Patterns of 20th Century Treeline Advance in Alaska: Insights from Dendrochronology and Permanent Plot Studies

Andrea H. Lloyd and Christopher L. Fastie
Middlebury College, Vermont
http://gec.cr.usgs.gov/archive/alaska/

This image shows trends in mean surface air temperature over the period 1960 to 2011. Notice that the Arctic is red, indicating that the trend over this 50 year period is for an increase in air temperature of more than 2° C (3.6° F) across much of the Arctic, which is larger than for other parts of the globe. The inset shows linear trends over the period by latitude.

—Credit: NASA GISS

https://nsidc.org/cryosphere/arctic-meteorology/climate_change.html
CO₂ concentration

air temperature

forested area

surface albedo
above treeline

treeline
Fig. 2. Decade in which the population of ≥5 trees/ha was established at eight sites in Alaska. Site names and references are as indicated in Fig. 1.
How fast is treeline expanding?

**2005**: 0.11 watts per m² from 11,600 km² of new forest

**maximum**: all tundra converted to forest
Year in which tree density in tundra will reach current treeline tree density:

<table>
<thead>
<tr>
<th>Site</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska Range: Monahan</td>
<td>2067</td>
</tr>
<tr>
<td>Alaska Range: Canyon</td>
<td>2165</td>
</tr>
<tr>
<td>Alaska Range: Wrangell</td>
<td>2033</td>
</tr>
<tr>
<td>Alaska Range: Usibelli</td>
<td>2083</td>
</tr>
<tr>
<td>White Mts: Eagle Summit</td>
<td>2130</td>
</tr>
<tr>
<td>White Mts: Nome Creek</td>
<td>2103</td>
</tr>
<tr>
<td>White Mts: Twelvemile Summit</td>
<td>2006</td>
</tr>
<tr>
<td>Seward: Fox Braid</td>
<td>2031-2036</td>
</tr>
<tr>
<td>Seward: Bear Creek</td>
<td>2004</td>
</tr>
</tbody>
</table>
Key findings:

• Treeline expanded throughout Alaska.
Seedling density increased significantly from 1998 to 2014. (F=4.2133, P=0.056)
Observed # of spruce in 2014
Key findings:

- Treeline expanded throughout Alaska.
- From 1998 to 2014, the observed rate of increase in tree density at treeline exceeded predictions.
area burned (%)

Treeline  
Above treeline

Elevation

$t=1.2563$, $df=4$, $P=0.2615$
Seedlings killed (%)

Elevation

\[ t = 2.2469, \ df = 4, \ P = 0.08795 \]
Age structure of seedlings alive in 2009

Fire

Number of seedlings

Establishment year

1990 and before
1991-1992
1993-1994
1995-1996
1997-1998
1999-2000
2001-2002
2003-2004
2005-2006
2007-2008

Treeline
Above treeline
Seedling composition in 2009

- Treeline: Aspen and Spruce
- Above Treeline: Aspen
Aspen
Elevation: $F=2.187$, $P=0.158$
**Year: $F=15.318$, $P=0.001$**
Elevation * Year: $F=1.864$, $P=0.191$

Spruce
Elevation: $F=3.178$, $P=0.093$
Year: $F=2.954$, $P=0.105$
Elevation * Year: $F=2.708$, $P=0.119$
Key findings:

• Treeline expanded throughout Alaska.

• From 1998 to 2014, the observed rate of increase in tree density at treeline exceeded predictions.

• Fire at treeline initiates rapid switches in forest composition.
Thank you

• Bonanza Creek LTER (DEB-1026415)

• National Science Foundation (ARC-0902088 and OPP-9731717)