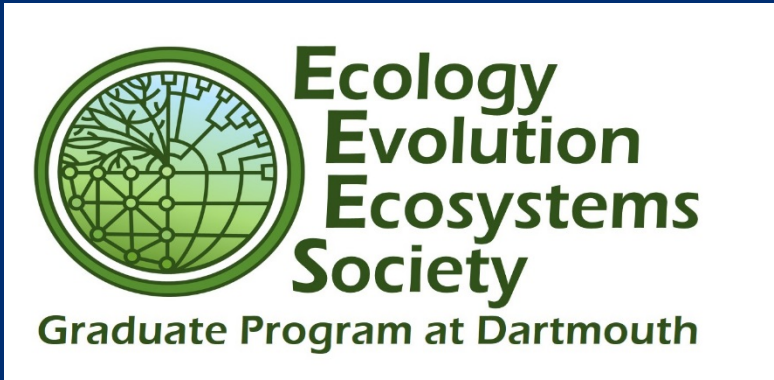


Forest pests and forest management in the Anthropocene

Matt Ayres and many others



United States
Department of
Agriculture

National Institute
of Food and
Agriculture

From 1st US National Climate Assessment. 2000.

“The short life cycles, high mobility, reproductive potential, and physiological sensitivity to temperature suggest that even modest climate change will possibly have rapid effects on the distribution and abundance of many forest insects and pathogens.”

e.g., “An increase of 3°C in the coldest night of the winter would permit the occurrence of SPB outbreaks ~ 178 km farther north than in historical times”

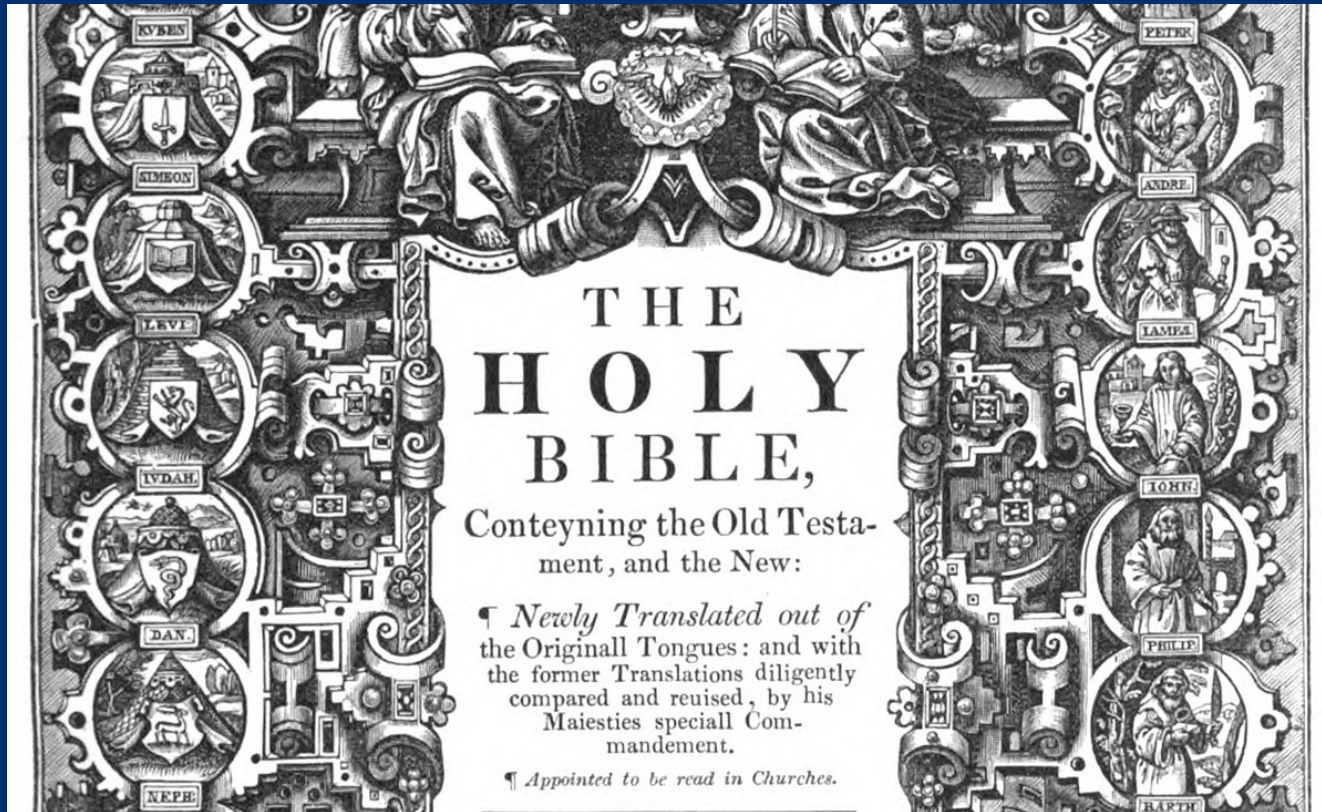
From US National Climate Assessment. 2014.

“Predictions from the first U.S. National Climate Assessment of expansions in forest disturbances from climate change have been upheld, in some cases more rapidly and dramatically than expected.”

“Clear examples are offered by recent epidemics of spruce beetles in Alaska, mountain pine beetle in high-elevation five-needle pine forests of the Rocky Mountains, and southern pine beetle in the New Jersey Pinelands.”

Δ pestilence challenge environmental security

Locusts will cover the face of the ground so that it cannot be seen. They will devour what little you have left, including every tree that is growing in your fields. Exodus 10.



*Some Observations of swarms of strange Insects,
and the Mischiefs done by them.*

The like Plague is said to happen frequently in the Country of the *Cosacks* or *Ukrani*, where in dry Summers they are infested with such swarms of *Locusts*, driven thither by an *East*, or *South-East* Wind, that they darken the Air in the fairest weather, and devour all the Corn of that Country; laying their Eggs in *Autumn*, and then dying; but the Eggs, of which every one layeth two or three hundred, hatching the next Spring, produce again such a number of *Locusts*, that then they do far more mischief than afore, unless Rains do fall, which kill both Eggs and the Insects themselves, or unless a strong *North* or *North-West* Wind arise, which drives

Δ pestilence challenges environmental security

Strategic responses

- Improved pest monitoring, prediction, mitigation

Δ pestilence challenges environmental security

Strategic responses

- Improved pest monitoring, prediction, mitigation
- Increased sharing of knowledge among regions, countries, and continents

Δ pestilence challenges environmental security

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Δ pestilence challenges environmental security

Strategic responses

- Improved pest monitoring, prediction, mitigation
- Increased sharing of knowledge among regions, countries, and continents
- Improved biosecurity against future invasions
- **Management plans that anticipate continuing change**

Δ pestilence challenges environmental security

Strategic responses

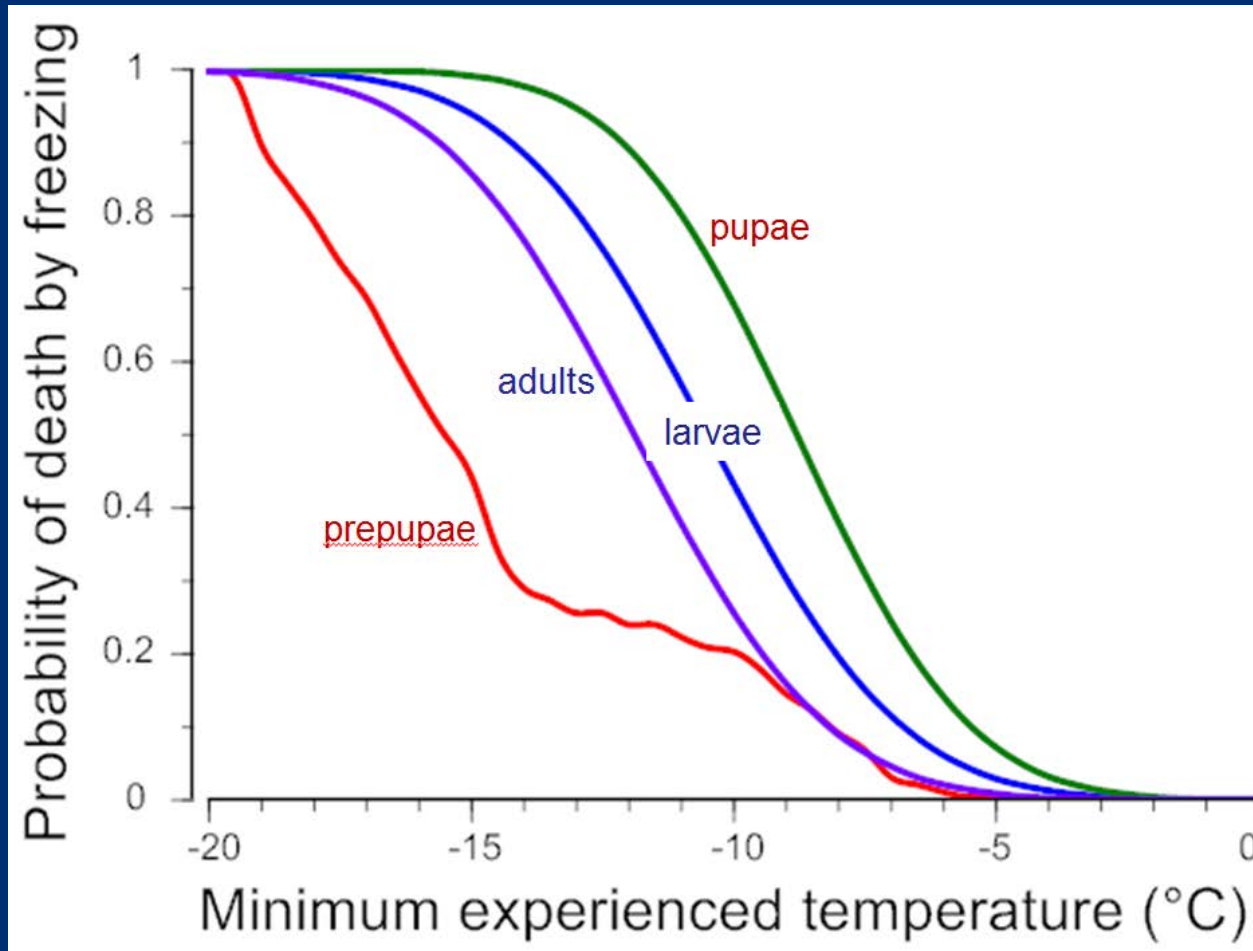
- Improved pest monitoring, prediction, mitigation
- Increased sharing of knowledge among regions, countries, and continents
- Improved biosecurity against future invasions
- Management plans that anticipate continuing change
- Growth of practical theory that is transportable among forests and regions

*There is nothing more practical
than good theory*

Temperature affects insect survival.



Dendroctonus frontalis



Lombardero, Ayres, Ayres, Reeve. 2000. *Env. Entomol.*

Tran, Ylioja, Regniere, Billings, and Ayres. *Ecological Applications*, 2007

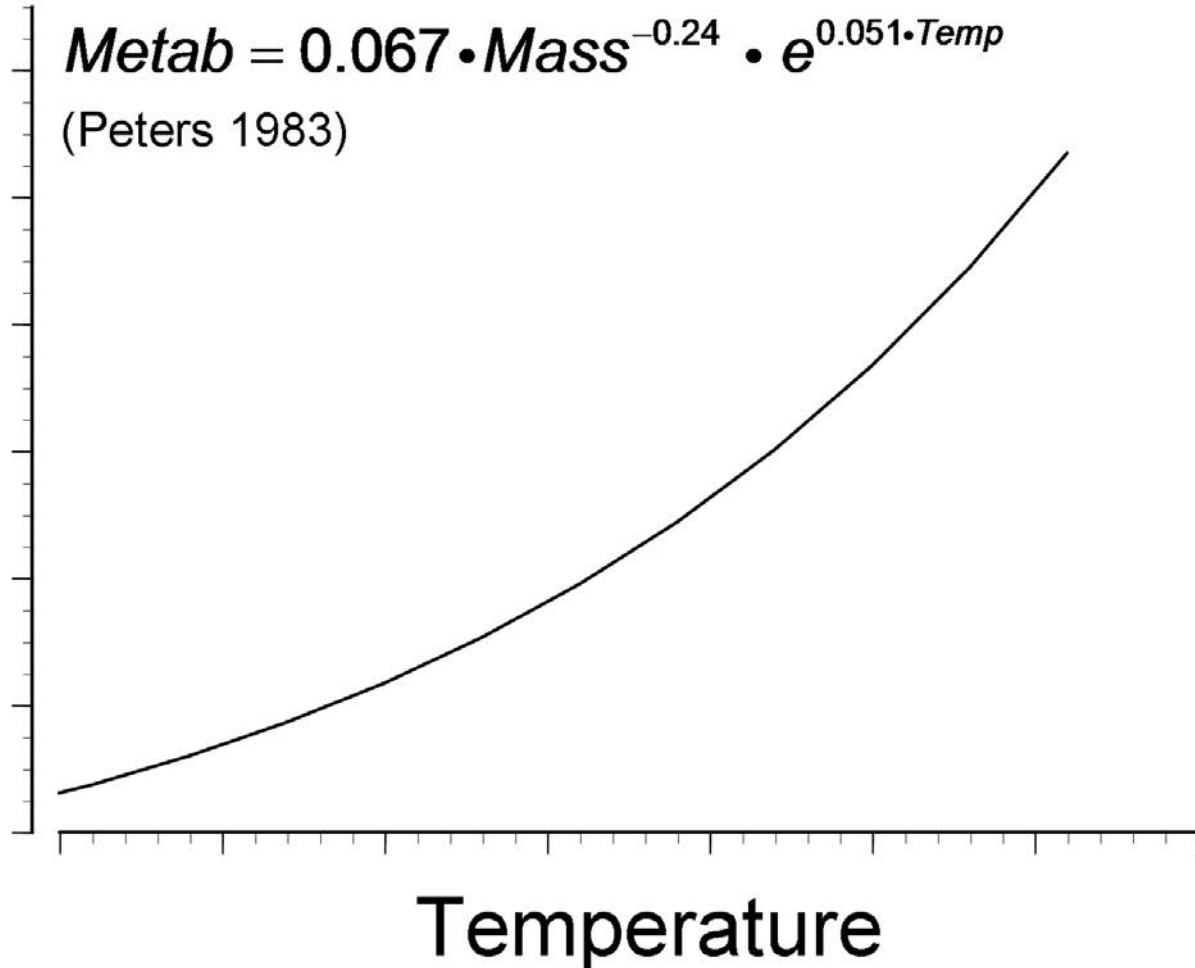


Warmer temperatures increase metabolic rate, consumption, growth, movements, and dispersal

Metabolic rate
($J \cdot g^{-1} \cdot h^{-1}$)

$$Metab = 0.067 \cdot Mass^{-0.24} \cdot e^{0.051 \cdot Temp}$$

(Peters 1983)

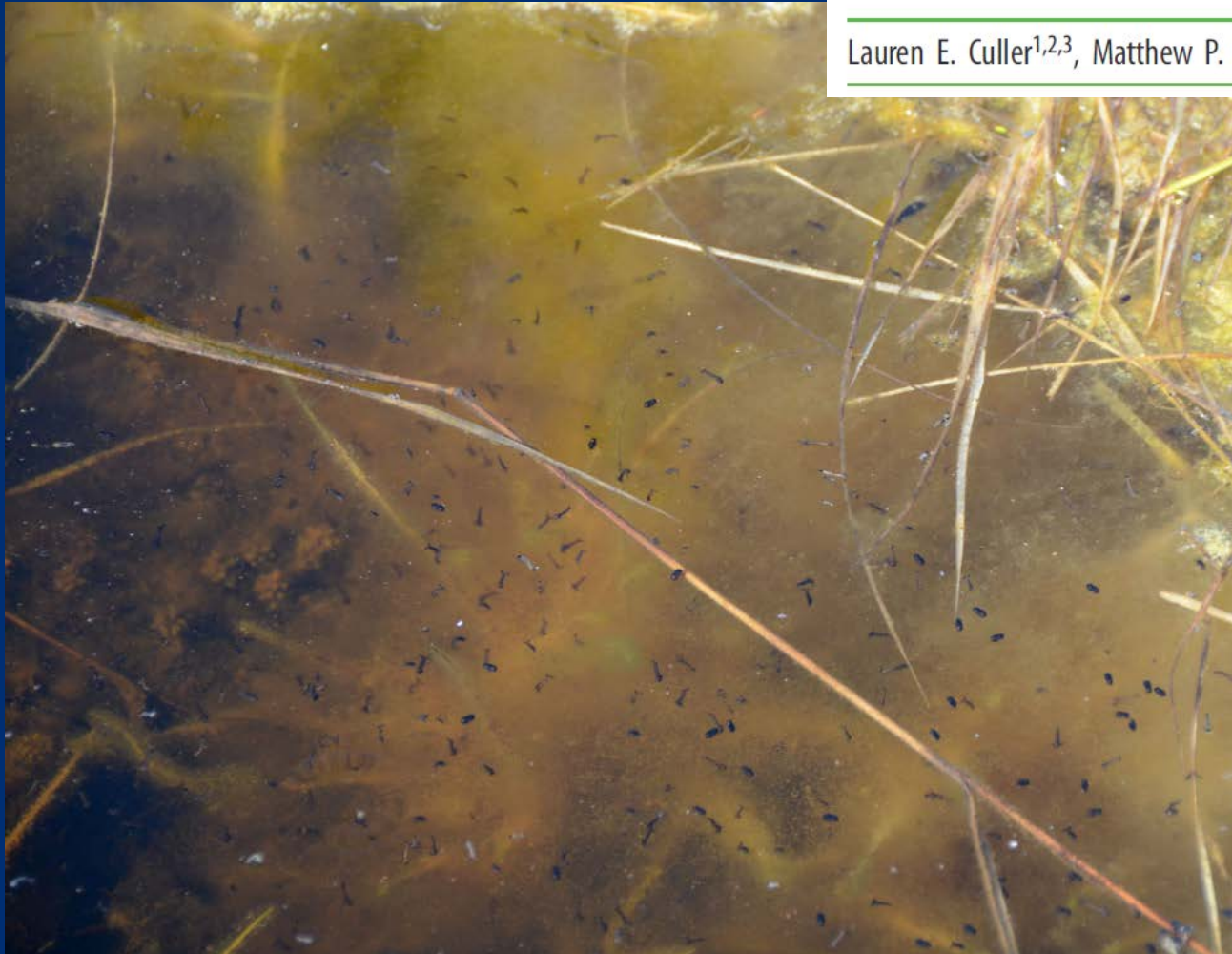


Temperature affects phenology and species interactions

In a warmer Arctic, mosquitoes avoid increased mortality from predators by growing faster

Lauren E. Culler^{1,2,3}, Matthew P. Ayres^{1,3} and Ross A. Virginia^{1,2}

Proc. R. Soc. B. 2015



Lauren Culler



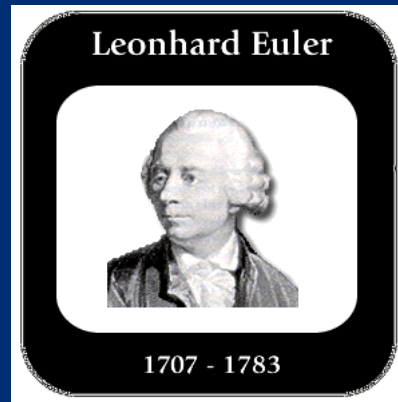
$$Pestilence = f \left\{ Abundance (N) \right\}$$

Pestilence = f { *Abundance* (N) }

$$N_{t+1} = N_t e^R$$

R = Births – Deaths + Immigration – Emigration

R = per capita growth rate (ind · ind⁻¹ · time⁻¹)



$$Pestilence = f \left\{ Abundance (N) \right\}$$

$$N_{t+1} = N_t e^R$$

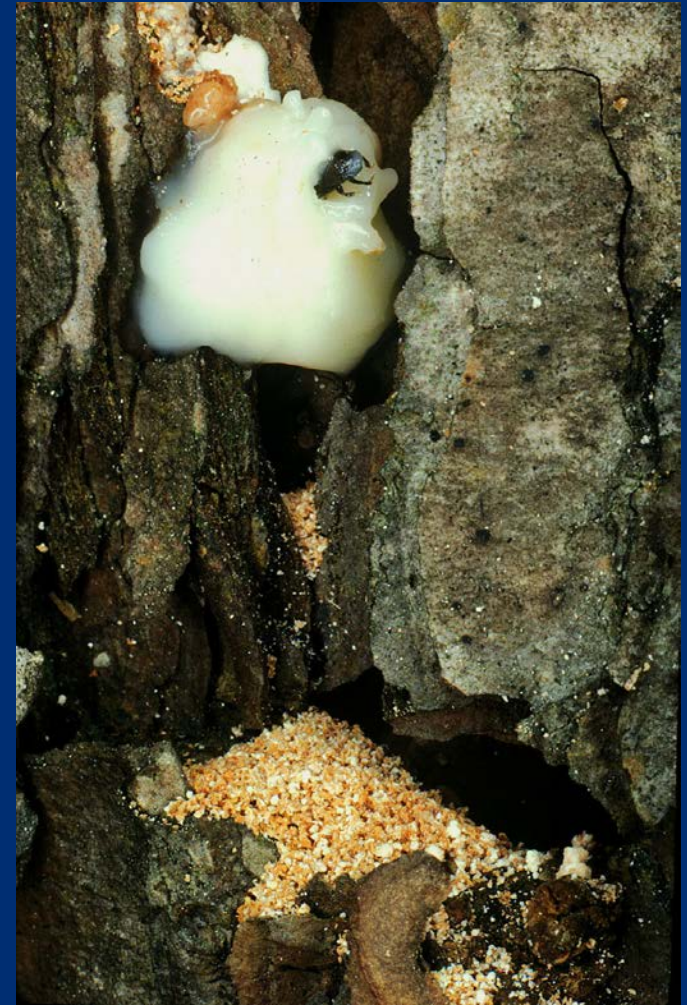
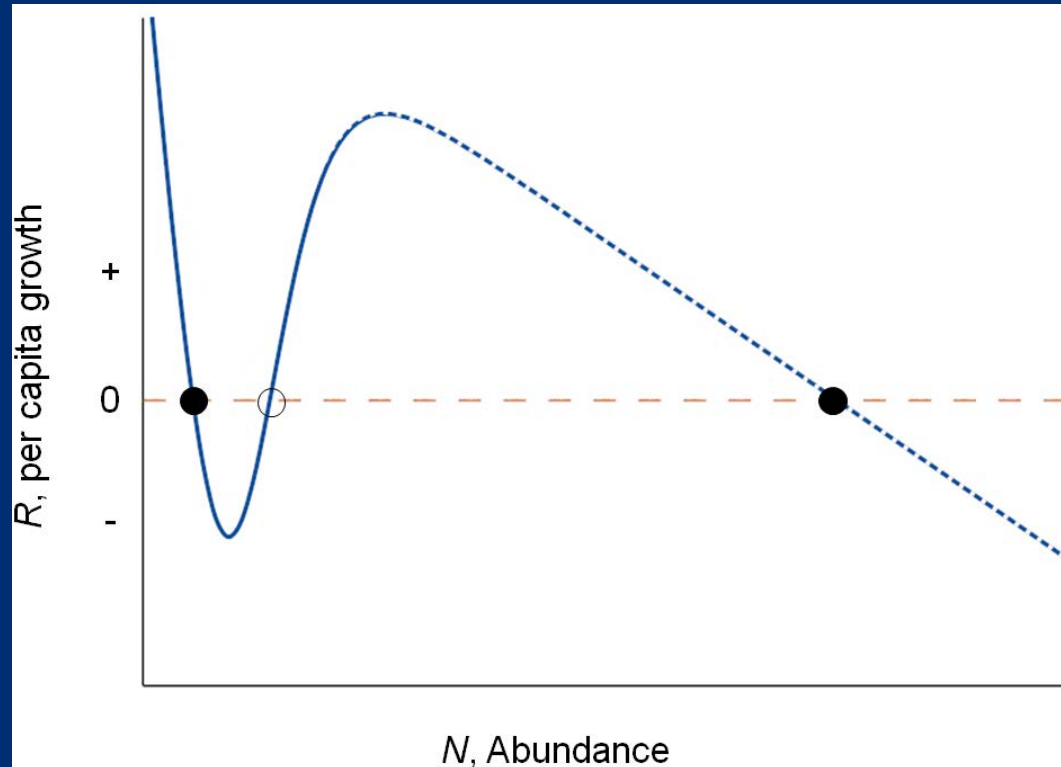
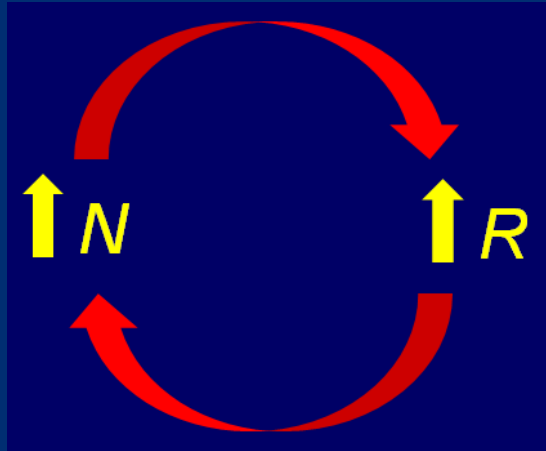
$$R = \text{Births} - \text{Deaths} + \text{Immigration} - \text{Emigration}$$

$$R = f \left\{ \begin{array}{l} N_t, N_{t-i} \\ \varepsilon \end{array} \right.$$

Density-dependence, endogenous feedback, instantaneous & delayed

Exogenous effects

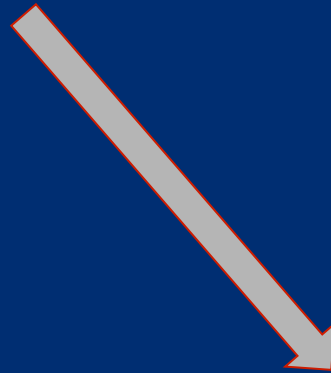
Positive feedback destabilizes pop dynamics



Sharon Martinson, Tiina Ylloja, Brian Sullivan, Ron Billings, and Matt Ayres. Alternate attractors in the population dynamics of a tree-killing bark beetle. *Population Ecology* 2014

Many herbivores have hosts beyond their current range.

pre-existing hosts
newly suitable climate
short generation times
high reproductive potential
rapid dispersal



frequent rapid range expansion

Invasions and
range expansions



Risks of
pestilence

Enemy release

Susceptible trees and forests

Naïve pest management

Phylogenetic conservatism of pestilence

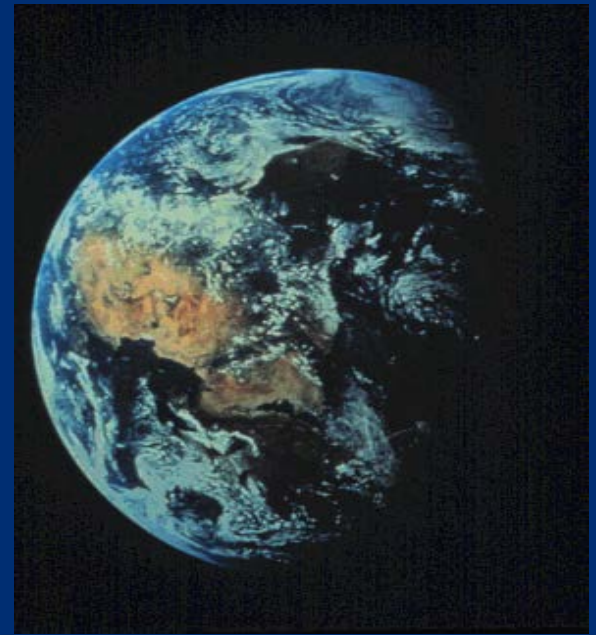
Similar: phenology and life history;
hosts and feeding mode;
enemies and symbionts;
→ similar population dynamics.

Therefore, new pestilence tends to involve familiar pests

<i>Dendroctonus</i>	<i>Adelges</i>
<i>Ips</i>	<i>Hylastes</i>
<i>Scolytus</i>	<i>Pissodes</i>
	<i>Sirex</i>
<i>Lymantria</i>	<i>Agrilus</i>
<i>Malacosoma</i>	<i>Bursaphelenchus</i>
<i>Choristoneura</i>	<i>Rhyacionia</i>
<i>Operophtera</i>	<i>Matsucoccus</i>

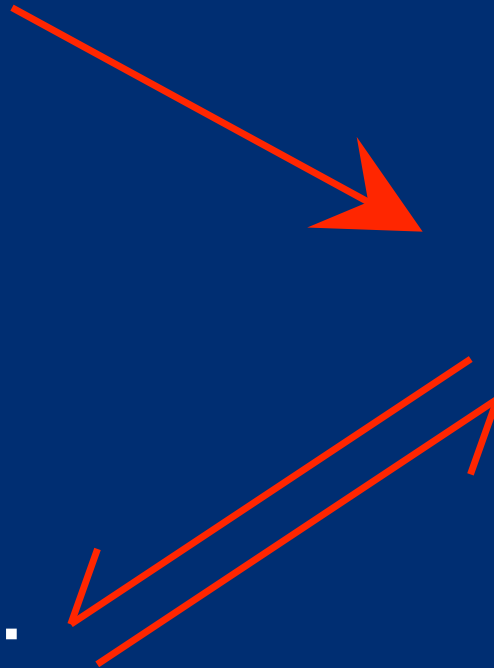


Δ climate



↑ invasions & expansions

Globalization;
 Δ land use

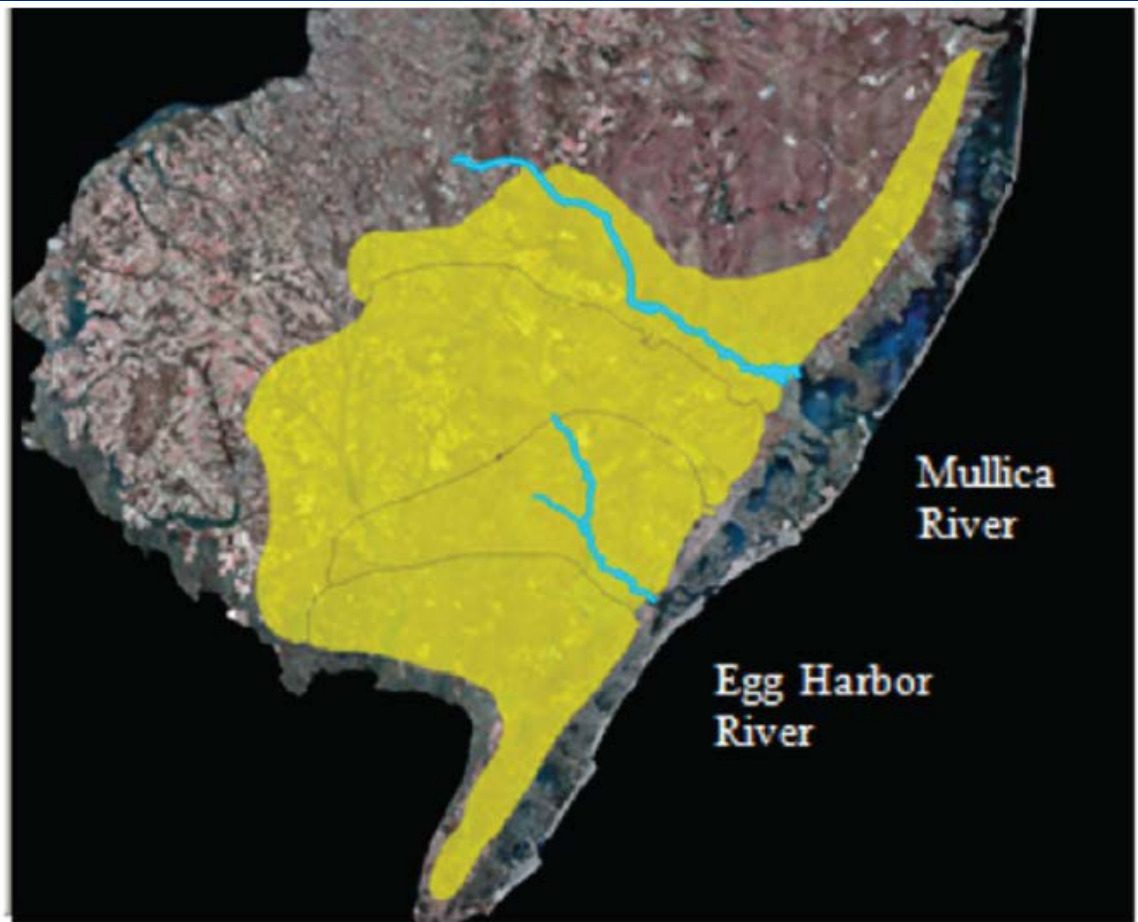


Dendroctonus frontalis, Southern pine beetle

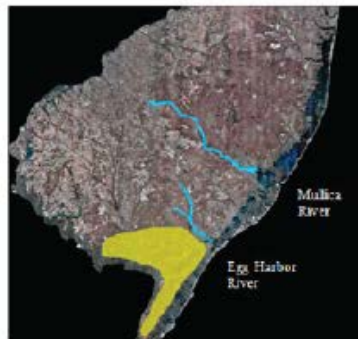


Ron Billings
TX Forest Service

Southern pine beetle epidemics expand into New Jersey Pinelands



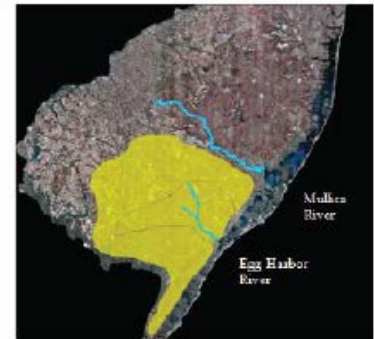
Southern pine beetle spread, 2015



2002-2008



2009



2010

Weed, Hicke, and Ayres.
2013. *Ecological Monographs*

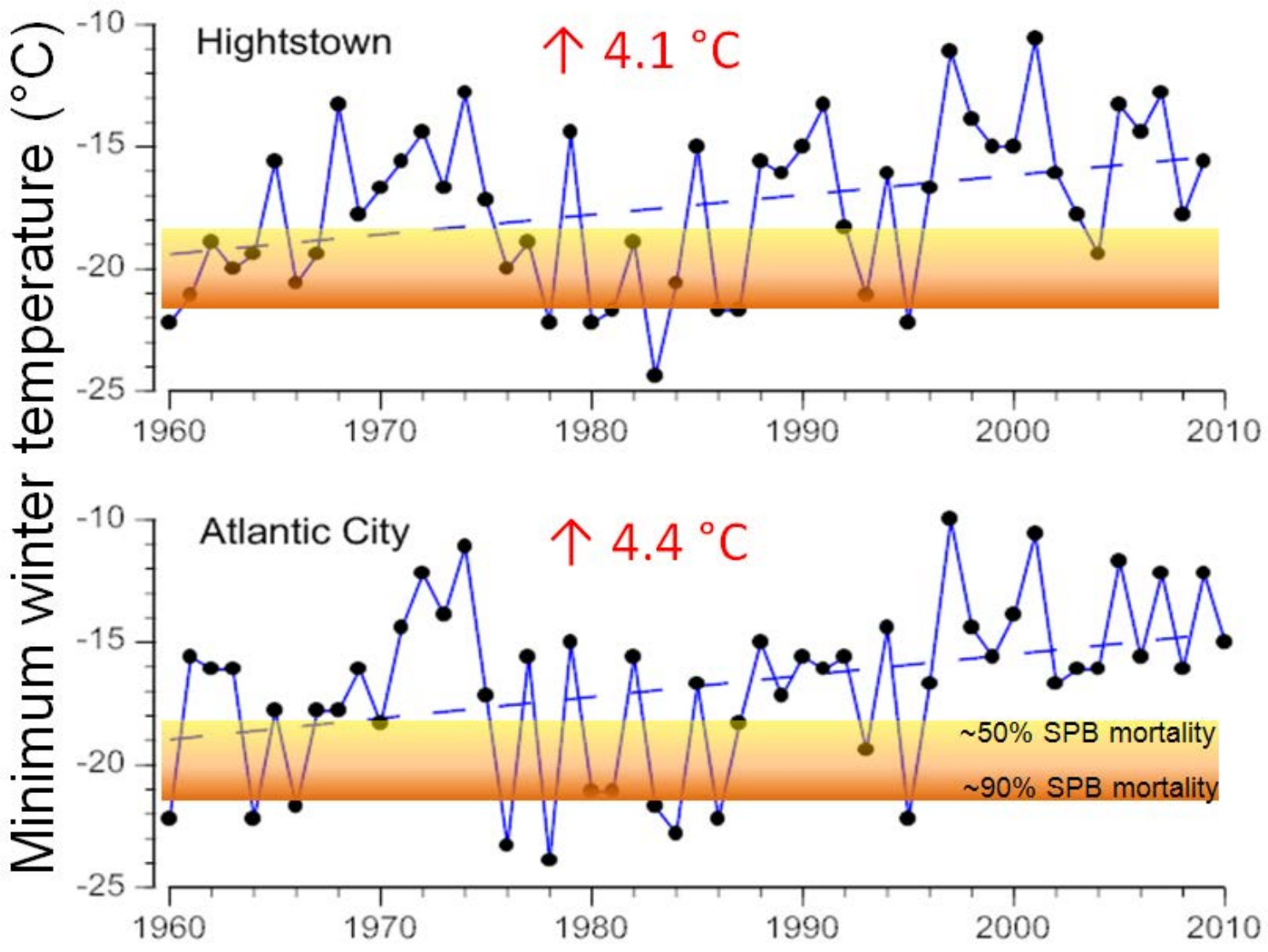
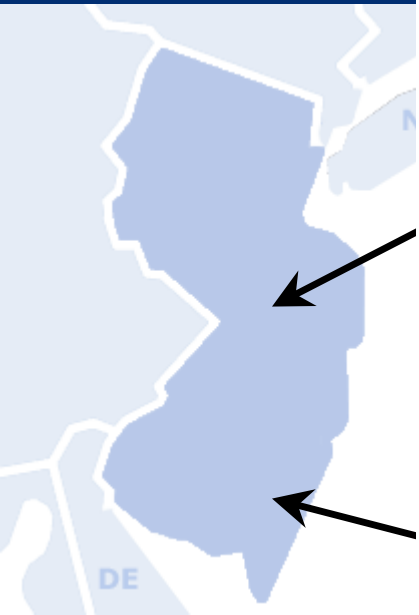
New Jersey pines killed within weeks by *D. frontalis*



Photo by Bob Williams, Land Dimensions

New Jersey pines killed by *D. frontalis*





Weed et al., 2013. *Ecol. Monographs*
Tran et al., 2007. *Ecol. Applications*
Lombardero et al., 2000. *Env. Entomology*
Ungerer et al., 1999. *J. Biogeography*.

"All the News
That's Fit to Print"

The New York Times

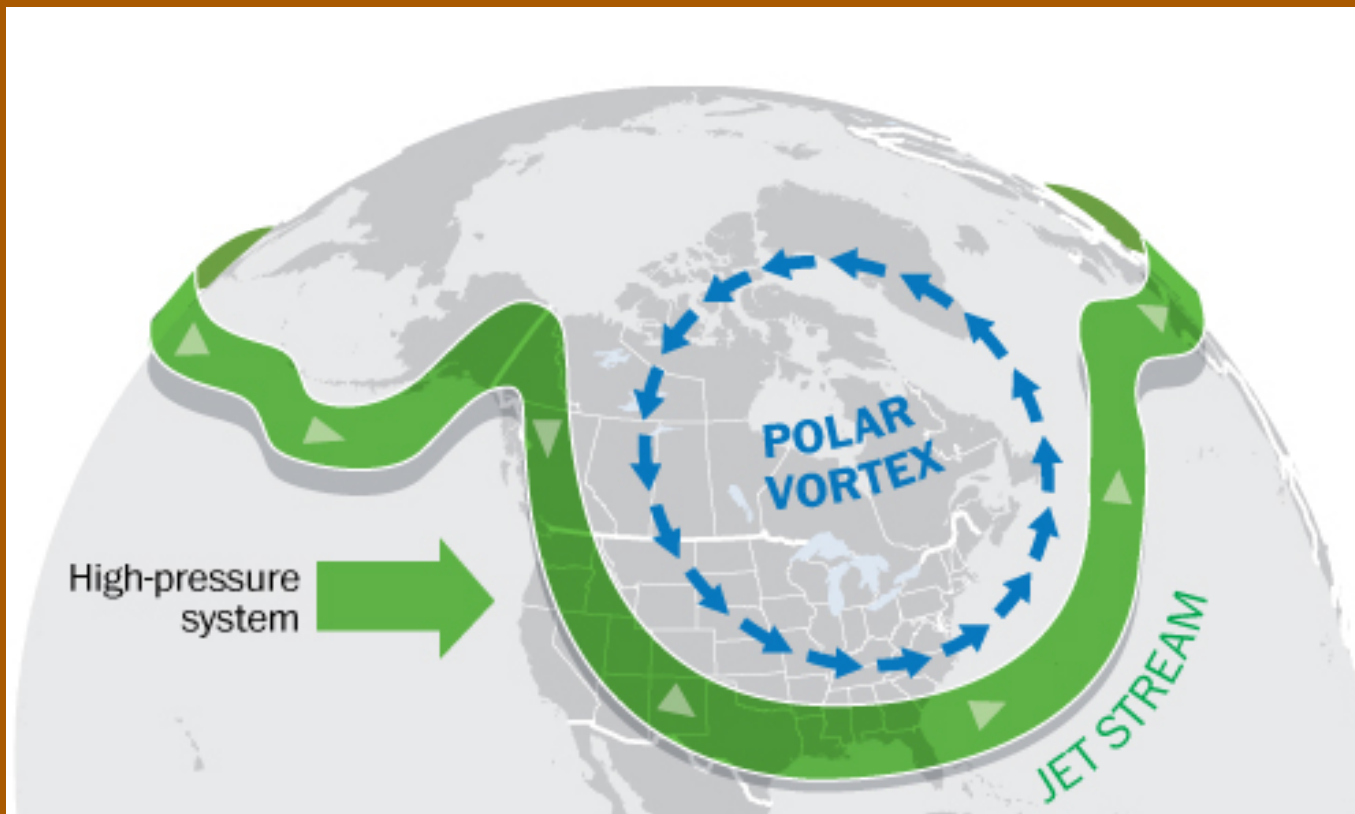
Late Edition

Today, more clouds than sunshine, seasonable, light wind, high 48. **Tonight**, rather cloudy, low 40. **Tomorrow**, clouds giving way to some sun, high 49. Weather map, Page B7.

Celebrating Deep Freeze, Insect Experts See a Chance to Kill Off Invasive Species

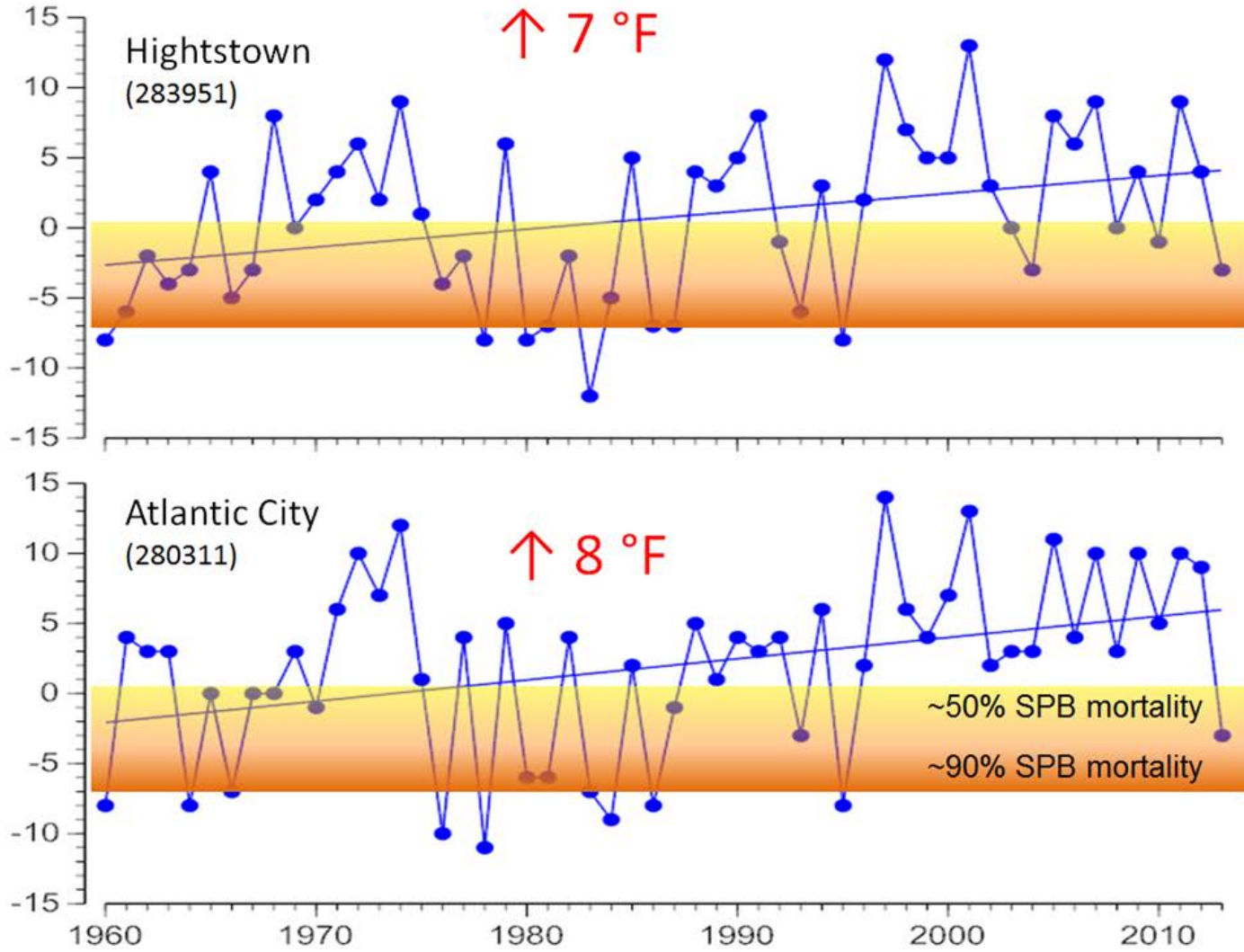
By LISA W. FODERARO

Jan 8, 2014

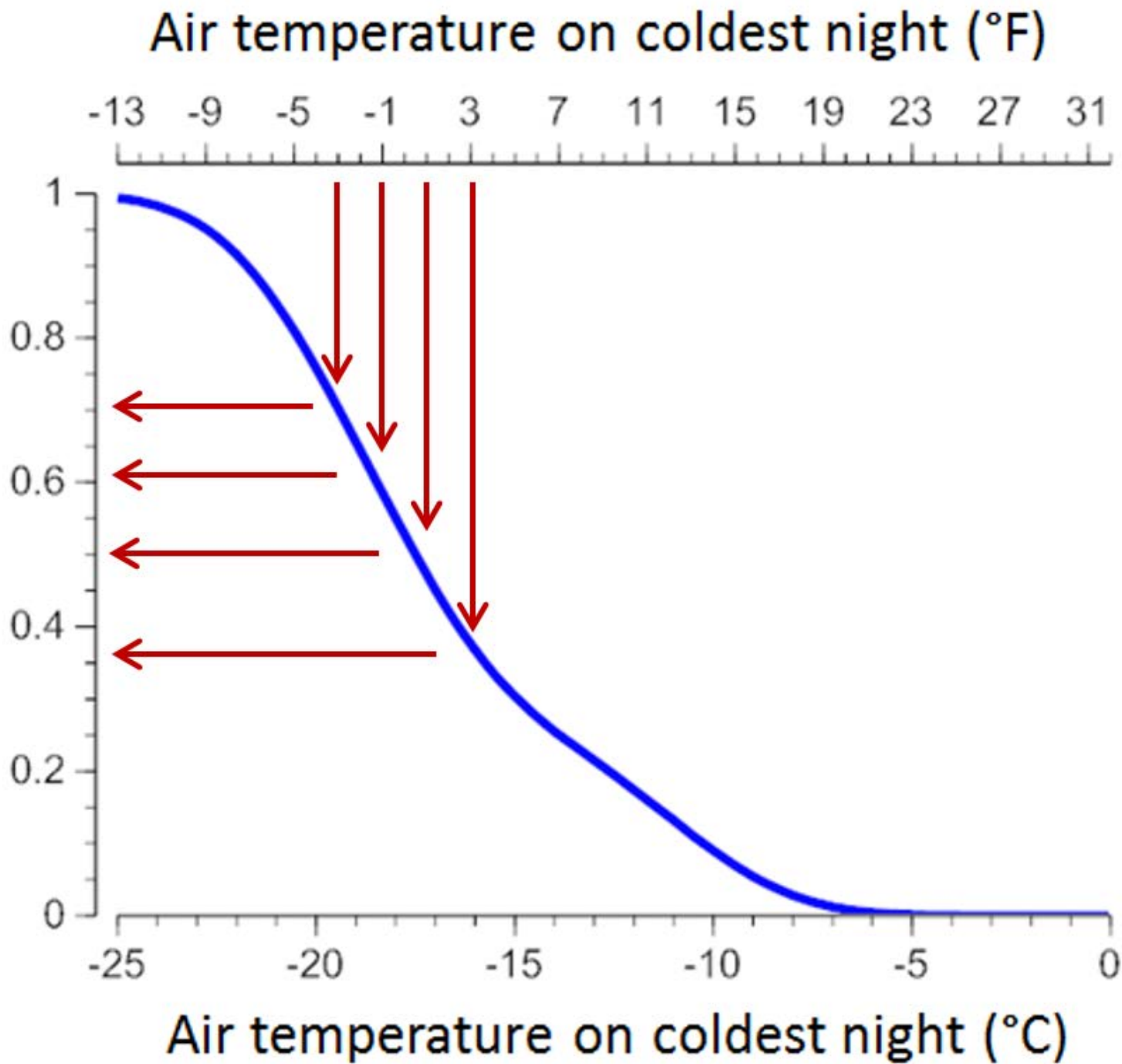




Minimum winter temperature ($^{\circ}\text{F}$)



Estimated proportion of southern
pine beetles dying from freezing



Potential Southern Pine Beetle Infestations

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

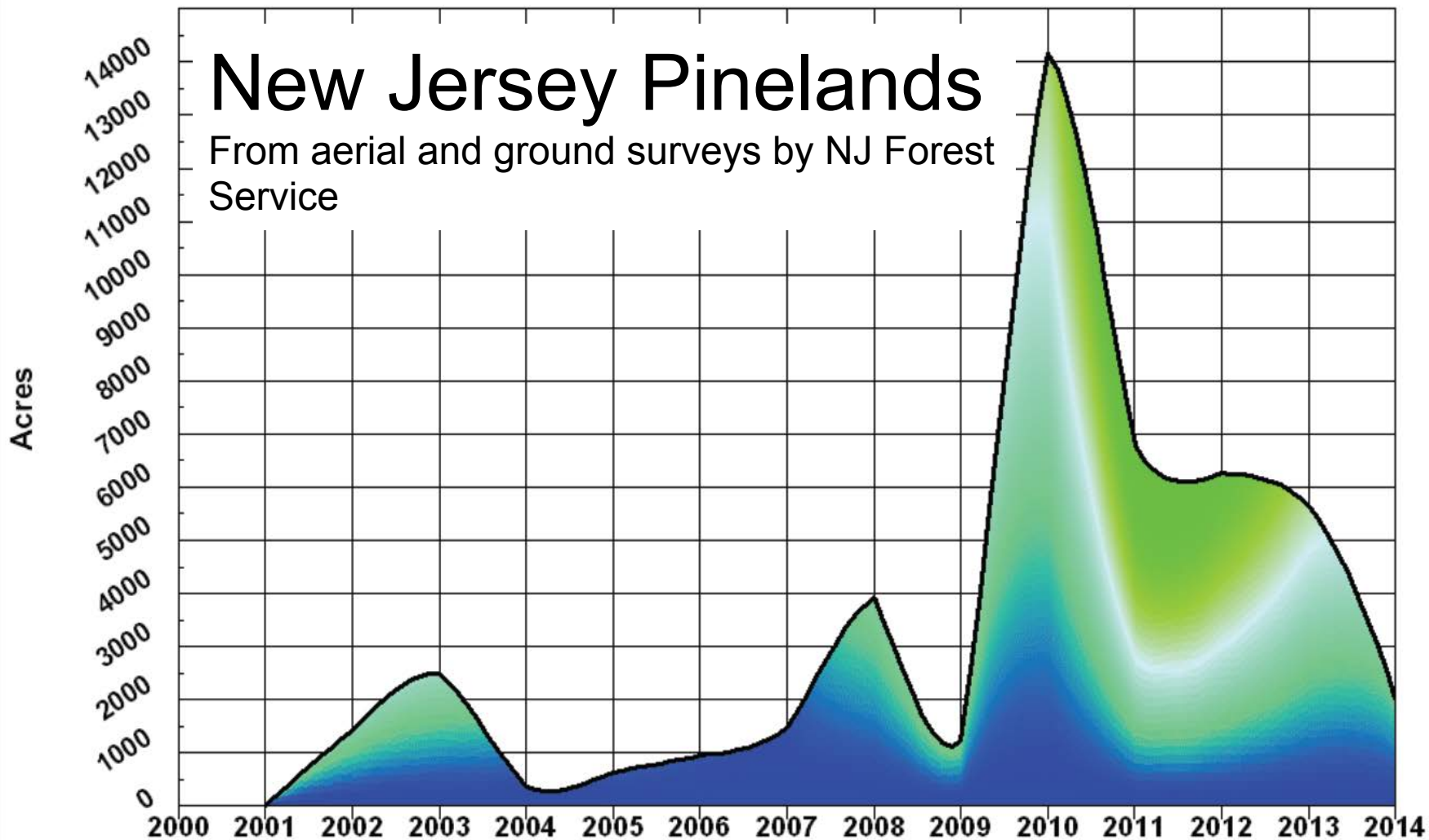
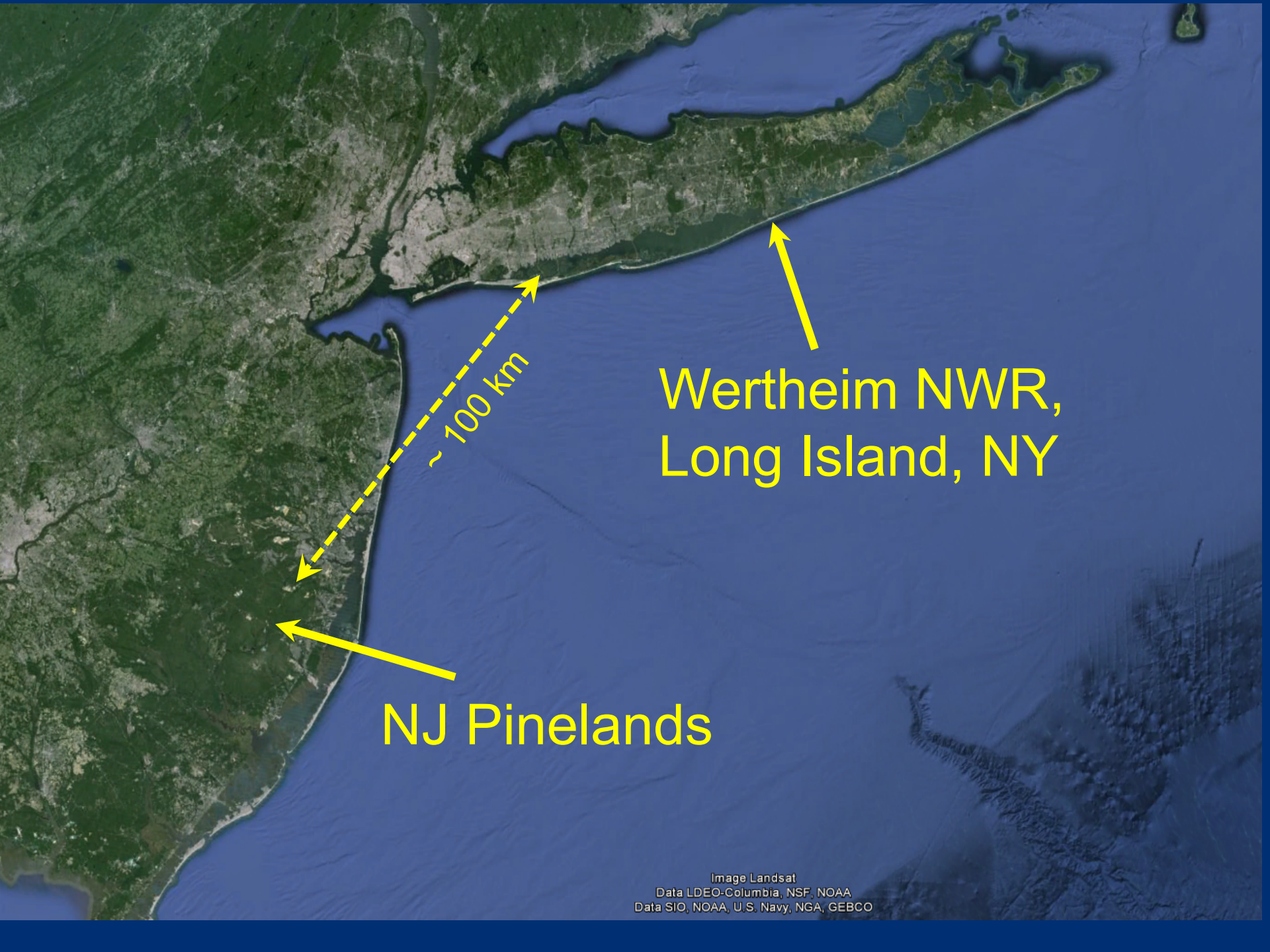


Figure 1 SPB outbreaks by acreage 2001-2014



Wertheim NWR,
Long Island, NY

NJ Pinelands

"All the News
That's Fit to Print"

The New York Times

Late Edition

Today, more clouds than sunshine, seasonable, light wind, high 48. **Tonight**, rather cloudy, low 40. **Tomorrow**, clouds giving way to some sun, high 49. Weather map, Page B7.

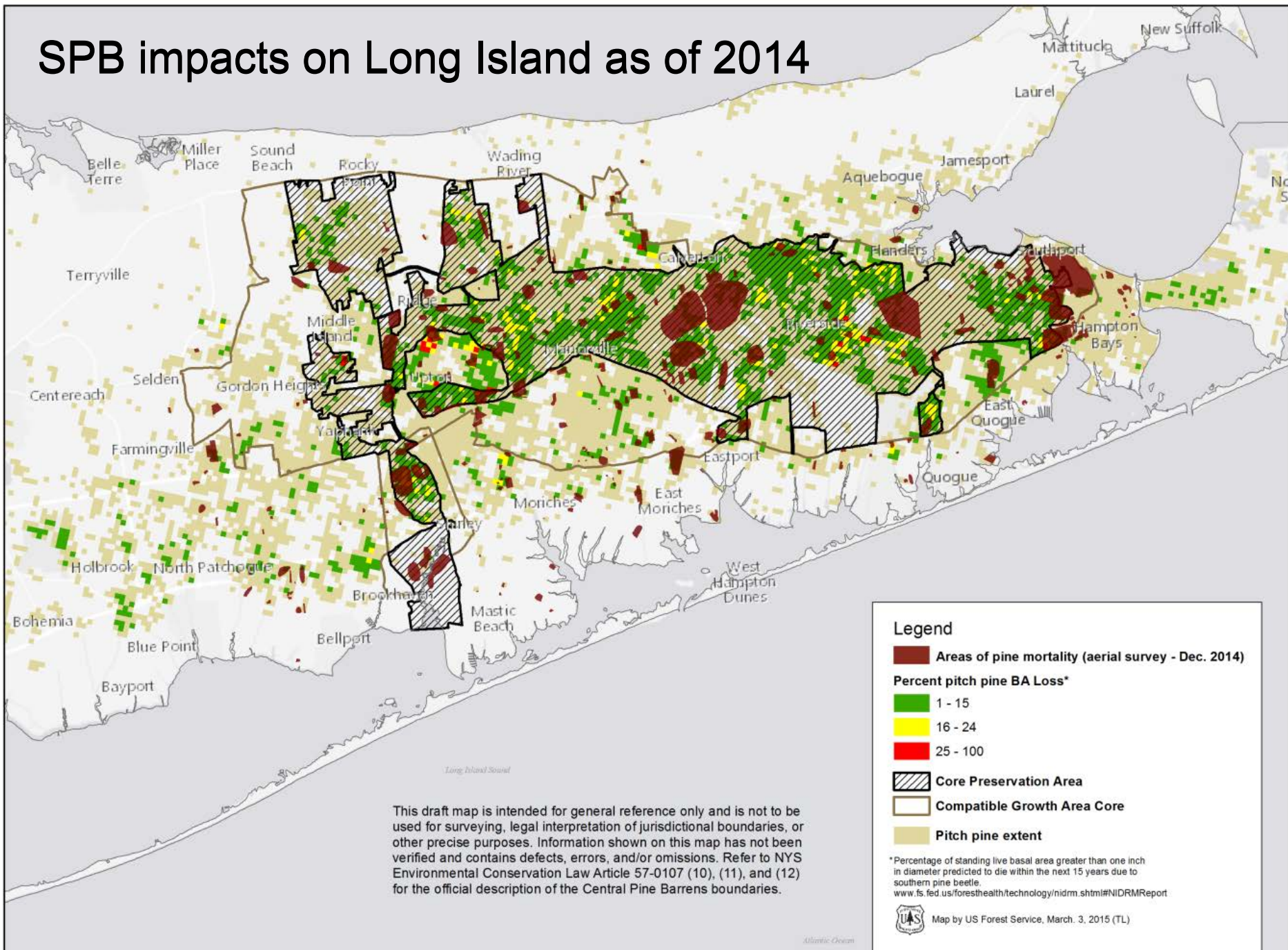
Long Island Confronts Destructive Southern Pine Beetles

By TATIANA SCHLOSSBERG OCT. 28, 2014



Robin Donohue, a wildlife biologist, inspected a pitch pine at the Wertheim National Wildlife Refuge in Shirley, N.Y., this week. Gordon M. Grant for The New York Times

SPB impacts on Long Island as of 2014

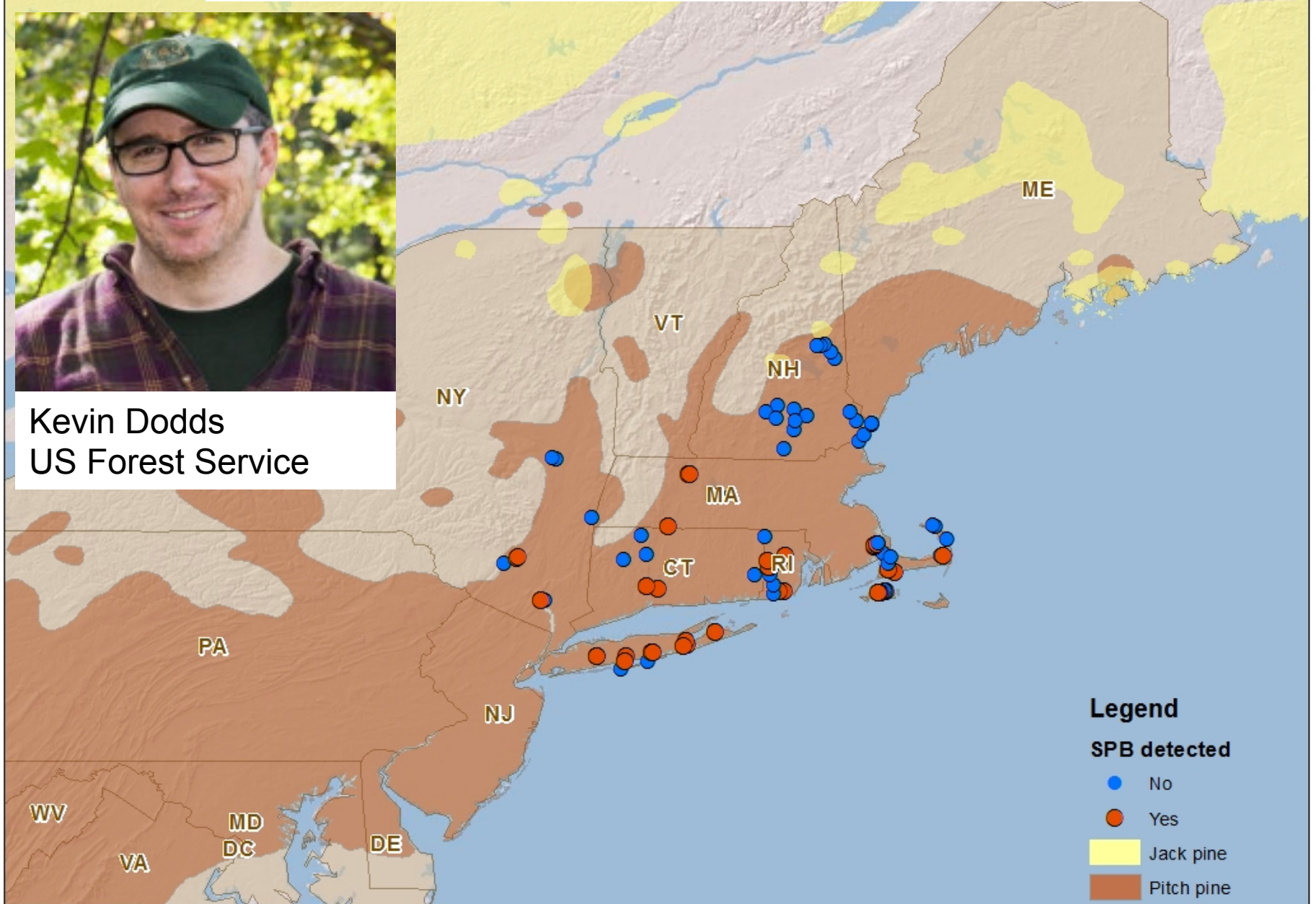


This draft map is intended for general reference only and is not to be used for surveying, legal interpretation of jurisdictional boundaries, or other precise purposes. Information shown on this map has not been verified and contains defects, errors, and/or omissions. Refer to NYS Environmental Conservation Law Article 57-0107 (10), (11), and (12) for the official description of the Central Pine Barrens boundaries.

SPB trapping results from spring 2015



Kevin Dodds
US Forest Service



Why is the southern pine beetle not so southern anymore?

- Coldest winter night is not as cold as it used to be.
- Naïve forests?

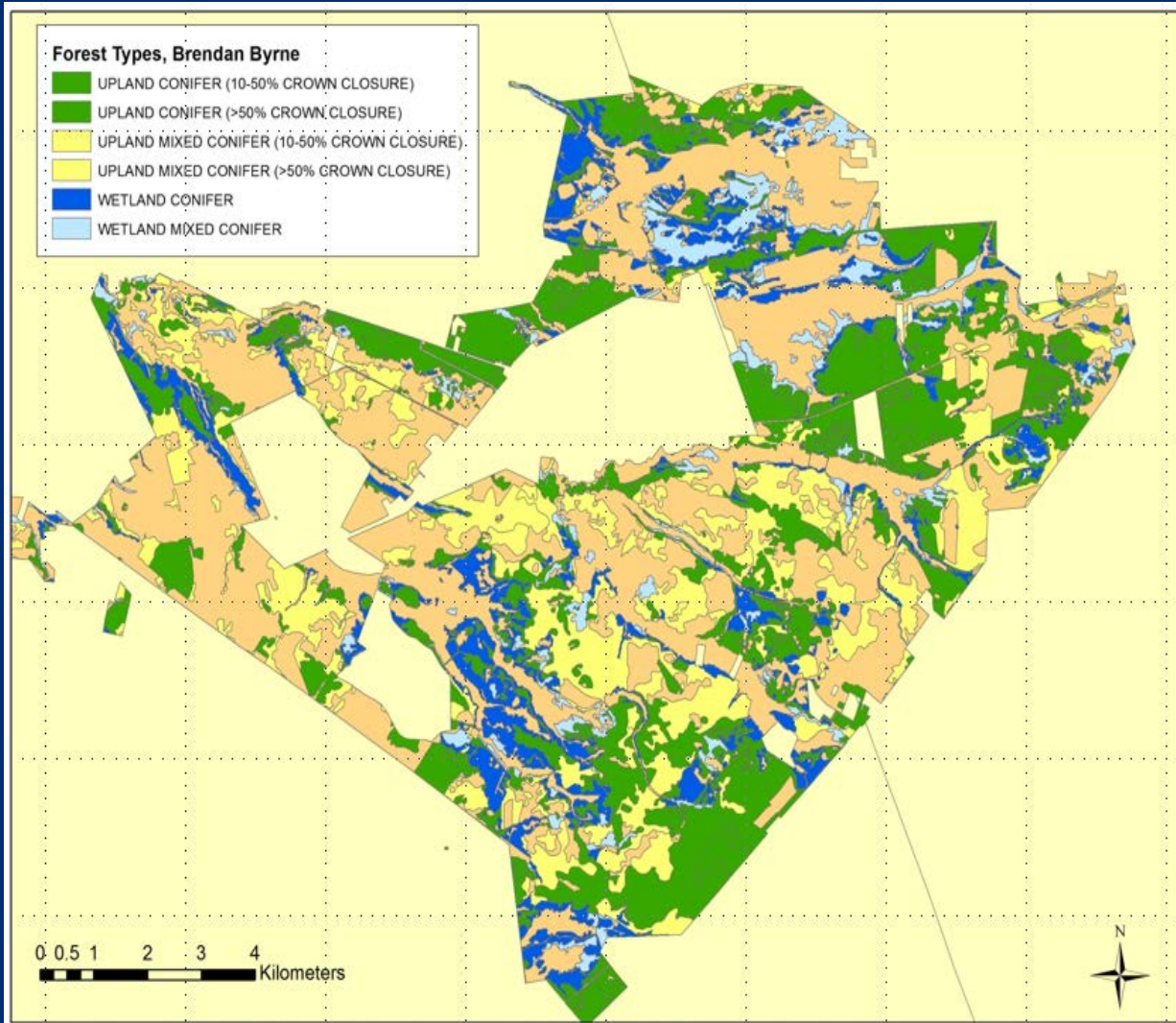
Defenses of *Pinus rigida*?



Carissa Aoki

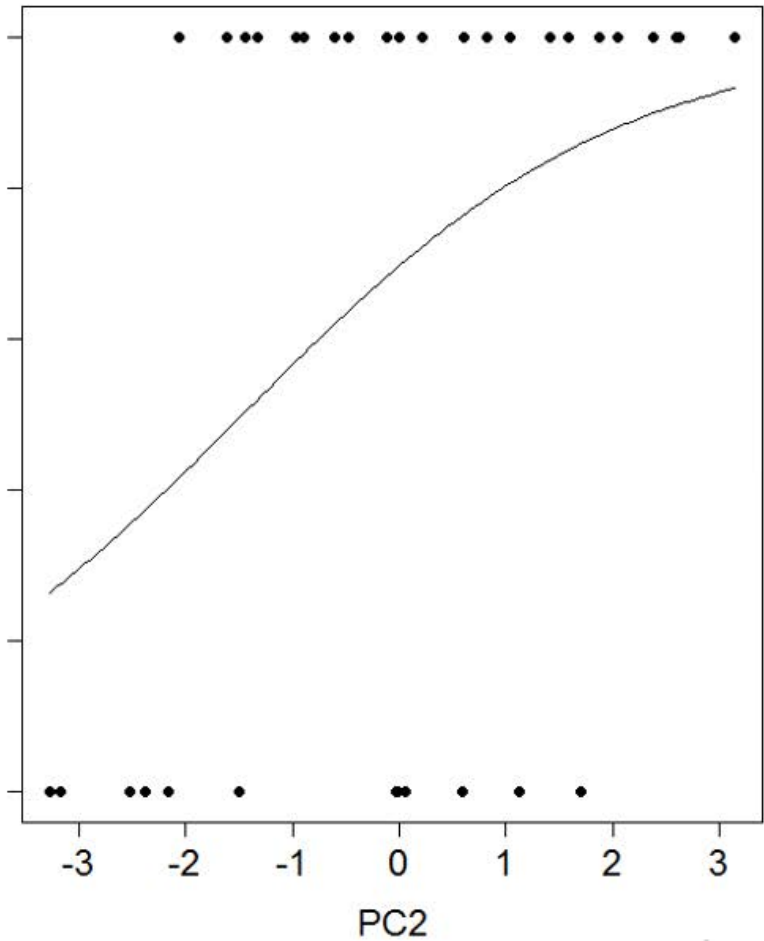
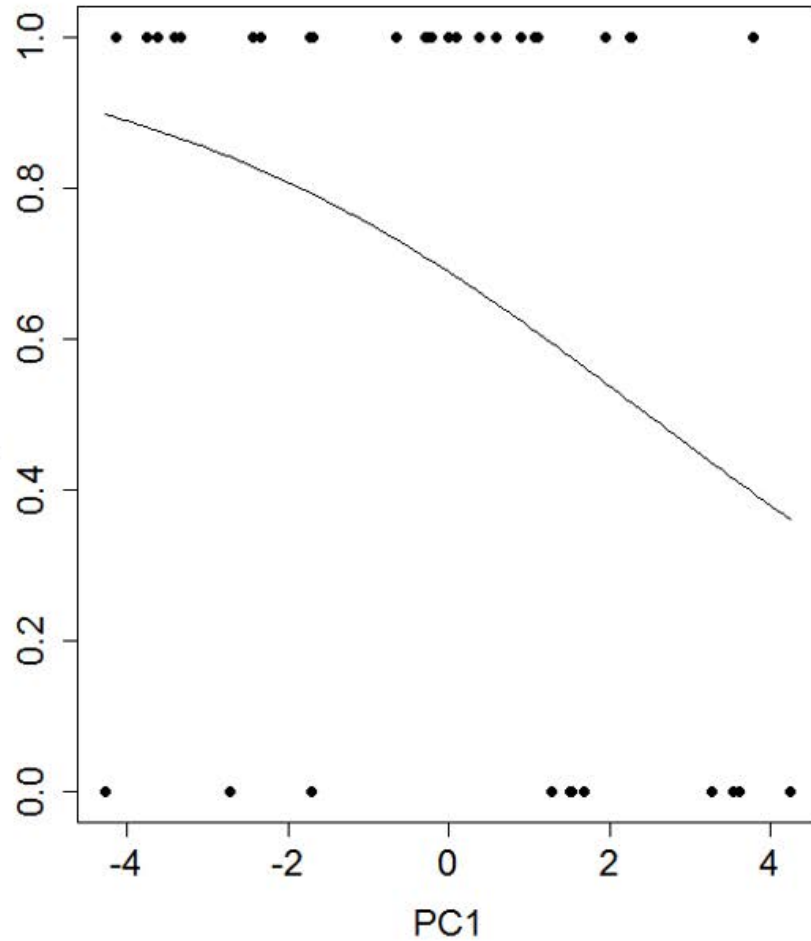


Old pests in new places: testing and extending risk rating models from southern pine forests



Carissa Aoki

Probability of infestation



High % pine
High stem density
Smaller DBH

Increased risk with:

High Basal area
Small crowns

Carissa Aoki

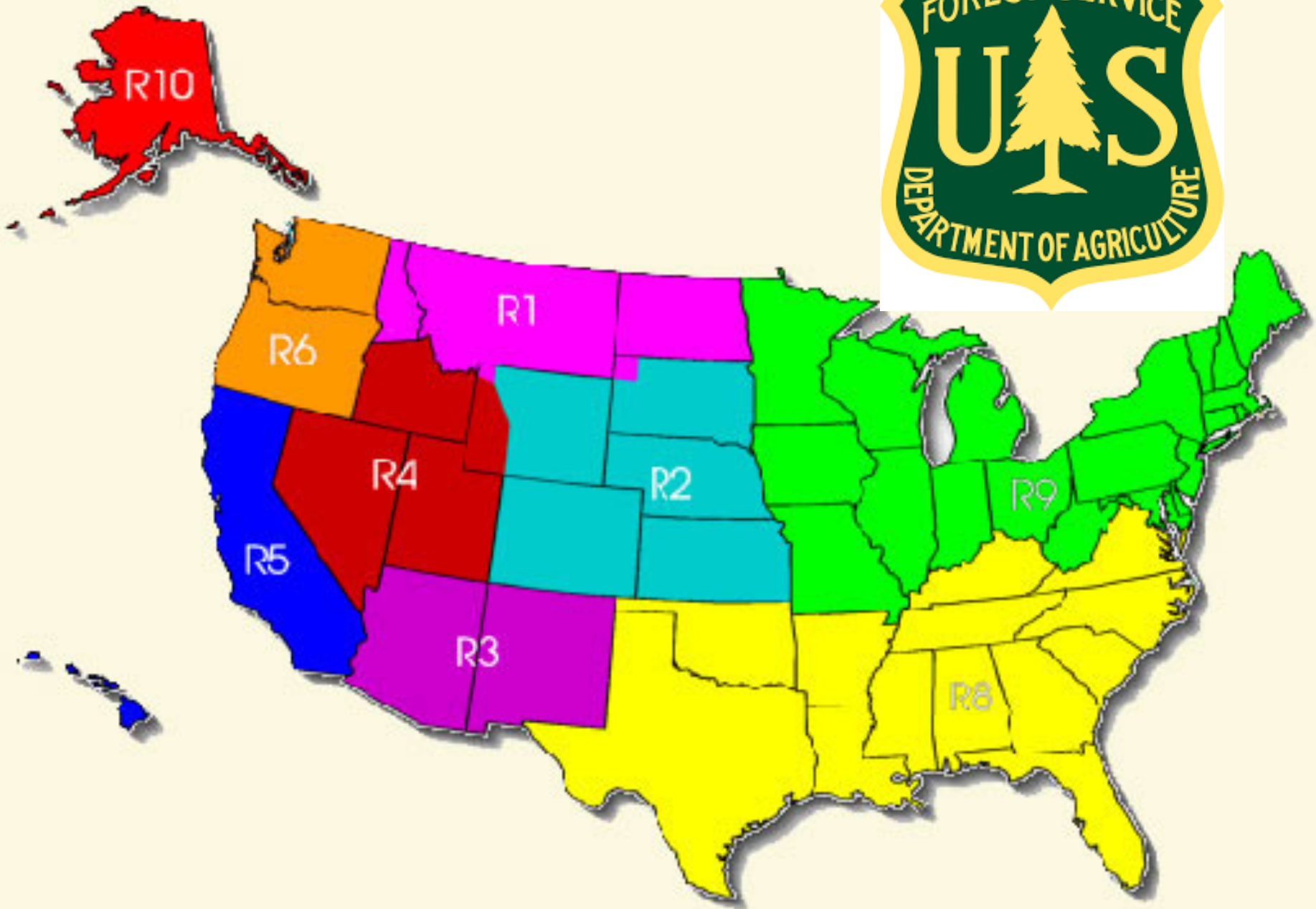


Expanding epidemic
as of 2015

Extensive tree mortality
2005-2014

Why is the southern pine beetle not so southern anymore?

- Coldest winter night is not as cold as it used to be.
- Naïve forests.
- Naïve forest managers?





Dec 2014

I am contacting you as an identified person with expertise in this matter to request your opinion on whether the SPB should be considered (1) an invasive species or (2) a native pest expanding into New York State

From NY law ([link](#))

(s) 'Invasive Species' means a species that is nonnative to the ecosystem under consideration, and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. For the purposes of this Part, the harm must significantly outweigh any benefits.

(u) 'Native Species' means with respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem, or in New York State.

(j) 'Ecosystem' means the complex of a community of organisms and its environment functioning as an interactive unit.

29 March 2015



DENDROCTONE MÉRIDIONAL DU PIN **DES QUÉBÉCOIS AU SECOURS D'UNE FORÊT DE NEW YORK**

DES QUÉBÉCOIS AU SECOURS D'UNE FORÊT DE NEW YORK

Des pompiers forestiers du Québec ont été appelés en renfort sur la réserve nationale de faune Wertheim pour combattre un petit insecte ravageur.

RICHARD HÉTU
COLLABORATION SPÉCIALE

Attempted SPB suppression on Long Island



Maintaining pitch pine forests in the new world?




NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF PARKS AND FORESTRY

**GYPSY MOTH
TREATMENT AREA**

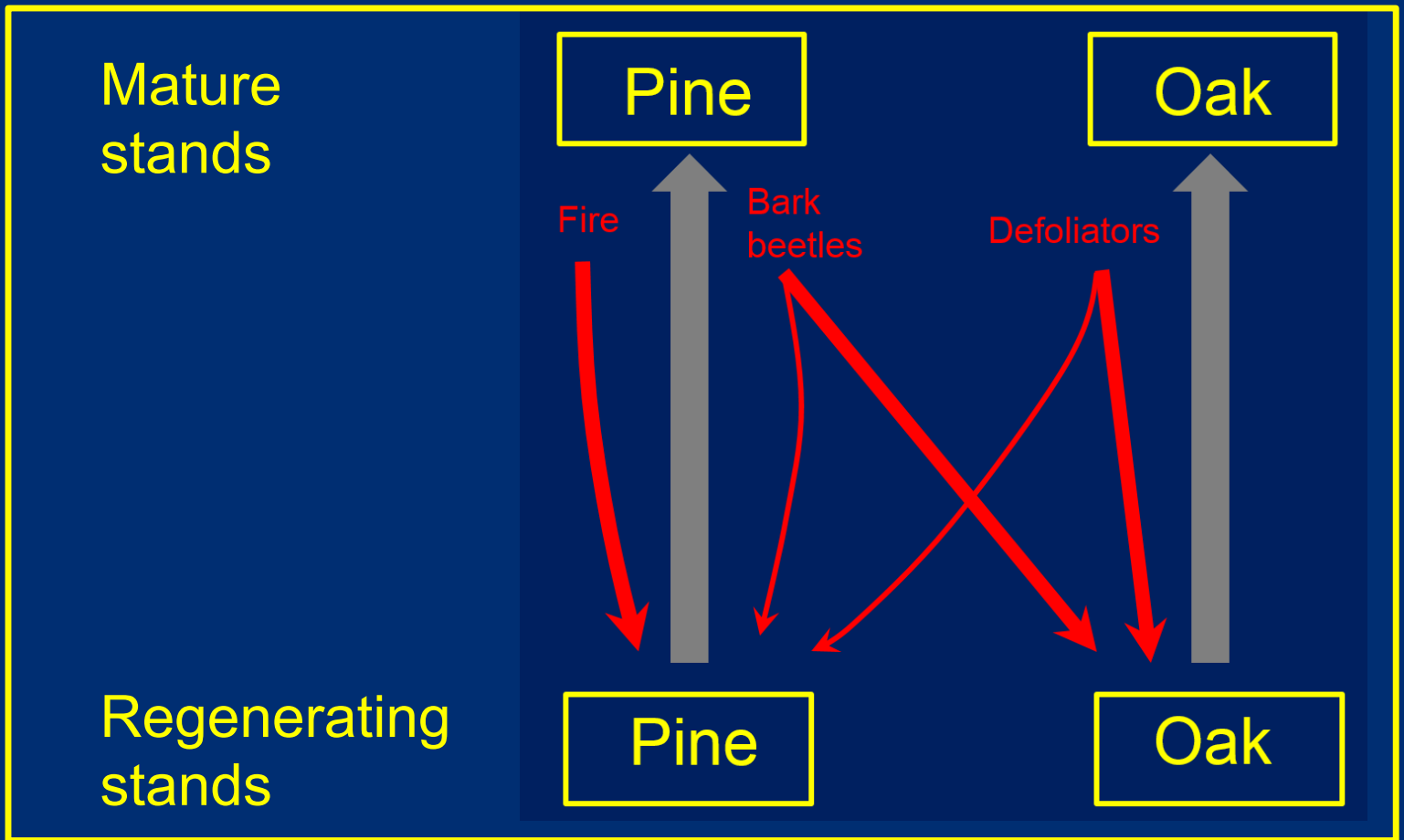


**THIS AREA WILL BE SPRAYED BY
AIRPLANE WITH
THE INSECTICIDE BT
DURING THE MONTH OF MAY**

FOR MORE INFORMATION
CONTACT THE STATE PARK OR FOREST OFFICE



CAUTION !



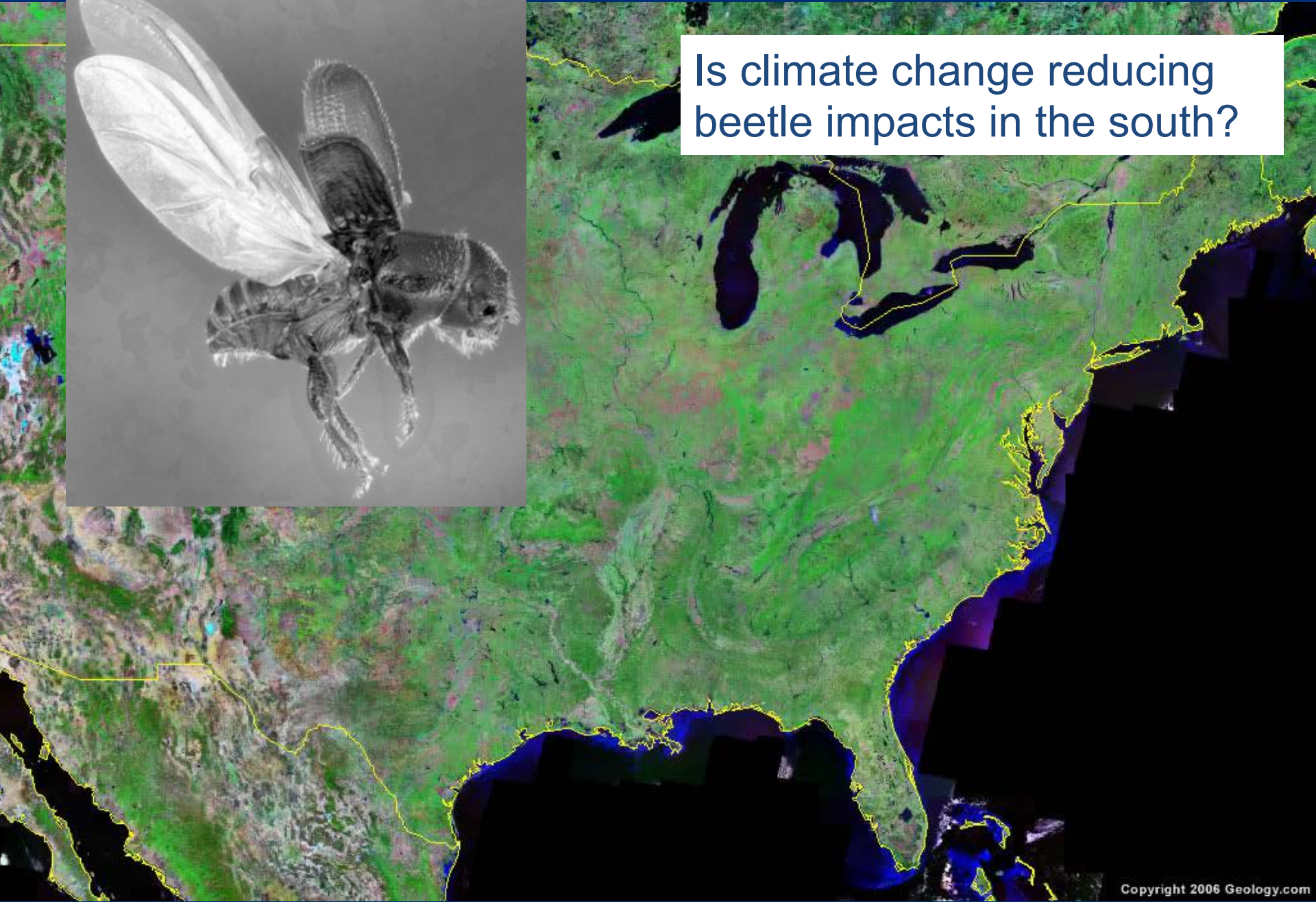
Carissa Aoki



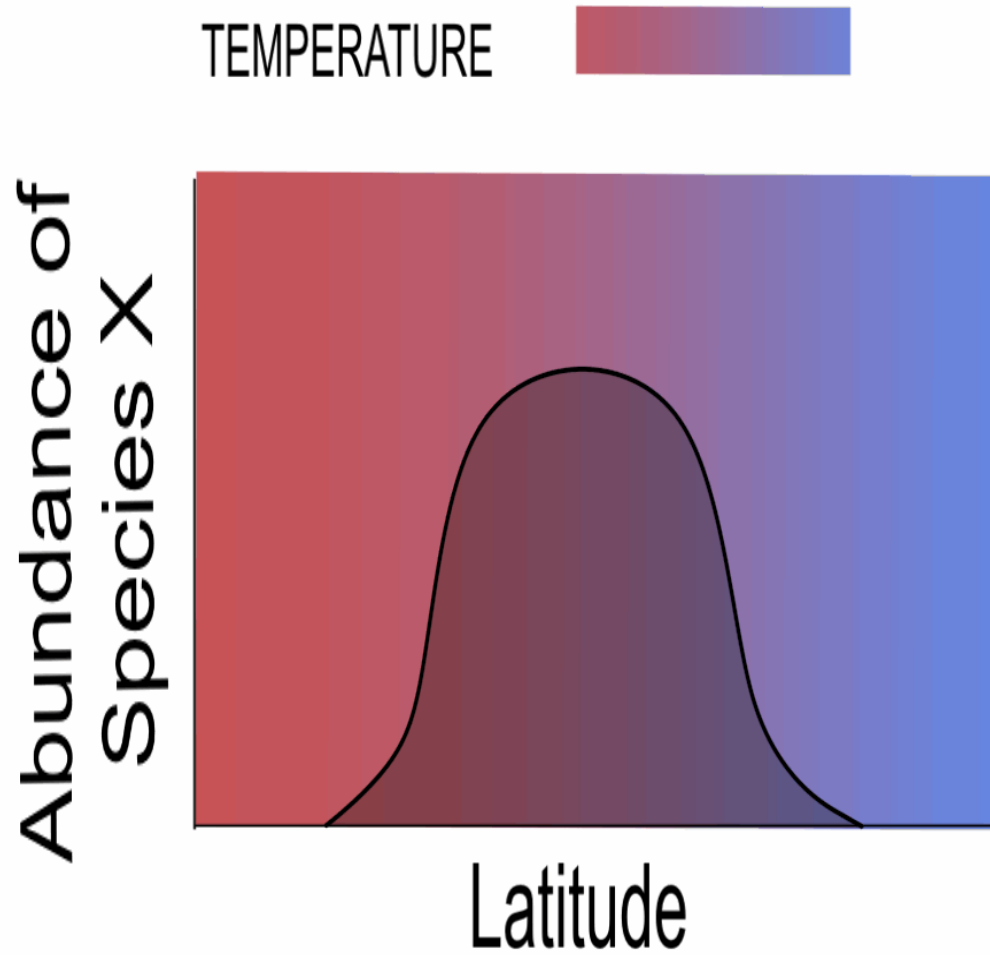
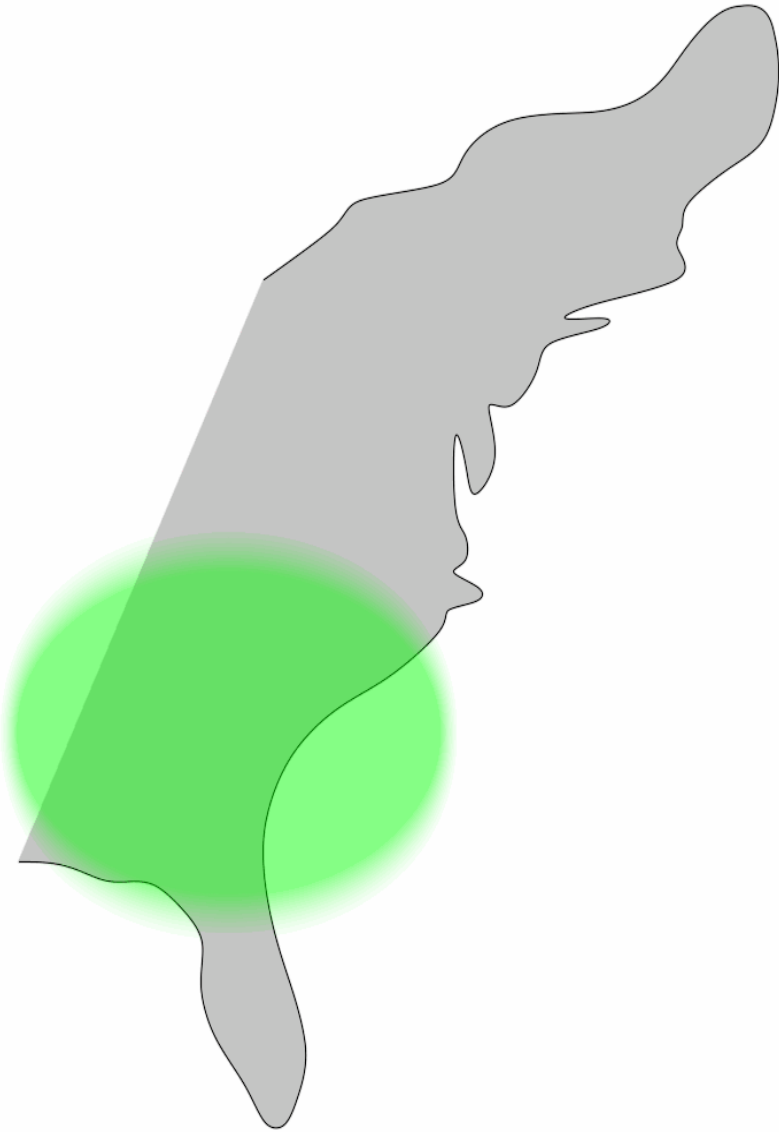
Ken Clark



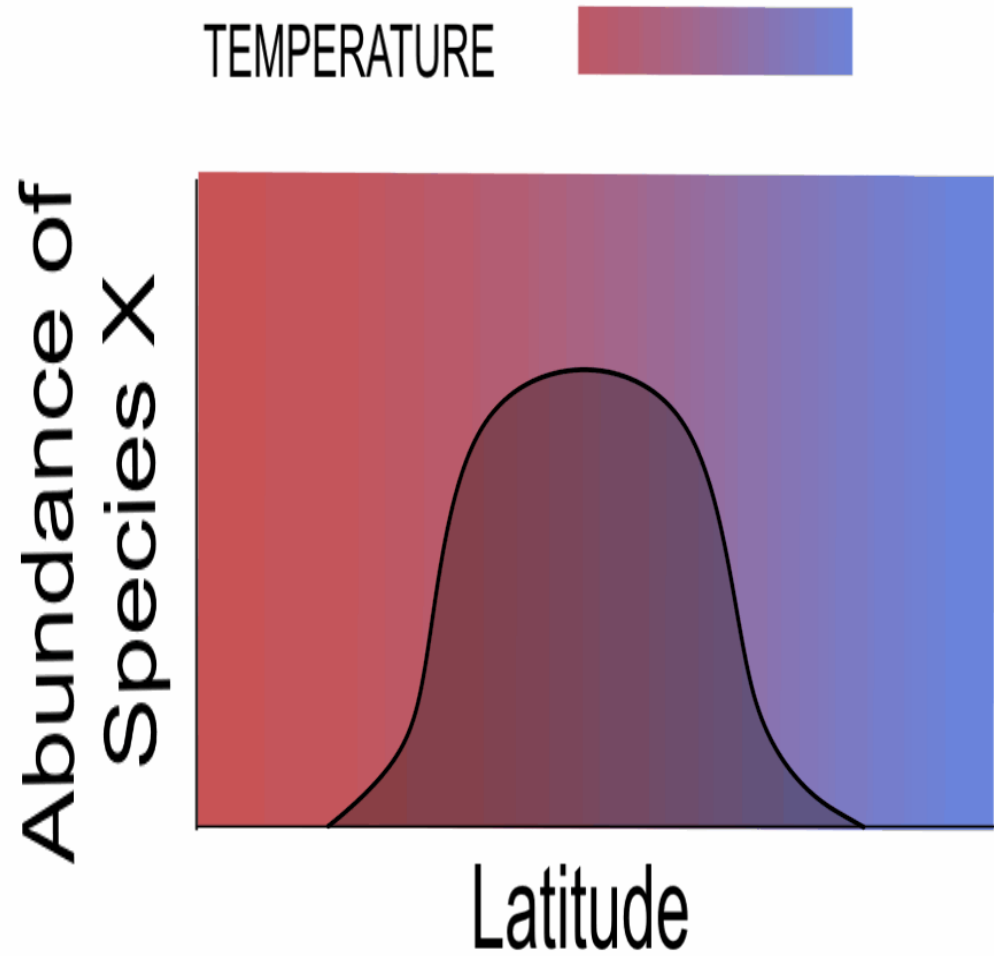
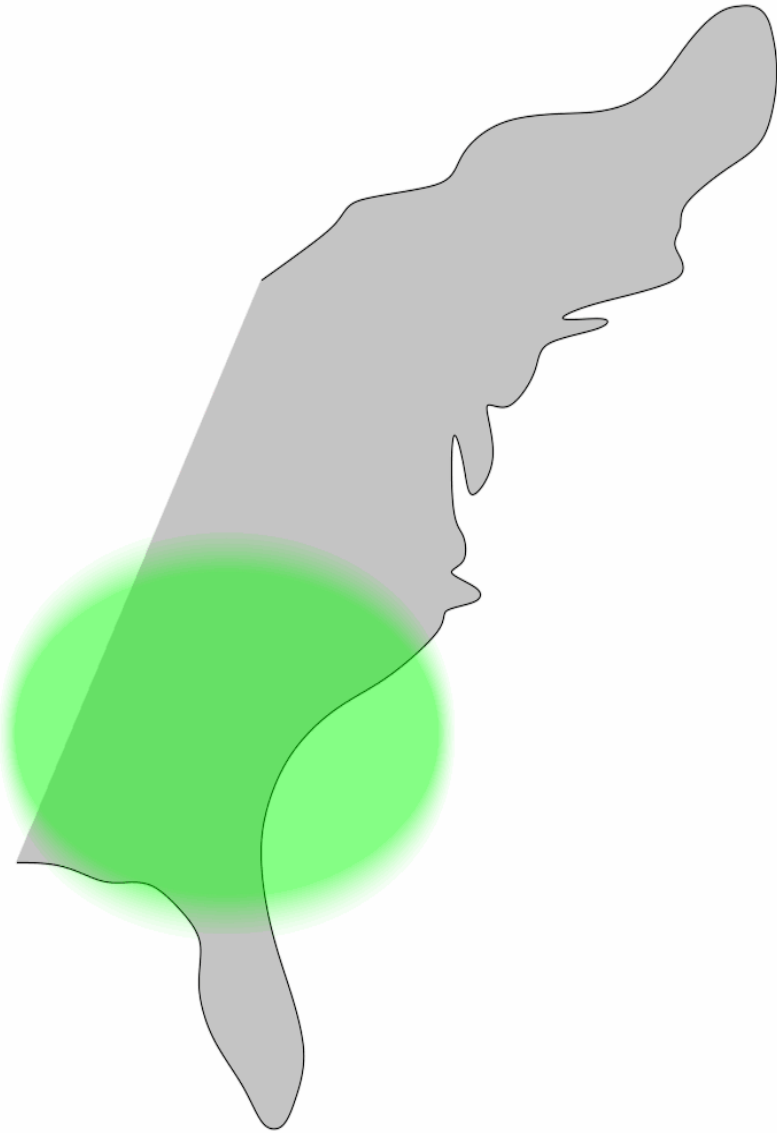
Is climate change reducing beetle impacts in the south?



CLIMATIC ENVELOPE



TYRANNY OF THERMODYNAMICS

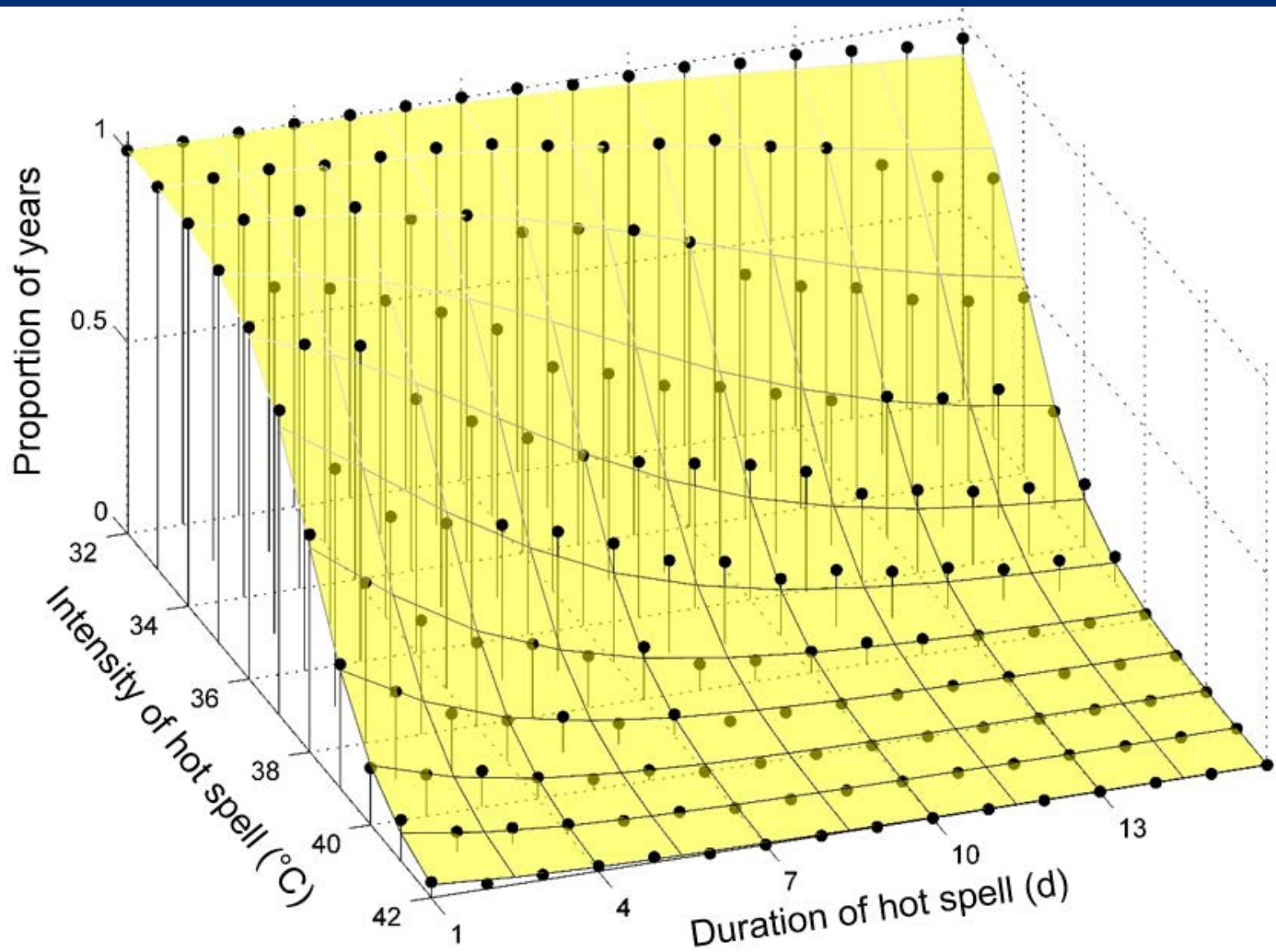




Measurement of upper
lethal temperatures in *D.*
frontalis (acute and
chronic exposure)

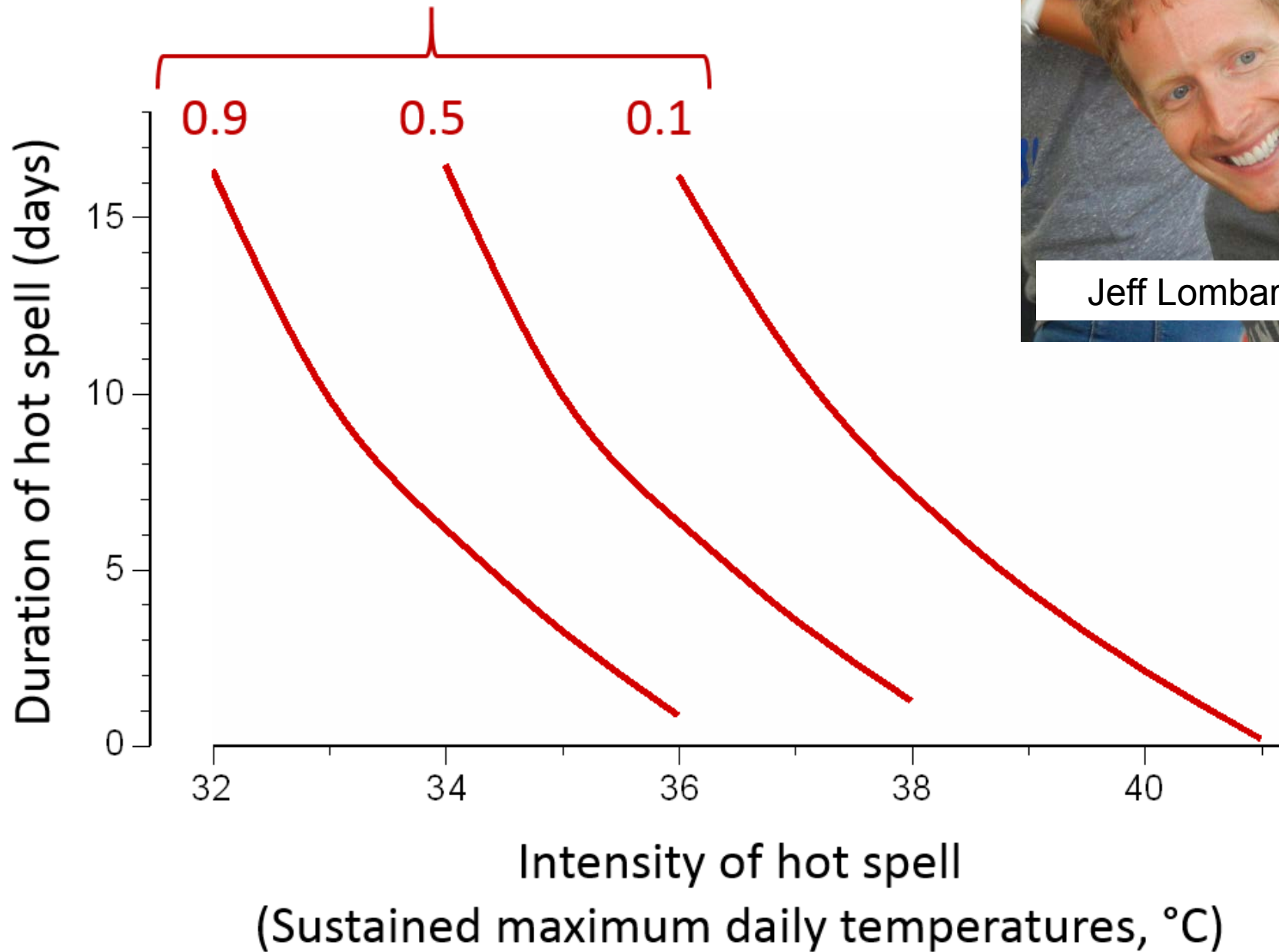
Climatic patterns in hot
spells in the southeastern
U.S.

Hot spells in Kisatchie National Forest, Louisiana: 1940 – 2013 (from NOAA data)

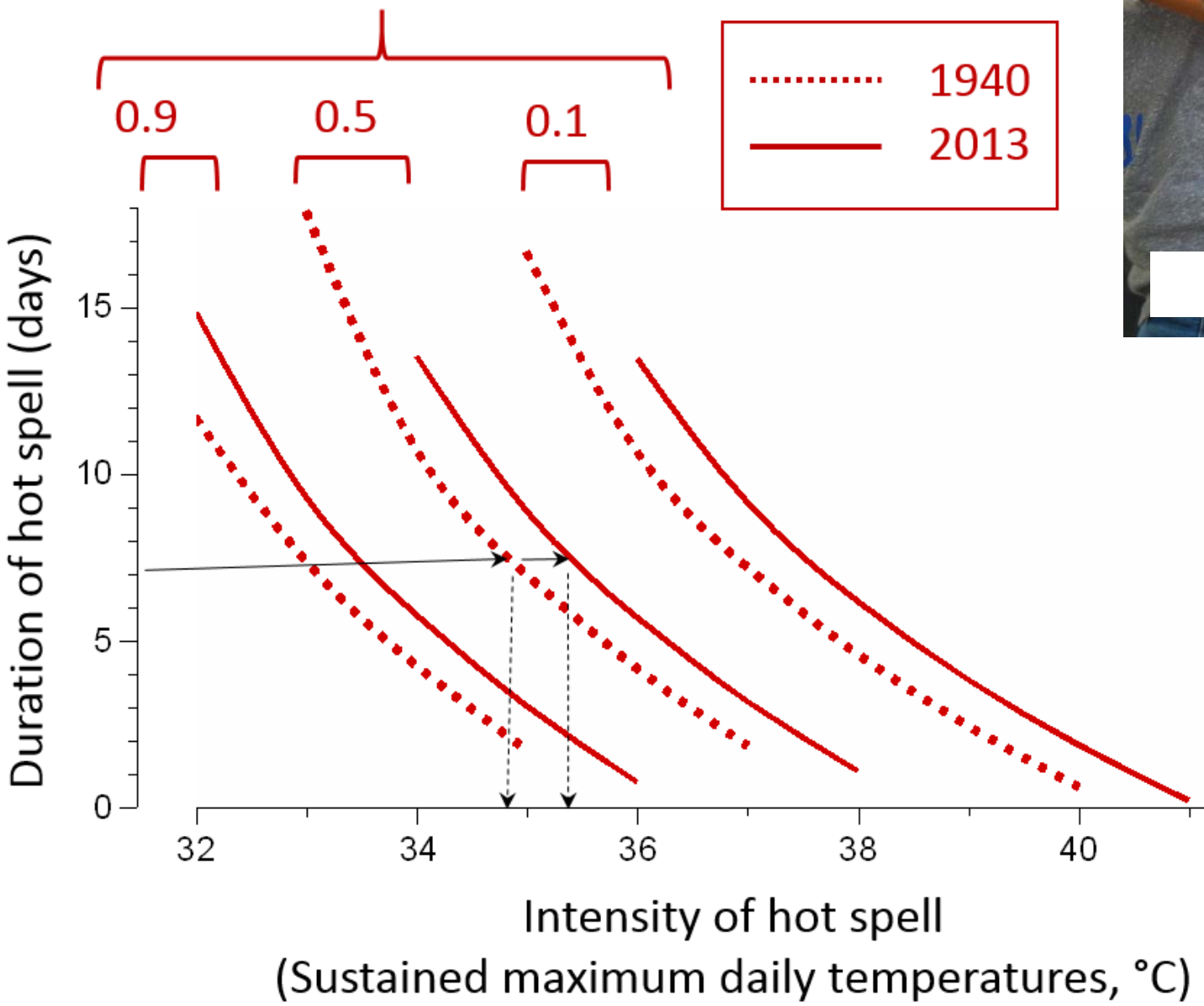


$$\text{Logit}(p) = b_0 + b_1 \cdot X + b_2 \cdot Y + b_3 \cdot X^2 + b_4 \cdot Y^2 + b_5 \cdot X \cdot Y$$

Proportion of years with hot spell of specified intensity and duration



Expected proportion of years with hot spell of specified intensity and duration



Jeff Lombardo

Why is the southern pine beetle not so southern anymore?

- Coldest winter night is not as cold as it used to be.
- Naïve forests.
- Naïve forest managers.
- ~~Warming summers limit SPB in the south.~~

Why is the southern pine beetle not so southern anymore?

- Coldest winter night is not as cold as it used to be.
- Naïve forests.
- Naïve forest managers.
- ~~Warming summers limit SPB in the south.~~
- Effective monitoring, suppression, and prevention in historic outbreak regions.

Southern Pine Beetle Infestations in Relation to Forest Stand Conditions, Previous Thinning, and Prescribed Burning: Evaluation of the Southern Pine Beetle Prevention Program

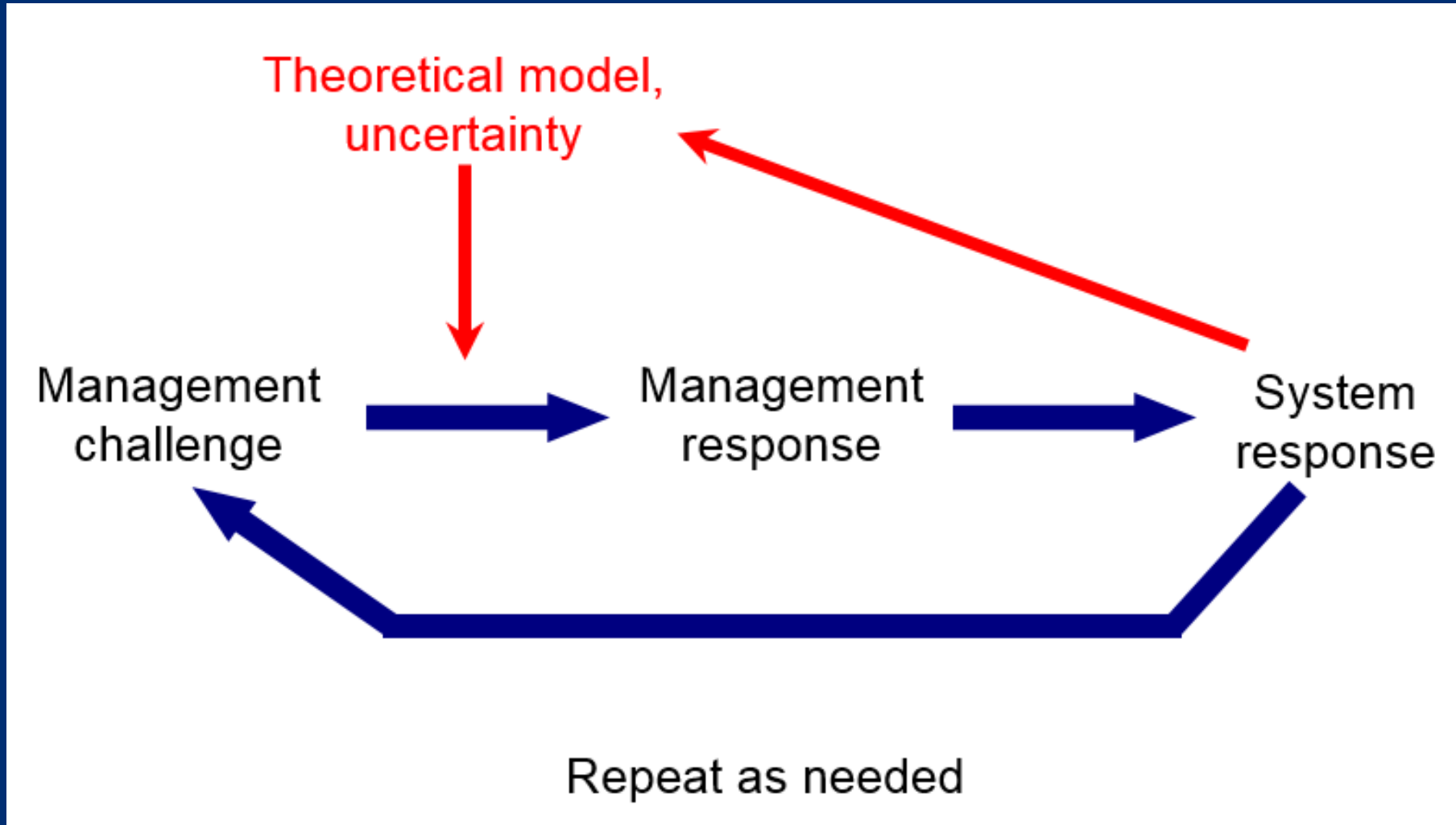
John T. Nowak, James R. Meeker, David R. Coyle,
Chris A. Steiner, and Cavell Brownie

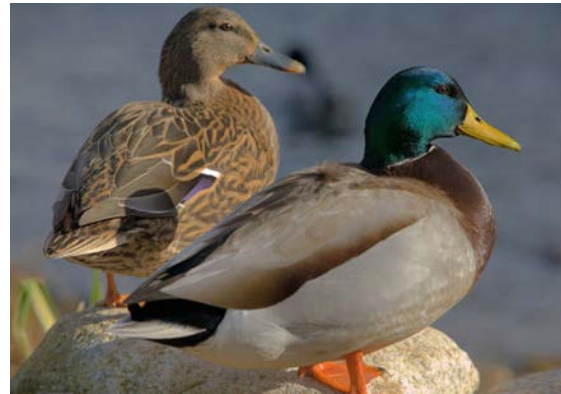
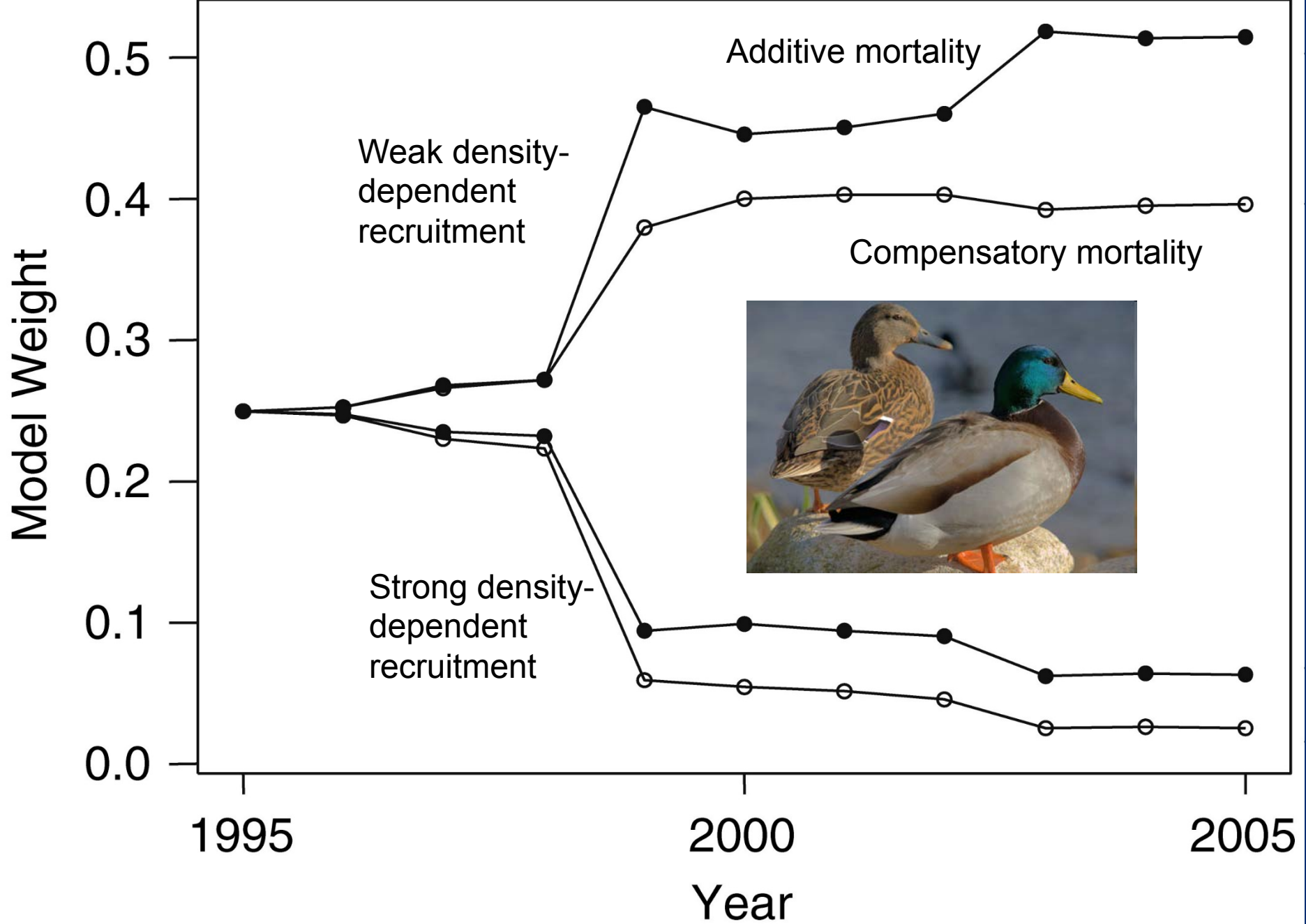
Journal of Forestry, 2015

Tactics for environmental security in the Anthropocene

1. Adaptive management

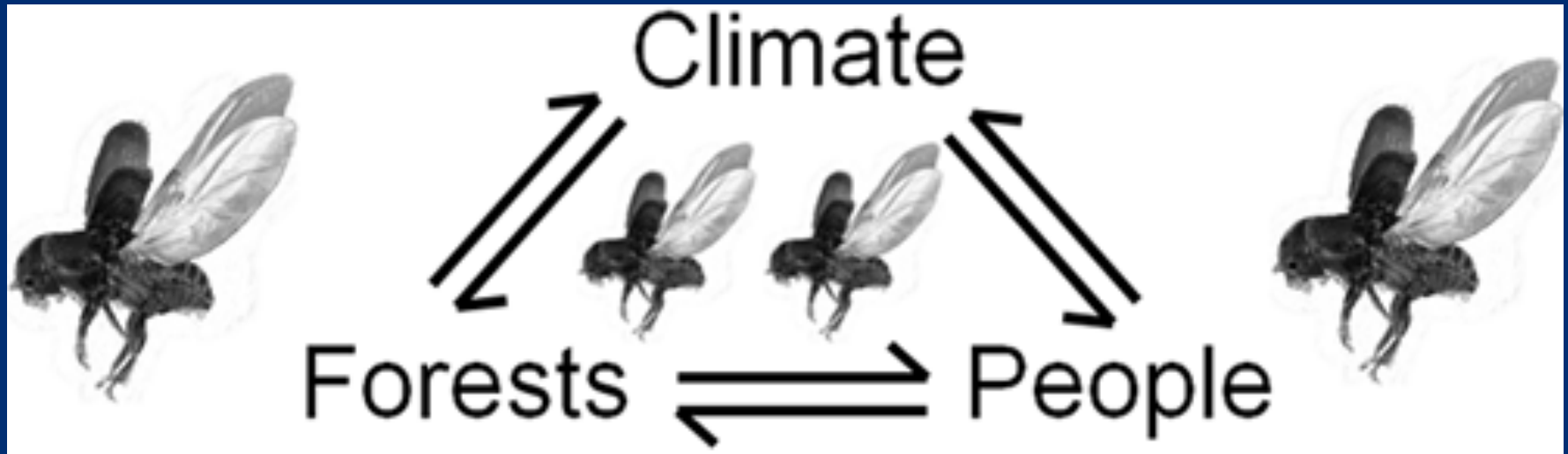
But why don't we do it?!





Tactics for environmental security in the Anthropocene

1. Adaptive management
2. Transdisciplinary study of coupled human-natural systems. How to do it faster and better?



Examples of transdisciplinary challenges for forest management

1. How to slow the flood of human-aided biological invasions

Ecological Applications, 0(0), 2016, pp. 1–19
© 2016 by the Ecological Society of America

Nonnative forest insects and pathogens in the United States: Impacts and policy options

GARY M. LOVETT,^{1,12} MARISSA WEISS,^{2,3} ANDREW M. LIEBHOLD,⁴ THOMAS P. HOLMES,⁵ BRIAN LEUNG,⁶ KATHY FALLON LAMBERT,^{2,3} DAVID A. ORWIG,³ FAITH T. CAMPBELL,⁷ JONATHAN ROSENTHAL,⁸ DEBORAH G. McCULLOUGH,⁹ RADKA WILDOVA,⁸ MATTHEW P. AYRES,¹⁰ CHARLES D. CANHAM,¹ DAVID R. FOSTER,³ SHANNON L. LADEAU,¹ AND TROY WELDY¹¹

 Cary Institute
of Ecosystem Studies
[the science behind environmental solutions]

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Tree-SMART Trade

Growing reliance on both trees and trade makes imported forest pests the most pressing, and under-appreciated, forest health issue in the US today. Five high-priority policy actions that build on proven prevention measures can reduce the arrival and establishment of new forest pests.

New laws are in
“the mill” for U.S.
Farm Bill, 2018

Examples of transdisciplinary challenges for forest management

2. Valuation of forests and forest pestilence

Direct costs

Nonmarket costs

Long term accounting

Hedonic modeling

Opportunity costs?

- underinvestment in a forest region where climatic changes are reducing impacts from forest insects and diseases?

Cost of changing risks?

- insuring against the collapse of forest-based taxes that support local schools;
- disruptions of hydrology in the Kirkwood-Cohansey aquifer of NJ Pinelands

Examples of transdisciplinary challenges for forest management

3. Social perceptions of forests, forestry, and forest science



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Lay of the Land
Celebrating the great outdoors

July 15, 2015

Focus on Forestry Health, Not Chopping Down Trees

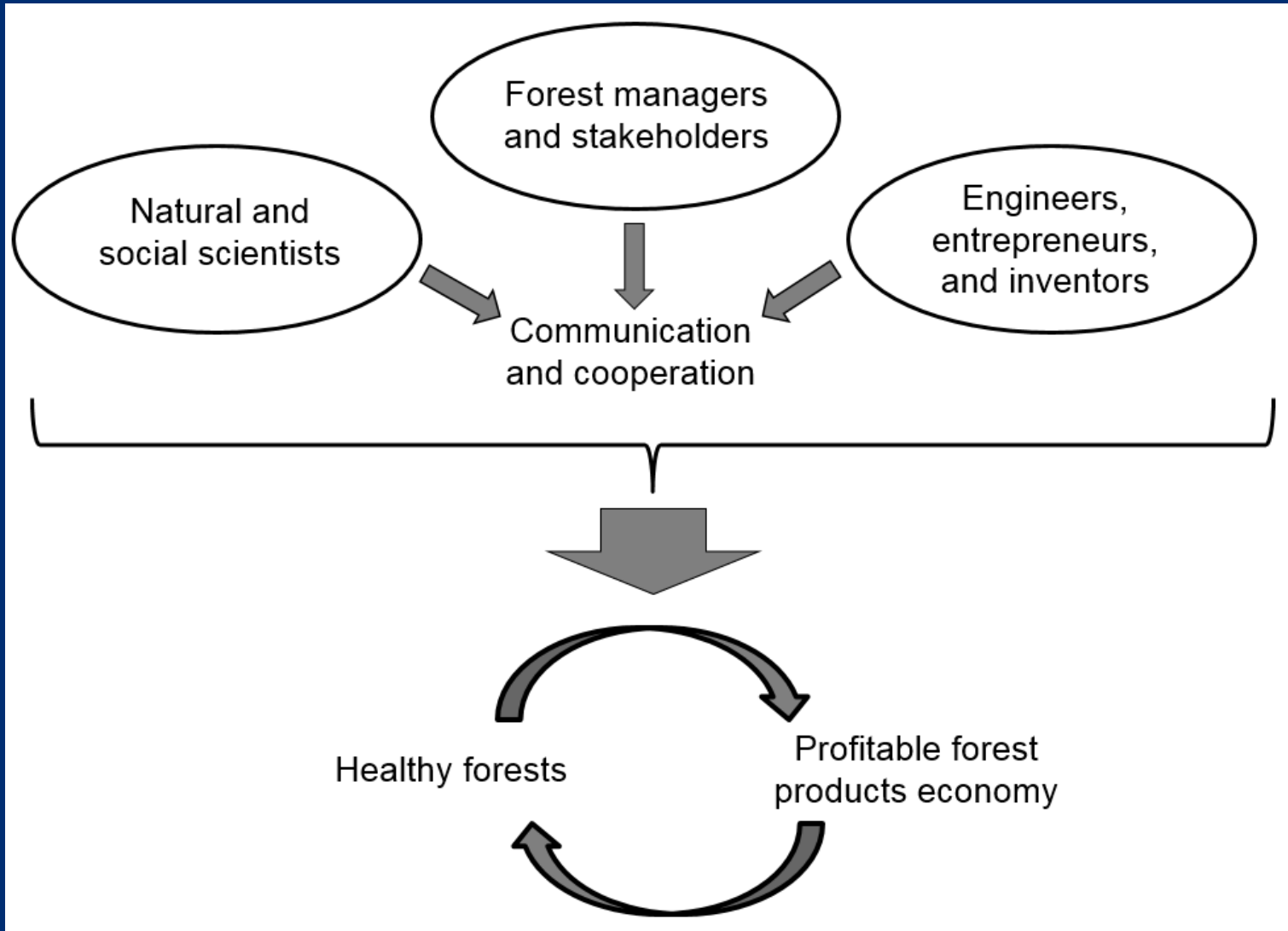
By [Marni Salmon](#)

Late last week, the House passed H.R. 2647, a piece of forestry legislation that will undermine bedrock environmental protections and the public's ability weigh in on logging projects that affect public lands.

The ironically titled "Resilient Federal Forests Act," is nothing more than a buffet for the timber industry. From making it nearly impossible for citizens to prevent harmful logging of our public forests, to allowing the possibility of fast tracked logging after a heavy rain storm, to reallocating funds from restoration and land stewardship in favor of timber sale projects, this bill will cripple our country's forests.

Examples of transdisciplinary challenges for forest management

4. Profitable forest products industry in a changing economy



Examples of transdisciplinary challenges for forest management

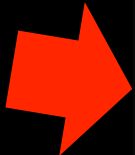
4. Profitable forest products industry in a changing economy



Human
land use



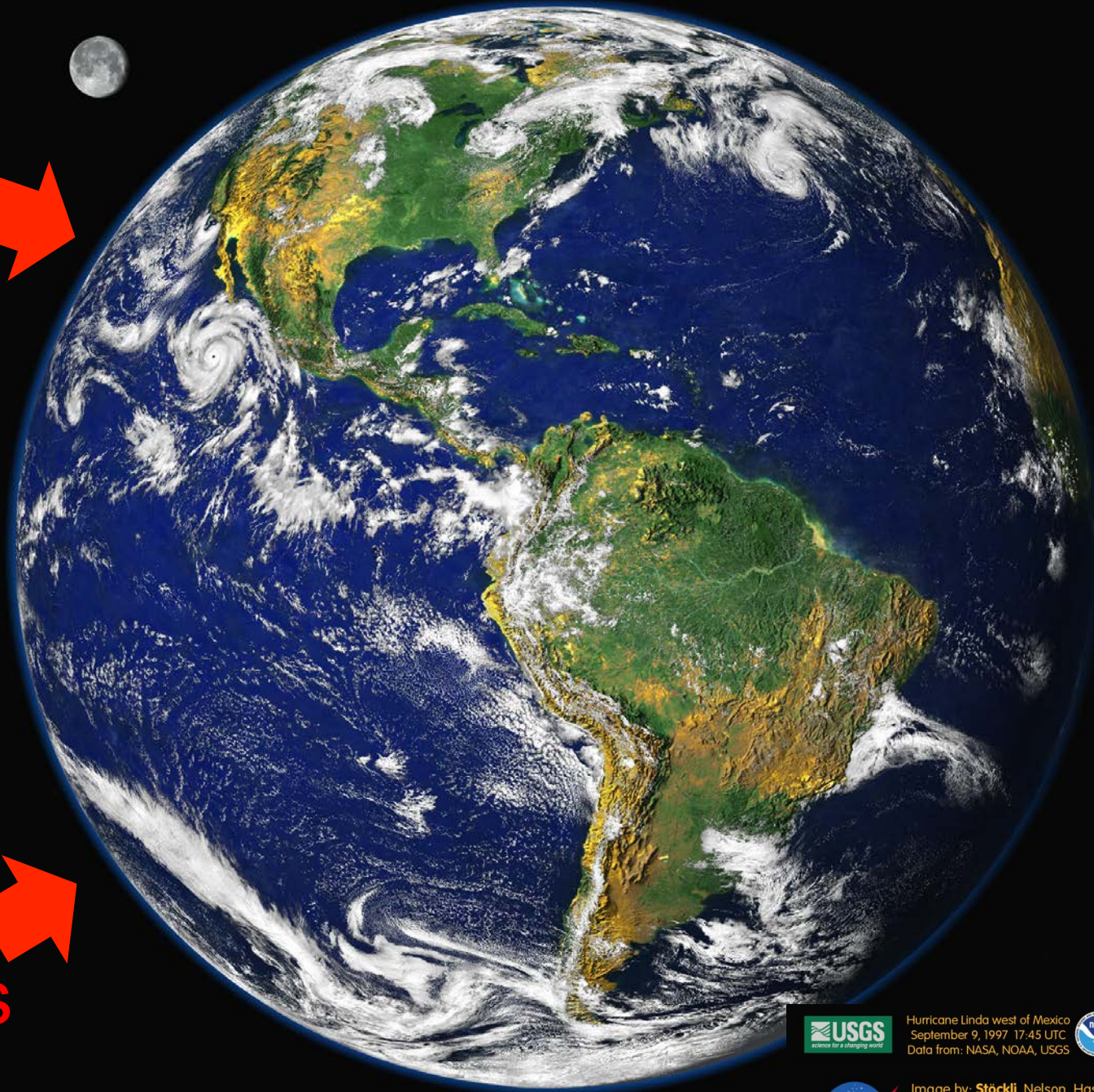
Climate
change



Invasive
species



Shifting
distributions



Hurricane Linda west of Mexico
September 9, 1997 17:45 UTC
Data from: NASA, NOAA, USGS



Image by: **Stöckli**, Nelson, Hasler
Laboratory for Atmospheres
Goddard Space Flight Center
<http://rsd.gsfc.nasa.gov/rsd>