Earth Gauge
A National Environmental Education Foundation Program

# Climate Change and America's Public Lands and Waters

***About 30 percent of America's land area, or 700 million acres, is owned by the public. Additionally, there are about 15,600 square nautical miles of ocean water designated as National Marine Sanctuaries. These lands and waters contain some of America's most iconic landmarks, and the National Parks alone receive close to 300 million visits annually. Some of the last habitats for rare and endangered species are in these areas, and most of the West's water supply originates in watersheds on public lands. Read on for examples of how recent climate change has impacted America's public lands and waters.***

## *CASE STUDY: GLACIER NATIONAL PARK*

Established in 1910 in northwestern Montana, Glacier National Park features steep topography with numerous microclimates that are particularly sensitive to global climate fluctuations. The two most visible effects of climate change in Glacier National Park have been glacial retreat and increases in tree cover.

***Glacial Retreat:*** In 1850, as the planet came out of the "Little Ice Age," about 150 glaciers existed in Glacier National Park (GNP). Tree-ring data suggest that these glaciers retreated by about 23 feet per year between 1860 and 1910. In 1910, temperature recording began and since then, average summertime temperatures have risen by about three degrees Fahrenheit. Records indicate that between 1917 and 1926, the rate of glacial retreat averaged 130 feet per year, and then accelerated to over 300 feet per year until 1942.

This period of rapid glacial retreat corresponded to a period of rising temperatures, and also a predominately positive phase of the Pacific Decadal Oscillation (PDO), or the periodic shift in heat distribution in the Pacific Ocean. Positive PDO phases mean less snowfall in GNP, and changes in PDO phase account for 70 percent of the variability in snowfall there. As the PDO entered a negative phase in the 1940's, the rate of retreat slowed, but continued. The melting intensified after the late 1970's, as global temperatures began to rise and the PDO re-entered a positive phase. Today, only about 27 percent of the area of GNP covered by glaciers in 1850 is still covered, and the number of glaciers has been cut from 150 to 37. Grinnell Glacier has shrunk from an area of 1.11 square miles in the 1850's, to less than 0.4 square miles today.

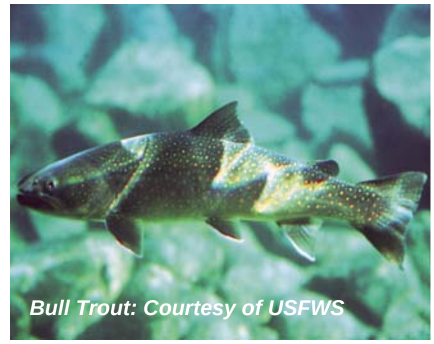
**Above: Grinnell Glacier in 1981 (left, by Carl Key) and again in 2006 (right, by Karen Holzer). Courtesy of Glacier National Park Archives**

***Tree Cover:*** Over the past century, tree cover in Glacier National Park has advanced into areas that were formerly alpine tundra, and the number of trees per unit of area in the Park has increased. Recent surveys conducted on sites where comparisons with historic photographs are possible demonstrate that over half of these sites have had a 35 percent or greater increase in tree cover extent, with an average increase of 60 percent. Increases in tree density occurred at almost all sites examined, with the greatest increases in density occurring at sites with the least amount of areal expansion. Ninety (90) percent of the trees that have expanded into the tundra were established in the last 40 years. There appears to be some relationship between tree establishment and the PDO: negative PDO winters mean more snowfall in the park. More snowfall means more insulation for the soil during winter, which allows for more microbial activity (and more nutrient cycling). More snow also means the soil remains moister for longer periods during the growing season. Both of these factors promote tree growth. Additionally, snow tends to accumulate around vegetation, which means more snowpack around areas where vegetation is the most likely to expand. This results in a positive feedback cycle where tree establishment promotes more tree establishment.

***CASE STUDY: THE BOISE RIVER WATERSHED***

Because 75 percent of the West's water supply originates from snowmelt, the annual amount of snowpack, as well as the timing of snowmelt, are crucial factors for the region's water resources.

- In the Pacific Northwest over the last 50 years, there has been a 4.5 degree Fahrenheit increase in November through March temperatures, which means more late winter precipitation is now falling as rain instead of as snow.
- The Pacific Northwest has experienced a nine percent decline in the average extent of March snow cover, and the day when there ceases to be snow on the ground is now arriving an average of 16 days earlier than it did 50 years ago.


*Bull Trout: Courtesy of USFWS*

Idaho's Boise River originates in the rugged backcountry of the Boise and Sawtooth National Forests. About 78 percent of the River's flow originates from snowmelt, and reaches peak flow sometime between mid-April and mid-June. About 78 percent of the total discharge from the Boise into the Snake River occurs between March and July. In addition to supplying southwest Idaho with water, the river provides habitat for fish species such as Steelhead and Bull Trout, which cannot survive if water temperatures become too warm. Over the last 60 years, conditions in the Boise River Watershed have changed:

- The date on which the Boise River reaches its peak flow now arrives an average of two weeks earlier.
- Overall precipitation in the Boise River watershed has declined by 13 percent, with the biggest decreases occurring during January, February and March.
- The biggest decreases in stream flow volume have occurred during the months of May, June and July.
- Overall stream flow volume has declined by almost 25 percent.

Warmer air and reduced precipitation mean reduced snowpack, increased evaporation, and reduced stream flow volume. All of these factors promote warmer streams. This general warming and drying trend also results in a lengthening of the fire season, which has grown by 78 days since the 1970's throughout the west. Since 1992, about 15 percent of the Boise River Watershed has been affected by fire. Stream flow volume can actually increase after fires that kill many large trees, as precipitation that would be absorbed and used by large trees instead flows directly into streams. While this effect can cool streams, fire-induced tree mortality also allows more sunlight and debris to reach the streams, which results in warmer waters. The net effect of fire appears to be warmer streams. Since 1993, parts of the Boise River Watershed have warmed by up to four degrees Fahrenheit. Once water temperatures exceed 57 degrees, juvenile Bull Trout become physiologically stressed. Recent increases in water temperature have led to a 20 percent decrease in suitable Bull Trout habitat in the Boise River Watershed.

***CASE STUDY: FLORIDA KEYS NATIONAL MARINE SANCTUARY***

Around the 126-mile long Florida Keys island chain lies Florida Keys National Marine Sanctuary (FKNMS), a 2,900 square nautical mile reserve managed by NOAA's Ocean Service. FKNMS provides habitat for 5,500 marine species, as well as nursing, feeding, and breeding grounds that ultimately support a 20 million pound per year fishery. The Florida Current brings warm water up from the south, which enables coral reefs to exist at the relatively high latitudes of the Keys. Corals depend on a steady supply of dissolved carbonate ($CO_3$) in the water in order to build their skeletons. Over the last 200 years, as atmospheric carbon dioxide ($CO_2$) levels have risen, the oceans have absorbed about 525 billion tons of $CO_2$. When $CO_2$ enters the ocean, it bonds with water to create carbonic acid, releasing an extra proton in the process. The extra proton bonds to a carbonate molecule in the water, creating more carbonic acid and leaving fewer carbonate molecules for coral to use to build skeletons.

Coral polyps can only survive in warm ocean waters, but if waters become too warm, algae which help the coral polyps absorb nutrients will die.  When this happens, "coral bleaching" occurs – corals turn white and die. Sea-surface temperatures (SSTs) in the tropical and sub-tropical Atlantic are the warmest that they have been since at least the 1870's. In the Florida Keys, water temperatures fluctuate annually between about 68 and 86 degrees Fahrenheit. Once water temperatures exceed 86 degrees, coral bleaching begins to occur. Coral bleaching events in the Florida Keys have become more common as Atlantic SSTs have risen. During El Niño years, such as 1982-1983 and 1997-1998, conditions where water temperatures are particularly high for an especially long period of time are common. Elevated water temperatures can also occur during ENSO neutral years, such as the warmest year on record, 2005. Florida Keys coral cover fell from about 11.7 percent before the bleaching events that happened during the El Niño years of 1997-1998, to about 6.7 percent in 2005. While there was extensive coral bleaching throughout the Caribbean during 2005, the corals at FKNMS experienced only minor impacts because Hurricanes Katrina, Rita, and Wilma helped to dissipate the heat in the waters around the Sanctuary without doing much physical damage to the corals.

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