



All information in this summary is entirely based on "Global Climate Change Impacts in the United States" (USGCRP, 2009). To enhance clarity, slight modifications were made that maintain the intended meaning of the report.

Alaska

CLIMATE

Over the past 50 years, Alaska has warmed at more than twice the rate of the rest of the United States.

- Its annual average temperature has increased 3.4°F, while winters have warmed even more, by 6.3°F.
- As a result, climate change impacts are much more pronounced than in other regions of the United States.
- Average annual temperatures in Alaska are projected to rise about 3.5 to 7°F by the middle of this century.
- How much temperatures rise later in the century **depends strongly on global emissions choices**, with increases of 5 to 8°F projected with a lower-emissions scenario, and increases of 8 to 13°F with a higher-emissions scenario.

Climate models also project increases in precipitation over Alaska.

- Simultaneous increases in evaporation due to higher air temperatures, however, are expected to lead to **drier conditions** overall, with **reduced soil moisture**.
- In the future, therefore, model projections suggest a **longer summer growing season** combined with an **increased likelihood of summer drought and wildfires**.

TRANSPORTATION AND ENERGY

Thawing permafrost damages roads, runways, water and sewer systems, and other infrastructure. Permafrost temperatures have increased throughout Alaska since the late 1970s. The largest increases have been measured in the northern part of the state. While permafrost in interior Alaska so far has experienced less warming than permafrost in northern Alaska, it is more vulnerable to thawing during this century because it is generally just below the freezing point, while permafrost in northern Alaska is colder.

Land subsidence (sinking) associated with the thawing of permafrost presents substantial challenges to engineers attempting to preserve infrastructure in Alaska. Public infrastructure at risk for damage includes roads, runways, and water and sewer systems. It is estimated that thawing permafrost would add between \$3.6 billion and \$6.1 billion (10 to 20 percent) to future costs for publicly owned infrastructure by 2030 and between \$5.6 billion and \$7.6 billion (10 to 12 percent) by 2080. Private infrastructure impacts have not been evaluated.

The majority of Alaska's highways are located in areas where permafrost is discontinuous, and dealing with thaw settlement problems already claims a significant portion of highway maintenance dollars. Bridges and large culverts are particularly sensitive to movement caused by thawing permafrost and are often much more difficult than roads to repair and modify for changing site conditions. Thus, designing these facilities to take climate change into account is even more critical than is the case for roads.

Another impact of climate change on bridges is **increased scouring**. Hotter, drier summers in Alaska have led to increased glacial melting and longer periods of high streamflows, causing both increased sediment in rivers and scouring of bridge supporting piers and abutments. Temporary ice roads and bridges are commonly used in many parts of Alaska to access northern communities and provide support for the mining and oil and gas industries.

Rising temperatures have already shortened the season during which these critical facilities can be used. Like the highway system, the Alaska Railroad crosses permafrost terrain, and frost heave and settlement from thawing affect some portions of the track, increasing maintenance costs.

Thawing ground also has implications for oil and gas drilling. As one example, the number of days per year in which travel on the tundra is allowed under Alaska Department of Natural Resources standards has dropped from more than 200 to about 100 days in the past 30 years. This results in a 50 percent reduction in days that oil and gas exploration and extraction equipment can be used.

Later this century and beyond, shippers are looking forward to **new Arctic shipping routes**, including the fabled Northwest Passage, which could provide significant costs savings in shipping times and distances. However, the next few decades are likely to be very unpredictable for shipping through these new routes. The past three decades have seen very high year-to-year variability of sea-ice extent in the Canadian Arctic, despite the overall decrease in September sea-ice extent. The loss of sea ice from the shipping channels of the Canadian Archipelago might actually allow more frequent intrusions of icebergs, which would continue to impede shipping through the Northwest Passage.

THREATS TO COASTLINES

Coastal storms increase risks to villages and fishing fleets.

- Alaska's coastlines, many of which are low in elevation, are increasingly threatened by a combination of the loss of their protective sea ice buffer, increasing storm activity, and thawing coastal permafrost.
- Lack of sea ice, especially on the northern shores of Alaska, creates conditions whereby storms produce waves that cause serious coastal erosion. Already a number of small towns, roads, and airports are threatened by retreating coastlines, necessitating the planned relocation of these communities.

Alaska has more coastline than the 49 other states combined. Frequent storms in the Gulf of Alaska and the Bering, Chukchi, and Beaufort seas already affect the coasts during much of the year. Increasing storm activity in autumn in recent years has delayed or prevented barge operations that supply coastal communities with fuel.

Commercial fishing fleets and other marine traffic are also strongly affected by Bering Sea storms. Highwind events have become more frequent along the western and northern coasts. The same regions are experiencing increasingly long sea-ice free seasons and hence longer periods during which coastal areas are especially vulnerable to wind and wave damage. Downtown streets in Nome, Alaska, have flooded in recent years. Coastal erosion is causing the shorelines of some areas to retreat at average rates of tens of feet per year. The ground beneath several native communities is literally crumbling into the sea, forcing residents to confront difficult and expensive choices between relocation and engineering strategies that require continuing investments despite their uncertain effectiveness

The rate of erosion along Alaska's northeastern coast line has doubled over the past 50 years. Over the coming century, an increase of sea surface temperatures and a reduction of ice cover are likely to lead to northward shifts in the Pacific storm track and increased impacts on coastal Alaska. Climate models project the Bering Sea to experience the largest decreases in atmospheric pressure in the Northern

Hemisphere, suggesting an increase in storm activity in the region. In addition, the longer ice-free season is likely to make more heat and moisture available for storms in the Arctic Ocean, increasing their frequency and/or intensity.

AGRICULTURE

Longer summers and higher temperatures are causing drier conditions, even in the absence of strong trends in precipitation.

- Between 1970 and 2000, the snow-free season increased by approximately 10 days across Alaska, primarily due to earlier snowmelt in the spring.
- A longer growing season has potential economic benefits, providing a longer period of outdoor and commercial activity such as tourism. However, there are also downsides. For example, white spruce forests in Alaska's interior are experiencing declining growth due to drought stress and continued warming could lead to widespread death of trees.
- The decreased soil moisture in Alaska also suggests that agriculture in Alaska might not benefit from the longer growing season.

FISHERIES

Displacement of marine species will affect key fisheries.

- Alaska leads the United States in the value of its commercial fishing catch. Most of the nation's salmon, crab, halibut, and herring come from Alaska.
- In addition, many Native communities depend on local harvests of fish, walrus, seals, whales, seabirds, and other marine species for their food supply.

- Climate change causes significant alterations in marine ecosystems with important implications for fisheries.
- Ocean acidification associated with a rising carbon dioxide concentration represents an additional threat to cold-water marine ecosystems.

One of the most productive areas for Alaska fisheries is the northern Bering Sea off Alaska's west coast. The world's largest single fishery is the Bering Sea pollock fishery, which has undergone major declines in recent years. Over much of the past decade, as air and water temperatures rose, sea ice in this region declined sharply. Populations of fish, seabirds, seals, walrus, and other species depend on plankton blooms that are regulated by the extent and location of the ice edge in spring. **As the sea ice retreats, the location, timing, and species composition of the blooms changes, reducing the amount of food reaching the living things on the ocean floor.** This radically changes the species composition and populations of fish and other marine life forms, with significant repercussions for fisheries.

Over the course of this century, changes already observed on the shallow shelf of the northern Bering Sea are likely to affect a much broader portion of the Pacific-influenced sector of the Arctic Ocean. As such changes occur, the most productive commercial fisheries are likely to become more distant from existing fishing ports and processing infrastructure, requiring either relocation or greater investment in transportation time and fuel costs. These changes also will affect the ability of native peoples to successfully hunt and fish for the food they need to survive. Coastal communities already are noticing a displacement of walrus and seal populations. Bottom-feeding walrus populations are threatened when their sea ice platform retreats from the shallow coastal feeding grounds on which they depend.³⁶

FORESTS

Insect outbreaks and wildfires are increasing with warming. Climate plays a key role in determining the extent and severity of insect outbreaks and wildfires. Higher air temperature is a key factor. In Alaska, for example, June air temperatures alone explained approximately 38 percent of the increase in the area burned annually from 1950 to 2003.

During the 1990s, south-central Alaska experienced the largest outbreak of spruce bark beetles in the world. This outbreak occurred because rising temperatures allowed the spruce bark beetle to survive over the winter and to complete its life cycle in just 1 year instead of the normal 2 years. Healthy trees ordinarily defend themselves by pushing back against burrowing beetles with their pitch. From 1989 to 1997, however, the region experienced an extended drought, leaving the trees too stressed to fight off the infestation.

Prior to 1990, the spruce budworm was not able to reproduce in interior Alaska. Hotter, drier summers now mean that the forests there are threatened by an outbreak of spruce budworms. This trend is expected to increase in the future if summers in Alaska become hotter and drier. Large areas of dead trees, such as those left behind by pest infestations, are highly flammable and thus much more vulnerable to wildfire than living trees. The area burned in North America's northern forest that spans Alaska and Canada tripled from the 1960s to the 1990s. Two of the three most extensive wildfire seasons in Alaska's 56-year record occurred in 2004 and 2005, and half of the most severe fire years on record have occurred since 1990.

Under changing climate conditions, the average area burned per year in Alaska is projected to double by the middle of this century. By the end of this century, area burned by fire is projected to triple under a moderate greenhouse gas emissions scenario and to quadruple under a higher emissions scenario. Such increases in area burned would result in numerous impacts, including hazardous air quality conditions such as those suffered by residents of Fairbanks during the summers of 2004 and 2005, as well as increased risks to rural Native Alaskan communities because of reduced availability of the fish and game that make up their diet. This would cause them to adopt a more "Western" diet, known to be associated with increased risk of cancers, diabetes, and cardiovascular disease.

SEA-ICE, FOREST and LAKE ECOSYSTEMS

Lakes are declining in area. Across the southern two-thirds of Alaska, the area of closed-basin lakes (lakes without stream inputs and outputs) has decreased over the past 50 years. This is likely **due to the greater evaporation and thawing of permafrost** that result from warming. A continued decline in the area of surface water would present challenges for the management of natural resources and ecosystems on National Wildlife Refuges in Alaska. These refuges, which cover over 77 million acres (21 percent of Alaska) and comprise 81 percent of the U.S. National Wildlife Refuge System, provide a breeding habitat for millions of waterfowl and shorebirds that winter in the lower 48 states.

Perhaps most vulnerable of all to the impacts of warming are Arctic ecosystems that rely on sea ice, which is vanishing rapidly and is projected to disappear entirely in summertime within this century.

- Algae that bloom on the underside of the sea ice form the base of a food web linking zooplankton and fish to seals, whales, polar bears, and people. As the sea ice disappears, so too do these algae.
- The ice also provides a vital platform for ice-dependent seals (such as the ringed seal) to give birth, nurse their pups, and rest.
- Polar bears use the ice as a platform from which to hunt their prey.
- The walrus rests on the ice near the continental shelf between its dives to eat clams and other shellfish. As the ice edge retreats away from the shelves to deeper areas, there will be no clams nearby.

The spring melt of sea ice in the Bering Sea has long provided material that feeds the clams, shrimp, and other life forms on the ocean floor that in turn provide food for the walruses, gray whales, bearded seals, eider ducks, and many fish. The earlier ice melt resulting from warming, however, leads to later phytoplankton blooms that are largely consumed by zooplankton near the sea surface, vastly decreasing the amount of food reaching the living things on the ocean floor. This will radically change the makeup of the fish and other creatures, with significant repercussions for both subsistence and commercial fishing.

Ringed seals give birth in snow caves on the sea ice, which protect the pups from extreme cold and predators. Warming leads to earlier snow melt, which causes the snow caves to collapse before the pups are weaned. The small, exposed pups

might die of hypothermia or be vulnerable to predation by arctic foxes, polar bears, gulls, and ravens. Gulls and ravens are arriving in the Arctic earlier as springs become warmer, increasing the birds' opportunity to prey on the seal pups.

Polar bears are the top predators of the sea ice ecosystem. Because they prey primarily on ice associated seals, they are especially vulnerable to the disappearance of sea ice. The rapid rate of warming in Alaska and the rest of the Arctic in recent decades is sharply reducing the snow cover in which polar bears build dens and the sea ice they use as foraging habitat. Female polar bears build snow dens in which they hibernate for four to five months each year and in which they give birth to their cubs. Born weighing only about 1 pound, the tiny cubs depend on the snow den for warmth. The bears' ability to catch seals depends on the presence of sea ice. In that habitat, polar bears take advantage of the fact that seals must surface to breathe in limited openings in the ice cover. In the open ocean, bears lack a hunting platform, seals are not restricted in where they can surface, and successful hunting is very rare. On shore, polar bears feed little, if at all. About two-thirds of the world's polar bears are projected to be gone by the middle of this century, and Alaska's polar bears are projected to be extinct within 75 years.

Continued warming will inevitably entail major changes in the sea-ice ecosystem, to the point that its viability is in jeopardy. Some species will become extinct, while others might adapt to new habitats. The chances of species surviving the current changes might depend critically on the rate of change. The current rates of change in the sea-ice ecosystem are very rapid relative to the life spans of animals including seals, walruses, and polar bears, and as such, are a major threat to their survival.