CCSP

U.S. Climate Change Science Program

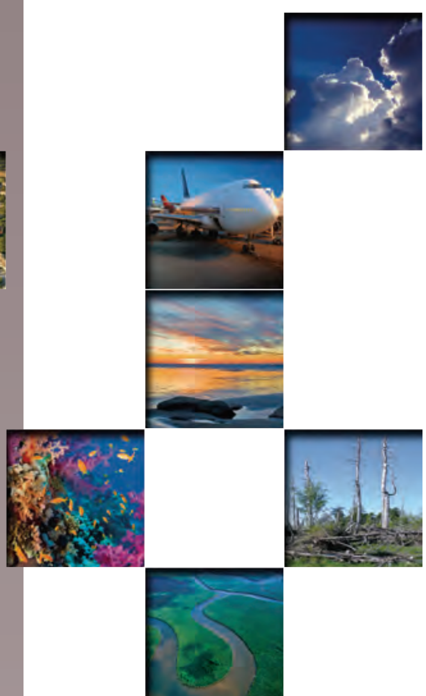
Climate Change and Ecosystems

Summary of Recent Findings

Climate is a dominant factor influencing the distributions, structures, functions, and services of ecosystems. Changes in climate can interact with other environmental changes to affect biodiversity and the future condition of ecosystems.[1]

An ecosystem can be described as a community of organisms and its relationship with a particular environment. A forest is an ecosystem, so is a pond, or a desert. Climate is a key driver of changes in ecosystems, and strategies for protecting climate-sensitive ecosystems will be increasingly important for management, because impacts resulting from a changing climate system are already evident and will persist into the future.[1]

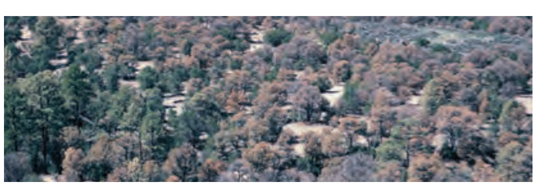
A series of 21 reports is being issued by the Climate Change Science Program to determine the impacts of changing climate on the United States. Several of these reports include an assessment of impacts on different ecosystems. This fact sheet summarizes the findings of those reports, and includes information from a recent assessment of possible adaptation options to protect climate-sensitive ecosystems in the United States.

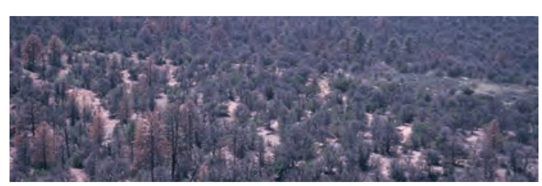


Is Climate Change Already Affecting Some Ecosystems?

Like global average temperatures, U.S. average temperatures increased during the last century and into the present one, and the last decade is the warmest in more than a century of direct observations in the United States. Along with temperature, other features of the climate have already been observed to change, such as an increase in the proportion of heavy precipitation events, especially in the last three decades, changes in snow cover and an increase in sea level.[2]

Ecosystems and their services (land and water resources, agriculture, biodiversity) experience a wide range of stresses, including pests and pathogens, invasive species, air pollution, extreme events, wildfires, and floods. Climate change can cause or exacerbate direct stress through high temperatures, reduced water availability, and altered frequency of extreme events and severe storms. It can ameliorate stress through warmer springs and longer growing seasons, which, assuming adequate moisture, can increase agricultural and forest productivity. Climate change can also modify the frequency and severity of stresses. For example, increased minimum temperatures and warmer springs extend the range and lifetime of many pests that stress trees and crops.[3]





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An emerging but growing body of literature indicates that over the past three decades, the changes in the climate system described above—including the human-caused component of warming—have caused physical and biological changes in a variety of ecosystems that are discernible at the global scale. These changes include:

- Shifts in genetics (evolutionary responses)
- Species' ranges
- Phenological patterns (climate-related timing of annual biological activity such as migration or plant flowering)
- Life cycles.[1]

Some specific examples in the United States follow:

- Climate change has very likely increased the size and number of forest fires, insect outbreaks, and tree mortality in the interior West, the Southwest, and Alaska, and will continue to do so.
- Earlier spring onset, lengthening of the growing season, and net primary productivity increase are noticeable in the higher latitudes of North America.
- Migration of plant and animal species is changing the composition and structure of arid, polar, aquatic, coastal, and other ecosystems.[3]

Will Future Climate Change Have an Even Greater Impact on Ecosystems?

Continued greenhouse gas emissions at or above current rates are expected to cause further warming and to induce many climate changes during the 21st century that will very likely be larger than those of the last century.[2]

For example, findings from the IPCC as well as the CCSP Synthesis and Assessment Products indicate:

- All of North America is very likely to warm during this century, and to warm more than the global average increase in most areas.
- Nearly all the models used in the United Nations' Intergovernmental Panel on Climate Change (IPCC) assessment project that the average warming in the United States will exceed 3.6°F, with 5 out of 21 models projecting that average warming will exceed 7.2°F.
- In the 21st century, precipitation over North America is projected to be less frequent but more intense.

- The IPCC projects that global sea level will rise between 7 and 23 inches by the end of the century (2090-2099) without including consideration of accelerated ice melt, which is also now being observed.
- Storm surge levels are expected to increase due to projected sea-level rise.
- For North Atlantic, it is likely that hurricane rainfall and wind speeds will increase in response to human-caused warming.[2]

As a consequence:

- The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g., land-use change, pollution).
- In North America, warming has generally resulted in and is expected to continue to result in shifts of species ranges poleward and to higher altitudes.[2]

What Ecosystems Are Most Likely to Be Affected?

The extent to which ecosystem condition may be affected will depend on the amount of climate change, the degree of sensitivity of the ecosystem to the climate change, and the availability of adaptation options for effective management responses, but major changes in ecosystem structure, composition, and function are very likely to occur where temperature increases exceed 2.7-4.5°F (1.5-2.5°C)[1]—well within the projections for most parts of the United States this century.

Some examples of anticipated impacts are:

- Stream temperatures are likely to increase as the climate warms and are very likely to have effects on aquatic ecosystems and water quality.
- Climate change in arid lands will very likely create physical conditions conducive to wildfire, and the proliferation of exotic grasses will very likely provide fuel, thus causing fire frequencies to increase in a self-reinforcing fashion.
- River ecosystems in arid lands will very likely be negatively impacted by decreased streamflow, increased water removal, and greater competition from non-native species.
- Subtropical and tropical corals in shallow waters have already suffered major bleaching events that are clearly driven by increases in sea surface temperatures. Increases in ocean acidity, which are a direct consequence of increases in atmospheric carbon dioxide, are calculated to have the potential for serious negative consequences for corals.
- The rapid rates of warming in the Arctic observed in recent decades, and projected for at least the next century, are dramatically reducing the snow and ice covers that provide denning and foraging habitat for polar bears.[3]

What Are Some Options For Protecting Our Ecosystems?

Strategies for protecting climate-sensitive ecosystems will be increasingly important for management, because impacts resulting from a changing climate system are already evident and will persist into the future. While there will always be uncertainties associated with the future path of climate change, the response of ecosystems to climate impacts, and the effects of management, it is both possible and essential for adaptation to proceed using the best available science. Adaptation options for enhancing ecosystem resilience include changes in management processes, practices, or structures to reduce anticipated damages or enhance beneficial responses associated with climate variability and change.

Some examples of specific fey findings with respect to management of ecosystems in the face of climate change follow.

Many existing best management practices for "traditional" stressors of concern have the added benefit of reducing climate change exacerbations of those stressors.

Changes in temperature, precipitation, sea level, and other climate-related factors can often exacerbate problems that are already of concern to managers. For example, increased intensity of precipitation events can further increase delivery of non-point source pollution and sediments to rivers, estuaries, and coasts. Fortunately, many management practices that exist to address such "traditional" stressors can also address climate change impacts. For example, the construction of buffer strip along watercourses (such as rivers) both manage pollution loadings from agricultural lands into rivers today and also establish protective barriers against increases in both pollution and sediment loadings due to climate changes in the future.[1]

The specific "adaptation approaches" described below are derived from discussions of existing (and new) management practices to maintain or increase ecosystem resilience:

- **Protecting key ecosystem features** involves focusing management protections on structural characteristics, organisms, or areas that represent important "underpinnings" or "keystones" of the overall system.
- **Reducing human stresses** is the approach of minimizing localized human stressors (e.g., pollution, fragmentation) that hinder the ability of species or ecosystems to withstand climatic events.
- **Representation** refers to protecting a portfolio of variant forms of a species or ecosystem so that, regardless of the climatic changes that occur, there will be areas that survive and provide a source for recovery.
- **Replication** centers on maintaining more than one example of each ecosystem or population such that if one area is affected by a disturbance, replicates in another area provide insurance against extinction and a source for recolonization of affected areas.
- **Restoration** is the practice of rehabilitating ecosystems that have been lost or compromised.
- **Refugia** are areas that are less affected by climate change than other areas and can be used as sources of "seed" for recovery or as destinations for climate-sensitive migrants.
- **Relocation** refers to human-facilitated transplantation of organisms from one location to another in order to bypass a barrier (e.g., urban area).[1]

MANAGERS' PAST EXPERIENCES WITH UNPREDICTABLE AND EXTREME EVENTS HAVE ALREADY LED TO SOME EXISTING APPROACHES THAT CAN BE ADJUSTED FOR USE IN ADAPTING TO LONGER TERM CLIMATE CHANGE.

One essential element of any adaptation approach will be identifying thresholds in ecosystems.

Climate changes may cause ecological thresholds to be exceeded, leading to abrupt shifts in the structure of ecosystems. Threshold changes in ecosystems have profound implications for management because such changes may be unexpected, large, and difficult to reverse. If these ecosystems cannot then be restored, actions to increase their resilience will no longer be viable. Understanding where thresholds have been exceeded in the past and where (and how likely) they may be exceeded in the future allows managers to plan accordingly and avoid tipping points where possible.[1]

Beyond "managing for resilience," the Nation's capability to adapt will ultimately depend on our ability to be flexible in setting priorities and "managing for change."

Over time, our ability to "manage for resilience" of current systems in the face of climate change will be limited as temperature thresholds are exceeded, climate impacts become severe and irreversible, and socioeconomic costs of maintaining existing ecosystem structures, functions, and services become excessive. At this point, it will be necessary to "manage for change," with a reexamination of priorities and a shift to adaptation options that incorporate information on projected ecosystem changes. It will be necessary to continuously refine and add to our current body of knowledge in order to meet the challenge of preserving the Nation's lands and waters in a rapidly changing world.[1]

1 SAP 4.4: Adaptation Options for Climate-Sensitive Ecosystems and Resources

2 The Scientific Assessment of the Effect of Global Change on the United States

3 SAP 4.3: The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity

This fact sheet was generated by the Climate Change Science Program Office
For further information, see <www.climatescience.gov>.