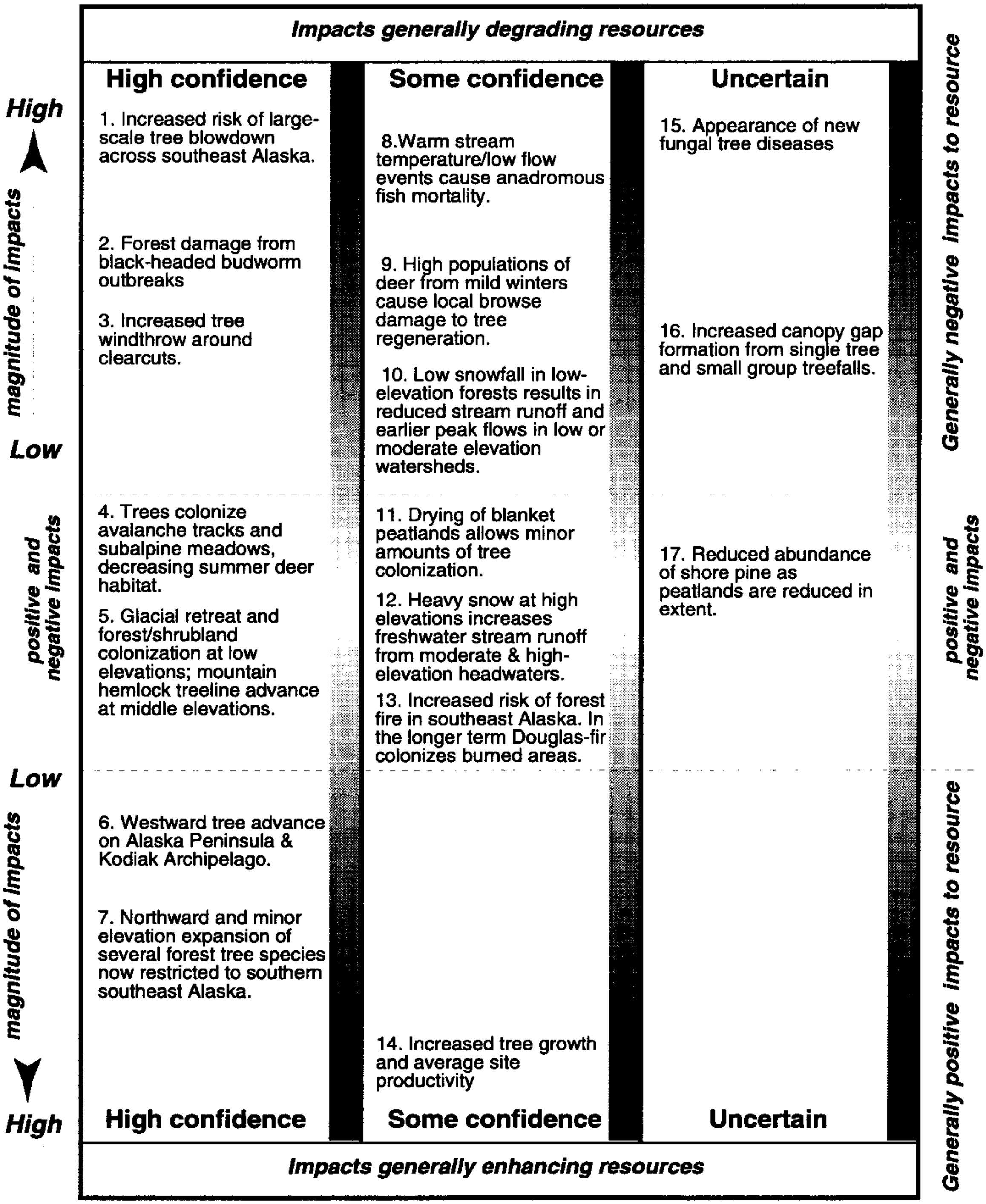
Figure 3.16 Potential primary or direct global change impacts on coastal forest in Alaska



Impacts generally degrading resources

	High confidence	Some confidence	Uncertain	
High ▲ magnitude of impacts Low	1. Increased risk of large-scale tree blowdown across southeast Alaska. 2. Forest damage from black-headed budworm outbreaks 3. Increased tree windthrow around clearcuts.	8.Warm stream temperature/low flow events cause anadromous fish mortality. 9. High populations of deer from mild winters cause local browse damage to tree regeneration. 10. Low snowfall in low-elevation forests results in reduced stream runoff and earlier peak flows in low or moderate elevation watersheds.	15. Appearance of new fungal tree diseases 16. Increased canopy gap formation from single tree and small group treefalls.	Generally negative impacts to resource
positive and negative impacts	4. Trees colonize avalanche tracks and subalpine meadows, decreasing summer deer habitat. 5. Glacial retreat and forest/shrubland colonization at low elevations; mountain hemlock treeline advance at middle elevations.	11. Drying of blanket peatlands allows minor amounts of tree colonization. 12. Heavy snow at high elevations increases freshwater stream runoff from moderate & high-elevation headwaters. 13. Increased risk of forest fire in southeast Alaska. In the longer term Douglas-fir colonizes burned areas.	17. Reduced abundance of shore pine as peatlands are reduced in extent.	positive and negative impacts
Low magnitude of impacts ▼ High	6. Westward tree advance on Alaska Peninsula & Kodiak Archipelago. 7. Northward and minor elevation expansion of several forest tree species now restricted to southern southeast Alaska.	14. Increased tree growth and average site productivity		Generally positive impacts to resource
	High confidence	Some confidence	Uncertain	

Impacts generally enhancing resources

Boreal Forest

Much of the risk to Alaska boreal forest from climate change scenarios associated with global warming involve (1) decreases in effective moisture sufficient for forest growth, (2) tree mortality from insect outbreaks, (3) probability of a transition period of large fires, (4) interference with reproduction of white spruce, and (5) changes caused by thawing of permafrost.

The effects of a projected warming of 4° C in summer and 5° C in the winter for interior Alaska (Weller et al. Chapter 2) would depend critically on accompanying changes in precipitation, if any. Hogg and Hurdle (1995) applied climate changes that would be caused by a doubling of CO_2 to 254 climate stations in the boreal forest region of western Canada. Previous studies have found that the southern boreal forest currently is restricted to areas where annual precipitation is greater than total water needed by vegetation (potential evapotranspiration[4]). They found that an 11% increase in precipitation would not be sufficient to meet the increased water demand caused by a projected warming of 4° to 5°C. Under such a climate, half of the western Canadian boreal forest would be transformed into aspen parkland, in which conifers are absent and aspen is restricted to stunted patches within a grassland. Aspen parkland occurs in the interior Alaska landscape today as a narrow zone separating steep south bluff grasslands and boreal forest. Warming of the interior Alaska climate without an increase in precipitation sufficient to supply water to the forest in the driest part of the year (the mid and late summer) would probably transform large areas of productive lowland Alaska boreal forest to aspen parkland.

Insect outbreaks are a dominant disturbance factor in the boreal forest and can cause tree death over vast areas (Juday 1996, Fleming and Volney 1995). The risk from future global change to the Alaska boreal forest includes both (1) increased damage from defoliators and tree-boring insects that have appeared in outbreaks to date, and (2) damage from outbreaks of insect species that have not been observed to produce landscape-level effects on Alaska's forests in the recent past. An example of the latter is the bronze birch borer (*Agrilus anxius*), a species which is present in Alaska at relatively low levels today. The bronze birch borer has been identified as a species that can cause severe damage to paper birch and may be effective in limiting birch along the southern margin of its distribution (Haak 1996).

The probability of a transition period of large fires in the Alaskan boreal forest is substantial, largely because (1) overall area burned is well correlated with the average summer temperature (Figure 3.15), and (2) once ignited, large areas of standing dead forest will be difficult to keep from burning. Fire is an important disturbance agent in the boreal forest, and most of the Alaska boreal forest system displays adaptations to it. Fire removes organic accumulations that would otherwise depress site productivity, prepares seedbeds, and renews early successional vegetation important as browse species for many harvested wildlife species. The main global change issues associated with fire in the boreal forest are the scale, timing, pattern, and intensity of fire. Any of those fire disturbance characteristics could pose unique problems with significant consequences to the forest. Less certain is the fire potential following a transition period of large fires. The new landscape probably would support a significantly lower proportion of conifers and instead large areas of relatively pure hardwood stands that would be relatively fire-resistant. However, a warmer and drier climate might still cause a significant amount of burning in the new landscape.

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[4] Potential evapotranspiration is the amount of water loss from the land surface and soil both directly and through vegetation into the atmosphere that a given climate will cause

The disruption of white spruce reproduction in a warmer and more stressful climate would have both significant biological and economic effects on the Alaskan boreal forest. Even the uncertainty over this potential becomes a forest management issue because forests are managed over the relatively long lifespans of the trees. If reproduction of the desired species is not certain in the future, forest management plans may need to be adjusted today. To some degree artificial tree regeneration can mitigate this problem, but issues of costs and other land management objectives must then be addressed.

Changes to the Alaskan 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, reroute, and alter 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 that which grew on permafrost (although there is little data on which to base a prediction). The disappearance of a 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 considerably altered.

The following potential changes in the Alaska boreal forest under the projected climate change scenarios are summarized according to confidence and degree of impact in Figure 3.17.

- A period of widespread insect-caused mortality and severe/extensive forest fires across interior and southcentral Alaska would occur.
- Earlier onset of plant growth in the spring and prolonged growing seasons in the fall ("shoulder seasons") will deepen the regional moisture deficit at low elevation forest sites. The Tanana and Yukon Valleys will become more like the aspen parkland typical of Edmonton, Alberta.
- Aspen, birch, and tamarack forests would experience more frequent and widespread defoliation by insects, including the large aspen tortrix (*Choristoneura conflictana*), spear-marked black moth (*Rheumaptera hastata*), birch leaf roller (*Epinotia solandriana*), larch sawfly (*Pristiphora erichsonii*), and bronze birch borer (*Agrilus anxius*).
- Forest regeneration failure and drought-induced tree mortality on low-elevation south slopes would occur, followed by grassland expansion.
- Forest expansion into tundra would occur westward on the Seward Peninsula.
- Forest expansion into tundra would occur upward in elevation in a relatively limited zone in the Brooks Range, Alaska Range, Chugach Mountains, and Yukon-Tanana Uplands.
- Following the fires, there would be a shortage of white spruce seed for regeneration because of unfavorable climate, population reduction, and tree isolation. Newly regenerating forests will be composed of greater proportions of aspen, birch, grassland, and shrubland than the current landscape.
- Fire frequency would increase in general, and the average fire return interval in any given forest landscape will be decreased. More frequent fires will help maintain grassland against forest recolonization.

- Permafrost would spontaneously (regardless of surface-disturbing events) thaw in most locations south of the Yukon River. Effects such as altered drainage and water quality and tree toppling and death would occur during a transition period while the thawing is underway. For at least a period of a few decades numerous new thaw ponds and lakes would form, and methane would be released from the thaw lakes as a result of anaerobic decomposition of organic matter.

- On a regional basis, the change in forest composition from conifer to hardwood would increase the input of high quality hardwood litter into streams, increasing aquatic productivity and ultimately fish populations. On an individual site basis, if forest composition remains stable the quality of hardwood litter produced under warmer, drier, and elevated CO_2 conditions would contain increased tertiary compounds and be of lower quality and locally reduce aquatic productivity.

- Ultimate effects of permafrost thawing will occur such as greater plant productivity because of warmer soil, increased water storage capacity, and lowering of the water table and drying of soil once thawing is completed.

- White spruce cone crops will be produced less frequently because of sustained periods of warm and dry weather.

- Wildland fire frequency may locally decrease once white spruce is significantly reduced and aspen and paper birch make up a greater proportion of forest cover.

- Cold-adapted vertebrate animals that are limited by warm climate factors may experience poorer productivity and locally abandon current distributions and establish new distributional limits.

- The taiga, especially along its southern extent, could become a net carbon source, not a carbon sink, resulting in elevated atmospheric CO2 levels because of greater wildland fire frequency, more widespread fires, higher soil temperatures, and reduced conifer dominance causing increased carbon decomposition and reduced soil carbon storage. Along the northern margin of the taiga the opposite could occur.

- Widespread changes in land vegetation cover will change the local albedo (reflectivity of the Earth's surface). An increased area of newly burned land surfaces will be associated with increased atmospheric convection, resulting in increased lightning strikes and local short-term increases in convective precipitation.

- As climate warms on both sides of the Bering Straits region, the boreal forests of North America and Eurasia could expand toward each other and initiate an exchange of organisms, especially the most mobile species such as birds and bird-dispersed plants.

- Earthworms may expand their distribution into the boreal regions of Alaska and significantly increase the efficiency of forest litter decomposition, increasing site productivity and decreasing carbon storage in the taiga.

- Warm-adapted vertebrate wildlife species that are limited by winter cold may experience higher productivity, survival, and expansion of distributions, and then produce changes through plant consumption and dispersal activities and other factors.

Figure 3.17 Potential primary or direct global change impacts on boreal forest in Alaska

Impacts generally degrading resources

High ▲ ***magnitude of Impacts*** **Low**	**High confidence**	**Some confidence**	**Uncertain**	***Generally negative impacts to resource***
	1. Widespread insect-caused tree mortality and severe/extensive forest fire. 2.Earlier springs and later falls deepen deficit of effective precipitation. Great expansion "aspen parkland". 3. More frequent and widespread defoliation of aspen, birch, and tamarack. 4. Drought-induced tree mortality and tree regeneration failure on south slopes - grassland expansion.	7. White spruce cone crops are less able to effectively disperse into large disturbed areas. 8. Forest fire magnitude increases & fire return interval decreases, helping maintain grassland against forest invasion.	12. White spruce cone crops are less frequent. 13. White spruce declines markedly in abundance, and aspen and paper birch increase (which may ultimately reduce forest susceptibility to fire). 14. Vertebrate animals that are limited by warm climate experience poorer survival. 15. The boreal forest no longer serves as an atmospheric sink for carbon and becomes a short-term carbon source.	
positive and negative impacts	5. Westward expansion of boreal forest, especially on Seward Peninsula.	9. Thawing of permafrost alters forest hydrology and initiates erosion and plant succession. Numerous thaw lakes, increased methane. 10. Changes in forest litter quality at both the stand and individual plant level increase and decrease aquatic productivity.	16. Widespread land cover change alters albedo (reflectivity) and causes local increases in convective storms. 17. A greater number of Eurasian and North American forest species, especially animals, are exchanged.	***positive and negative impacts***
Low ***magnitude of Impacts*** ▼ **High**	6. Forest expansion through movement of treeline upward in elevation.	11. Warmer soils cause increased tree growth and average site productivity where moisture is not limiting.	18. Earthworms colonize Alaska and enhance forest decomposition, increasing forest site productivity. 19. Vertebrate animals that are limited by winter cold experience better productivity.	***Generally positive impacts to resource***
	High confidence	**Some confidence**	**Uncertain**	

Impacts generally enhancing resources

3.4 Additional research needed

- Determine the kinds of new forests, tundra, and shrublands that will develop following large scale fire in current and warmer climate conditions.
- Identify and obtain monitoring information on plant and animal species that are expected to expand significantly in abundance or extent or colonize Alaska as a result of climate change.
- Identify additional insect species with the potential to experience population buildups in a warmer Alaska climate and/or a climate that stresses forests and other economically important vegetation.
- Identify the specific factors (climatic, plant-insect chemistry, genetic, forest management, historic or accidental) that allow or promote the buildup of insects to damaging outbreak levels on Alaska vegetation.
- Conduct more accurate and timely monitoring of forest insect population levels (pre- and post- outbreak).
- Conduct research and monitoring of tree diseases likely in a warmer and/or more stressful climate.
- Initiate research on market and product potentials of Alaska boreal hardwood trees and their growth characteristics and responses under recent and warmer climates.
- Identify wildlife species that are currently or are likely to be negatively affected by climate warming and landscape change, giving priority attention to important harvested resources, and depleted or threatened species.
- Determine the effects of changing vegetation inputs on freshwater fish stocks and aquatic productivity.
- Determine the likely interactive effects of climate change, such as higher winter survival of animals leading to change in vegetation composition or structure.

3.5 Mitigation and adaptation measures

- Establish an adaptive forest management policy. Plan and identify now, with public involvement in advance of events, land allocations that will pre-authorize the expeditious salvage of wind/fire/insect-killed timber once it has died on areas where timber management is selected as the eventual land use. Export of insect-affected timber may not be possible because of quarantine restrictions, so local uses and markets may need to be developed or enhanced. Identify best management practices to treat affected landscapes for a variety of future values including timber production.
- Design clearcut stand edges in the coastal forest to be more windfirm.
- Design and fund a forest regeneration program to enhance or supplement forest responses to global warming effects. Prepare to plant increased amounts of local seed sources of white spruce and to supplement it on managed or salvage logged sites. Launch a tree improvement program to find the best adapted genotypes of white spruce in a changing environment.

- When conducting marketing efforts for Alaska forest resources, give priority to industries that use boreal hardwoods.
- Reduce the number of trees in overstocked managed stands to reflect lower actual carrying capacity in new higher-stress environments. Manage more carefully to avoid creating dense stagnant stands that could serve as local initiation points for widespread tree-damaging insect outbreaks.
- Promote a diverse mix of tree and other plant species.
- Maintain highly qualified fire suppression forces, enhance capabilities to apply insect reduction measures on strategically identified resources of high value, and develop the ability to rapidly adopt new biological control measures for insect and disease outbreaks.
- Establish an integrated system to apply new research and enhanced monitoring information into the process of adjusting consumption of harvested animal species so that local and total consumption do not harm species that are coping with rapidly changing environments.

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