Climate Change — Effects on Invasive Species and Their Impacts on Forests and Rangelands

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National Assessment of Invasive Species
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Chapter 4—Effects of Climate Change on Invasive Species

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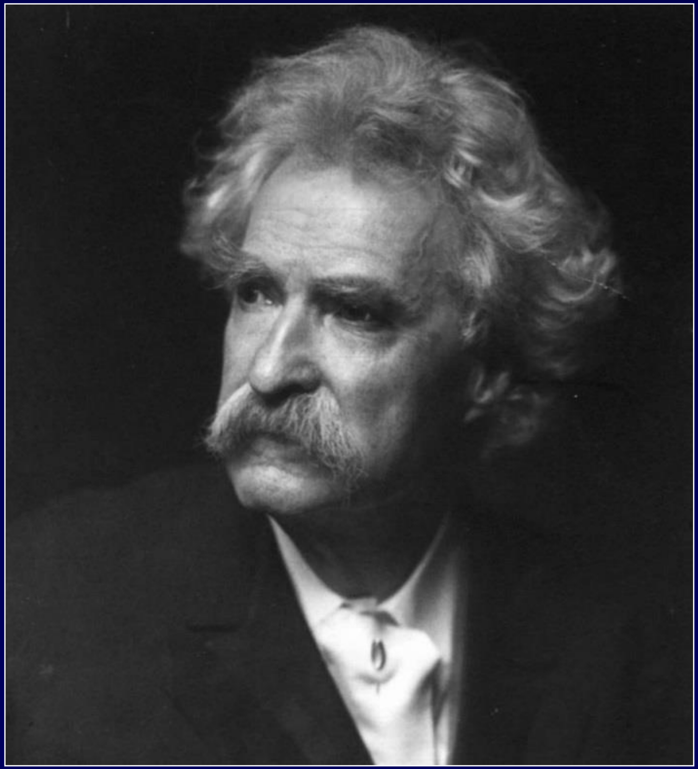
Green spruce aphid on Sitka spruce, Whale Park, Sitka, Alaska, 2005.

Outline

1. Climate change
2. Direct effects
3. Indirect effects on resource availability and interactions with other species (section 4.5)
4. Humans and other practical matters

Subalpine fir killed by balsam woolly adelgid, Uinta-Wasatch-Cache National Forest, Utah, 2018.

Climate change

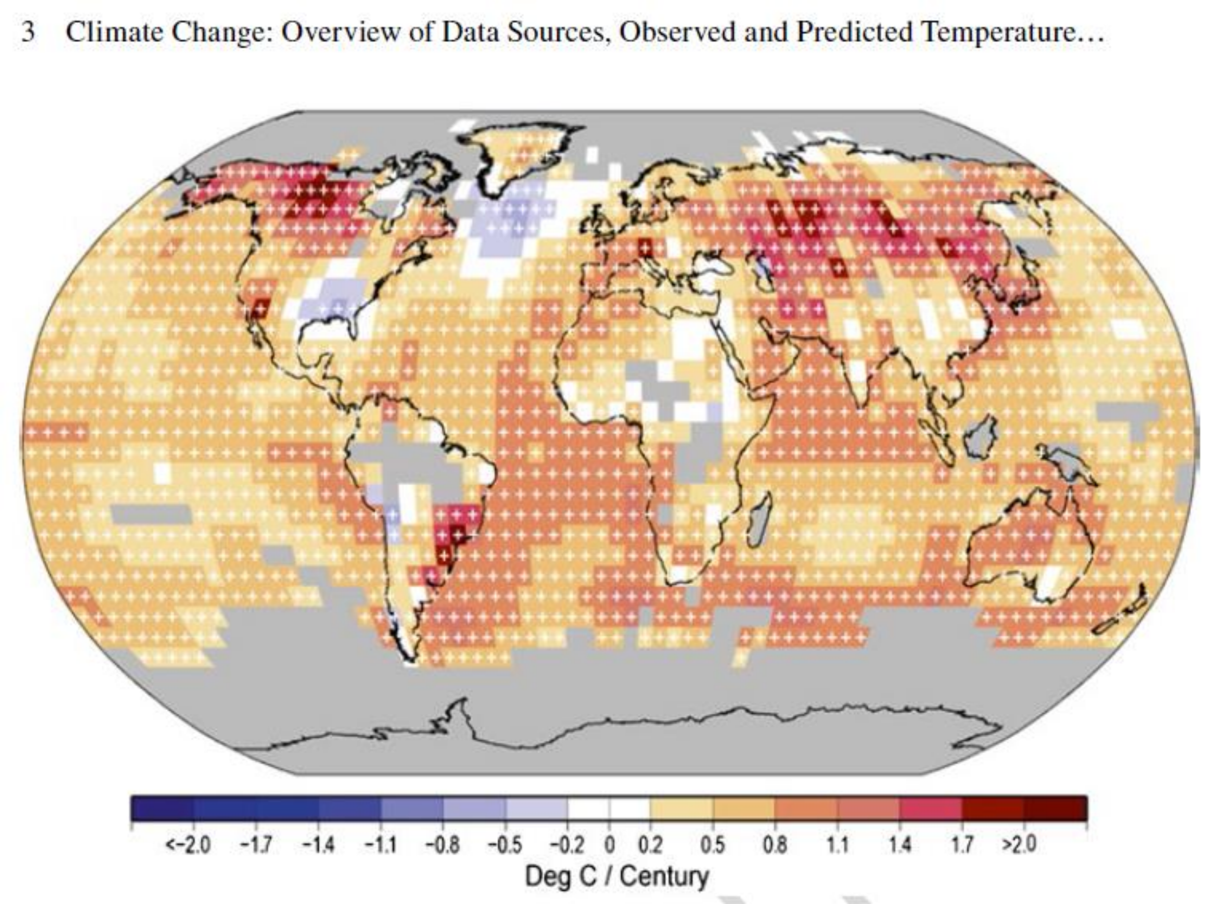


www.bing.com/MarkTwain

Mark Twain (Samuel L. Clemens), noted American author and humorist of the late 19th century.

- "Climate is what you expect, weather is what you get"
- Meteorological conditions (e.g., temp., precip., and wind) characteristic of a particular place (e.g., "Mediterranean").

The vast <u>majority</u> of the earth's surface has warmed during the 20th and early 21st Century, with the largest increases observed at mid- to high-latitudes in the Northern Hemisphere…



Levinson and Fettig 2014 in Climate Change and Global Public Health

"Alaska: The First Frontier"

Table 6.1. Observed changes in annual average temperature (°F) for each National Climate Assessment region. Changes are the difference between the average for present-day (1986–2016) and the average for the first half of the last century (1901–1960 for the contiguous United States, 1925–1960 for Alaska, Hawai'i, and the Caribbean). Estimates are derived from the nClimDiv dataset[1,2].

NCA Region	Change in Annual Average Temperature	Change in Annual Average Maximum Temperature	Change in Annual Average Minimum Temperature
Contiguous U.S.	1.23°F	1.06°F	1.41°F
Northeast	1.43°F	1.16°F	1.70°F
Southeast	0.46°F	0.16°F	0.76°F
Midwest	1.26°F	0.77°F	1.75°F
Great Plains North	1.69°F	1.66°F	1.72°F
Great Plains South	0.76°F	0.56°F	0.96°F
Southwest	1.61°F	1.61°F	1.61°F
Northwest	1.54°F	1.52°F	1.56°F
Alaska	1.67°F	1.43°F	1.91°F
Hawaii	1.26°F	1.01°F	1.49°F
Caribbean	1.35°F	1.08°F	1.60°F

Local-scale climate change stressors and policy response: the case of Homer, Alaska

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Northern communities are experiencing greater climate variability, with extreme climate impacts occurring more frequently and with more intensity; with the need for adaptation to reduce the risk becoming more immediate. Specific stressors and decision dynamics surrounding the nature of local government policy and planning for climate adaptation are underrepresented in the scholarship. This paper seeks to contribute to the literature by exploring the case of Homer, Alaska. Through narratives of key informants connected to the community's climate change agenda, this research explores primary climate stressors and the nature of adaptation policy integration. Findings suggests that while Homer is experiencing a variety of climate change impacts, adaptation remains a low priority for city officials. This study sheds light on some of the challenges of integrating climate adaptation policy with strategic community planning, and in turn provides decision-makers with insight into considerations for mainstreaming resilience thinking at a local government scale.

Keywords: community planning; climate resilience; coastal communities; climate adaptation; decision-makers

www.globalchange.gov/nca4

Its getting warmer and its getting warmer faster….

Since 2000, 18 of the 19 warmest years on record have occurred.

Table 3.1 The observed differences in annual global temperature anomaly for 2010 and its rank relative to the entire historical record since 1880 for the three primary datasets used to determine global average temperatures

	2010 Global anomaly relative to the 1961–1990 annual mean	Rank of 2010 to all years since 1880
HadCRUT3	0.50 °C	Second warmest after 1998
NASA-GISS	0.56 °C	Tied warmest with 2005
NOAA-NCDC	0.52 °C	Tied warmest with 2005

From Sanchez-Lugo A, Kennedy JJ, Berrisford P (2011) Surface temperatures. In "State of the Climate 2010," *Bull Amer Meteor Soc* 92:6:S36-S37, with permission

Levinson and Fettig 2014 in *Climate Change and Global Public Health*

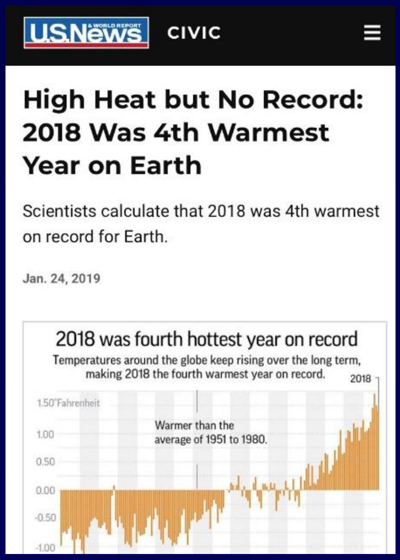
Time marches on…

2014

2015

2016

2017[a]



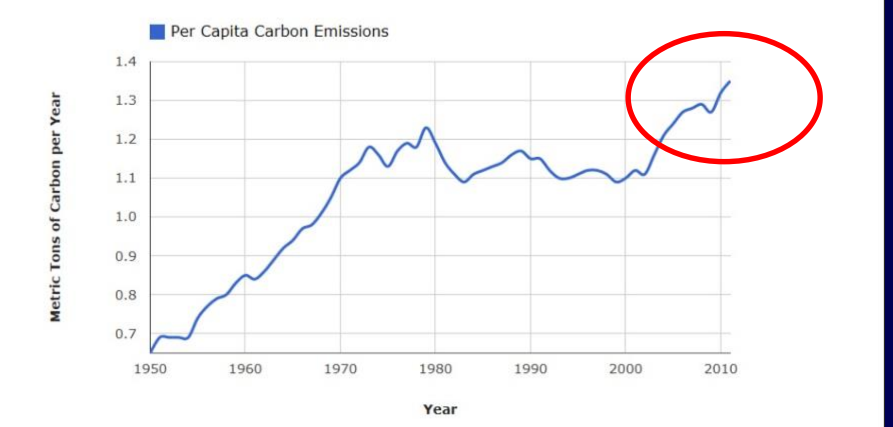
2018[a,b]

[a] During a La Niña, the positive phase of the El Niño Southern Oscillation that is associated with cooler-than-average sea surface temperatures.

[b] With the U.S. government shutdown, NOAA/NASA calculations are delayed. Based on analyses provided by UC-Berkeley.

- Most of the warming has been attributed to the radiative effects of CO_2, but other greenhouse gases such as methane, nitrous oxide and halocarbons are also important.

- Prior to the Industrial Revolution, atmospheric CO_2 was stable at ~270 ppm. Today, ~406 ppm, and by the middle of this century is expected to reach 550 ppm and to surpass 700 ppm by the end of the century (IPCC).



Source: Boden, T.A., G. Marland, and R. J. Andres. 2015. Global, Regional, and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi: 10.3334/CDIAC/00001_V2015.

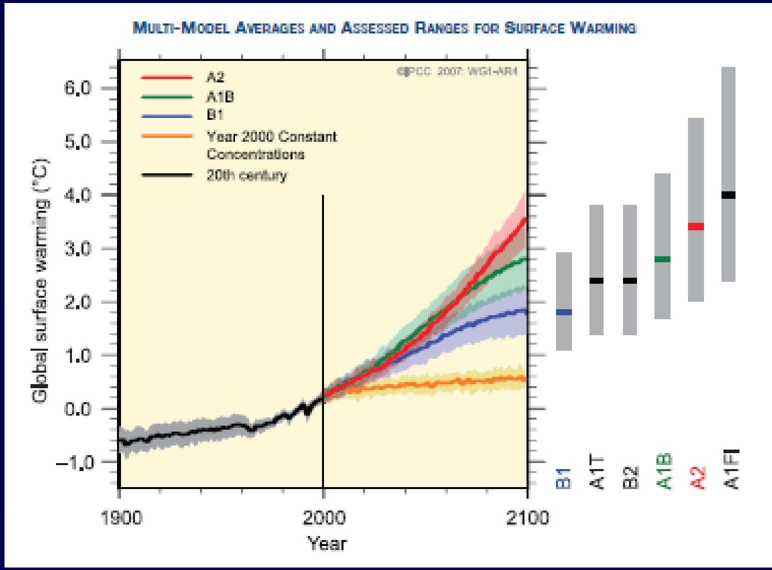
ww.esrl.noaa.gov

Since 1751, 374 billion metric tons of carbon have been released from the consumption of fossil fuels and cement (second most consumed substance on earth) production. <u>Half since 1980s</u>.

Projections

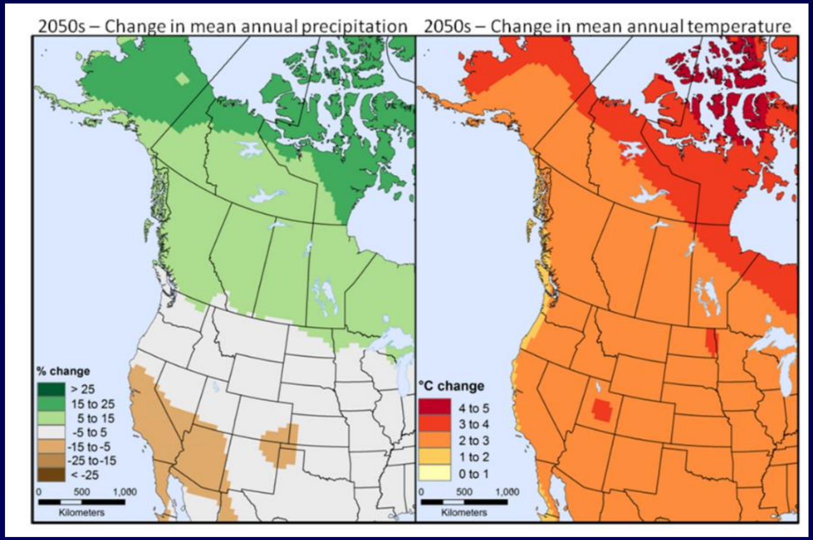
- Projections of future climates are based on assumptions about greenhouse gas emissions and simulations using global climate models (GCMs).

- Differences in the formulation and resolution of these models and the different emission scenarios result in a wide range of projections.

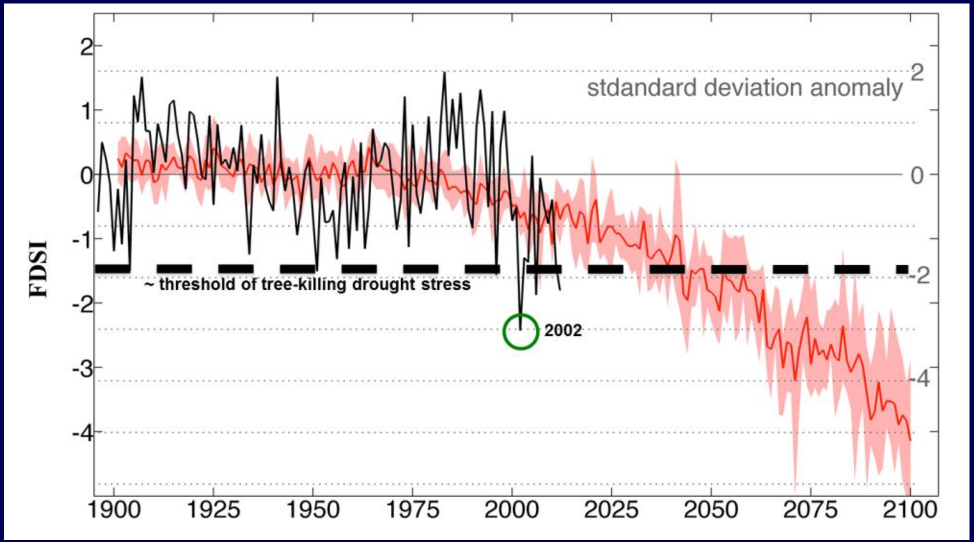


Projections of climate change depend on assumptions (scenarios) based on changes in human populations, technology, land use and global gross domestic production (GDP), which in turn influence greenhouse gas emissions. <u>All forecast a warmer climate than what we experience today</u>.

Some projections



Fettig et al. 2013. *Journal of Forestry* 111:214-228.

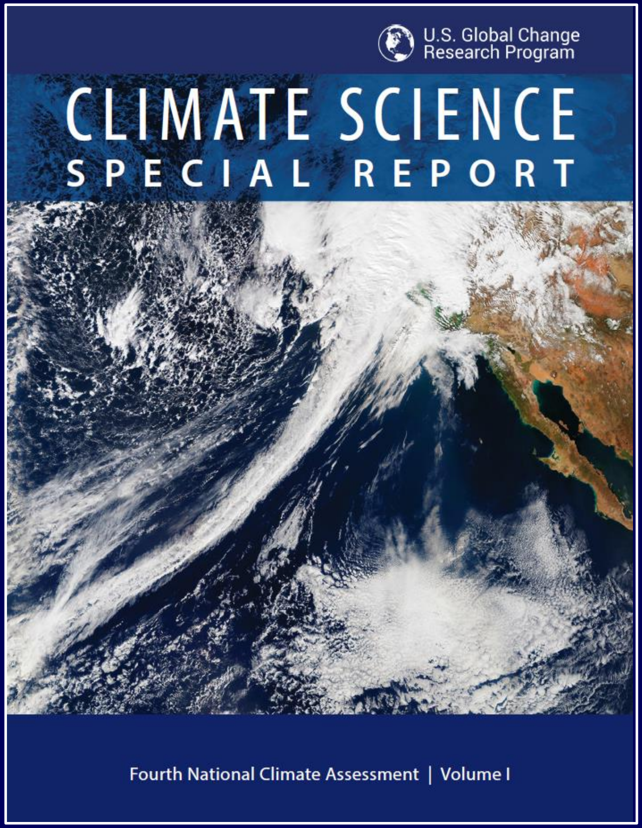


Williams et al. 2013. *Nature Climate Change* 3:292-297.

Median change in mean annual precipitation (left) and air temperature (right) compared to the climatic normal period (1961-90) based on projection by 13 global climate models (Fettig et al. 2013).

Projected warming drives persistent "megadrought" conditions by the 2040s, as severe drought stress becomes the norm in the southwestern U.S. (Williams et al. 2013).

4^{th} National Climate Assessment

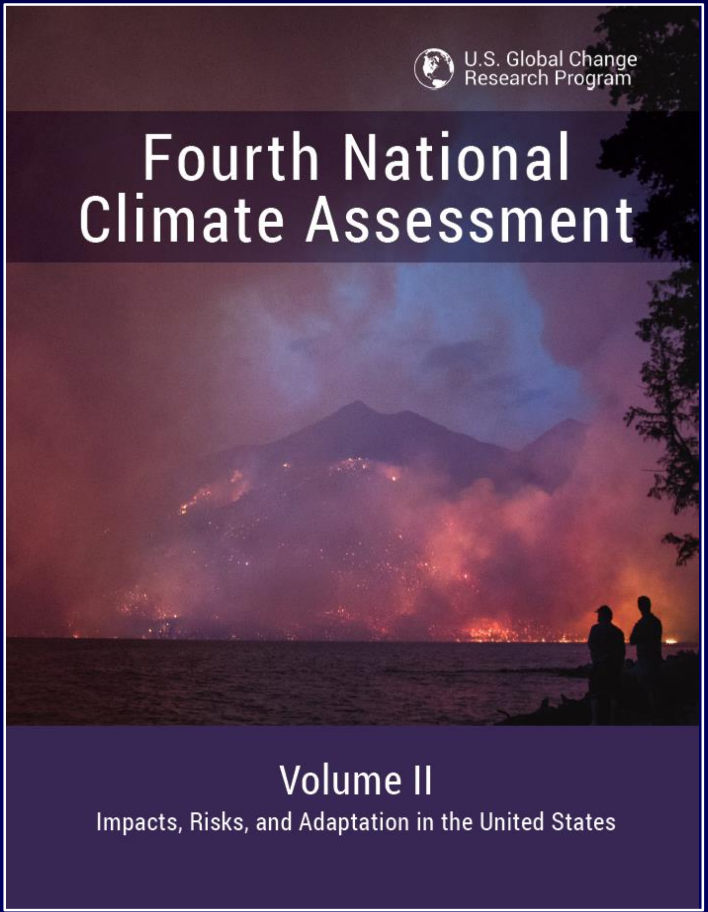


USGCRP was established by Presidential Order in 1989, and is mandated to prepare a quadrennial assessment, which has become known as the NCA. Volume I was released November 2017.

- "…it is extremely likely that human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming…there is no convincing alternative explanation…"

- "Continued growth in CO_2 emissions will lead to an atmospheric concentration not experienced in tens to hundreds of millions of years."

- "There is broad consensus that the further and faster the Earth system is pushed towards warming, the greater the risk of large and irreversible impacts."



Chapters in Volume II focus on impacts to sectors and regions. Volume II was released 23 November 2018.

- More frequent extreme weather events will increase the frequency and magnitude of severe ecological disturbances, driving rapid (months to years) and often persistent changes in forest structure and function across large landscapes (i.e., the CA example).

- Climate change will decrease the ability of forest ecosystems to provide EGS.

- Tree growth and carbon storage will be reduced in most locations by chronic higher temperatures, more frequent droughts, and increased disturbances.

Direct effects of climate change

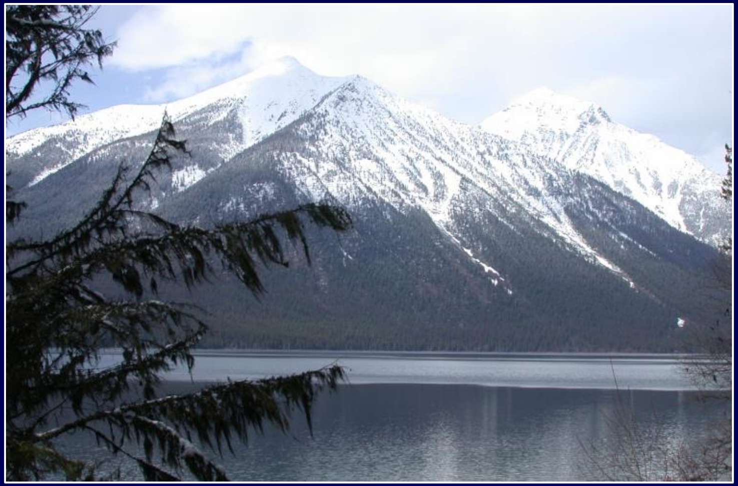
- The distribution and abundance of a species is governed by natality, growth, mortality, and dispersal of individuals comprising a population. These variables are influenced by environmental factors such as climate, among others.

- Fecundity, fitness, phenology and voltinism…

Ambermarked birch leafminer infesting paper birch, Fairbanks, Alaska, 2011.

Indirect effects of climate change

1. Habitat and Host Range
2. Disturbances
3. Host Physiology and Phenology
4. Trophic Interactions
5. Land Use and Management



1—Habitat and host range…

- Climate is a primary factor regulating the distributions of plants (upper treeline = 6.4 °C, mean warm season).

- Climate change causes shifts in the geographic distribution of climatic niches of plants, with broad implications (e.g., invasive herbivores) .

- Substantial shifts in the geographic distributions of bioclimatic envelopes (climatic niches) have been projected.

- To the extent that dispersal and resource availability allows, invasive species are expected to track associated shifts in bioclimatic envelopes over time.

There will be winners and losers…

The fate of any individual, species or population will depend on genetic variation, phenotypic variation, fecundity and dispersal mechanisms, and their resilience and resistance to a multitude of disturbances.

Shifts in bioclimatic envelopes

- E.g., increases in grassland and montane forest at the expense of Great Basin woodland and subalpine forest.
- Rehfeldt et al. (2006) suggested that ~48% of the western U.S. landscape is likely to experience climate profiles <u>with no contemporary analog</u> for the current coniferous vegetation by the end of this century.

2—Disturbances…

Mountain pine beetle outbreak, British Columbia, 2005

Cone Fire, Blacks Mountain Experimental Forest, California, 2003

Bark beetles

- 550 species in North America.
- Relatively few are economically important.
- Regulate certain aspects of primary production, nutrient cycling, ecological succession, and the size, distribution and abundance of forest trees.

Robber fly predating on red turpentine beetle attracted to residual trees following harvesting, Eldorado National Forest, California, 2005.

Principle tree-killing species in western U.S.

Common name	Scientific name	Primary host(s)
Arizona fivespined ips	*Ips lecontei*	*Pinus ponderosa*
California fivespined ips	*I. paraconfusus*	*P. contorta, P. jeffreyi, P. lambertiana, P. ponderosa*
Douglas-fir beetle	*Dendroctonus pseudotsugae*	*Pseudotsuga menziesii*
eastern larch beetle	*D. simplex*	*Larix laricina*
fir engraver	*Scolytus ventralis*	*Abies concolor, A. grandis, A. magnifica*
Jeffrey pine beetle	*D. jeffreyi*	*P. jeffreyi*
mountain pine beetle	*D. ponderosae*	*P. albicaulis, P. contorta, P. flexilis, P. lambertiana, P. monticola, P. ponderosa*
northern spruce engraver	*I. perturbatus*	*Picea glauca, Pi. x lutzii*
pine engraver	*I. pini*	*P. contorta, P. jeffreyi, P. lambertiana*
piñon ips	*I. confusus*	*P. edulis, P. monophylla*
roundheaded pine beetle	*D. adjunctus*	*P. arizonica, P. engelmannii, P. flexilis, P. leiophylla, P. ponderosa, P. strobiformis*
southern pine beetle	*D. frontalis*	*P. engelmannii, P. leiophylla, P. ponderosa*
spruce beetle	*D. rufipennis*	*Pi. engelmannii, Pi. glauca, Pi. pungens, Pi. sitchensis*
western balsam bark beetle	*Dryocoetes confusus*	*A. lasiocarpa*
western pine beetle	*D. brevicomis*	*P. coulteri, P. ponderosa*

Fettig and Hilszczański 2015 in *Bark Beetles: Biology and Ecology of Native and Invasive Species*

IN GENERAL

Elevated levels of bark beetle-caused tree mortality on the forested landscape

Mountain pine beetle (*D. ponderosae*)
(increase in winter temps)

Spruce beetle (*D. rufipennis*)
(increase in summer temps)

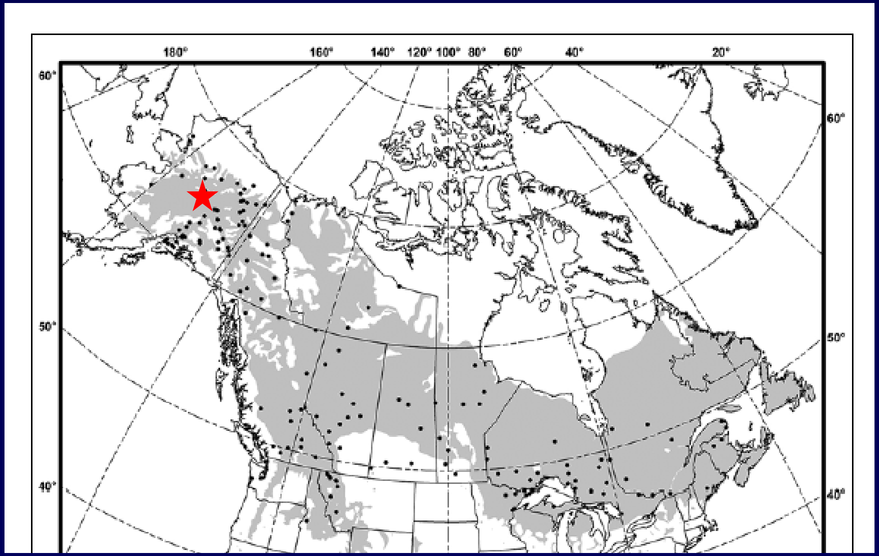
Pinyon ips (*I. confusus*)
(increase in summer temps X drought)

Western pine beetle (*D. brevicomis*)
(drought, drought and more drought)

Changes in pest status/impact (e.g., *Ips perturbatus*)

- Distribution generally coincides with that of its primary host, white spruce. Other hosts include Engelmann, Lutz, and in rare cases, black spruce.

- Recorded from Alaska, Idaho, Maine, Michigan, Minnesota, Montana, and Washington, and from nearly all of the Canadian provinces.



Burnside et al. 2011 (FIDL 180)

Range shifts:
MPB, a native goes invasive

- Mountain pine beetle was first observed attacking lodgepole pine in northern Alberta in ~2003 (de la Giroday et al. 2012).
- Has since been documented to infest jack pine at leading edge of the outbreak (Cullingham et al. 2011).
- Populations detected in NWT (2012) and Saskatchewan (Cypress Hills).

National Geographic


GSDUpdate

Mountain Pine Beetle Outbreaks Affect Invasive Plants

Mountain pine beetles [MPB; *Dendroctonus ponderosae*] have altered millions of acres of western North American forests over the past decade. A potential unwanted, but often overlooked, side-effect of these outbreaks is invasion by nonnative plants. Any activity that creates disturbance can promote plant invasions by increasing resource availability [e.g. light] and/or decreasing plant competition. Mountain pine beetles create disturbance by killing trees which opens the canopy, and dead trees eventually fall exposing disturbed soil. If MPB outbreaks promote plant invasions, land managers need to be aware of this and armed with the knowledge to monitor and, if necessary, manage weeds following outbreaks. An ongoing study by Forest Service scientists seeks to answer these questions by quantifying the changes to forests following MPB outbreaks.

Invasive plants were monitored in twenty-five 0.2 acre plots in each of five states [CO, ID, MT, UT, WY] in predominately lodgepole pine stands with recent MPB-caused tree mortality [125 total plots]. To date, invasion of exotic plants following MPB outbreaks has been minimal. However, according to Research Entomologist, Justin Runyon [RMRS-GSD, Bozeman] "In many plots trees are only now beginning to fall or be blown down – about six years after peak MPB activity – and early data suggest this disturbance may increase the abundance of invasive plants." For example, some plots in Colorado with numerous blown down trees are now being invaded by several invasive plant species [see photo]. However, more research is needed and this study will continue to monitor invasive plants as more trees fall.

This is part of a collaborative project involving USDA Forest Service, Pacific Southwest Research Station [Chris Fettig], RMRS [José Negrón, Justin Runyon], and USDA Forest Service, Forest Health Protection [Steve Munson, Carl Jorgensen, Brytten Steed, Ken Gibson] entitled "Quantifying the short- and long-term impacts of mountain pine beetle outbreaks on forest fuels and other stand attributes in the Intermountain West". This project is funded, in part, by a Forest Health Monitoring-Evaluation Monitoring grant [INT-EM-F-10-03].

ABOVE: Mountain pine beetle outbreaks kill trees and open canopy allowing more light to reach the forest floor which helps promotes invasion by exotic plants.

FAR RIGHT TOP: Lamb's quarter invading Colorado study plots.

FAR RIGHT BOTTOM: Canada thistle invading Colorado study plots.

RIGHT LOWER: Examining invading bull thistles [Cirsium vulgare] in a Colorado forest following a mountain pine beetle outbreak.

Photos: Justin Runyon

5

Rocky Mountain Research Station

Table 16.1—Year of sampling for variables collected across a network of 125 monitoring plots in lodgepole pine forests impacted by mountain pine beetle in 5 Western States

Variables measured	2010	2011	2012	2013	2014	2015	2016
Levels of tree mortality[a,b]	X	X	X	X	X	X	X
Fall rates of trees[b]	X	X	X	X	X	X	X
Tree species, d.b.h., and height[b]	X	—	—	—	X	—	—
Height to base of live crown[b]	X	—	—	—	X	—	—
Live crown cover	X	—	—	—	X	—	—
Checking of snags[b]	—	—	X	X	X	X	X
Bark retention of snags[b]	—	—	X	X	X	X	X
Tree regeneration	X	—	—	—	X	—	—
Forest floor composition	X	—	—	—	X	—	X
Invasive plants	—	—	X	—	X	—	X
Ladder fuels	X	—	—	—	X	—	—
Surface fuels	X	—	—	—	X	—	—
Litter and duff	X	—	—	—	X	—	—
Stand age	X	—	—	—	—	—	—

X = variable measured; — = variable not measured in this year.

[a] For trees killed prior to 2010, time of death was based on parameters adapted from Klutsch and others (2009), including: 1 year previous = crown of lime, yellow or yellow/red-colored needles; 2 years previous = ≥50 percent needles remaining; 3 years previous = <50 percent needles remaining; 4 years previous = no needles remaining but small and large twigs present; 5 years previous = only large twigs remaining; ≥6 years = both small and large twigs absent.

[b] All trees ≥7.6 cm diameter at breast height (d.b.h.).

Fettig et al. 2015. *Forest Health Monitoring: National Status, Trends, and Analysis, 2014*

3—Host phenology and physiology…

- Climate change will cause phenological shifts that may result in asynchrony between different trophic levels (e.g., herbivores and host plants).

A. Liebhold

Defoliation by gypsy moth, Pennsylvania, 2009

Phenology — Longer growing seasons

Current vs. 1901-1960 2036-2065

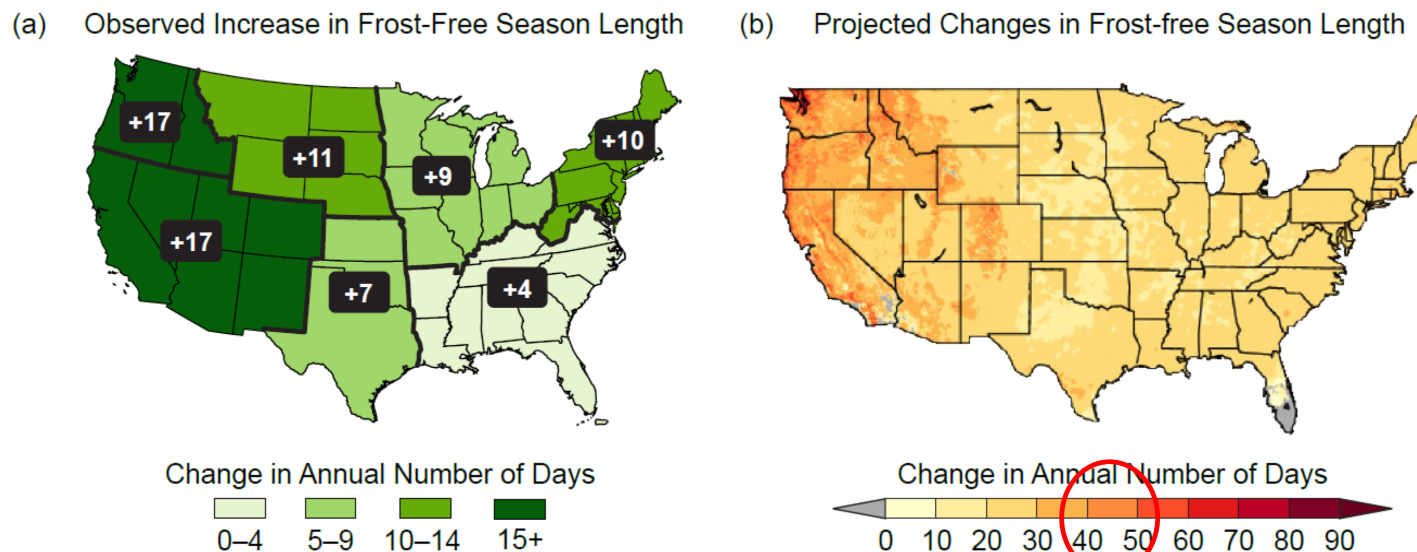


Figure 10.3: (a) Observed changes in the length of the frost-free season by region, where the frost-free season is defined as the number of days between the last spring occurrence and the first fall occurrence of a minimum temperature at or below 32°F. This change is expressed as the change in the average number of frost-free days in 1986–2015 compared to 1901–1960. (b) Projected changes in the length of the frost-free season at mid-century (2036–2065 as compared to 1976–2005) under the higher scenario (RCP8.5). Gray indicates areas that are not projected to experience a freeze in more than 10 of the 30 years (Figure source: (a) updated from Walsh et al. 2014;[30] (b) NOAA NCEI and CICS-NC, data source: LOCA dataset).

nca2018.globalchange.gov

Climate change has the capacity to cause phenological shifts that may result in asynchrony between different trophic levels, influencing competitive ratios.

Physiology — Elevated CO_2

- In terrestrial plants with C_3 photosynthetic pathways, CO_2 impacts Rubisco (the enzyme by which atmospheric CO_2 is converted to energy in plants) and stomatal movement within the range of CO_2 concentrations relevant to climate change.
- Elevated CO_2 increases net photosynthesis and decreases transpiration through reduced stomatal conductance and increased water-use efficiency.

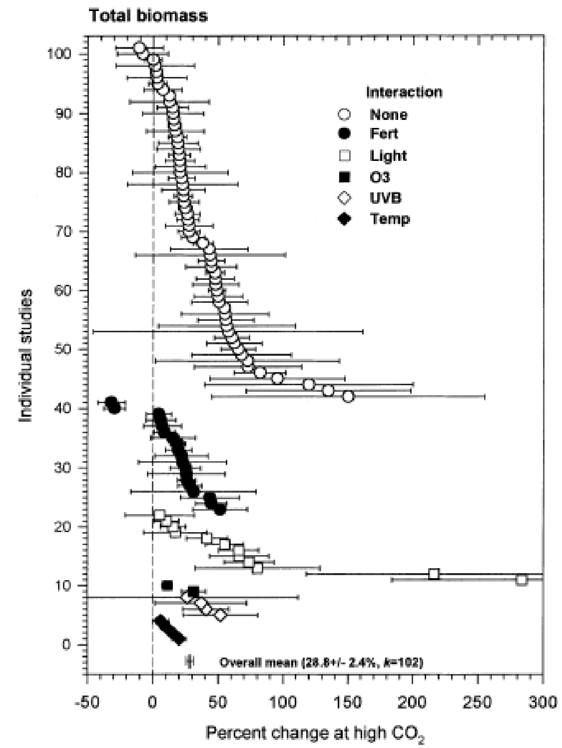


Fig. 1 Percent change in total (above + belowground) biomass in woody plants grown under elevated compared to ambient CO_2 as reported in 102 different experiments. Results are grouped according to whether plants were exposed either to no stress (*None*), low nutrient availability (*Fert*), low light levels (*Light*), high ozone (*O3*), high UVB (*UVB*) or low or high temperature (*Temp*) in addition to the CO_2 treatment. Mean ± 1 SE calculated from the log-transformed response ratio

Curtis and Wang. 1998. Oecologia 113:299-313.

4—Trophic interactions…

- Some fungal pathogens are important in regulating insect populations and are likely to be impacted by climate change.

- For example, *Entomophaga maimaiga*, which causes extensive epizootic in populations of the gypsy moth in the eastern U.S., requires high levels of moisture for conidial production and discharge (Hajek 1999). Consequently, drought is expected to reduce this pathogen's impact on gypsy moth populations (Kolb et al. 2016).

- Little is known about most of these relationships…

4—Trophic interactions…

- *Grosmannia clavigera* predominates during cool periods but decreases in prevalence as daily maximum temperatures approach 25°C, becoming extremely rare when temperatures ≥32°C. In contrast, *Ophiostoma montium* increases as temperatures approach 25°C, and becomes the predominant symbiont when temperatures ≥32°C (Six and Bentz 2007).

- While important in brood development, it is unknown if one fungus is more beneficial than the other or if effects vary by temperature.

Deceased mountain pine beetle in parental gallery. Note blue stain.

5—Land use and management…

- In response to climate change, <u>assisted migration</u> (i.e., the practice of planting species outside of their current distribution due to anticipated changes in the climatic niche) has been considered.

- While most efforts have been experimental, large-scale plantings could result in <u>unintended introductions of other plant and animal species and/or provide new dispersal routes</u> for established invasive species, both with unintended impacts to recipient communities.

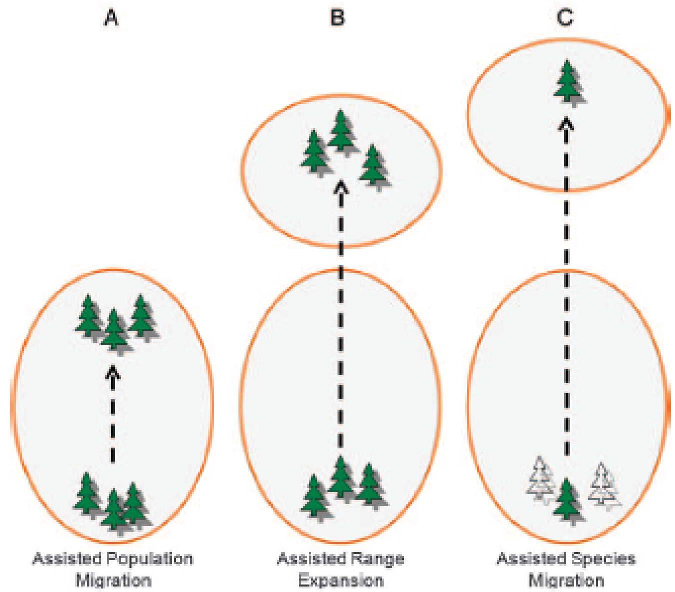


Figure 1. Assisted migration can occur in a variety of forms to fulfill diverse goals (Ste-Marie et al. 2011, Winder et al. 2011). To avoid economic loss in the timber industry, seed sources and populations (e.g., genotypes) of commercial trees could be moved within their current range (A) or from their current range to suitable areas just outside (B) to keep pace with changing conditions (e.g., warmer climates). Movement to locations far outside current ranges is an option to prevent species extinction (C). Risks can vary widely across the forms of assisted migration but would probably increase with migration distance (Mueller and Hellmann 2008, Vitt et al. 2010, Pedlar et al. 2012). For example, assisted migration to areas far outside its current range (e.g., C) would carry greater financial responsibilities and ecological risks (Winder et al. 2011).

William and Dumroese 2013. *Journal of Forestry* 111:287-297.

5—Land use and management…

- Accidental introduction of invasive species, specifically plants, is a major concern in areas that are rehabilitated after fire (Keeley 2006).

- Cerro Grande Fire in New Mexico, 2000.

5—Land use and management…

- Relatedly, prescribed fire and thinning of small-diameter trees are used to reduce fuels in order to increase the resilience of forests to high-intensity wildfire, but some studies have shown that these treatments promote an <u>increase in invasive species richness</u> (Schwilk et al. 2009).

- Although hazardous fuel reduction in some shrub systems (e.g., wildland urban interface) is desirable, treatments (mastication, fuel breaks, prescribed fire) can facilitate the spread of nonnative annuals (Fettig et al. 2018).

S. Stephens, UCB

Some practical matters…for Alaska

Reductions in ice pack affect oceanic and freshwater shipping routes, reducing travel time for cargo ships (Liu et al. 2013).

Reeling From Effects of Climate Change, Alaskan Village Votes to Relocate

An abandoned house at the west end of Shishmaref, Alaska, that slid during a storm in 2005. Residents have voted in favor of relocating the community to the mainland. Diana Haecker/Associated Press

By Christopher Mele and Daniel Victor

Aug. 19, 2016

Climate "refugees" and impacts on the distribution of plants and animals?

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National Assessment of Invasive Species (summer 2019)

Chapter 14: Conclusions

Appendix 1: Regional Summaries

REGION	AUTHORS	AFFILIATION
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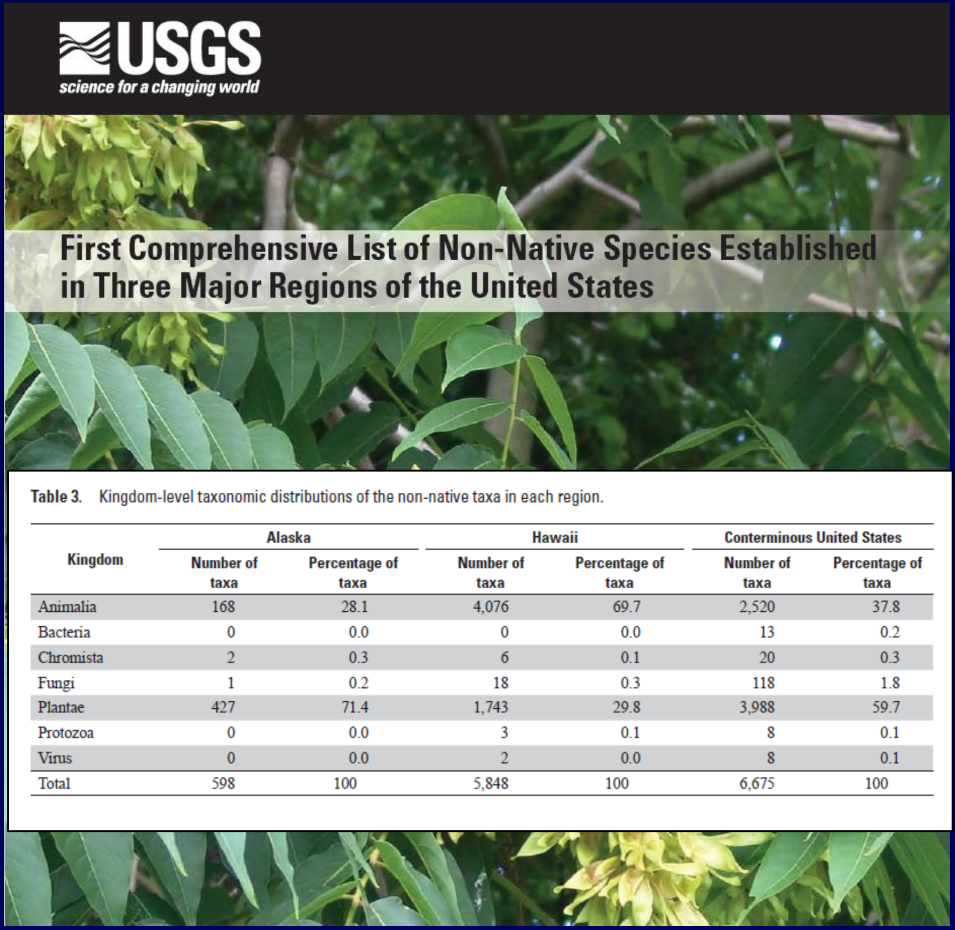
Hawaii & US affiliated Pacific Islands	Susan Cordell	USFS
Southwest	Steve Seybold, Susan Frankel, Andrew Graves, Allen White	USFS

https://scholar.google.com/citations?user=SnRHtAMAAAAJ&hl=en&oi=ao


USGS
science for a changing world

First Comprehensive List of Non-Native Species Established in Three Major Regions of the United States

Table 3. Kingdom-level taxonomic distributions of the non-native taxa in each region.

Kingdom	Alaska		Hawaii		Conterminous United States	
	Number of taxa	Percentage of taxa	Number of taxa	Percentage of taxa	Number of taxa	Percentage of taxa
Animalia	168	28.1	4,076	69.7	2,520	37.8
Bacteria	0	0.0	0	0.0	13	0.2
Chromista	2	0.3	6	0.1	20	0.3
Fungi	1	0.2	18	0.3	118	1.8
Plantae	427	71.4	1,743	29.8	3,988	59.7
Protozoa	0	0.0	3	0.1	8	0.1
Virus	0	0.0	2	0.0	8	0.1
Total	598	100	5,848	100	6,675	100