65 billion) and use the money to promote renewable fuels and other clean energy programs.

Democratic leaders hoped to complete the energy bill Thursday night, but senators close to the auto industry began an effort to derail the entire bill.

"We will be continuing to oppose it," said Democratic Sen. Carl Levin. "This is not over by any stretch."

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Today in Business

EADS to end dual management

Royal Bank of Scotland group raises offer for ABN AMRO

Nintendo's Wii is winning battle of the game builders

The legislation for the first time would establish a single fuel economy standard applicable to not only cars, but also SUVs and pickups which currently have to meet less stringent requirement.

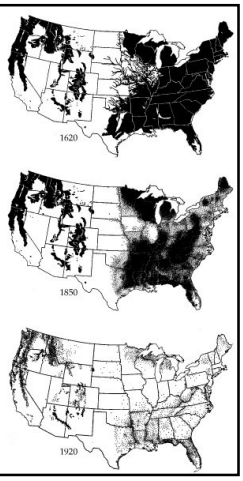
Fuel efficiency requirements would vary for different classes of vehicles based on weight and size. But manufacturers would be required to meet an overall fleetwide average of 35

Habitat Fragmentation

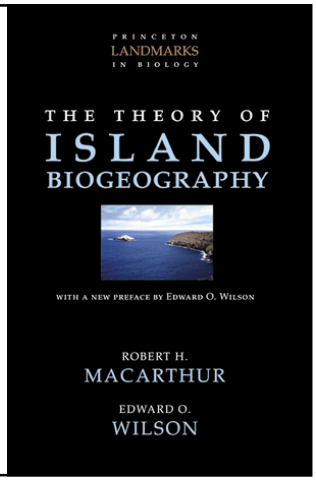
- Habitat fragmentation – turning one large continuous habitat into multiple smaller ones.

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.



- Robert MacArthur and E. O. Wilson (1967). The theory of Island Biogeography.
- 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?

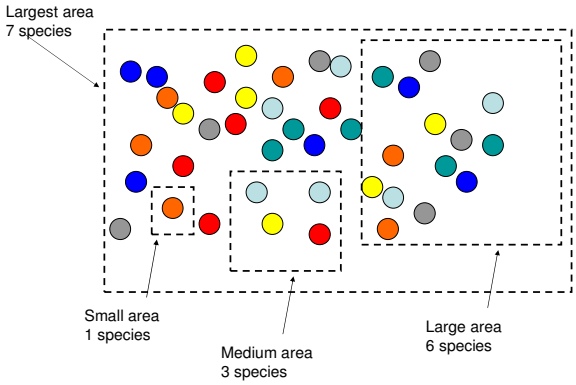


Used to be continuous forest, grassland - Now have isolated "islands" of habitat.

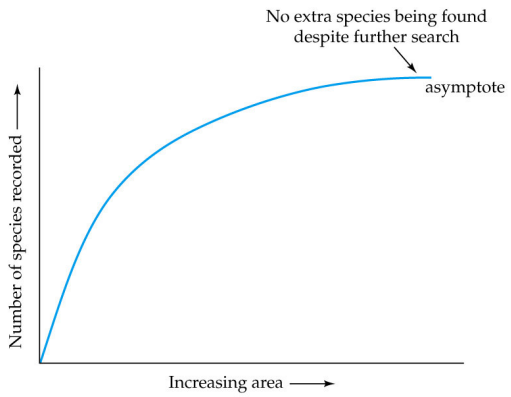
"Island" Processes and Properties

- Recall: $N_{t+1} = N_t + B + I - D - E$
- Immigration
- Emmigration
- Colonization
- Extinction
- Species diversity
- Population size
- Turnover rate

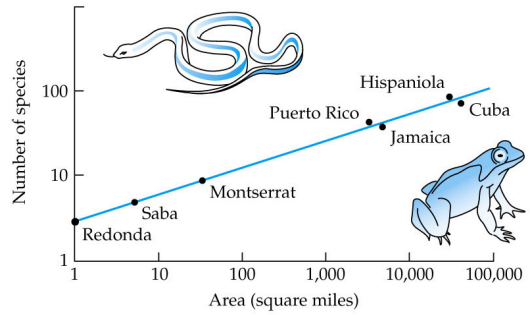
Species Area Relationship



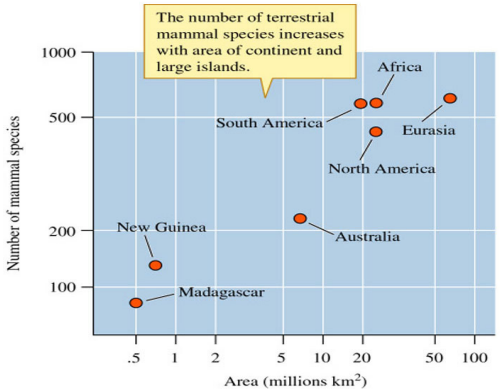
Species Area Relationship



Species Area Relationship on Islands

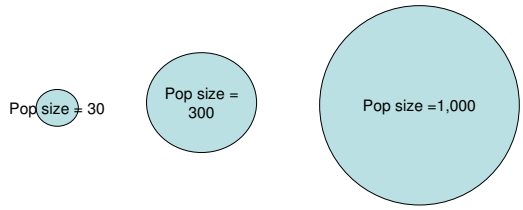


Species Area Relationship on Continents

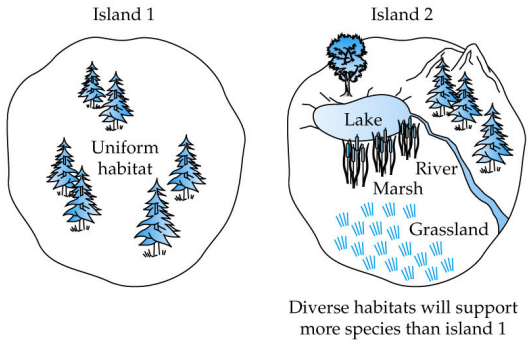


Immigration/Extinction and habitat size

- 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)

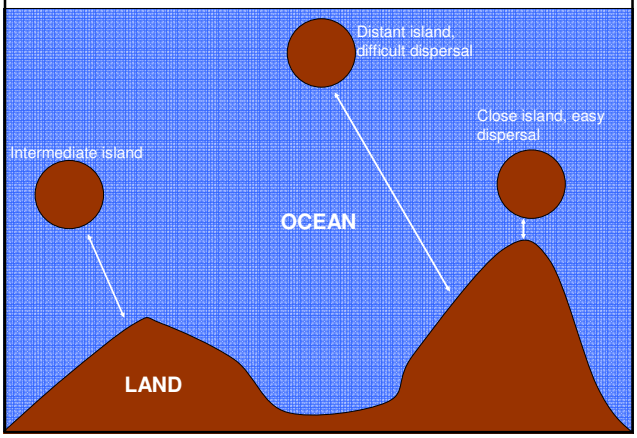


Species Diversity and Habitat Diversity

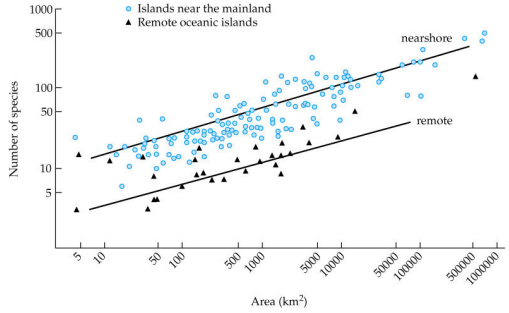


- Areas with more diverse habitats (more types of habitat) will support more species.
- Wider variety of niches available.

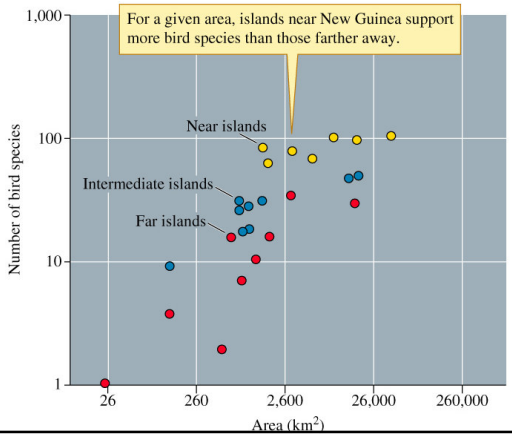
Island Proximity and Species Diversity



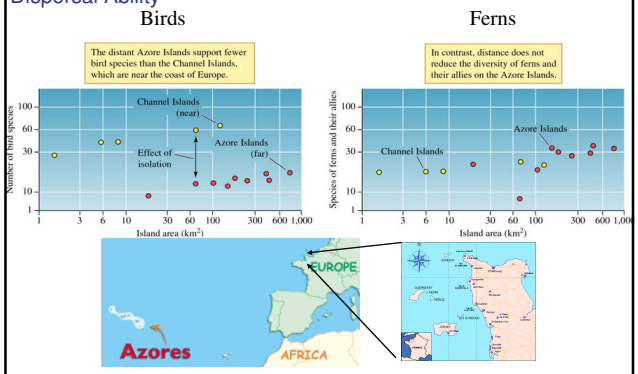
Island Proximity and Species Diversity



- Islands of the same area that are close to the mainland have more species.
- Colonization rate is higher, extinction rate the same.



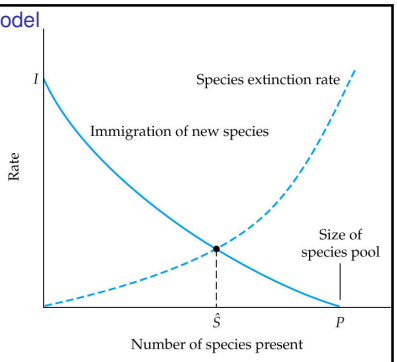
Dispersal Ability



Dispersal distance and dispersal ability of individual species needs to be considered.

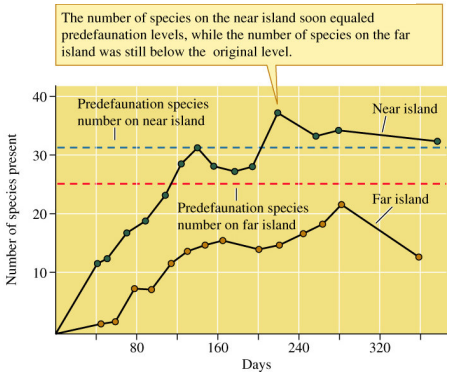
MacArthur and Wilson Model

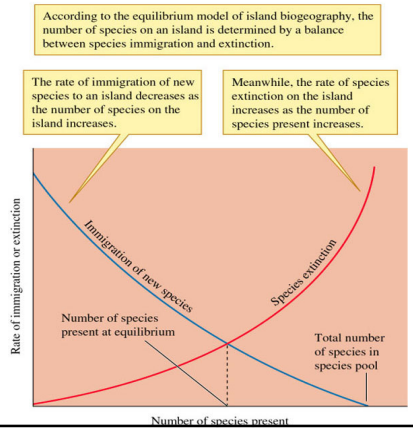
- Island species diversity should be at an equilibrium where immigration rate is equal to extinction rate.
- Island with few species (eg. recently disturbed) – high immigration and low extinction



Ŝ=equilibrium number of species

Experimentally Defaunated Islands



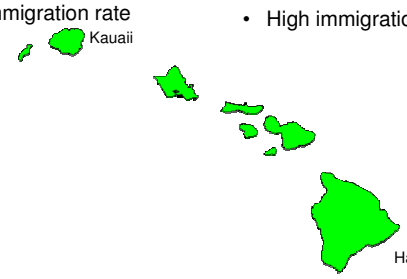


Immigration and Extinction by Island Size

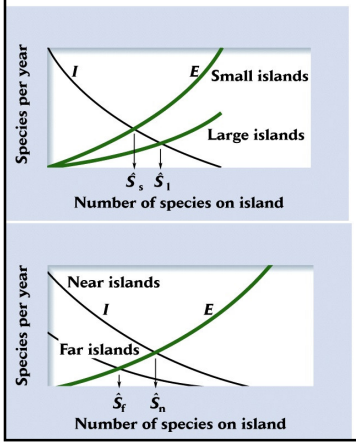
Small Island → **Large Island**

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

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



Interaction between size and proximity

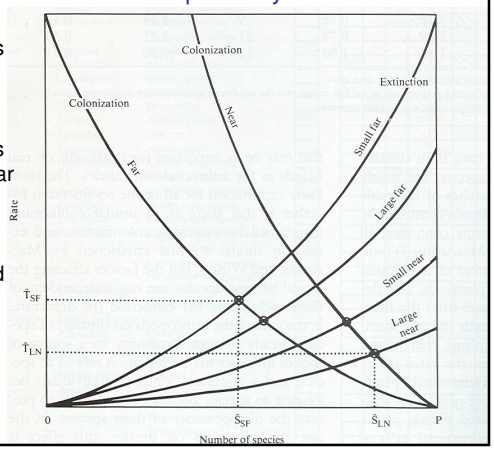


Interaction between size and proximity

S_{sf} = # species on a small, far island

S_{ln} = # species on a large, near island

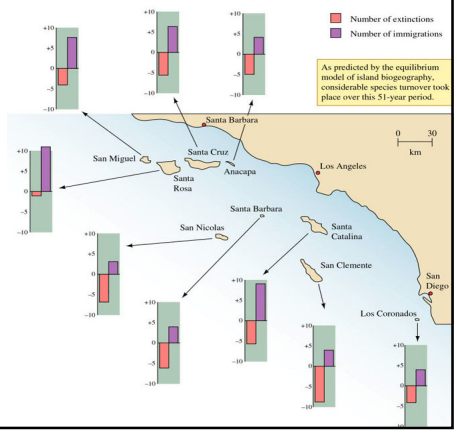
T_{sf} = turnover rate, small and far
etc…

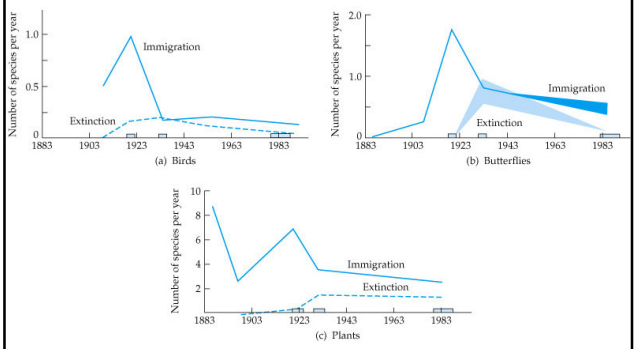


Island Archipelago

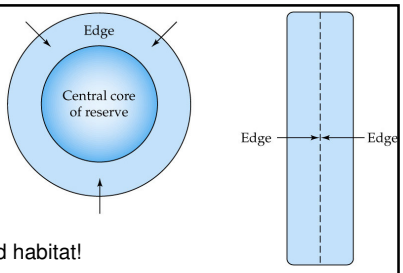
Allows for a test of immigration and extinction rate hypotheses.

If rates are at equilibrium (unlikely) then number of species ($\hat{S}$) is predictable.



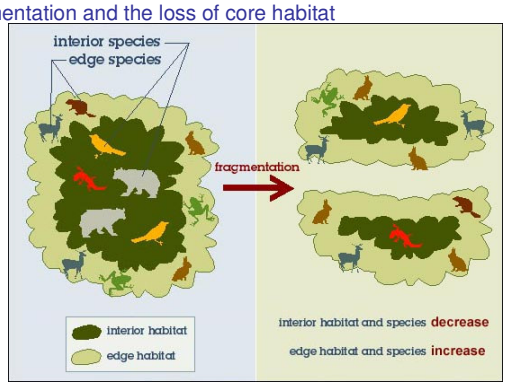


Edge Effects



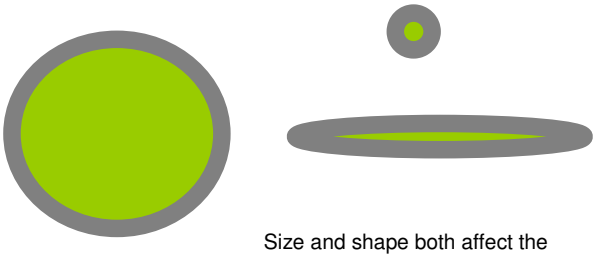
- Islands = fragmented habitat!
- Remember that habitats are not distinct, but consist of gradients of environmental variables.
- The edge of an island (habitat) is going to feature conditions intermediate to the core and outside.
- Shape and size of habitat determines proportion of edge vs core (interior)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

Fragmentation and the loss of core habitat



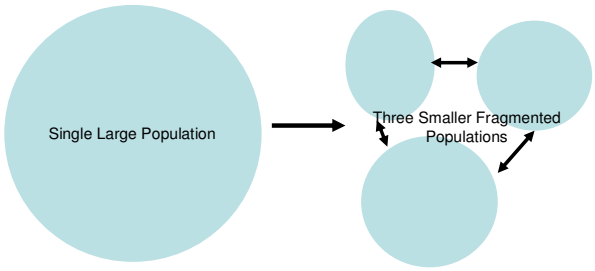
- Interior species tend to be k-selected specialists
- Edge species tend to be generalists

Fragmentation and the loss of core habitat



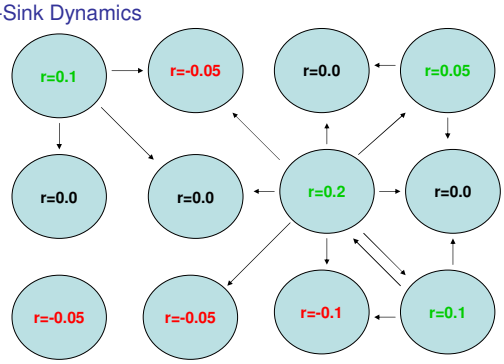
Size and shape both affect the relative proportions of edge and core habitat.

Source-Sink Dynamics



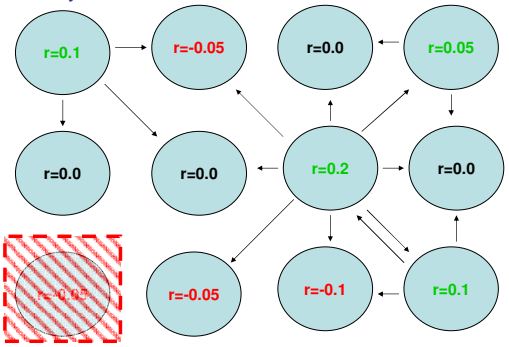
- Large population – single group of interbreeding individuals
- Smaller populations – each a group of interbreed individuals. Extinction, immigration and emmigration occur. **Metapopulation.**

Source-Sink Dynamics



- **Sink** - Islands with r<0 sustained by immigration from other islands
- **Sink** - Islands with r=0 increase due to immigration
- **Source** - Islands with r>0 supply other islands
- Remember – r is not constant! It's an instantaneous rate.

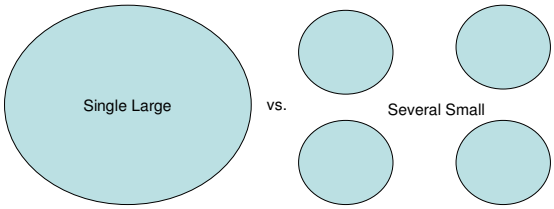
Source-Sink Dynamics



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

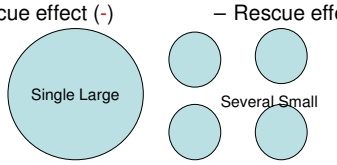
Application

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

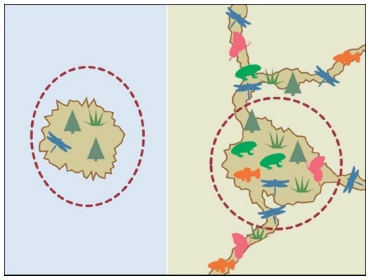


Advantages/disadvantages of each

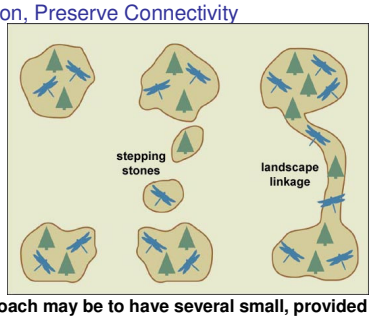
- Single Large
  - Less edge (+)
  - More core (+)
  - Only one population, single disturbance dangerous (-)
  - Fewer habitat types possible (-)
  - Large population (+)
  - No rescue effect (-)
- Several Small
  - More edge (-)
  - Less core (-)
  - Multiple populations, single disturbance less dangerous (+)
  - Multiple habitat types possible (+)
  - Small populations (-)
  - Rescue effect (+)



Island Isolation, Preserve Connectivity



Island Isolation, Preserve Connectivity



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

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?