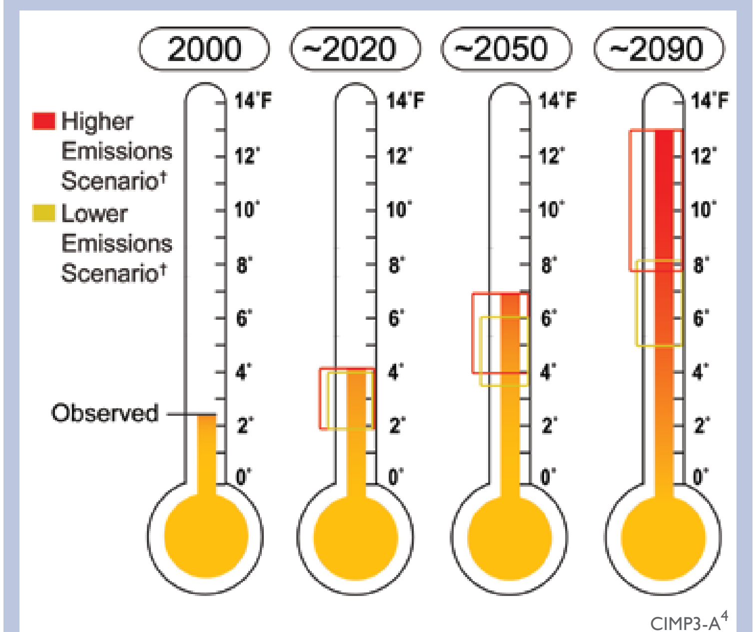
Alaska

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[1]. As a result, climate change impacts are much more pronounced than in other regions of the United States. The higher temperatures are already causing earlier spring snowmelt, reduced sea ice, widespread glacier retreat, and permafrost warming[1,2]. These observed changes are consistent with climate model projections of greater warming over Alaska, especially in winter, as compared to the rest of the country.

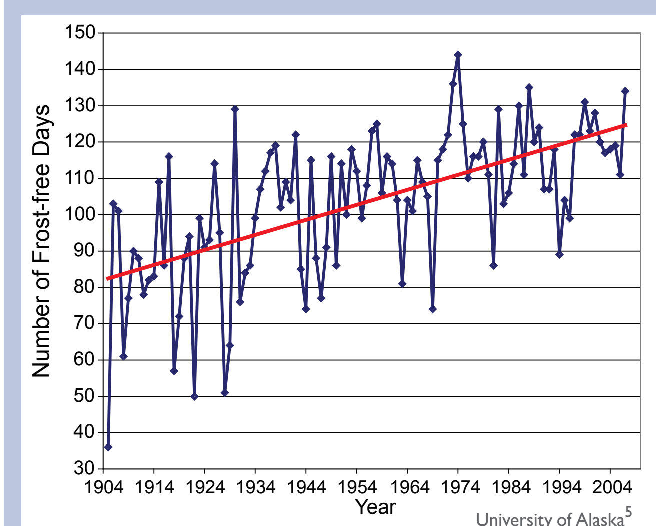
Climate models also project increases in precipitation over Alaska. Simultaneous increases in evaporation due to higher air temperatures, however, are expected to lead to drier conditions overall, with reduced soil moisture[3]. In the future, therefore, model projections suggest a longer summer growing season combined with an increased likelihood of summer drought and wildfires.

Observed and Projected Temperature Rise in Alaska



Alaska's annual average temperature has increased 3.4°F over the past 50 years. The observed increase shown above compares the average temperature of 1993 to 2007 to a 1960s and 1970s baseline, an increase of over 2°F. The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible. By the end of this century, the average temperature is projected to rise by 5 to 13°F above the 1960s and 1970s baseline.

Fairbanks Frost-free Season



Over the past 100 years, the length of the frost-free season in Fairbanks, Alaska, has increased by 50 percent. The trend toward a longer frost-free season is projected to produce benefits in some sectors and detriments in others.

Average annual temperatures in Alaska are projected to rise about 4 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 lower emissions†, and increases of 8 to 13°F with higher emissions†. Higher temperatures are expected to continue to reduce Arctic sea ice coverage. Reduced sea ice provides opportunities for increased shipping and resource extraction. At the same time, however, it increases coastal erosion, raises the risk of accidents as offshore commercial activity increases, and is expected to drive major shifts of marine species such as pollock and other commercial fish stocks.

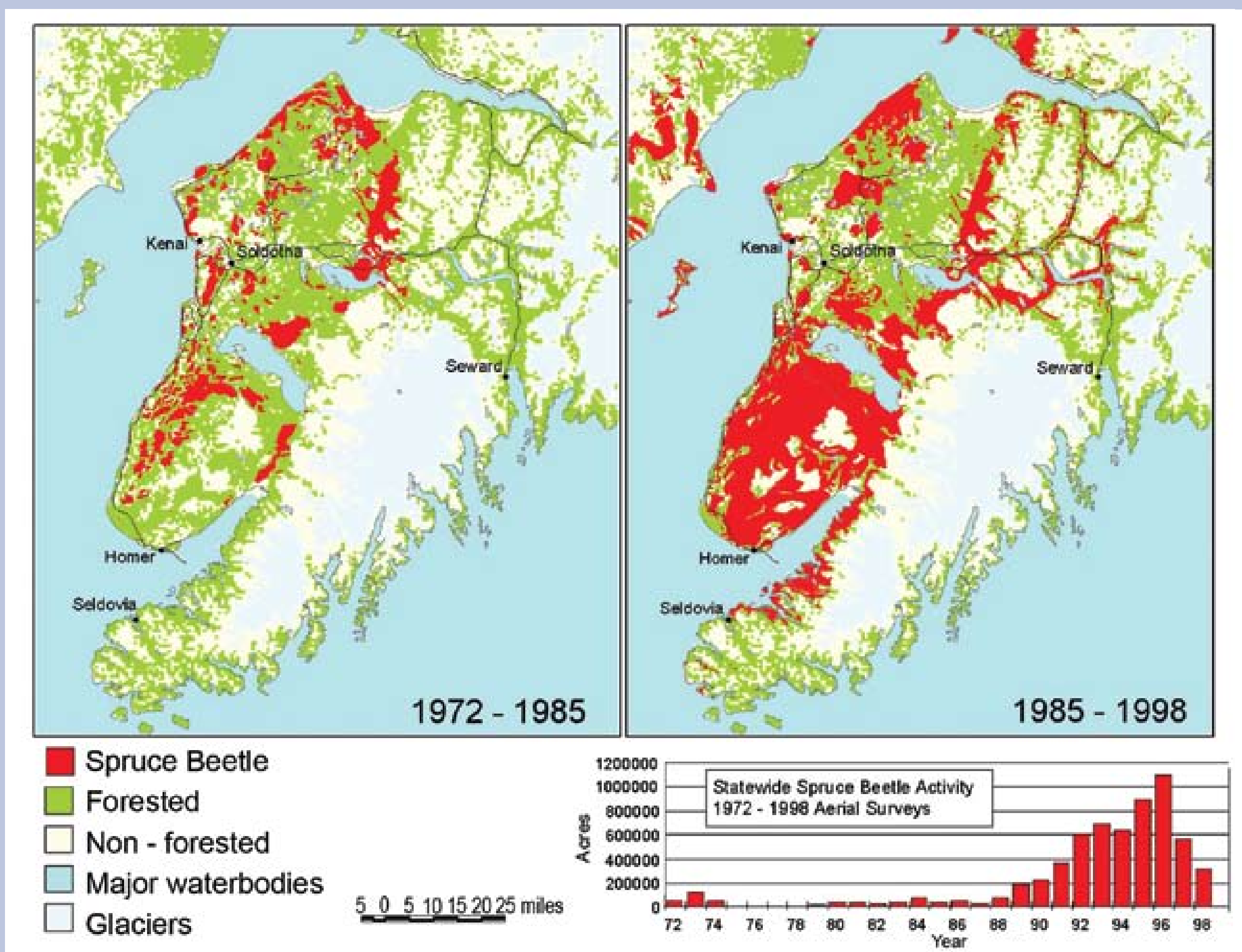
Summers are becoming longer and drier.

Between 1970 and 2000, the snow-free season increased by approximately 10 days across Alaska, primarily due to earlier snowmelt in the spring[6,7]. 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[8] and continued warming could lead to widespread death of trees[9]. The decreased soil moisture in Alaska also suggests that agriculture in Alaska might not benefit from the longer snow-free growing season.

Insect outbreaks and wildfires are increasing with warming.

Climate plays a key role in determining the extent and severity of insect outbreaks and wildfires[9,10]. During the 1990s, for example, south-central Alaska experienced the largest outbreak of spruce bark beetles in the world[9,11]. 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.

Alaska Spruce Beetle Infestation
Kenai Peninsula, 1971 to 1998



Berman *et al.*[12]

Warming in Alaska has caused insect outbreaks to increase. Red areas indicate spruce beetle infestations on the Kenai Peninsula.

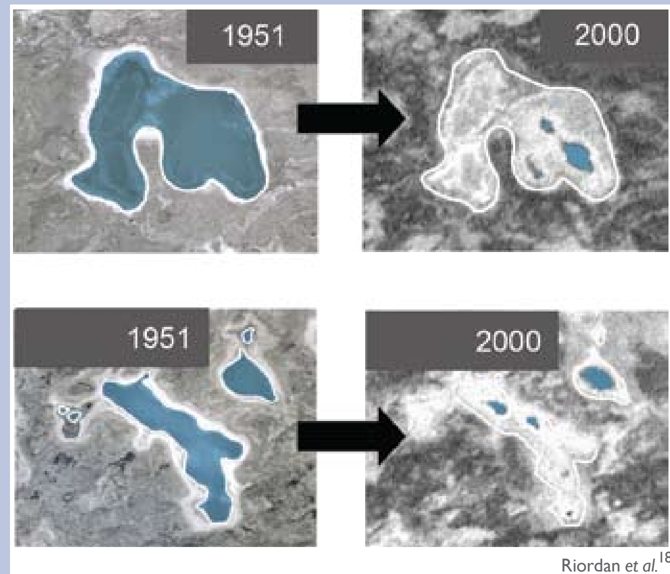
Prior to 1990, the spruce budworm was not able to reproduce in interior Alaska[9]. Hotter, drier summers, however, now mean that the forests there are threatened by an outbreak of spruce budworms[13]. This trend is expected to increase in the future if summers in Alaska become hotter and drier[9]. Large 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[14]. Under changing climate conditions, the average area burned per year in Alaska is projected to double by the middle of this century[10]. 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[15]. Such impacts on food security have the potential for significant impacts on health; shifts from a traditional diet to a more "Western" diet are known to be associated with increased risk of cancers, diabetes, and cardiovascular disease[16].

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[17,18]. 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. Wetlands are also important to Native peoples who hunt and fish for their food in interior Alaska. Many villages are located adjacent to wetlands that support an abundance of wildlife resources. The sustainability of these traditional lifestyles is thus threatened by a loss of wetlands.

Ponds in Alaska are Shrinking (1951-2000)
Yukon Flats National Wildlife Refuge, northeastern interior



Ponds across Alaska have shrunk as a result of increased evaporation and permafrost thawing. The pond in the top pair of images shrunk from 180 to 10 acres; the larger pond in the bottom pair of images shrunk from 90 to 4 acres.

Thawing permafrost damages roads, runways, water and sewer systems, and other infrastructure.

Permafrost temperatures have increased throughout Alaska since the late 1970s[19]. The largest increases have been measured in the northern part of the state[20]. 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.

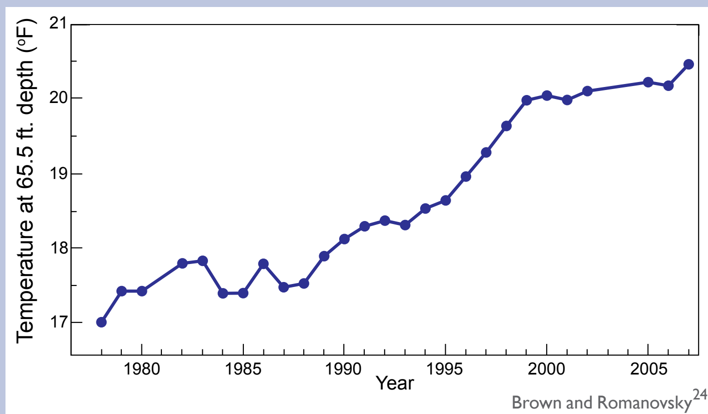
Land subsidence (sinking) associated with the thawing of permafrost presents substantial challenges to engineers attempting to preserve infrastructure in Alaska[21]. Public infrastructure at risk for damage includes roads, runways, and water and sewer systems. It is estimated that thawing permafrost 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[22]. Analyses of the additional costs of permafrost thawing to private property have not yet been conducted.

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[2,23].

Coastal storms increase risks to villages and fishing fleets.

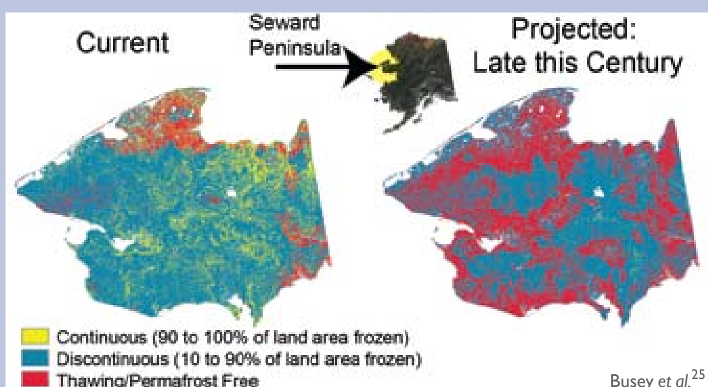
Alaska has more coastline than the other 49 states combined. Frequent storms in the Gulf of Alaska and the Bering, Chukchi, and Beaufort seas already affect the coasts during much of the year. Alaska's coastlines, many of which are low in elevation, are increasingly threatened by a combination of the loss of their protective sea ice buffer, increasing storm activity, and thawing coastal permafrost.

Permafrost Temperature
Deadhorse, northern Alaska



Permafrost temperatures have risen throughout Alaska, with the largest increases in the northern part of the state.

Changing Permafrost Distribution
Moderate Warming Scenario

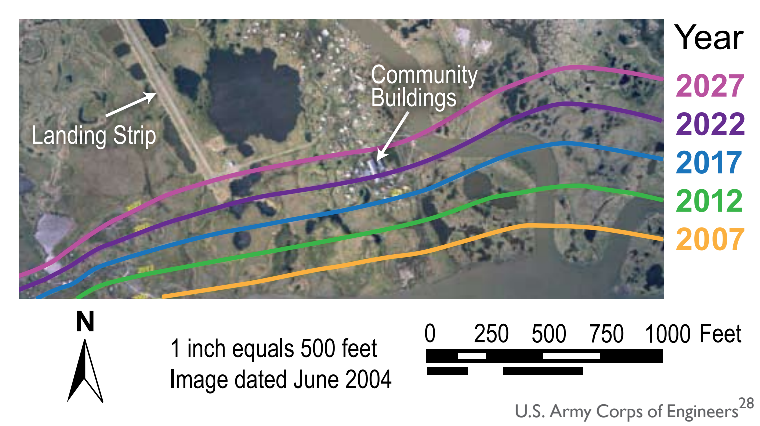


The graph shows projected thawing on the Seward Peninsula by the end of this century under a moderate warming scenario (Intergovernmental Panel on Climate Change scenario A1B, which is approximately half-way between the low- and high-emissions scenarios† used elsewhere in this report).

Adaptation: Keeping Soil Around the Pipeline Cool

When permafrost thaws, it can cause the soil to sink or settle, damaging structures built upon or within that soil. A warming climate and burial of supports for the Trans-Alaska Pipeline System both contribute to thawing of the permafrost around the pipeline. In locations on the pipeline route where soils were ice-rich, a unique above-ground system was developed to keep the ground cool. Thermal siphons were designed to disperse heat to the air that would otherwise be transferred to the soil, and these siphons were placed on the pilings that support the pipeline. While this unique technology added significant expense to the pipeline construction, it helps to greatly increase the useful lifetime of this structure[26].

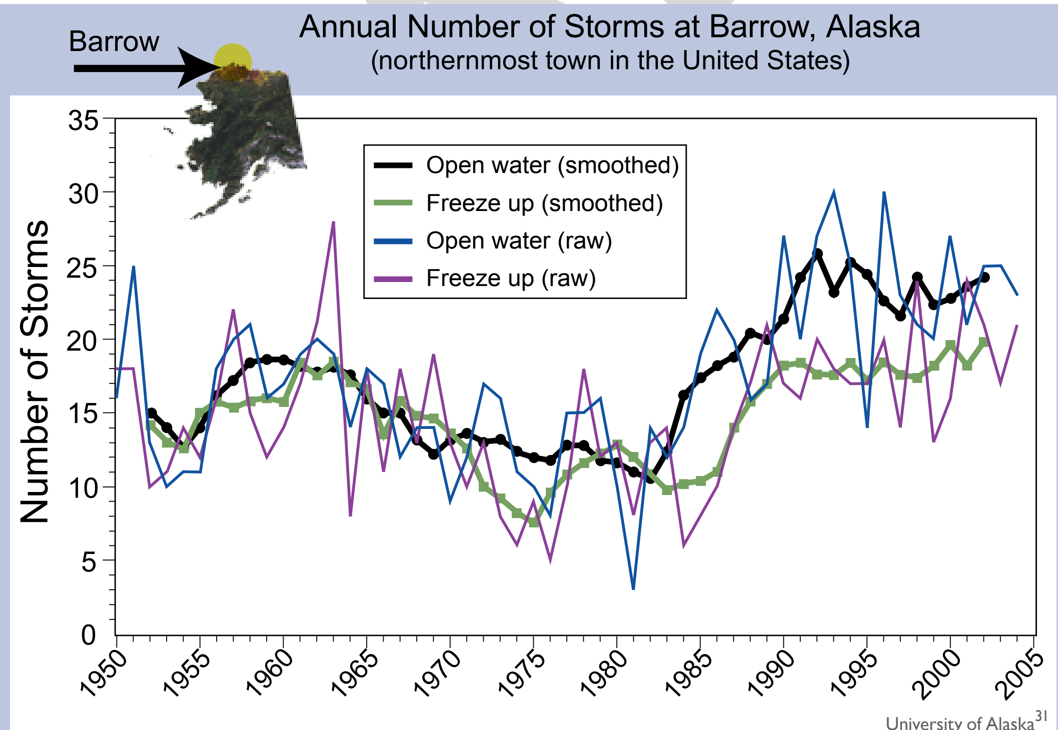
Projected Coastal Erosion
Newtok, western Alaska



Many of Alaska's coastlines are eroding rapidly; the disappearance of coastal land is forcing communities to relocate. The 2007 line on the image indicates where Newtok, Alaska's shoreline had eroded to by 2007. The other lines are projected assuming a conservative erosion rate of 36 to 83 feet per year; however, Newtok residents reported a July 2003 erosion rate of 110 feet per year.

Increasing storm activity in autumn in recent years[27] 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. High-wind 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 (see *Society* sector).

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[29,30]. 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[3]. 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.



The observed increase in coastal storms threatens commercial activity and communities in Alaska. Black and blue lines indicate the number of open-water storms (storms occurring in ice-free water); green and purple lines indicate the number of freeze-up storms (storms occurring with sea ice present).

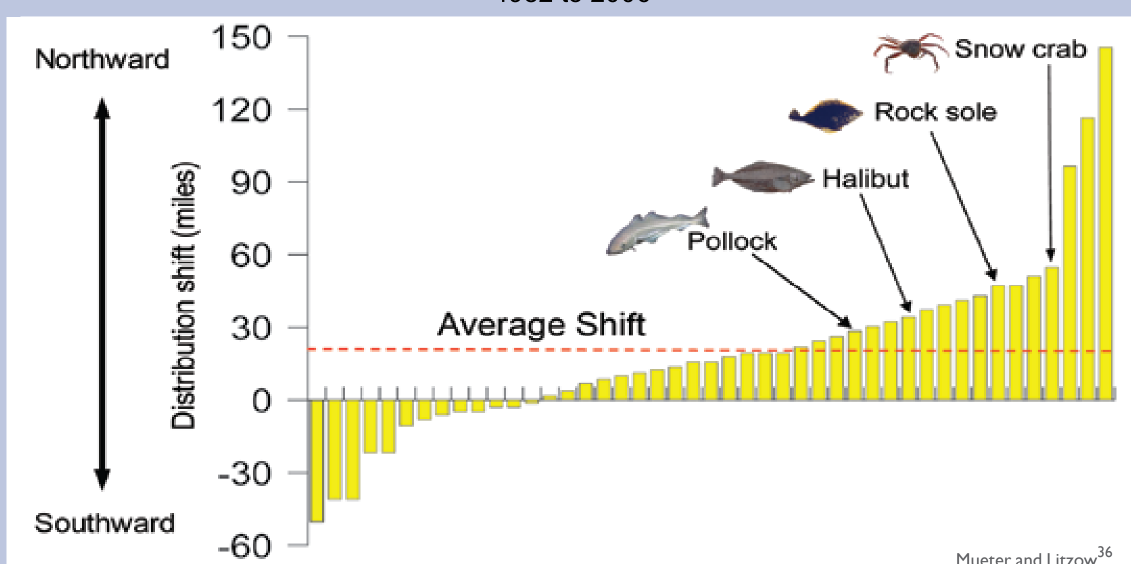
Displacement of marine species will affect key fisheries.

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, walruses, 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[32,33] (see *Ecosystems* sector and *Coasts* region).

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 the past decade, as air and water temperatures rose, sea ice in this region declined sharply. Populations of fish, seabirds, seals, walruses, 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[34] (see *Ecosystems* sector).

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[35].

Marine Species Shifting Northward
1982 to 2006



As air and water temperatures rise, marine species are moving northward, affecting fisheries, ecosystems, and coastal communities that depend on the food source. On average, by 2006, the center of the range for the examined species moved 19 miles north of their 1982 locations.