Climate Change:

Observed Impacts to Fish, Wildlife, Plants and their Habitats

How are FWP and Habitats Being Impacted?

Species Impacts

- Changes to timing of life history events (phenology)
- Physiological impacts (e.g., heat and water stress)
- Body size changes
- Changes in reproductive output
- Genetic change
- Changes in competitive interactions, predator-prey interactions, etc.
- Changes in distribution and abundance

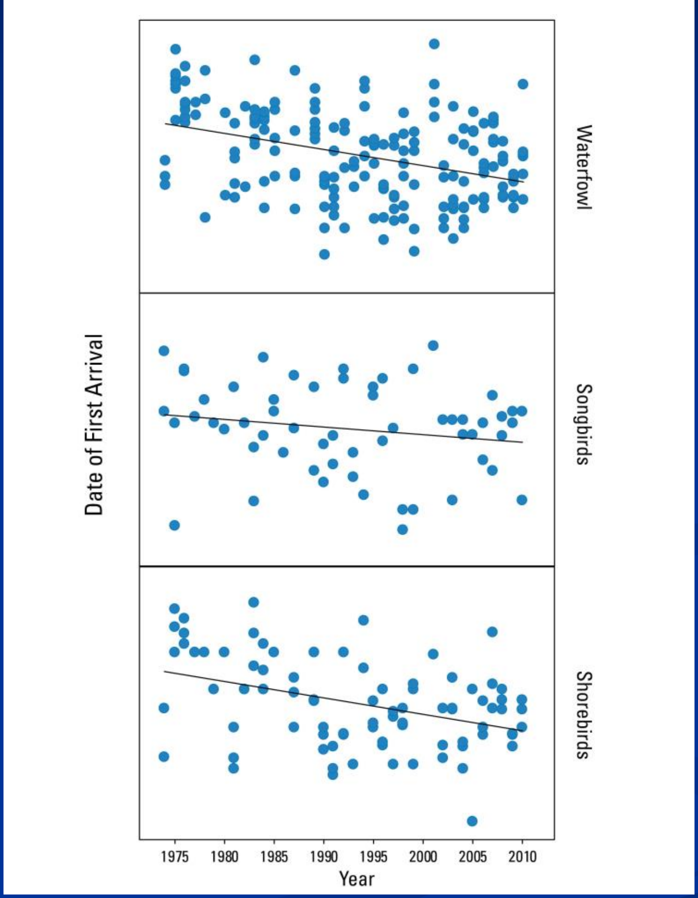
Habitat (ecosystem changes)

- Changes in species assemblages
- Changes in productivity
- Changes to disturbance regimes
- Changes to pests, diseases
- Changes to invasive species

Phenological Impacts -- Birds

Types of Observed Changes in Timing of Life History Events:

- ***Timing of migratory bird arrivals***
- Timing of animal emergence
- Timing of egg laying
- Timing of breeding in mammals
- Changes in species interactions – e.g., ecological mismatches

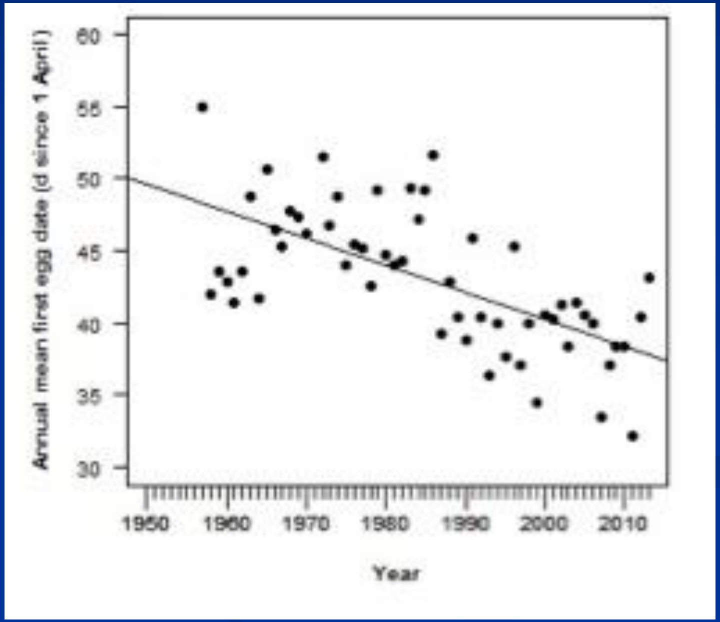


Trends toward earlier dates of spring arrival on the Arctic coast (1974–2010) for three types of birds. J. Helmericks and USGS data.

Phenological Impacts -- Birds

Types of Observed Changes in Timing of Life History Events:

- Timing of migratory bird arrivals
- Timing of animal emergence
- ***Timing of egg laying***
- Timing of breeding in mammals
- Changes in species interactions ecological mismatch



Annual mean first egg date of Pied Flycatchers at East Dartmoor, Devon. This population has been closely monitored since 1955 and provides long term data required to examine effects of changing spring climate on woodland birds

Phenological Impacts
– Columbian Ground Squirrel

Types of Observed Changes in Timing of Life History Events:

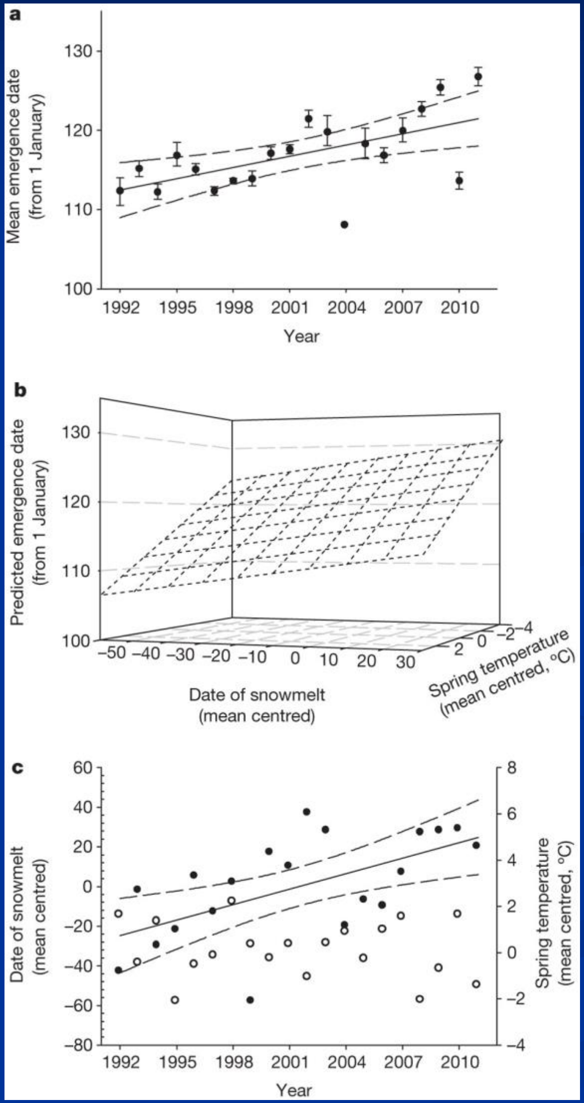
• Timing of migratory bird arrivals

• ***Timing of animal emergence (from hibernation)***

• Timing of egg laying

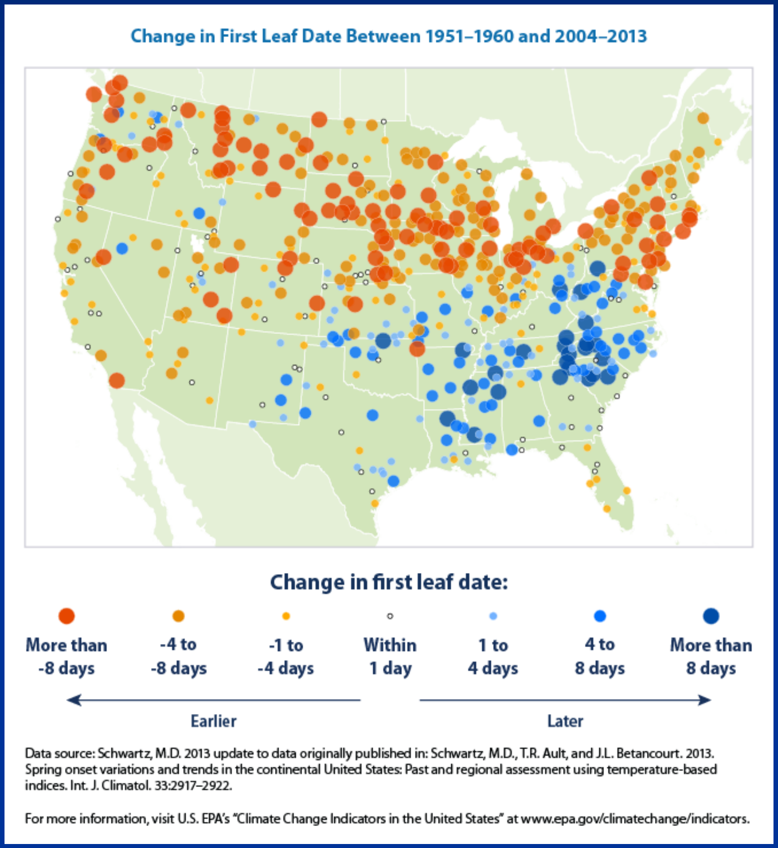
• Timing of breeding in mammals

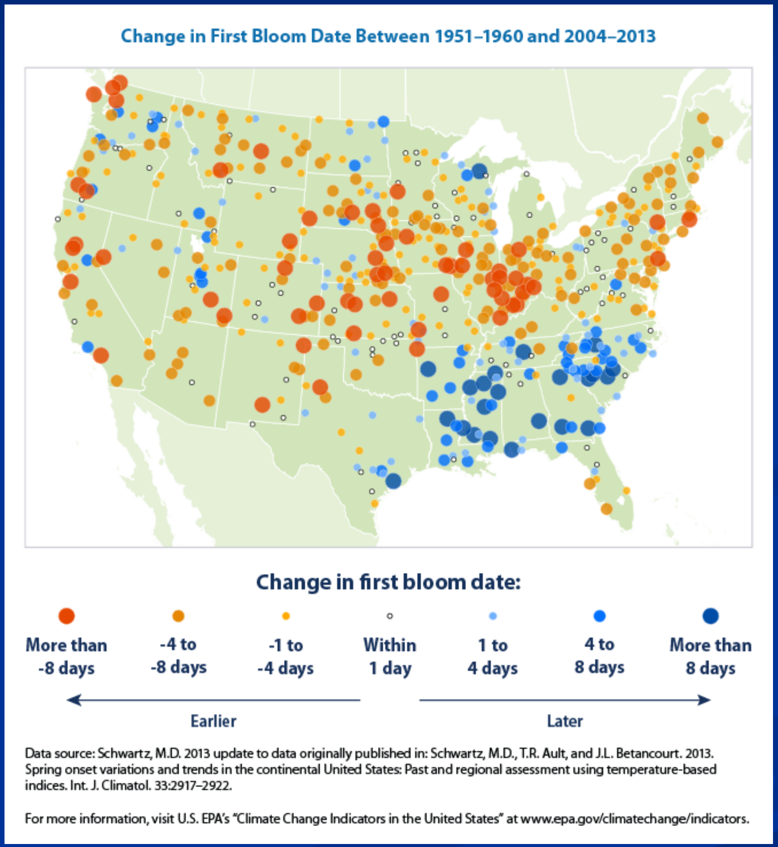
• Changes in species interactions – e.g., ecological mismatches



- Columbian ground squirrels are on a tight schedule -- females mate four days after emerging from hibernation. They give birth 24 days later. The newborns are nursed for 28 days, and then they're on their own.
- The date of snowmelt has become progressively later owing to an increasing prevalence of late-season snowstorms. This has delayed emergence from hibernation.
- Losing just 10 days during their short active period reduces opportunity to eat enough food so they can survive through the next hibernation period of 8-9 mos.

Phenological Impacts -- Plants



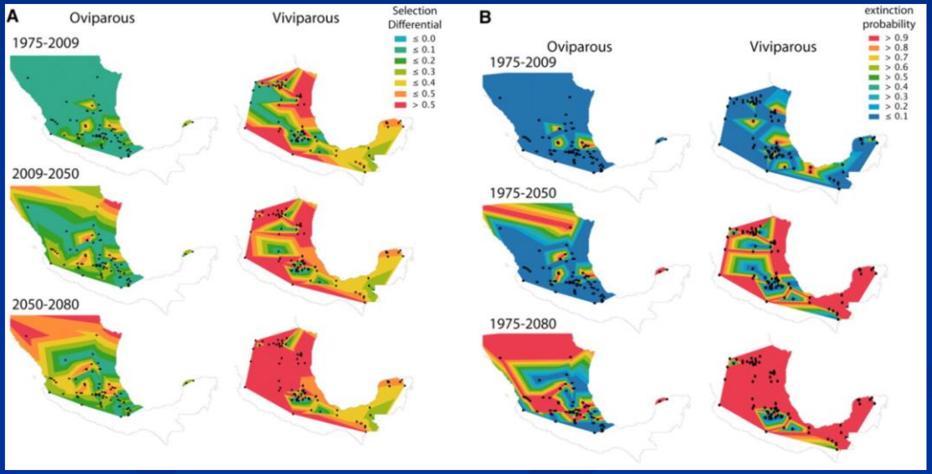


First leaf date (left)

First bloom date (right)

Physiological Impacts – Mexican Lizard Species

- From 2006-2008, researchers resurveyed 48 *Sceloporus* lizard species at 200 sites in Mexico first sampled in 1975 to 1995
- 12% of sites were locally extinct by 2009
- Correlation between rate of change in T*max* during winter-spring breeding periods and local extinctions of *Sceloporus* species.
- Extinction risk was significantly related to low latitudinal and altitudinal range limits where thermal physiology and/or ecological interactions limit species



(A) Sustained selection differentials per year required for Tb to keep pace with global warming. (B) Extinctions of Mexican *Sceloporus* lizards (1975 to 2009, 2009 to 2050, 2050 to 2080).

Physiological Impacts – Pinon Pine and Juniper

- Plant water stress documented in two widely distributed, co-occurring trees -- piñon pine (*Pinus edulis*) and juniper (*Juniperus monosperma*) -- over more than a decade, leading up to regional-scale die-off of piñon pine trees in response to global change-related drought.

- Data suggest that piñon mortality was driven by protracted water stress, leading to carbon starvation and associated increases in susceptibility to other disturbances (e.g., bark beetles).

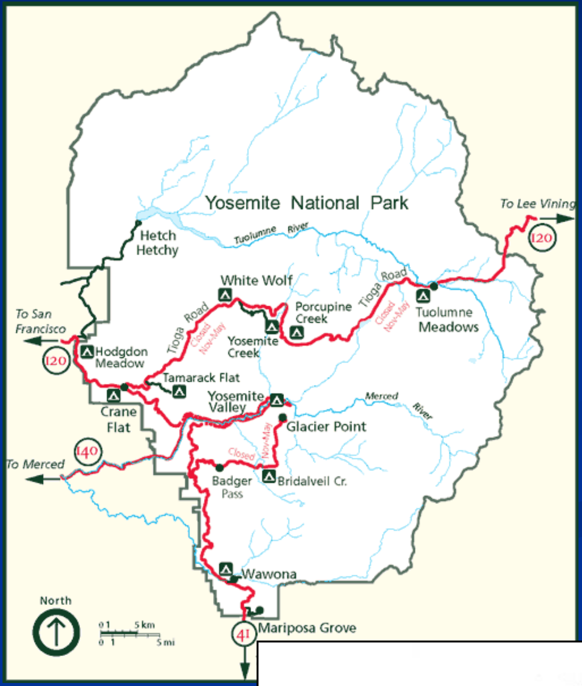
Photos show the massive die-off of pinyon pines that occurred during the recent drought. Pinyons, normally evergreen, have reddish-brown foliage in October 2002 (left). By May 2004, the dead pinyons have lost all their needles, exposing gray trunks. The photos were taken from the same vantage point in the Jemez Mountains near Los Alamos, N.M. Photo credit: Craig D. Allen, U.S. Geological Survey.

Genetics
– High Elevation Chipmunks in California

- Previous work showed that *T. alpinus* responded to warming in Yosemite by retracting its lower elevational limit upslope by more than 500 m, whereas the closely related chipmunk *T. speciosus* remained stable.

- Consistent with a reduced and more fragmented range, researchers found a decline in overall genetic diversity and increased genetic subdivision in *T. alpinus*.

- In contrast, there were no significant genetic changes in *T. speciosus* over the same time period.

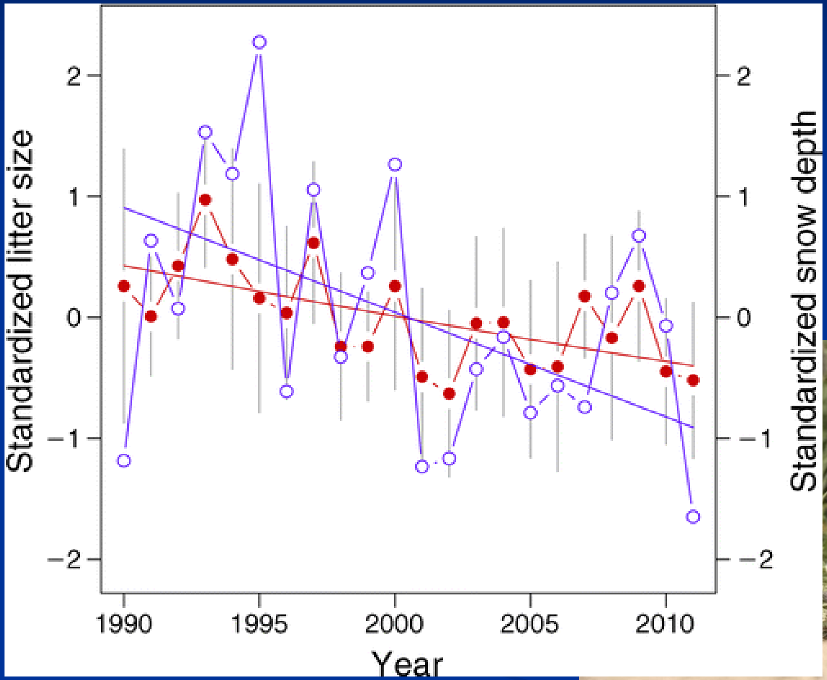


Changes in Reproduction – Alpine Marmots in France

- 20-year monitoring study in French Alps showed a continuous decrease in litter size of the Alpine marmot (*Marmota marmota*) since 1990.

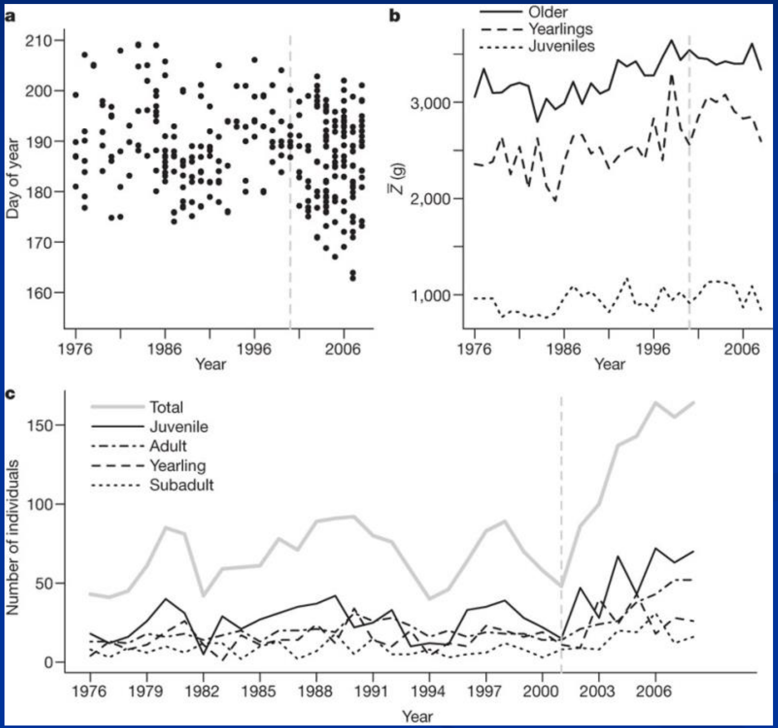
- To cope with harsh winters, Alpine marmots hibernate in burrows and their reproductive output should depend more on spring conditions compared to animals that are active year-round.

- However, litter size decreased over time because of the general thinning of winter snow cover that has occurred in the Alps over the same period, despite a positive effect of an earlier snowmelt in spring.



Increasing Body and Population Size – Yellow-bellied Marmots in Colorado

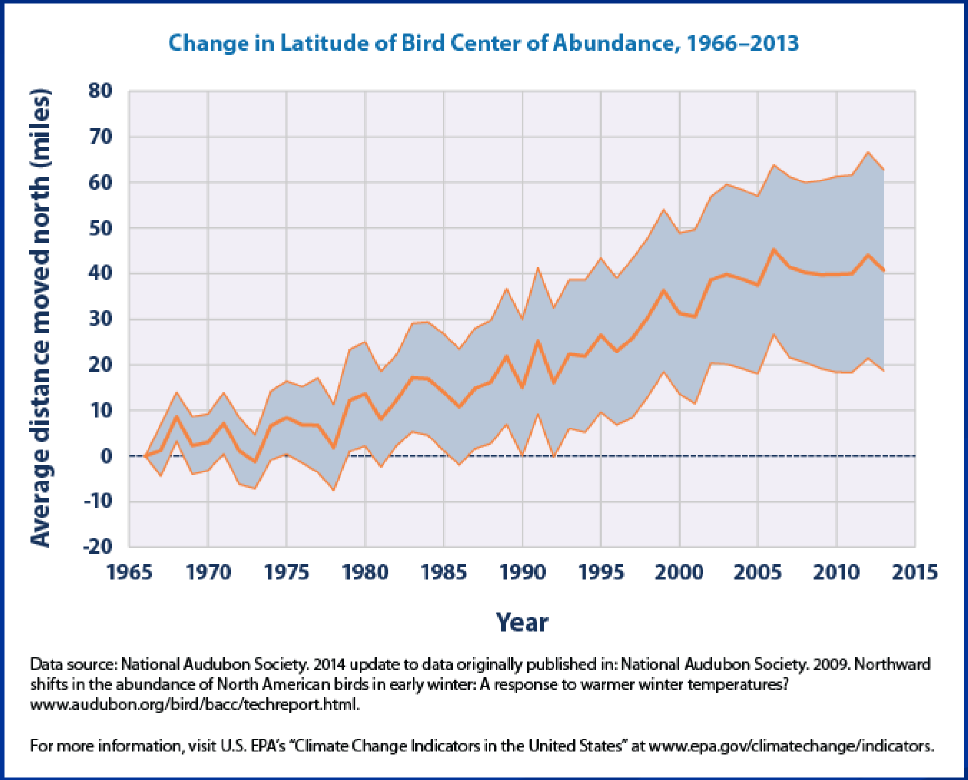
- Marmots in study area in Colorado have been emerging earlier from hibernation and giving birth earlier in the season, which allows individuals more time to grow until going back into hibernation.
- Longer growing season produced a pattern of coupled dynamics of body mass and population growth.
- Larger body mass at hibernation increased survival, especially of adult females between 2000 and 2008.



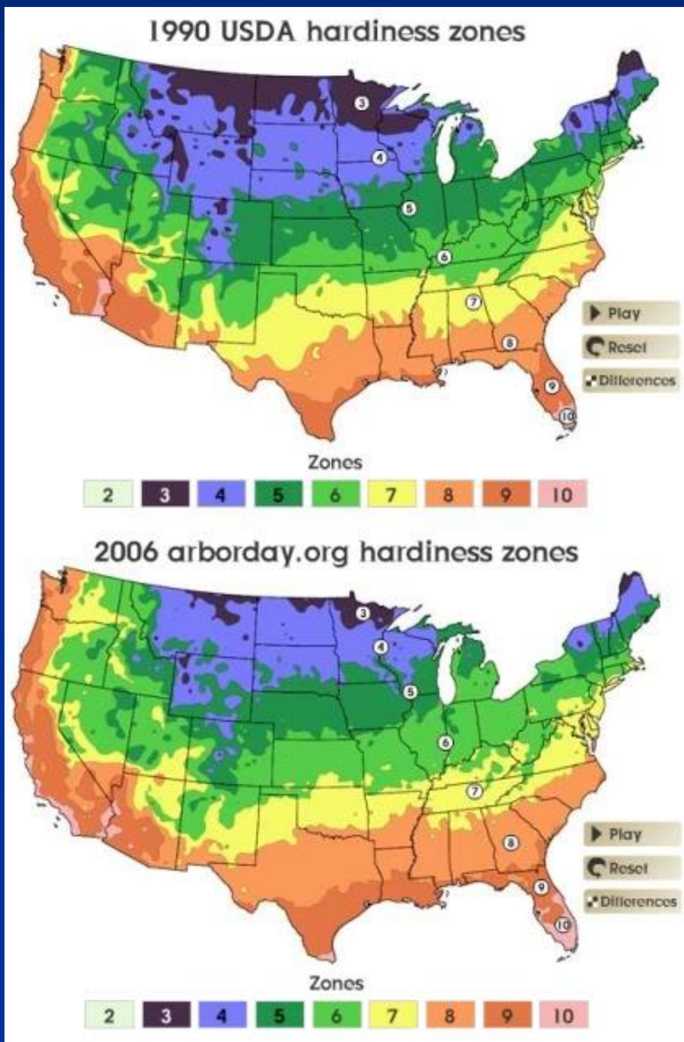
a–c, Time of weaning (−0.17 days per year, P < 0.01) (a), mean 1 August mass ( ) (b), and abundance in each age class (c). The four age classes are juvenile (<1 yr), yearling (1 yr-old), subadult (2 yrs-old) and adult (≥3 yrs-old). Subadult and adult masses are combined (older) in b. Vertical dotted lines delineate different phases of population dynamics.

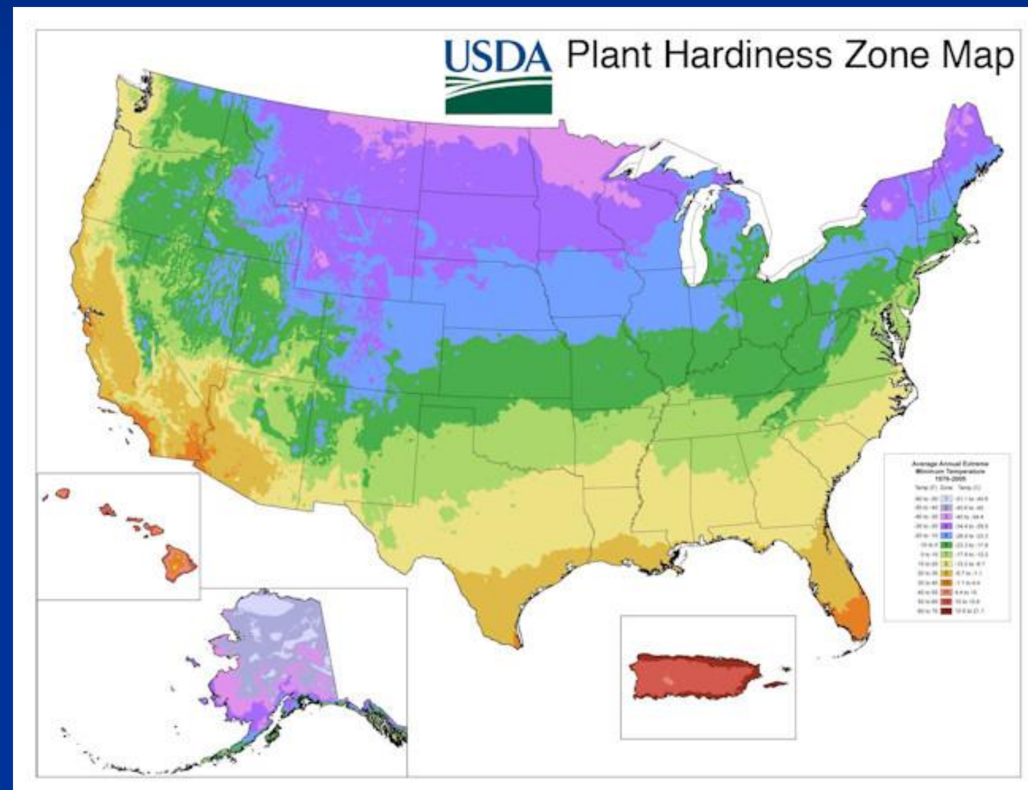
Geographic Range Shifts – Birds

- Many northward range shifts
- E.g., many NA bird species shifting center of distribution northwards.
- But….What about species with no place to go?
  - Mountain top species
  - Arctic species



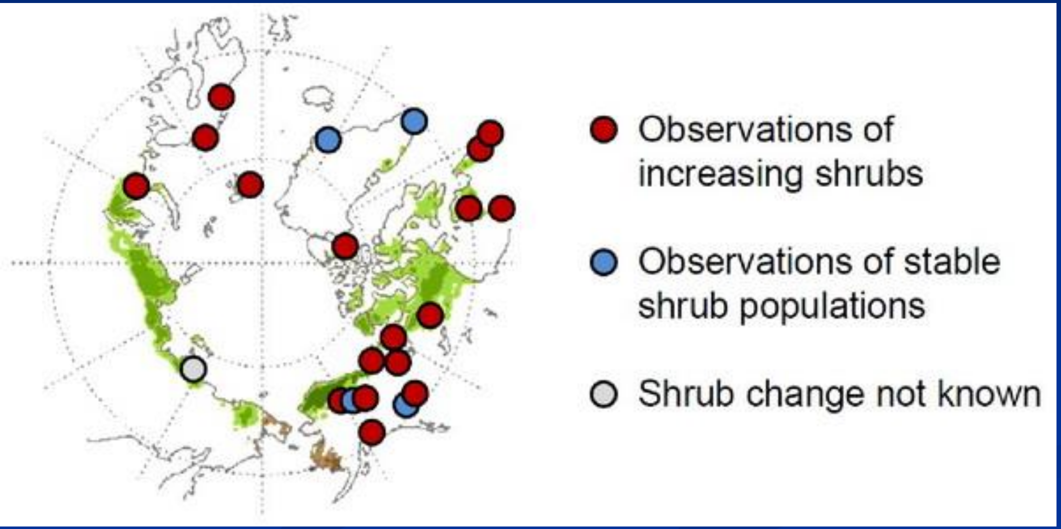
Potential Geographic Range Shifts - Plants

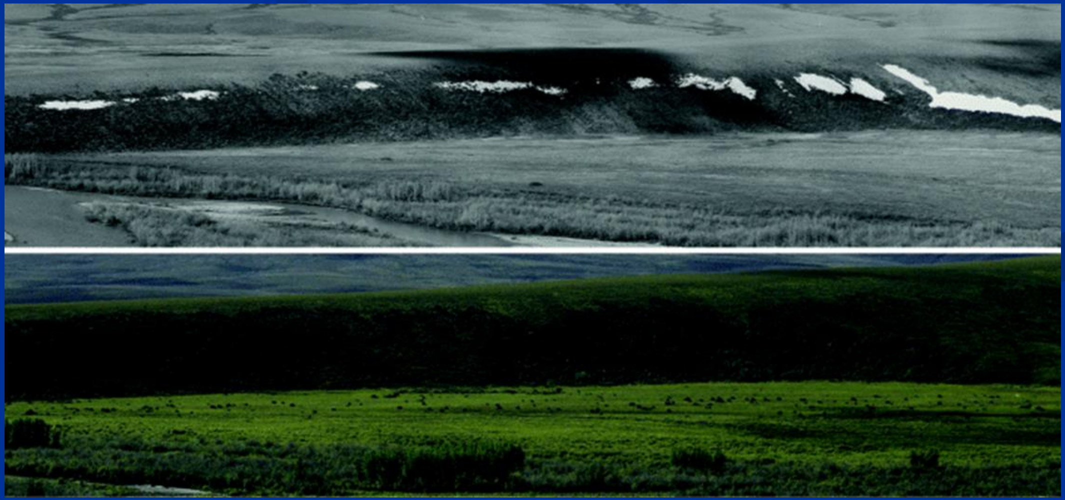




Geographic Range Shifts – Increasing Shrubs in the Arctic (Part I)

- A growing set of observations of increasing shrubs at sites around the Arctic (Figure).
- Circumpolar plot-based monitoring of vegetation changes indicates that shrub species have increased in canopy height and abundance at sites that have experienced recent summer warming, particularly in wetter versus drier conditions.
- Shrub expansion is not uniform: In Alaska it is becoming increasingly clear that some shrub communities are expanding, while others are stagnant.

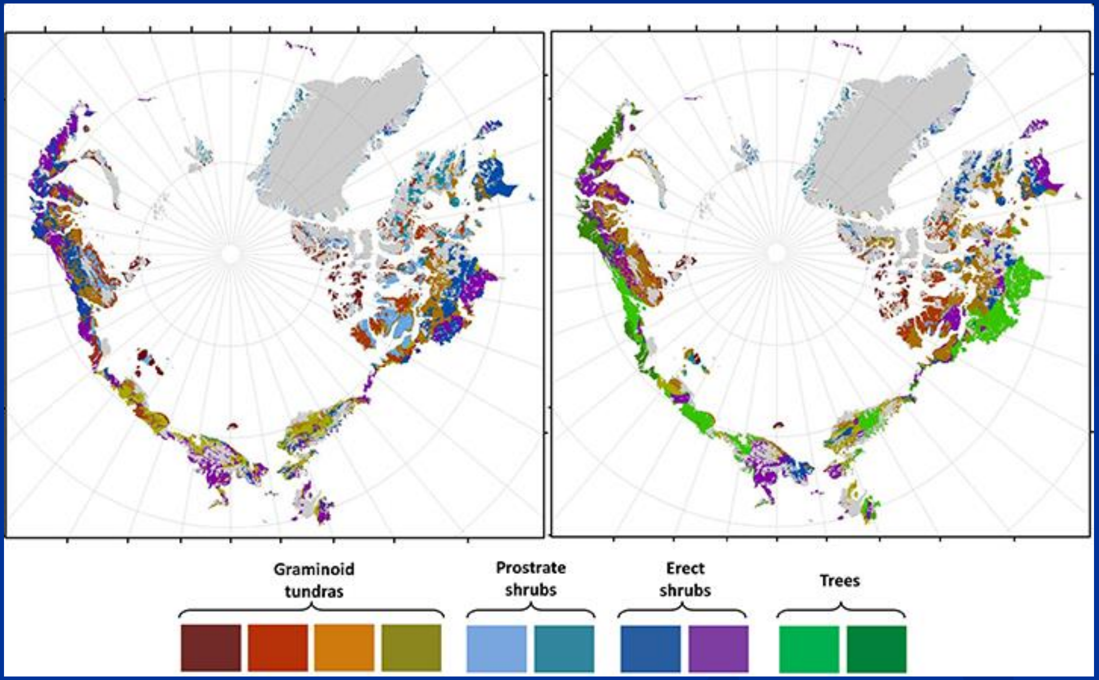




Geographic Range Shifts
– Increasing Woody Vegetation in the Arctic (Part II)

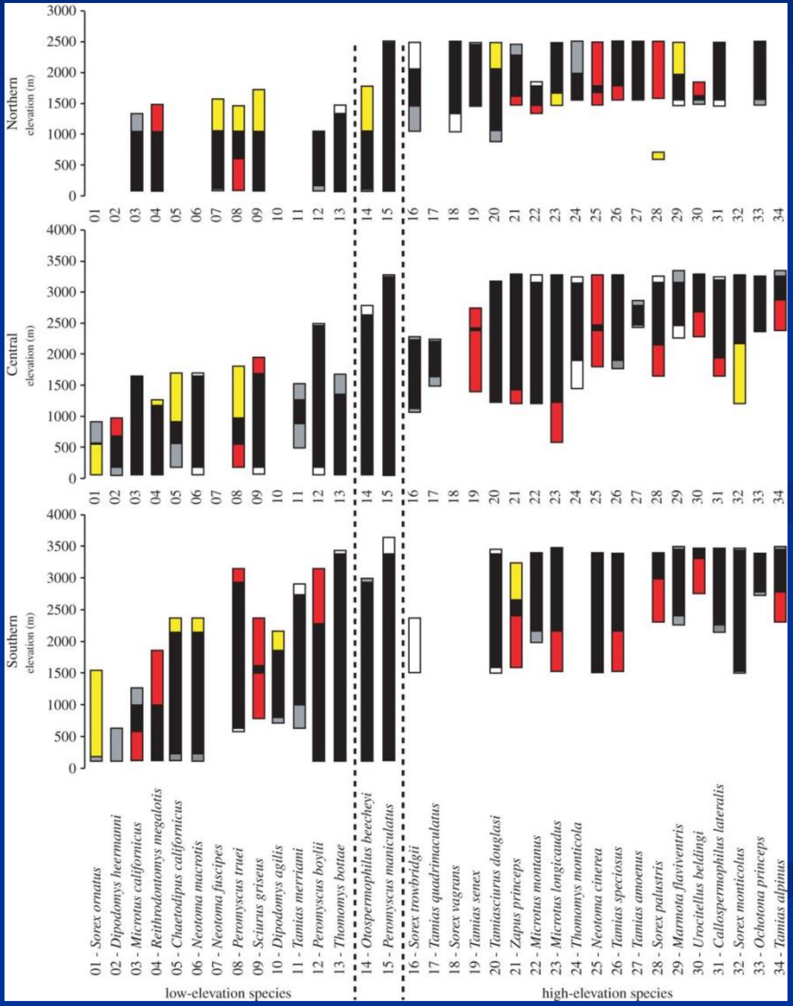
- Arctic "greening": Observed distribution (left) and predicted distribution of vegetation under a climate warming scenario for the 2050s (right).

- Data used to generate the observed image are from the Circumpolar Arctic Vegetation Map (2003).



Elevational Range Shifts
– Small Mammals in California

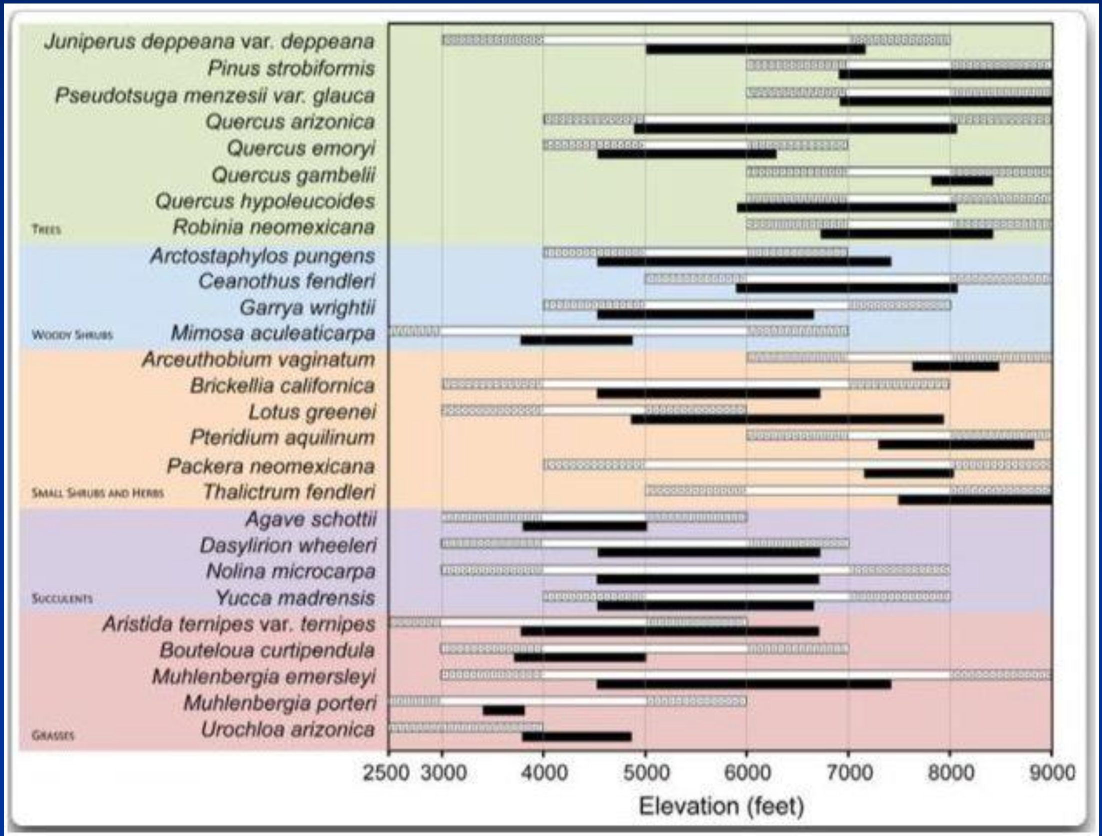
- Early 20th century surveys of small mammals along elevational gradients in northern, central and southern regions of montane California (conducted by Grinnell and colleagues) repeated in early 2000s.
- Figure shows elevation range limit shifts by region of the 34 modelled species, arranged by increasing average elevation range.
- 25 of 34 species analyzed shifted their ranges upslope or downslope in at least one region.
- However, 2/3 of ranges in the three regions remained stable at one or both elevational limits
- None of the 22 species found in all three regions shifted both their upper and lower limits in the same direction in all regions.



Elevation range contractions (red); Range expansions (yellow); Non-significant contractions (grey) and expansions (white). Lack of a bar indicates that species is not found in that region.

Elevational Range Shifts – Plants in Southern Arizona

- Models predict that SW plant communities will respond to increases in temperature through upward elevational shifts of montane species.
- Researchers reexamined Robert Whittaker's 1963 plant transect in the Santa Catalina Mountains of southern Arizona
- Survey revealed large changes in the elevational ranges of common montane plants, while mean annual rainfall decreased and annual temperature increased.
- Although elevational changes in species are individualistic, significant overall upward movement of the lower elevation boundaries, and elevational range contractions, have occurred.



Summary of elevation range of the 27 most common upland montane plants along the Catalina Highway. White bars are 1963 elevational range data from Whittaker and Niering (1964), the two terminal (stippled) 1000-ft bands denoting Whittaker's upper- and lowermost 1000-ft vegetation bands. Black bars represent 2011 elevation data from this study.

Changes in Distribution – Edith Checkerspot Butterfly

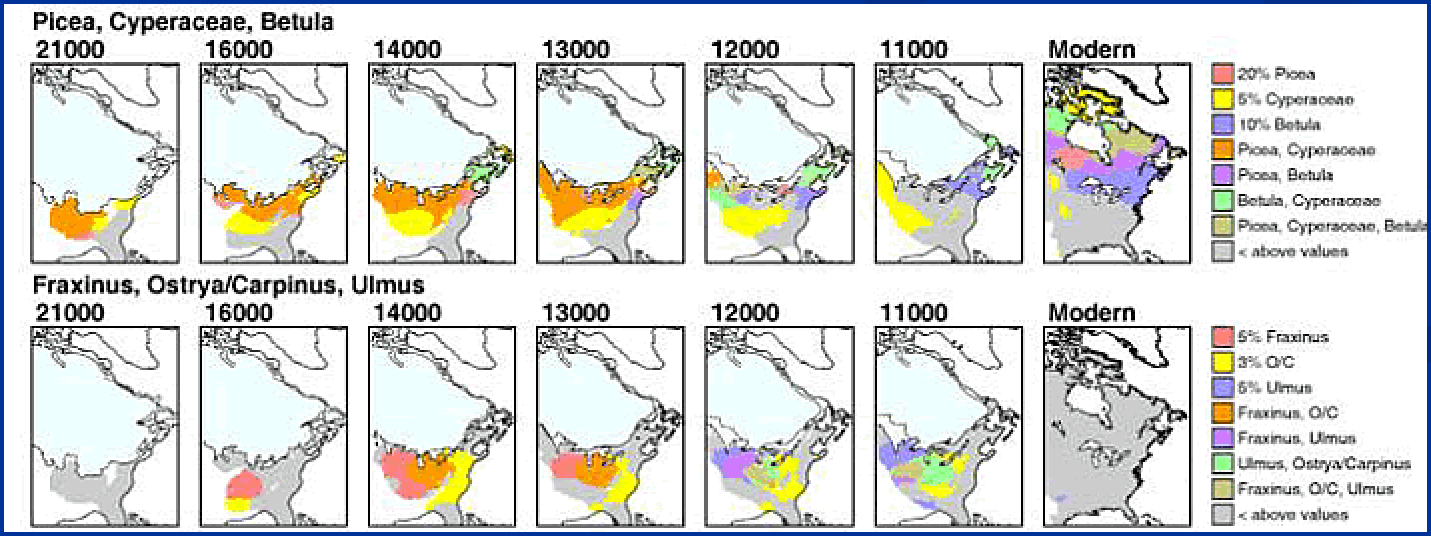
As climate warms, many species in the United States are shifting their ranges northward and to higher elevations. The map shows the response of Edith's checkerspot butterfly populations to a warming climate over the past 136 years in the American West. Over 70 percent of the southernmost populations (shown in yellow) have gone extinct. The northernmost populations and those above 8,000 feet elevation in the cooler climate of California's Sierra Nevada (shown in green) are still thriving. These differences in numbers of population extinctions across the geographic range of the butterfly have resulted in the average location shifting northward and to higher elevations over the past century, illustrating how climate change is altering the ranges of many species. Because their change in range is slow, most species are not expected to be able to keep up with the rapid climate change projected in the coming decades.[245]

Diseases

- Projected increasing spread of wildlife diseases
- E.g., avian malaria in forest birds in Hawaii
- Increasing temperatures are allowing malaria mosquitoes to move to higher elevations where they are infecting the remaining forest birds, which only occur at the higher elevations

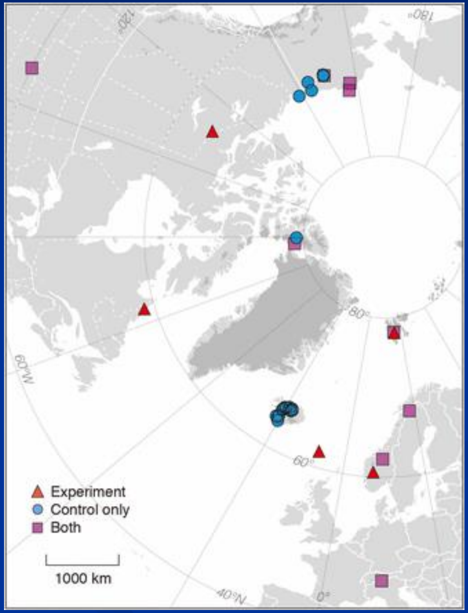
Changes in Species Assemblages – How Will Plant Communities Change?

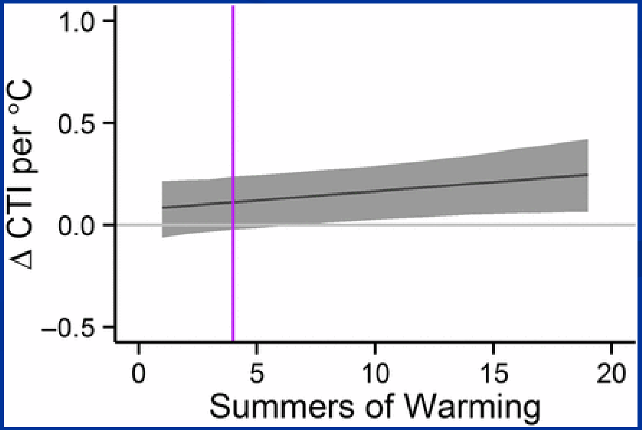
- Will plant communities move relatively intact or will species move individualistically, creating so-called “no-analog” communities?
- Work by Williams, Jackson and others on paleoecological records demonstrate that plant communities are ephemeral, and that plant taxa individualistically track shifts in climate.
- A strong and on-going research question is understanding the drivers that can cause the shuffling of species into combinations not seen at present.



Changes in Species Assemblages – Tundra Plant Community Composition

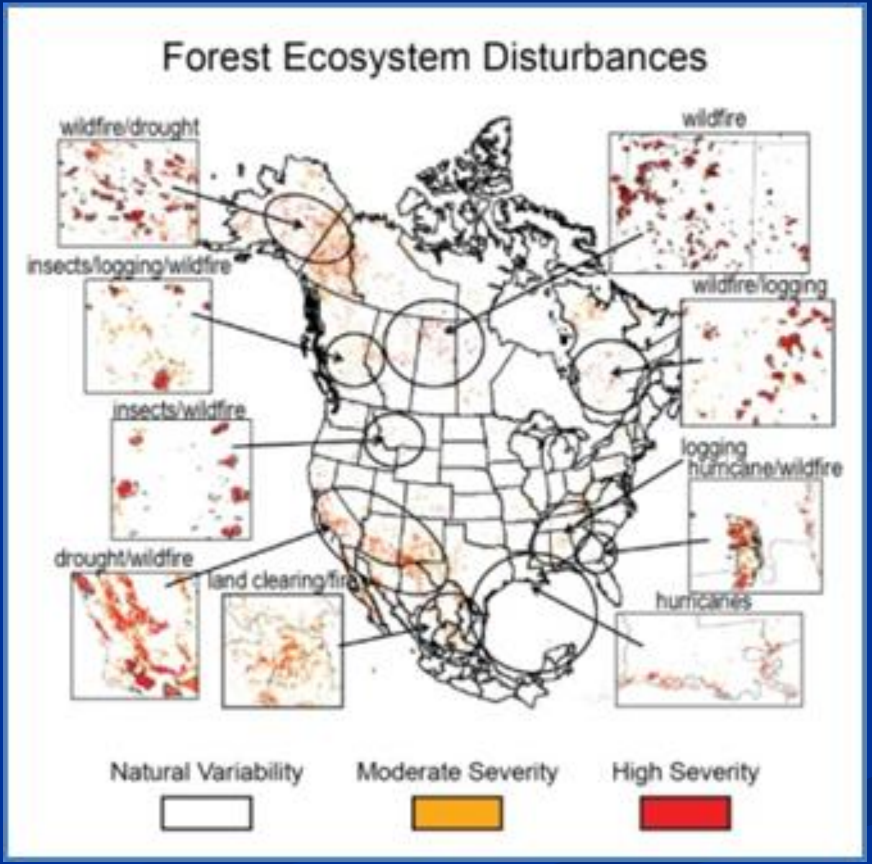
- Researchers analyzed changes in plant community composition from repeat sampling (85 plant communities in 28 regions) and experimental warming studies (28 experiments in 14 regions) throughout arctic and alpine North America and Europe.
- Increases in the relative abundance of species with a warmer thermal niche (increasing Community Temperature Index, CTI) were observed in response to warmer summer temperatures using all three methods





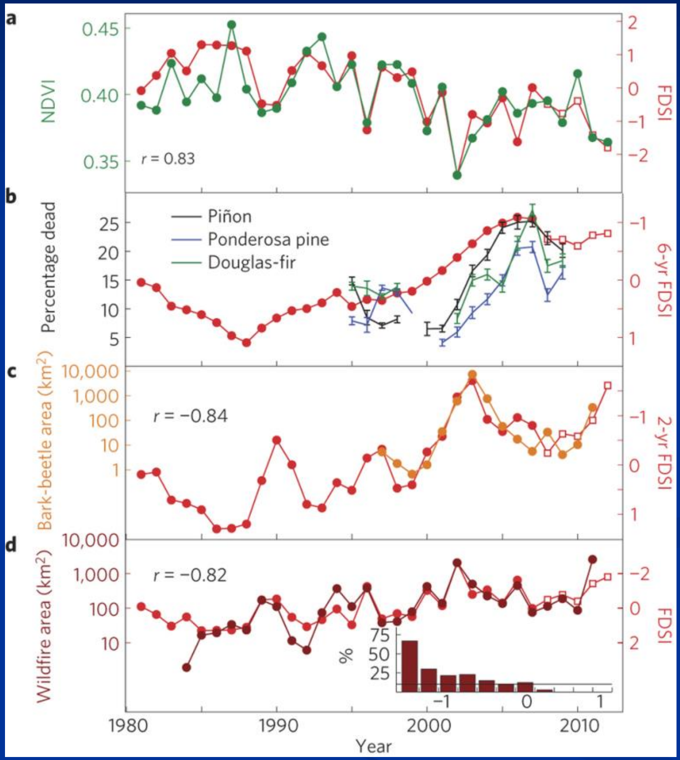
Changes in Disturbance Regimes

- Variability and distribution of major forest ecosystem disturbance types in North America, compiled from 2005 to 2009.
- Severity is mapped as a percent change in a satellite-derived Disturbance Index.
- White areas represent natural annual variability, orange represents moderate severity, and red represents high severity.
- Fire dominates much of the western forest ecosystems, and storms affect the Gulf Coast. Insect damage is widespread but currently concentrated in western regions, and timber harvest is predominant in the Southeast.



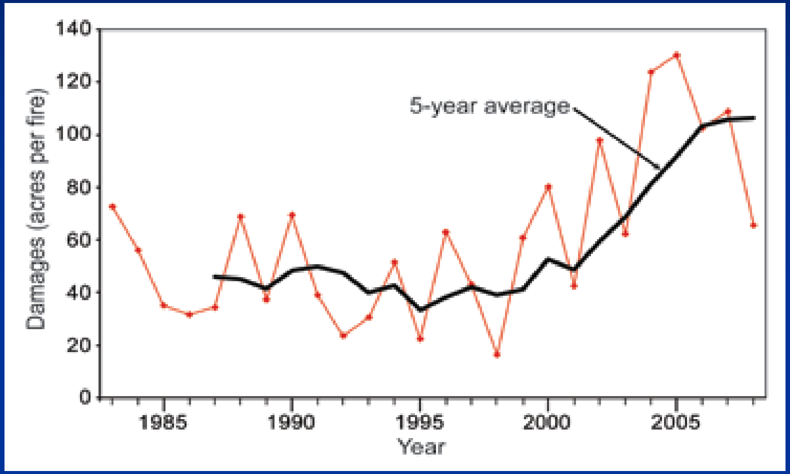
Changes in Disturbance Regimes -- SW Forests

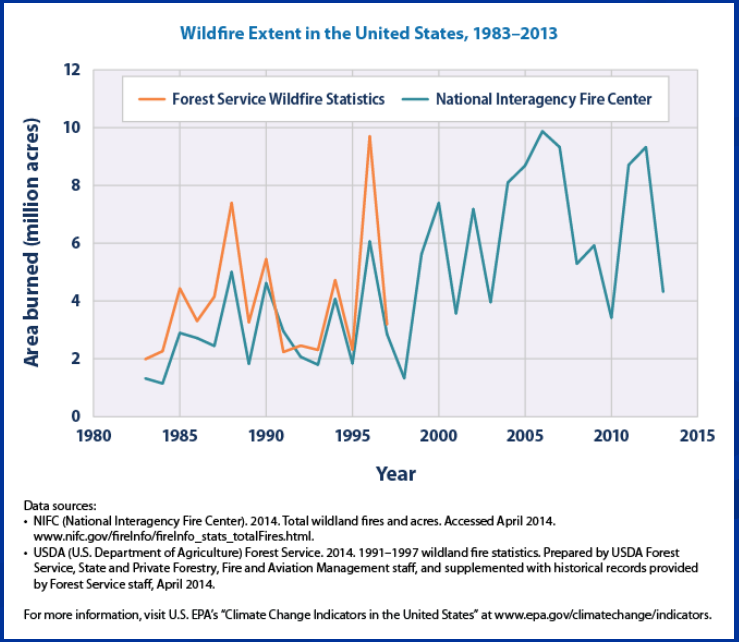
- A forest drought-stress index (FDSI) was developed for the Southwestern United States (SWUS) using a comprehensive tree-ring data set representing AD 1000–2007.
- FDSI approximately equally influenced by warm-season vapor-pressure deficit (largely controlled by temperature) and cold-season precipitation, together explaining 82% of FDSI variability.
- Correspondence between FDSI and measures of forest productivity, mortality, bark-beetle outbreak and wildfire validate the FDSI as a holistic forest-vigor indicator.



a) The annual average late-June to early-August NDVI calculated from satellite imagery. b) Annual FIA measurements of the percentage of standing dead trees in the SWUS for the three most common conifer species. c) Aerial-survey-derived estimates of the area where ≥10 trees per acre were killed by bark-beetle attack. d) Satellite-derived moderately and severely burned forest and woodland area in the SWUS.

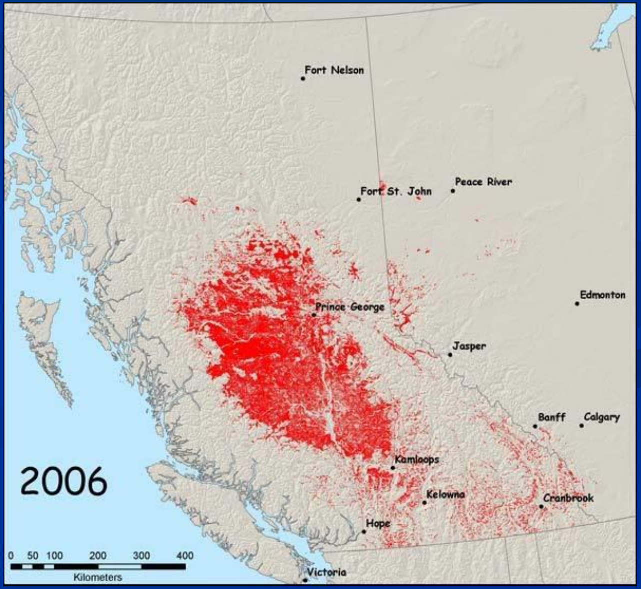
Changing Temp & Precip Contributing to Increases in Western Wildfires





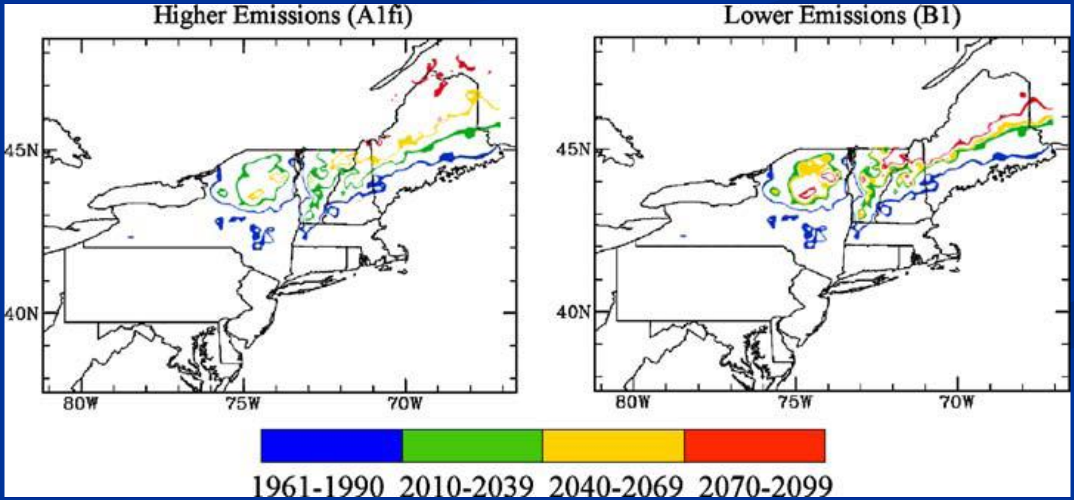
Insect Pests

- Increased incidence and severity of insect pest outbreaks
- E.g., mountain pine beetle in western North America which kill a variety of pine species
- Current outbreak much larger than any previously seen
- Believed to be related to climate factors:
  - (1) warming temperatures allow beetle to complete its lifecycle in one year and to have lower winter mortality;
  - (2) drought stress on trees making them more susceptible.
- Results in massive tree death:
  - provides fuel for wildfires
  - transforms the forest from carbon sink to carbon source



Invasives

- Contribute to the spread of invasive species
- E.g., Spread of hemlock woolly adelgid, an invasive insect that destroys Eastern hemlock
- As average temperatures climb, populations are creeping up the East Coast.
- Intolerance of cold weather has checked its spread north of Massachusetts, but…
- As temperatures rise, hemlock stands in northern New England are becoming vulnerable to this non-native species introduced from Japan.

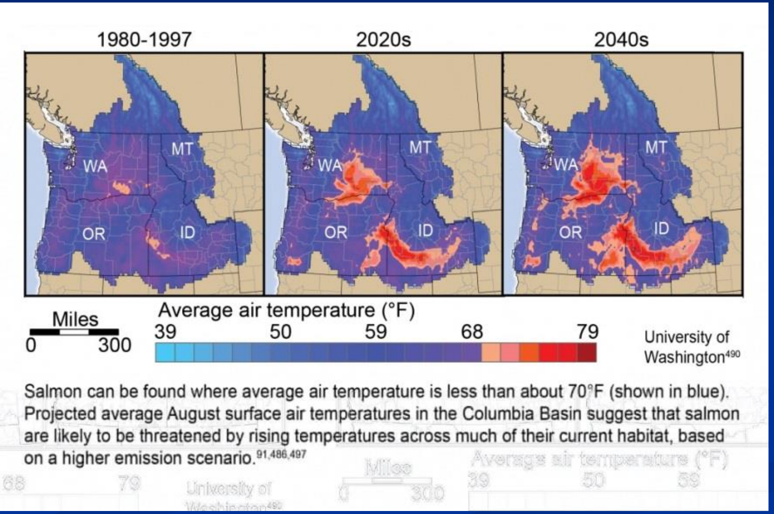


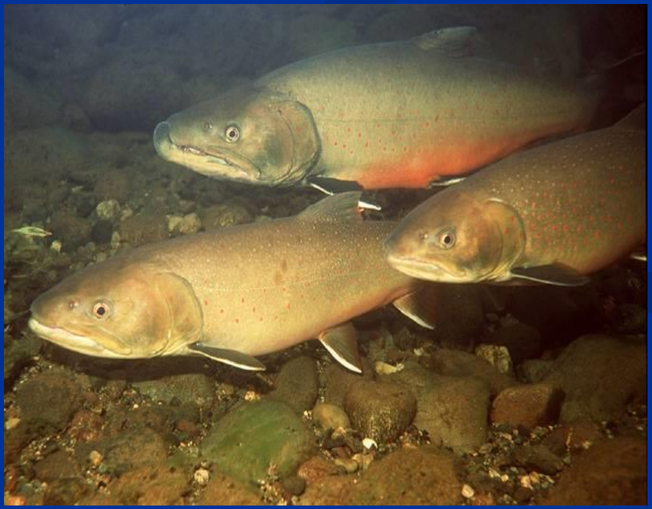
Tribal Subsistence Resources

- Indigenous peoples have historically depended on gathering and preparation of a wide variety of plant and animal species for food, medicines, ceremonies, community cohesion, and economic health. Some examples include:
  - Fish, shellfish, bison, bear, caribou, walrus, moose, deer, wild rice, berries, cottonwood trees, and a multitude of native flora and fauna.
- Climate change can affect the availability, tribal access to, and health of these resources. For example:
  - Climate change and other environmental stressors are affecting the range, quality, and quantity of berry resources for the Wabanaki tribes in the Northeast.
  - In the Great Lakes region, wild rice is unable to grow in its traditional range due to warming winters and changing water levels, affecting the Anishinaabe peoples life.

Range Changes due to Increasing Water Temps – Western Trout Taxa

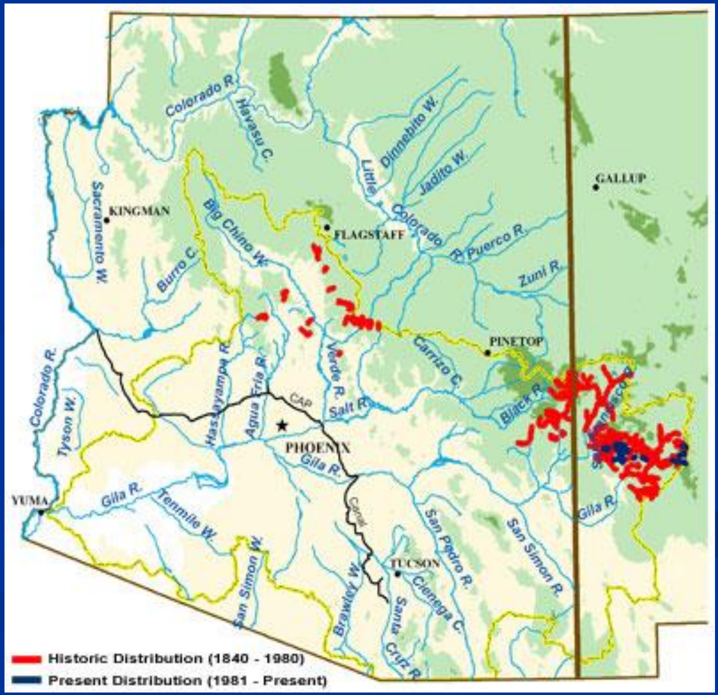
- Bioclimatic models predict large reductions in native trout across the Rocky Mountains in the 21st century but lack details about how changes will occur.
- Five case studies show that:
  - Trends in temperature and hydrographs are consistent with a warming climate in recent decades.
  - Biological implications include upstream shifts in thermal habitats, risk of egg scour, increased wildfire disturbances, and declining summer habitat volumes.
  - Importance of these factors depends on context, but temperature increases are most relevant where population boundaries are influenced by thermal constraints.
  - Summer flow declines and wildfires will be important where trout populations are fragmented and constrained to small refugia.





Gila Trout and Climate Change

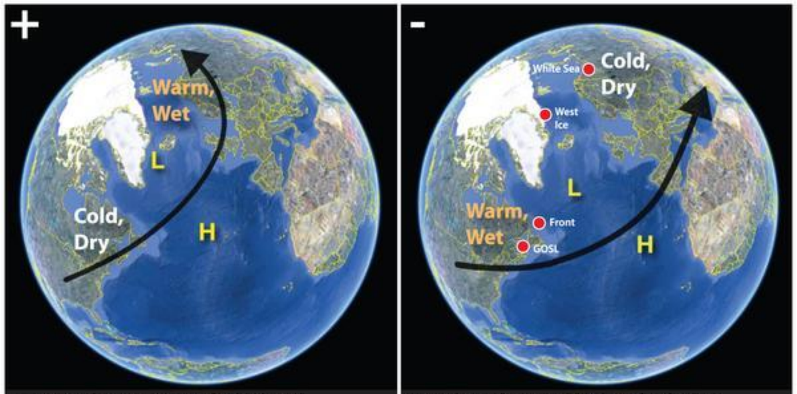
- Gila trout (*Oncorhynchus gilae*) is threatened under ESA
- Gila trout are now restricted to a few isolated streams in the upper Gila and San Francisco River drainages in New Mexico and Arizona.
- Fragmentation reduces the total area of habitat available, reduces habitat complexity, prevents gene flow, and accelerates extinction.
- The short length of the occupied stream fragments and resulting small population sizes is also of concern.
- Using a regional climate model, researchers predict a 20 percent decrease in summer precipitation and a 2° C increase in average summer time air temperature by mid-century in watersheds occupied by Gila trout.
- Because of warmer air temperatures and corresponding increase in water temperature, they predict a 70 percent loss of suitable habitat in existing Gila trout streams.



Profound Effects on Arctic Wildlife

- **“'Dramatic' loss of harp seals amid warming: study”**

- Warming in the North Atlantic over the last 32 years has significantly reduced winter sea ice cover in harp seal breeding grounds, resulting in sharply higher death rates among seal pups in recent years in eastern Canada, according to a new Duke University-led study.

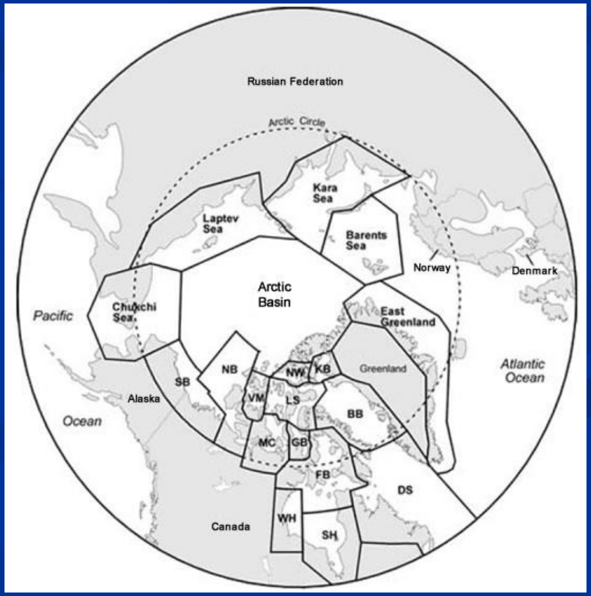


A greater than average polar high and subtropical low produces more northerly tracking storms crossing the Atlantic. This results in colder and dryer conditions in eastern Canada, and warmer and wetter conditions in Northern Europe.

A weaker subtropical high and polar low produces fewer storms on a more west-east trajectory. This results in warmer and wetter conditions in eastern Canada and colder, dryer conditions in Northern Europe. Red dots indicate harp seal breeding regions

Profound Effects on Arctic Wildlife

- Listing of the polar bear as a threatened species under the ESA in May 2008, largely because of:
  (1) observed declines in some populations;
  (2) actual and projected changes of Arctic sea-ice changes;
  (3) resultant population projections showing drastic declines in the polar bear population by the end of the 21st century.
- Cannot shift its range further north….
- On the verge of publishing a draft recovery plan for the species



Adaptation

What is Climate Change Adaptation?
Working Definition for Natural Resources

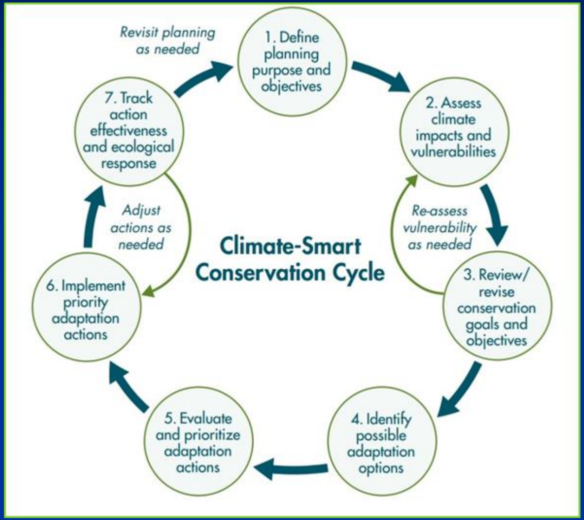
- In the context of climate-change planning the term adaptation generally refers to human activities intended to minimize the adverse effects of climate change on human infrastructure and sensitive aspects of the natural environment”

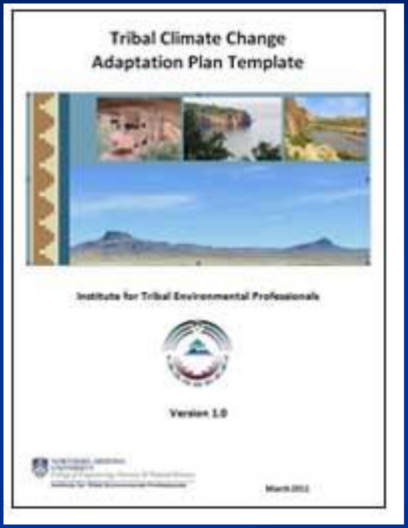
  - Fischlin et al. 2007; Julius & West 2007 – cited in Mawdsley et al. 2009

Climate Change Adaptation Planning

Many resources are available for vulnerability assessment and adaptation planning for species and habitats:

- Adaptation plans
- Planning guides & templates
- Case studies
- Expertise in NGO, govt and academic





ITEP Adaptation Planning Tool Kit: **A collection of templates and other resources developed by the Institute for Tribal Environmental Professionals (ITEP) to assist tribes in their climate change adaptation planning process.**

Take Home Messages!!

- Climate change is real
- Climate change is very likely due in large part to man's activities (it is not just "natural variability")
- Climate change impacts to fish, wildlife and plants and their habitats are occurring now and will continue into the future
- Extreme events are likely to be critically important to natural systems
- Climate change is not just another stressor
- Climate change will exacerbate other threats, but will also be a "game changer" in that habitats will change and move
- Can't look to the past as the sole guide for future management
- Many tools are available for climate change vulnerability assessment and adaptation planning