



### Fisheries

The fisheries in the Alaska region are among the most productive in the world. For example, over 28 percent of recent world total landings of fish, mollusks, and crustaceans have been harvested from the North Pacific Ocean and the Bering Sea. Walleye pollock (*Theragra chalcogramma*) landings alone exceeded 4.8 million metric tons in 1991, and accounted for approximately 5 percent of the combined world landings of fish, mollusks, and crustaceans. The productivity of these and other arctic fisheries is controlled by the interplay of biological and oceanographic processes. Changes in the velocity and direction of ocean currents affect the availability of nutrients and the disposition of larval and juvenile organisms, thereby influencing recruitment, growth, and mortality.

The effects of climate variation on some arctic fish populations are fairly well known in terms of empirical relationships but generally poorly known in terms of mechanisms. Data on commercially exploited species in the Bering Sea date back to the mid-1960s for some groundfish species and to the early part of this century for some stocks of Pacific salmon, Pacific halibut, and Pacific herring. The survival and growth of salmon depend on the influence of environmental factors in freshwater and oceanic life-stages. Elevated stream temperature, stream flow rates, and air temperatures have been identified as potentially beneficial factors (Rogers, 1984).

It has also been long known that salmonid populations show responses to changes in climatic conditions (Pearcy, 1984). The effect of warming has been positive for most stocks; some of the highest salmon catches on record in Alaska have occurred in the last decade. While there has

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still been interannual variability, catches and populations in this later period have been above average at the least. Positive correlations between salmon returns and positive air and sea surface temperature anomalies, reduced Bering Sea ice cover, and negative Southern Oscillation Index anomalies have been reported by Quinn and Marshall (1989), among others. It is likely, however, that salmon have a rather narrow range of tolerance and that the warming of the mixed layer is progressing to the point where the stocks are in danger.

Many groundfish stocks have also shown a positive response during this period (NRC, 1996). Conversely, some stocks have had a negative response. King crab stocks in the eastern Bering Sea and Kodiak declined during the 1980s, and this decline is thought to be due to a combination of factors including environmental effects, overfishing, natural mortality, and changes in reproductive parameters.

Less well understood are the effects of climate change on the spatial distributions of fish populations. While declines and increases in fish populations are often accompanied by contractions and expansions in range, this need not be the case. For Pacific salmon, it is well known from high seas studies that there are threshold temperature ranges that affect distribution. As a consequence, it is not well understood how climate change might affect the behavior of harvesters reacting to changes in fish behavior.

Factors other than climate change affect fisheries, including changes in fish prices, changes in technology for fish harvesting and utilization, changes in fisheries management and changes in societal needs and preferences. All of these make it difficult to fully assess the impacts of climate change on arctic fisheries. Nevertheless, the following impacts have been observed in recent years (BESIS, 1997; 1998; 1999). The signs following the bullet statements are: beneficial +; detrimental -.

- Significant correlations have been observed between abundance and/or harvests of various fish species. For example, major increases in catches of some Alaskan salmon have occurred in recent years (+).



- On the other hand, salmon stocks in Western Alaska, the Pacific Northwest and Canada have decreased, illustrating their narrow range of temperature tolerance (-).

Other impacts likely to occur if climate warming continues include:

- Climate change is likely to reduce the abundance of some species while increasing the abundance of others, affecting commercial harvests (+ and -).
- It is reasonable to assume that climate change could halve or double average harvests of any given species; some fisheries may disappear, other new ones may develop. This could increase or decrease local economies by hundreds of million dollars annually (+ and -).

### Forestry

Tree growth in the boreal forest depends critically on both temperature and precipitation (Fig. 8).

Much of the risk to the boreal forest from climate change associated with global warming involves decreases in effective moisture sufficient for forest growth, tree mortality from insect outbreaks, probability of an increase of large fires, and changes caused by thawing of permafrost. The effects of a projected warming would depend critically on accompanying changes in precipitation.

One of the characteristic features of the boreal forest is that insect outbreaks are a dominant disturbance factor and that outbreaks can result in tree death over vast areas (Juday, 1996; Fleming and Volney, 1995). The probability of an increase in large fires in the boreal forest is also substantial, largely because observations in Alaska have

shown that the overall area burned is well correlated with the average summer temperature. The total area burned in North America has increased substantially in recent decades (Fig. 9, from Kasischke and Stocks, 1999). The new landscape produced by burning probably would support a significantly lower proportion of conifers and instead there are likely to be large areas of relatively pure hardwood stands that would be relatively fire-resistant.

Changes to the boreal forest that would be caused by thawing of permafrost are potentially so extensive and so profound that it is difficult to summarize them. The major pathways of change would involve an unstable transition

when surface subsidence from the melting of the ground ice content would alter ground contours and collect and reroute water. Once the thawing had taken place the site productivity should increase substantially, but the vegetation community that would develop would probably not be similar to that which grew on permafrost. The disappearance of an impervious frozen layer would allow precipitation to infiltrate the ground much more effectively compared to the tendency of permafrost to shed rain immediately. The hydrology of streams and rivers would be quite different.

The following impacts have been observed in Alaska in recent years (BESIS, 1997; 1998; 1999):

- The warmer and drier climate in Southeast Alaska has caused forest problems such as increased fire frequency and insect outbreaks which have reduced economic forest yields (-).
- Insect (spruce bark beetle) outbreaks in Alaska have recently become the most widespread infestations observed to date (-).
- Forest fires in a fairly newly established vacation community near Anchorage, Alaska destroyed 454 structures in 1996 at a cost of about \$80 million (-).
- A warmer climate has lengthened the growing season and growing degree days by 20% for agriculture and forestry in Alaska, with the potential of producing higher yields (+).
- Boreal forests are expanding north at the rate of 60 miles (100 km) for each 2°F (1°C) increase, thus increasing potential yields in the long term (+).

Other impacts likely to occur if climate warming continues include:

- New settlements of vacation homes in northern forest areas increase the risk of wildfire damage and associated costs (-).
- By far the most important effect of climate change is the risk of catastrophic wildfire in settled areas (-).
- One projection (Rupp et al., 1999) shows a 200% increase in the total area burned per decade, leading to a deciduous forest-dominated landscape on the Seward Peninsula, presently dominated by tundra vegetation (+ and -).
- Changes in temperature and precipitation will affect coastal forest hydrology and salmon spawning streams important to subsistence, commercial and sport fisheries (-).

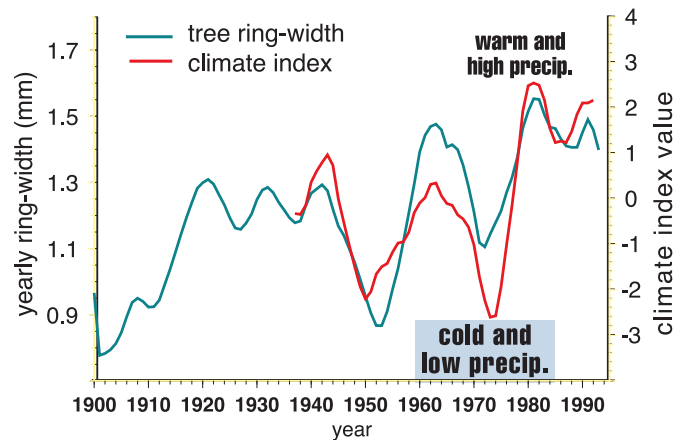


Fig. 8. Tree ring-width as a function of a climate index (temperature and precipitation), showing the favorable growing conditions during warm and high precipitation periods. (Juday, 1999)

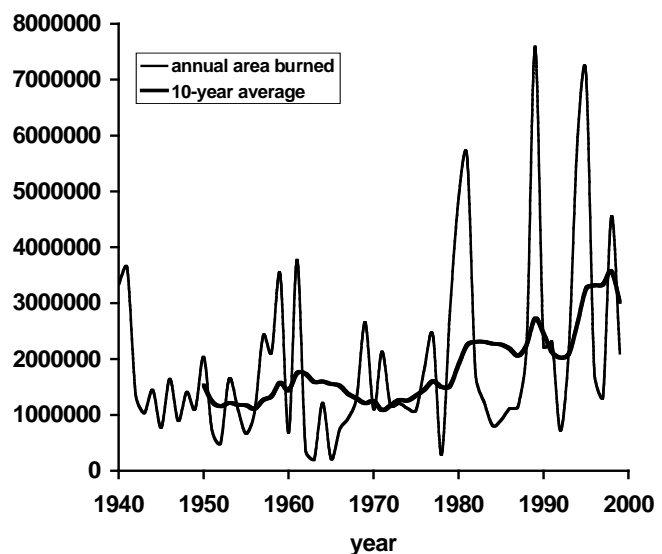


Fig. 9. Total area of boreal forest burned in North America. This plot contains a 10-year running average as well as the annual area burned for the time period 1950 to 1999 (Kasischke and Stocks, 1999).



- Hydrologic changes in forested watersheds include warmer stream temperatures and lower summer flow from low elevation streams, higher flow from higher elevation streams (+ and -).
- There are likely to be changes in the range of vertebrate animals and changes in productivity of aquatic ecosystems in forestlands (+ and -).
- Increased damage is likely to occur through windthrow and blowdown in coastal forests (-).
- Other long-term effects might include: general treeline advance in elevation and latitude; colonization of formerly glaciated lands; transition of tree species and ecotypes (+ and -).

### Agriculture

Alaska is involved in the production of a diverse array of agricultural products and enterprises, ranging from animals for sport and pleasure to crops and animals for food, clothing and shelter. The agricultural production includes:

- Grass fields for feed and pastures
- Grains for animal feed and food
- Potatoes
- Dairy animals
- Furred animals
- Land reclamation
- Exotic animal breeds (buffalo, elk, muskoxen, llamas, and yak)
- Vegetables
- Cattle
- Dogs
- Greenhouse products

Forestry and reindeer herding can also be considered to be part of agricultural production but both are discussed in

greater detail elsewhere. The most important climatic factor for agriculture in Alaska is precipitation. Another important factor, particularly in reference to climate change, is permafrost.

### i) Negative Impacts of Climate Change on Agricultural Production

As the temperature rises, the permafrost interface with unfrozen ground/seasonal frost will most likely recede. Regions that now contain soils with intermittent permafrost may become permafrost free. This could affect the fragile water balance in areas where precipitation is low. If the temperature rise is extreme, desertification could occur. There is already increasing erosion and loss of organic materials in the entire circumpolar region. Drying of the soil will cause this to increase. Revegetation programs are needed now and this need would increase accordingly.

There are three areas of production that could be severely affected if temperatures should rise. In traditional field agriculture it may be possible to avoid massive damages by irrigation, controlled environments, revegetation programs and conservation-oriented soil management. In forestry (see section above), problems will be intense and will include loss of soil moisture, severe insect attacks, increased fires, as well as a negative CO<sub>2</sub> balance which will feed back on the global climate. In reindeer herding, short-term damages will most likely be negligible. Long-term damages, however, will result from changes in vegetation and degradation of pasture quality (Weller and Lange, 1999).

### ii) Positive Effects of Climate Change on Agricultural Production

As the climate changes and temperatures rise, agricultural endeavors could benefit. There is a potential for new crops and animals in the circumpolar north. Temperature increases along with adequate moisture will mean higher productivity per unit. In short, the circumpolar north's agriculture could become important in world trade in more than just niche crops and livestock. As temperatures rise globally and if desertification occurs in more temperate zones, the economic frontier for production could move north and the risks of production there will be lowered. Land areas appropriate for both crop and animal production exist in Alaska. An important factor in this movement

