

# The Role of Biotic Disturbance Agents in Carbon-Climate Connections

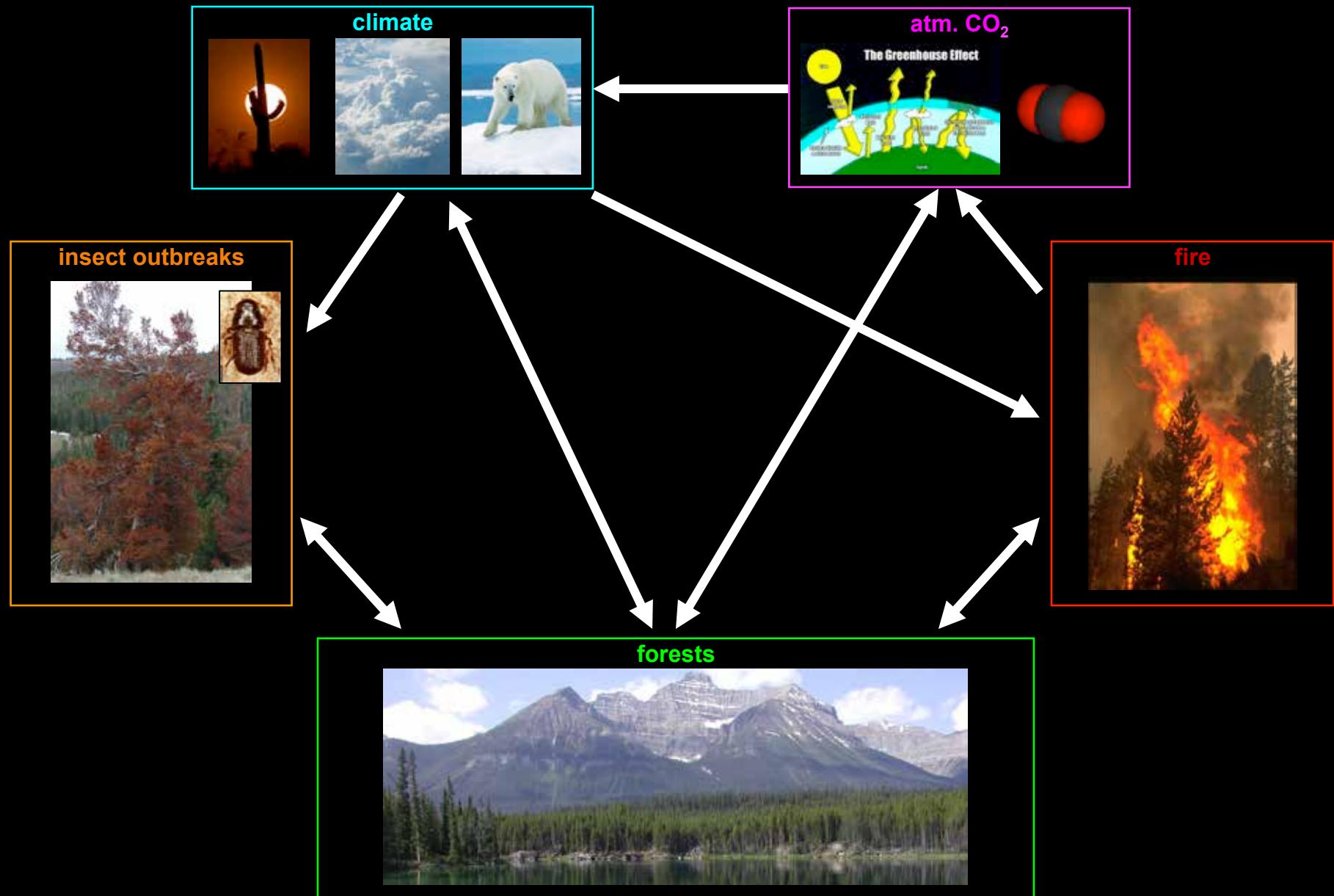
Jeffrey Hicke  
Department of Geography  
University of Idaho

*Emphasis: Forests, bark beetles, western North America*



*Credit: Leslie Manning/Canadian Forest Service*

# Interactions among forests, insects, fire, carbon, climate



Photo/image credits. Climate: [www.squidoo.com/desert-sunset-pictures-pics-photos-posters](http://www.squidoo.com/desert-sunset-pictures-pics-photos-posters), A. Rouvin and A.Walk ([commons.wikimedia.org](https://commons.wikimedia.org)), CO<sub>2</sub>: [www.odec.ca/projects/2005/stro5c0/public\\_html](http://www.odec.ca/projects/2005/stro5c0/public_html), [globalwarmingart.com](http://globalwarmingart.com); Insects: J. Hicke, [www.forestryimages.org](http://www.forestryimages.org); Fire: K. Wattenmaker, [firepix.blm.gov](http://firepix.blm.gov); Forests: J. Hicke

Global Change Biology (2012) 18, 7–34, doi: 10.1111/j.1365-2486.2011.02543.x

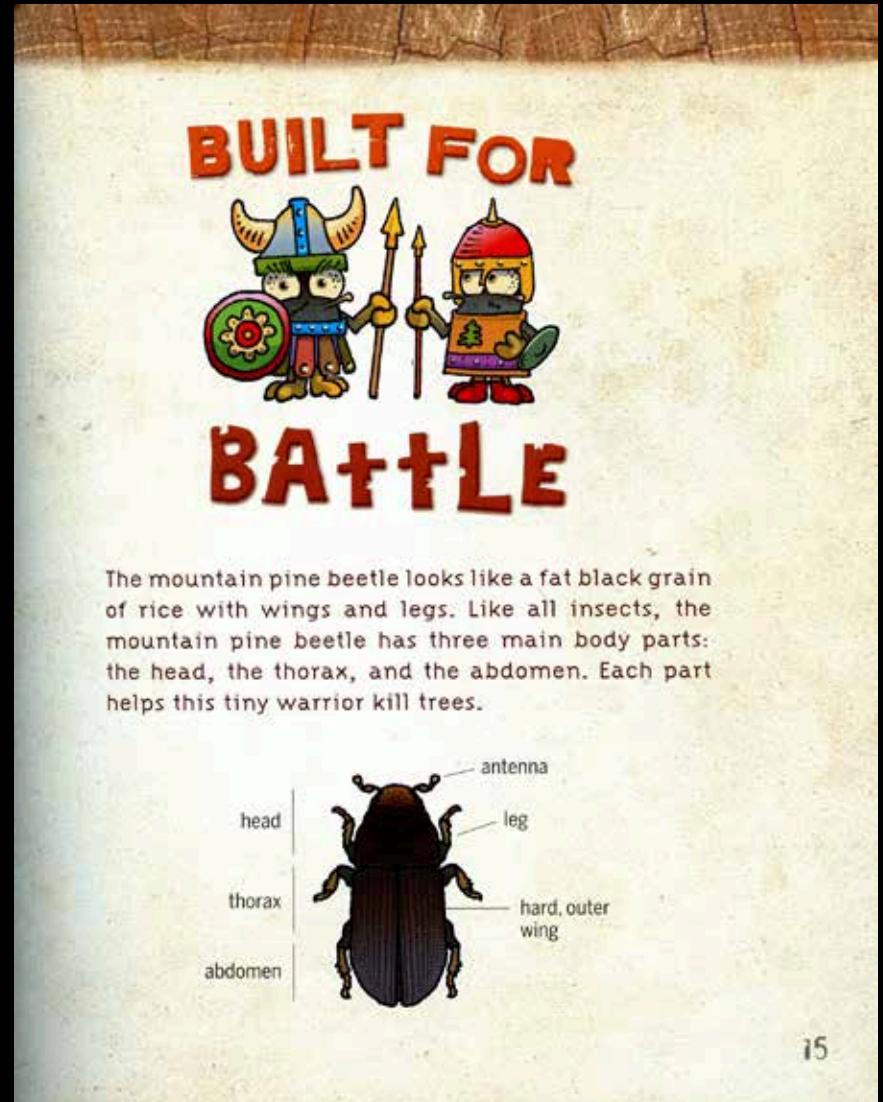
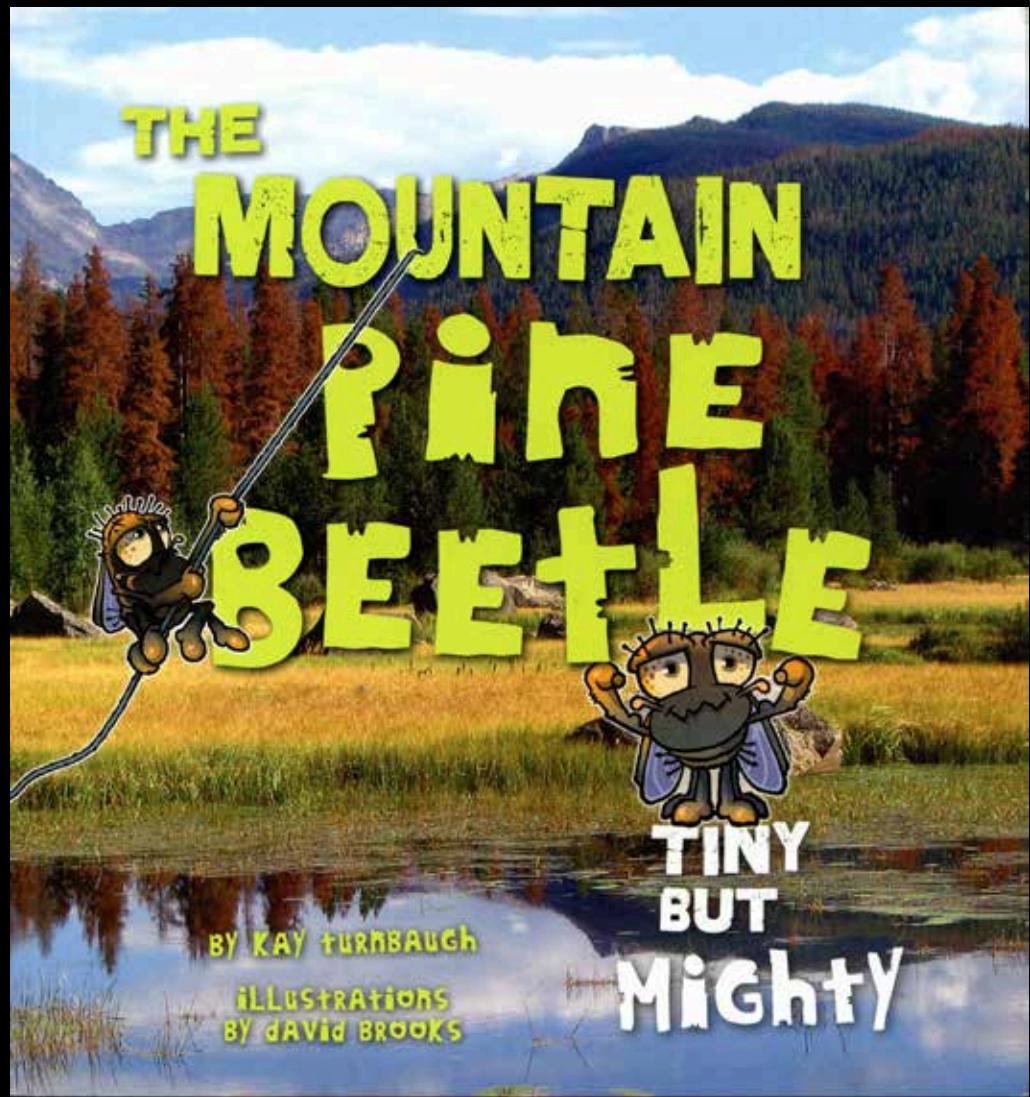
REVIEW

## Effects of biotic disturbances on forest carbon cycling in the United States and Canada

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RONALD J. HALL¶, EDWARD H. (TED) HOGG¶, DANIEL M. KASHIAN\*\*<sup>\*\*</sup>, DAVID  
MOORE††, KENNETH F. RAFFA‡, RONA N. STURROCK‡‡ and JAMES VOGELMANN§§



Another scholarly work...



# Questions

- Are biotic disturbances important in C cycling?
- What are the impacts of outbreaks on C stocks and fluxes?
- Can we predict future outbreaks?



Photo by Jeff Hicke

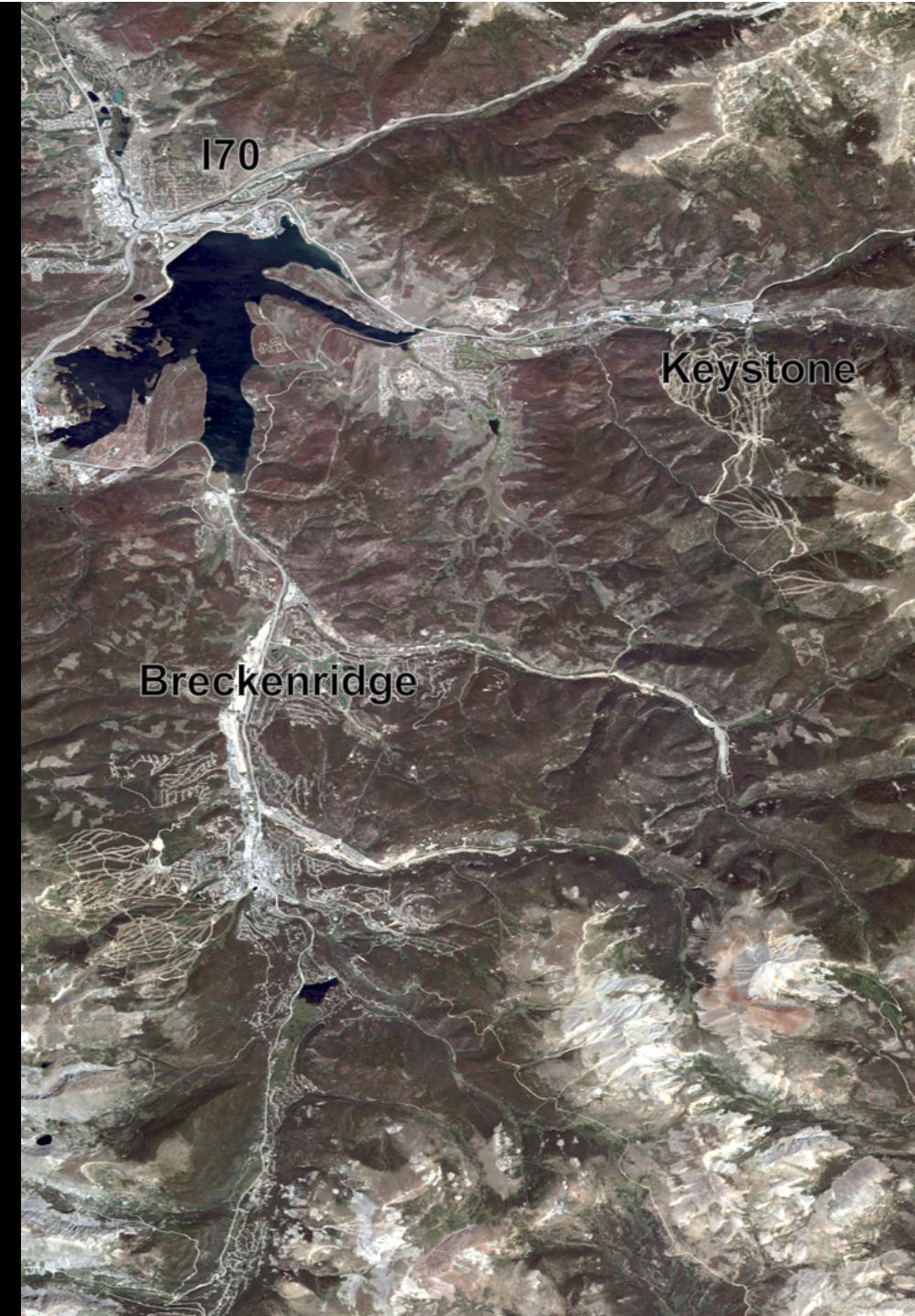


Photo by Jeff Hicke

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Mountain pine beetle outbreak

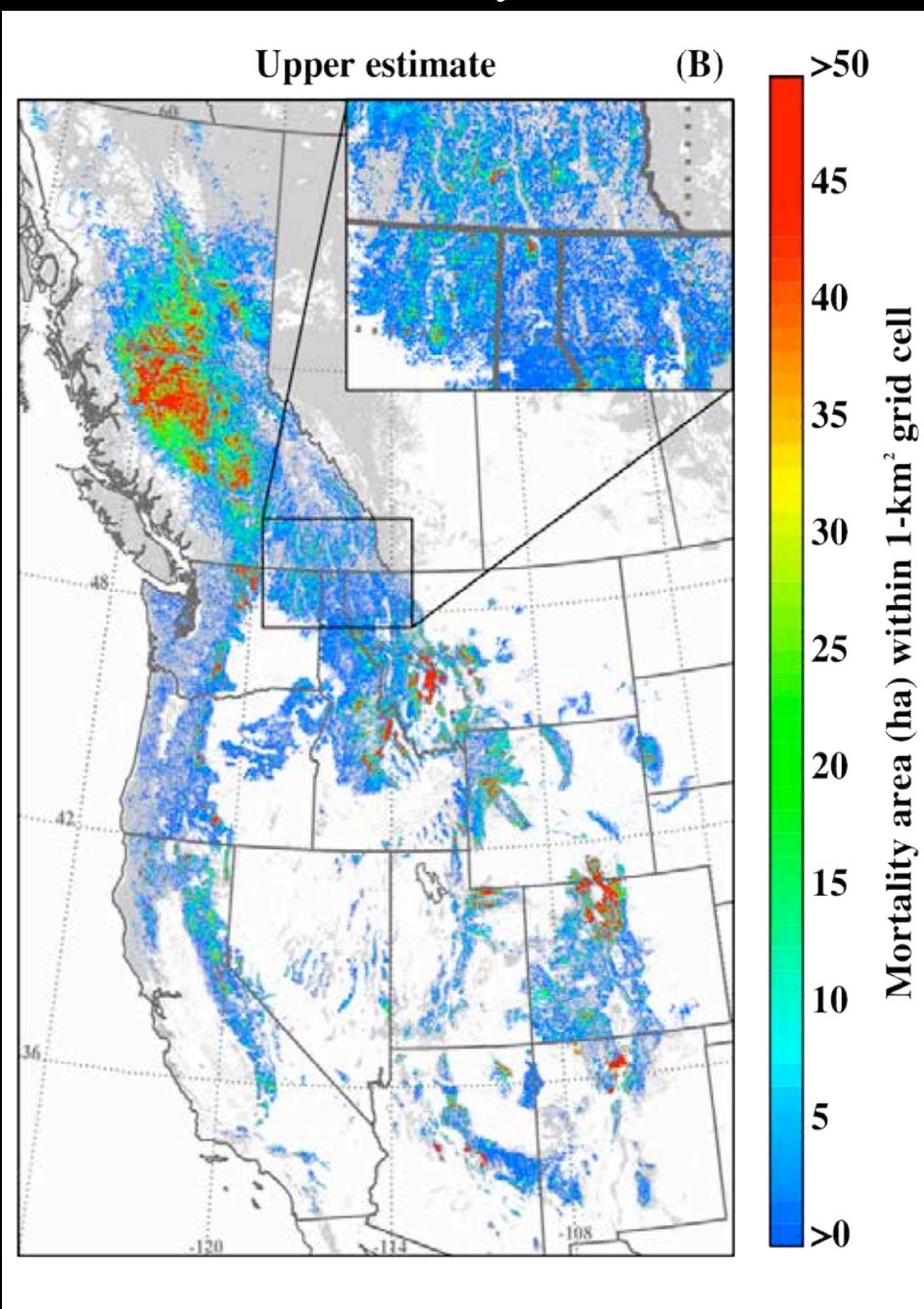
Central Colorado

August 2007

QuickBird satellite imagery

- 2.4-m spatial resolution
- true-color

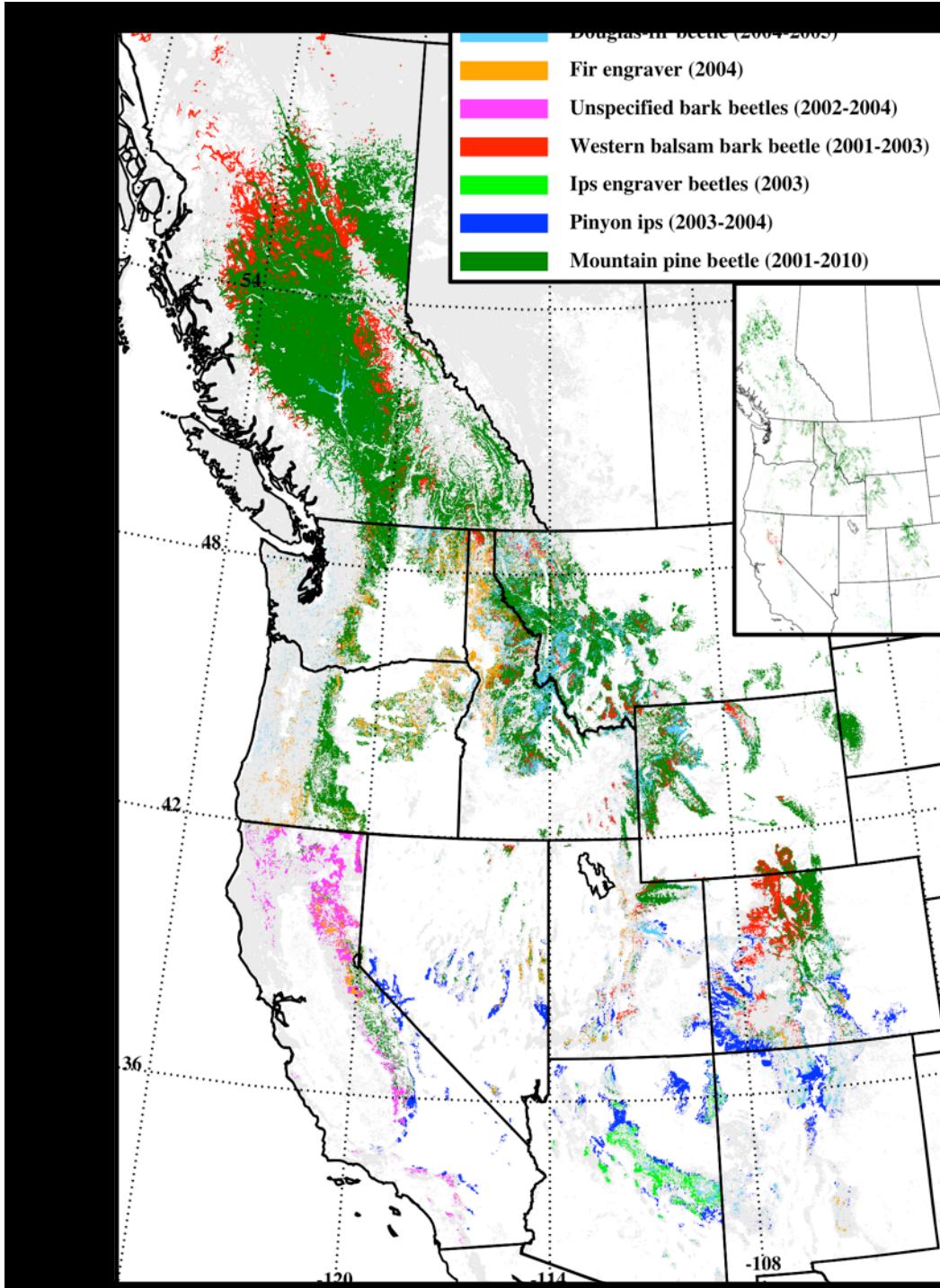
## Cumulative mortality area, 1997-2010



Bark beetles are significant forest disturbances

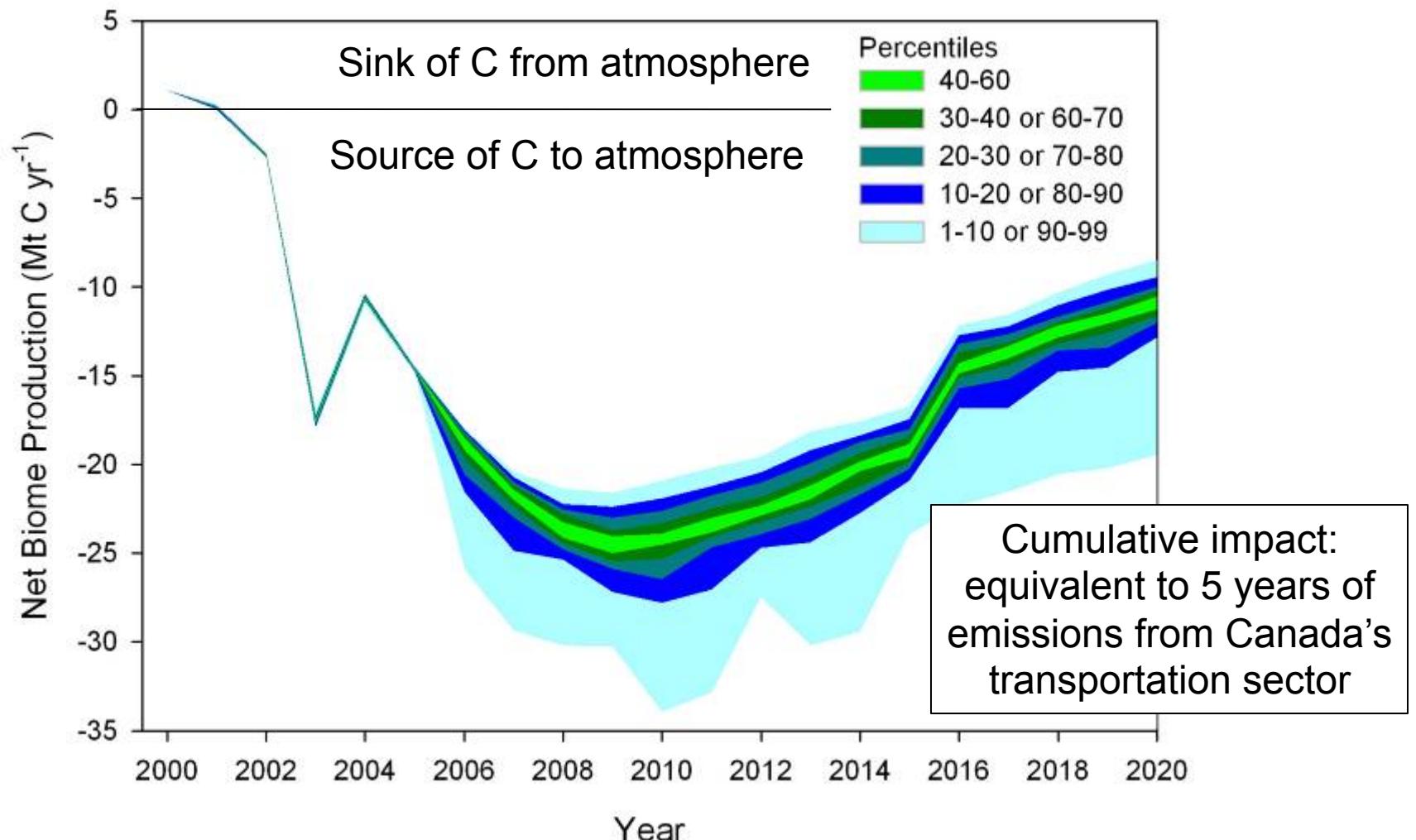
# Major bark beetle outbreaks, 1997-2010

- 2001-2004
  - pinyon ips
  - engraver beetles
  - Douglas-fir beetle
  - unspecified bark beetles
  - western balsam bark beetle
- mountain pine beetle
  - multiple outbreaks, 2001-2010



# Carbon Impacts of MPB in Western Canada

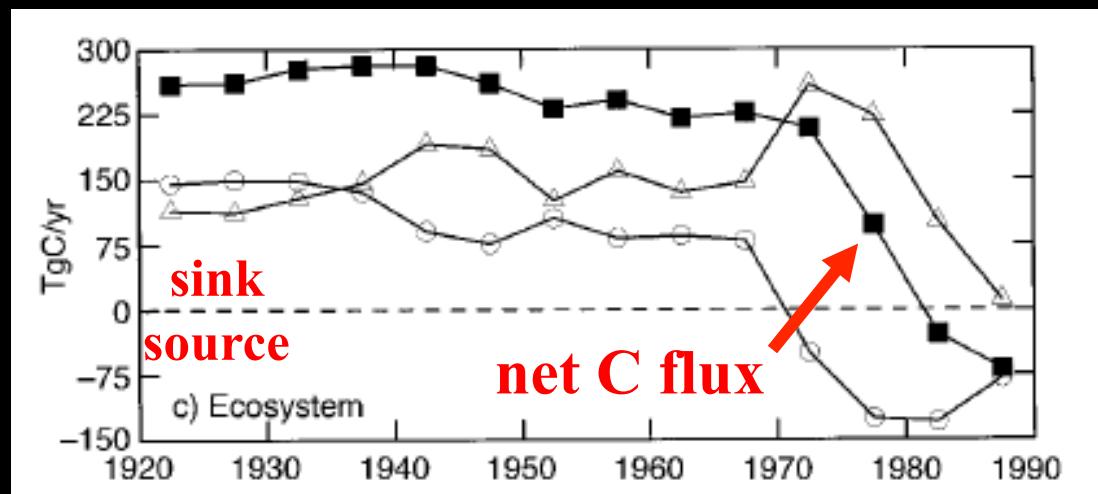
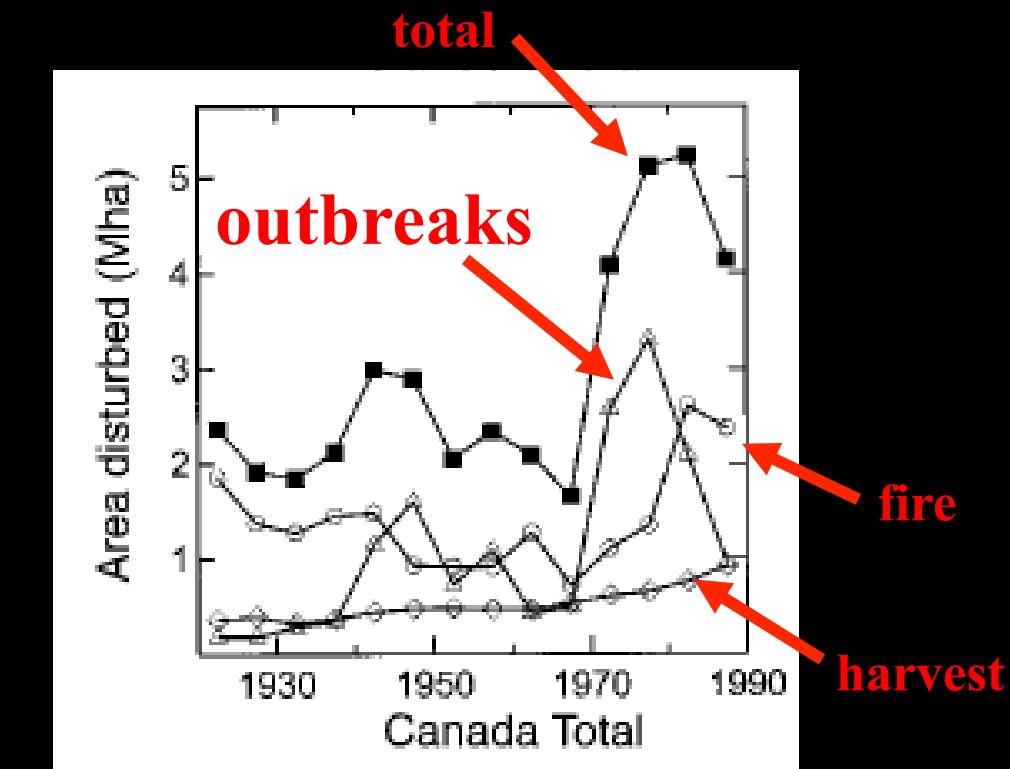
13 million ha affected in 2007



Source: Kurz et al. 2008, Nature

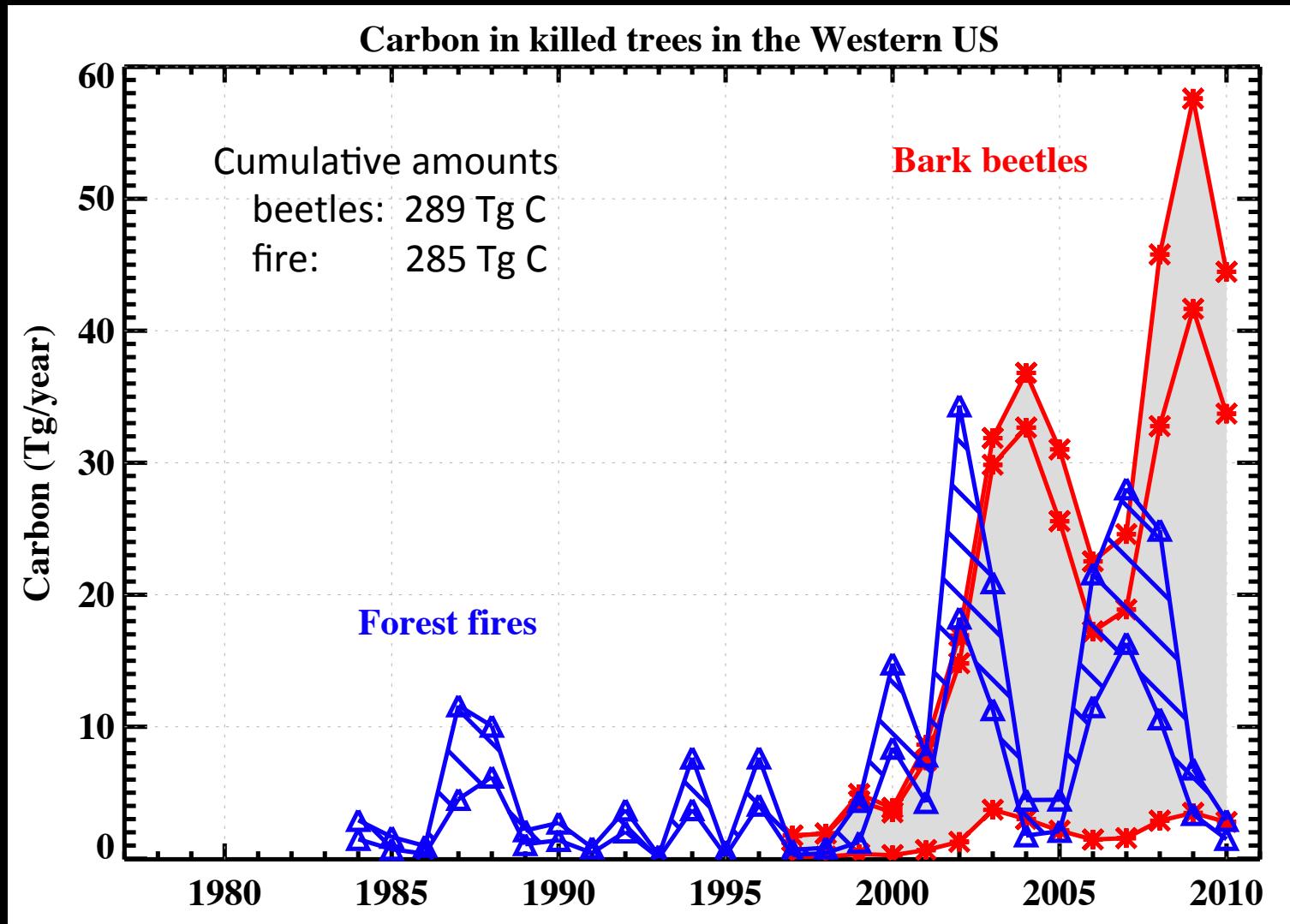
Slide courtesy W. Kurz, CFS

# Insect outbreaks and Canada's net carbon fluxes



Kurz and  
Apps, EA,  
1999

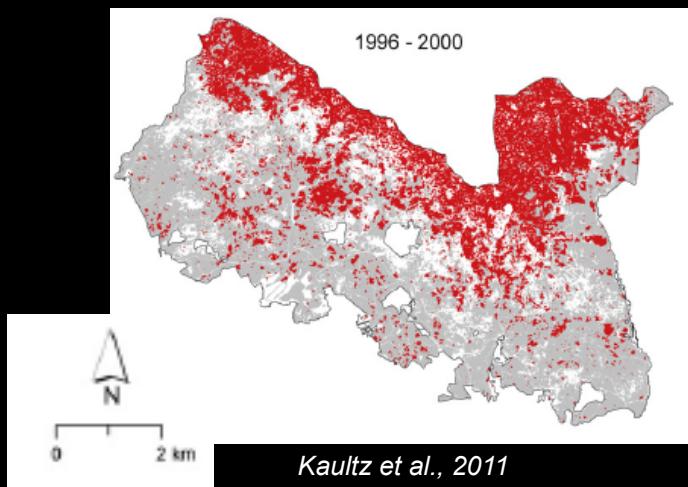
# Bark beetle outbreaks and C stocks



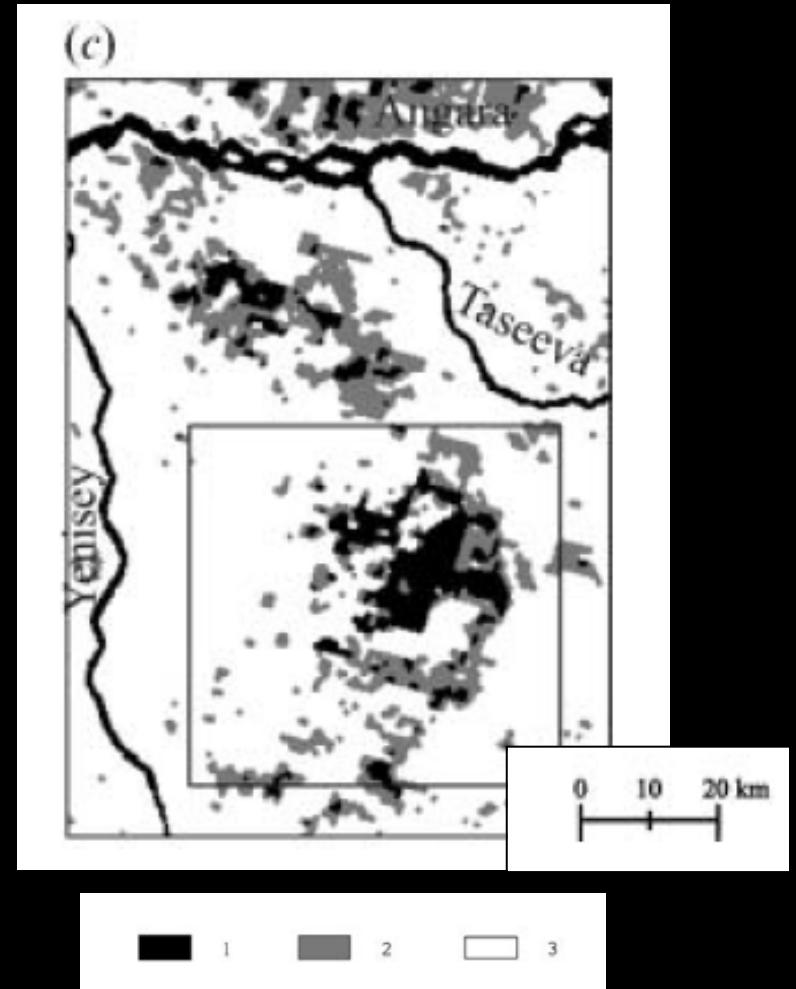
Hicke et al., ERL, in press

# Extensive forest damage in other parts of the world

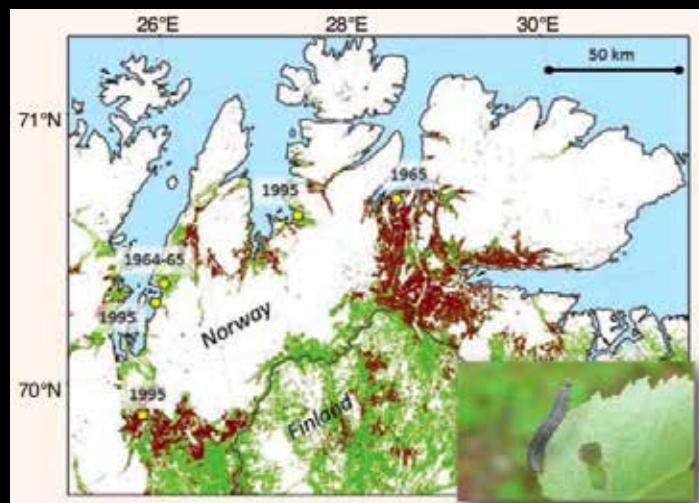
spruce bark beetle, Germany



Siberian silkworm, 1995



moths, Scandinavia



- 2: 50–75% of dead and dying trees
- 1: 75% of dead and dying trees

Kharuk et al., 2004

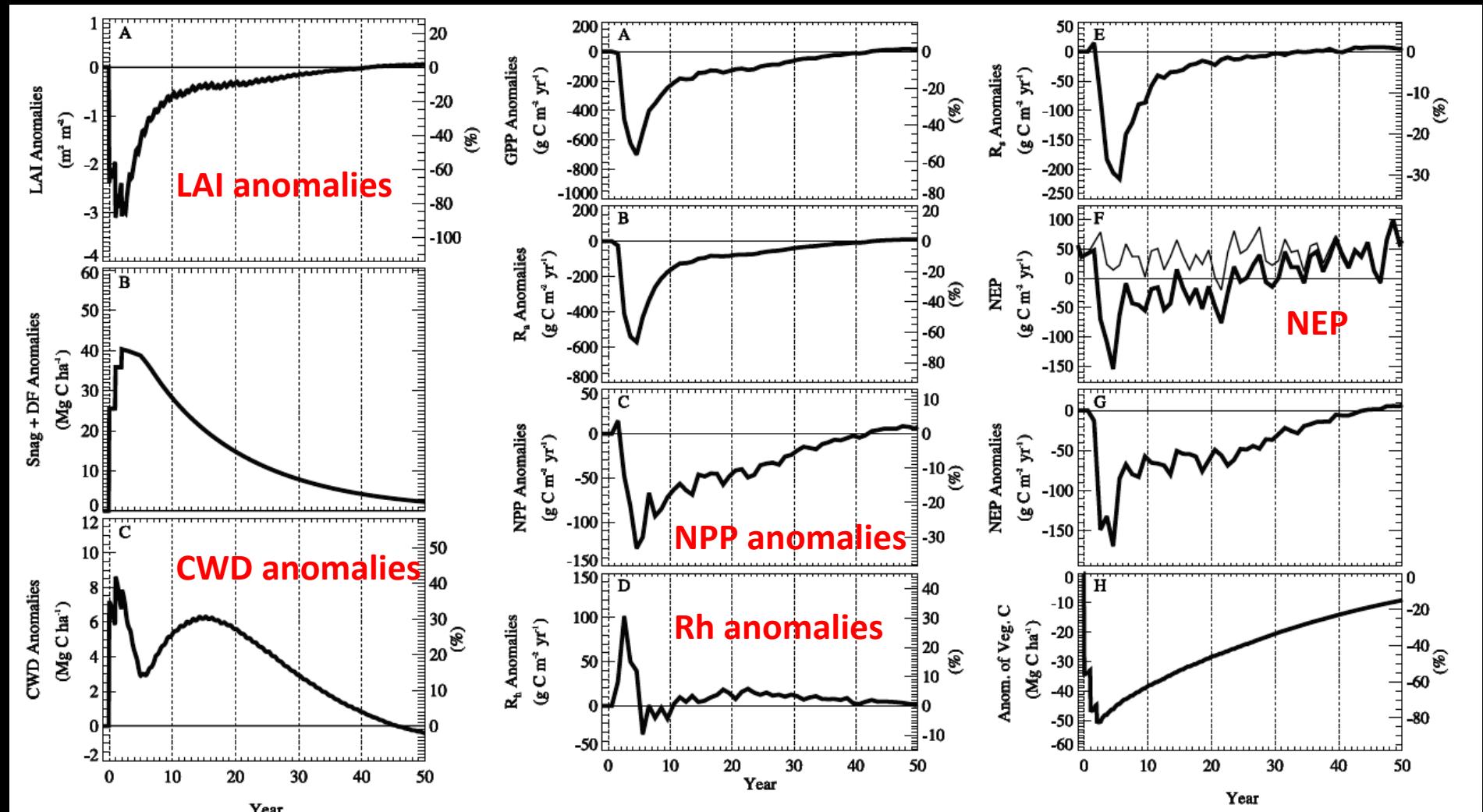
# Questions

- Are biotic disturbances important in C cycling?
- What are the impacts of outbreaks on C stocks and fluxes?
- Can we predict future outbreaks?



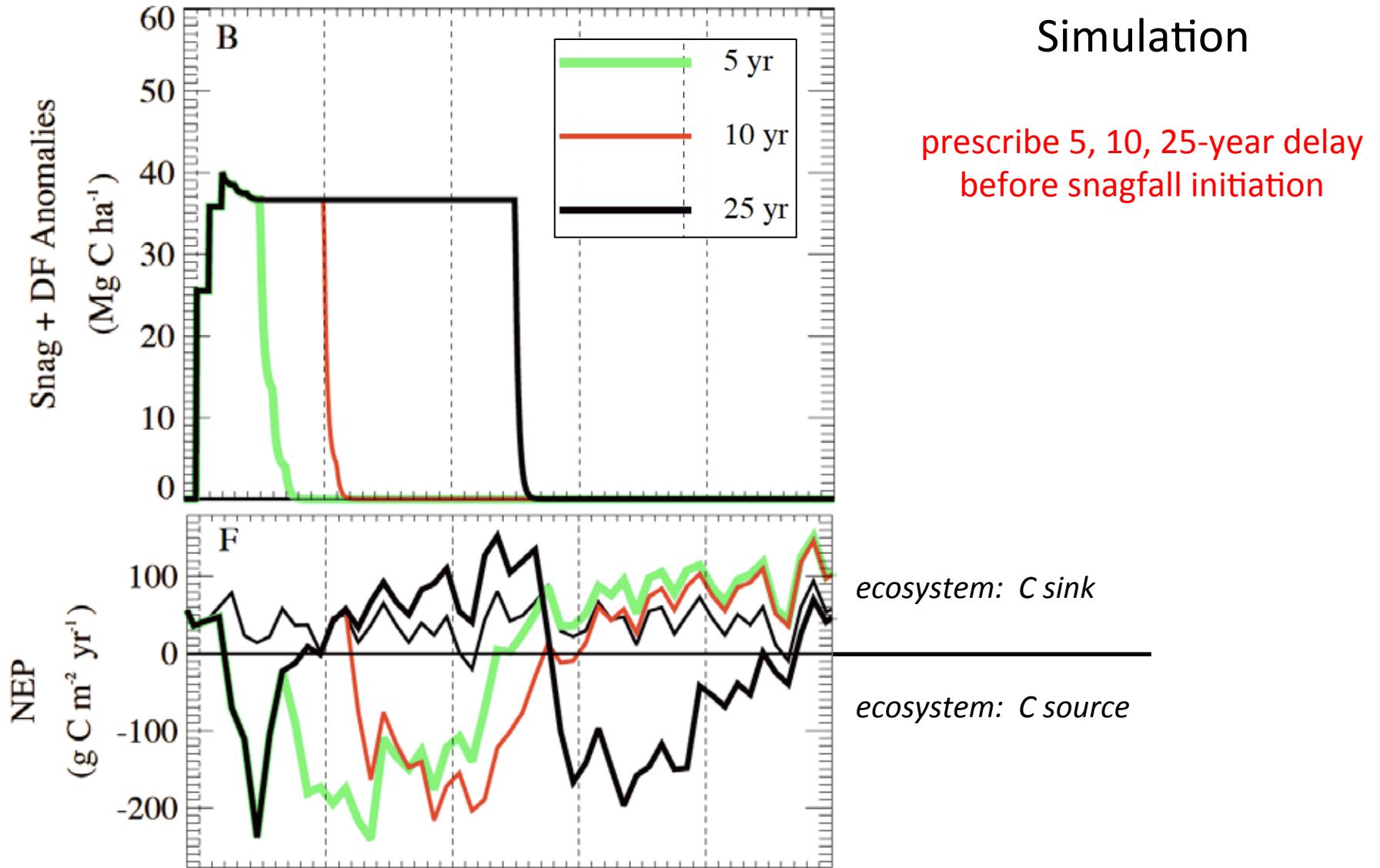
# 1. Time since disturbance

## Simulated C dynamics following severe beetle outbreak



Edburg et al., JGR, 2011

# NEP depends on timing of snagfall



## 2. Type of disturbance agent

Growth reducers

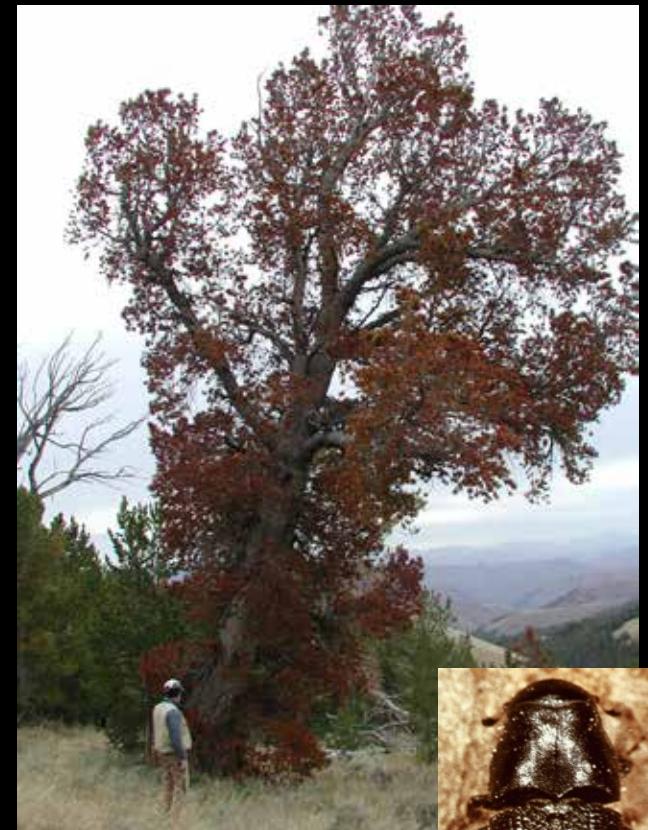


William M. Ciesla, Forest Health Management International



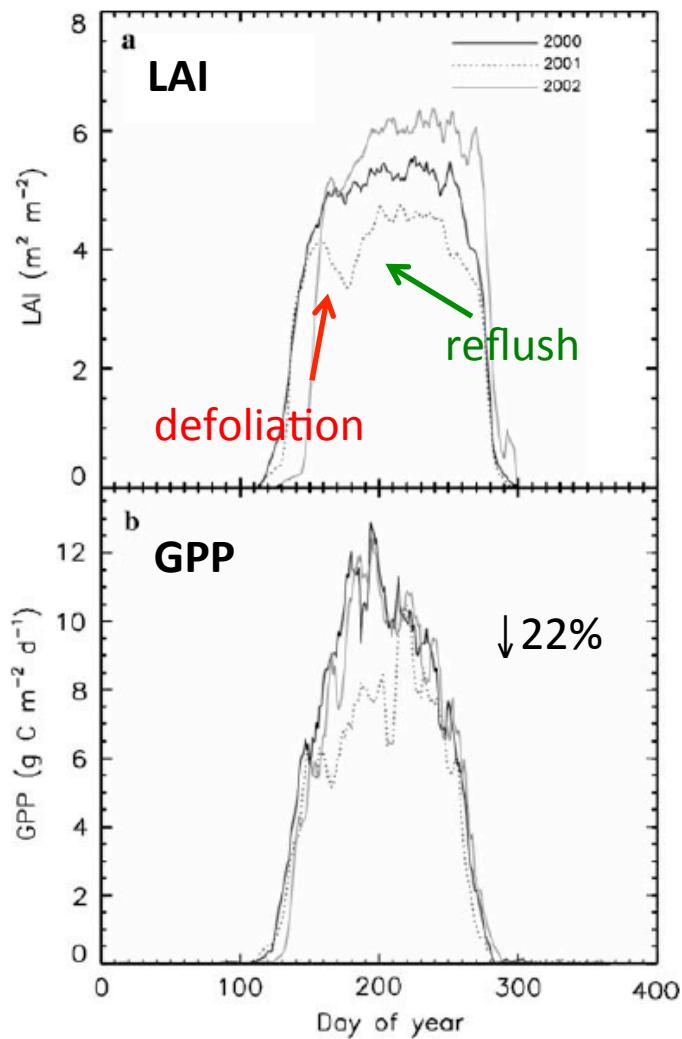
USDA Forest Service - Ogden Archive,  
USDA Forest Service, Bugwood.org

Tree killers

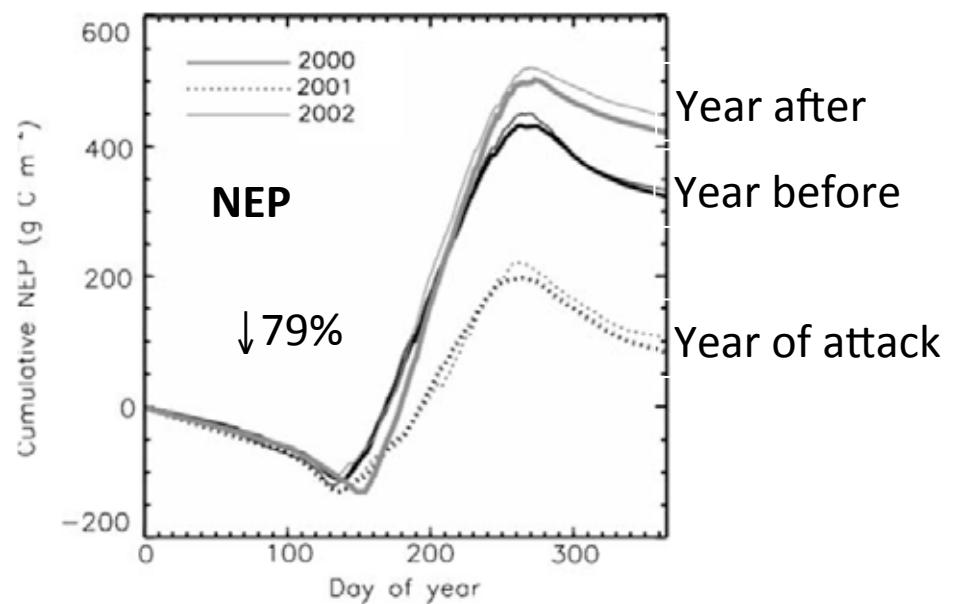


bugwood.org

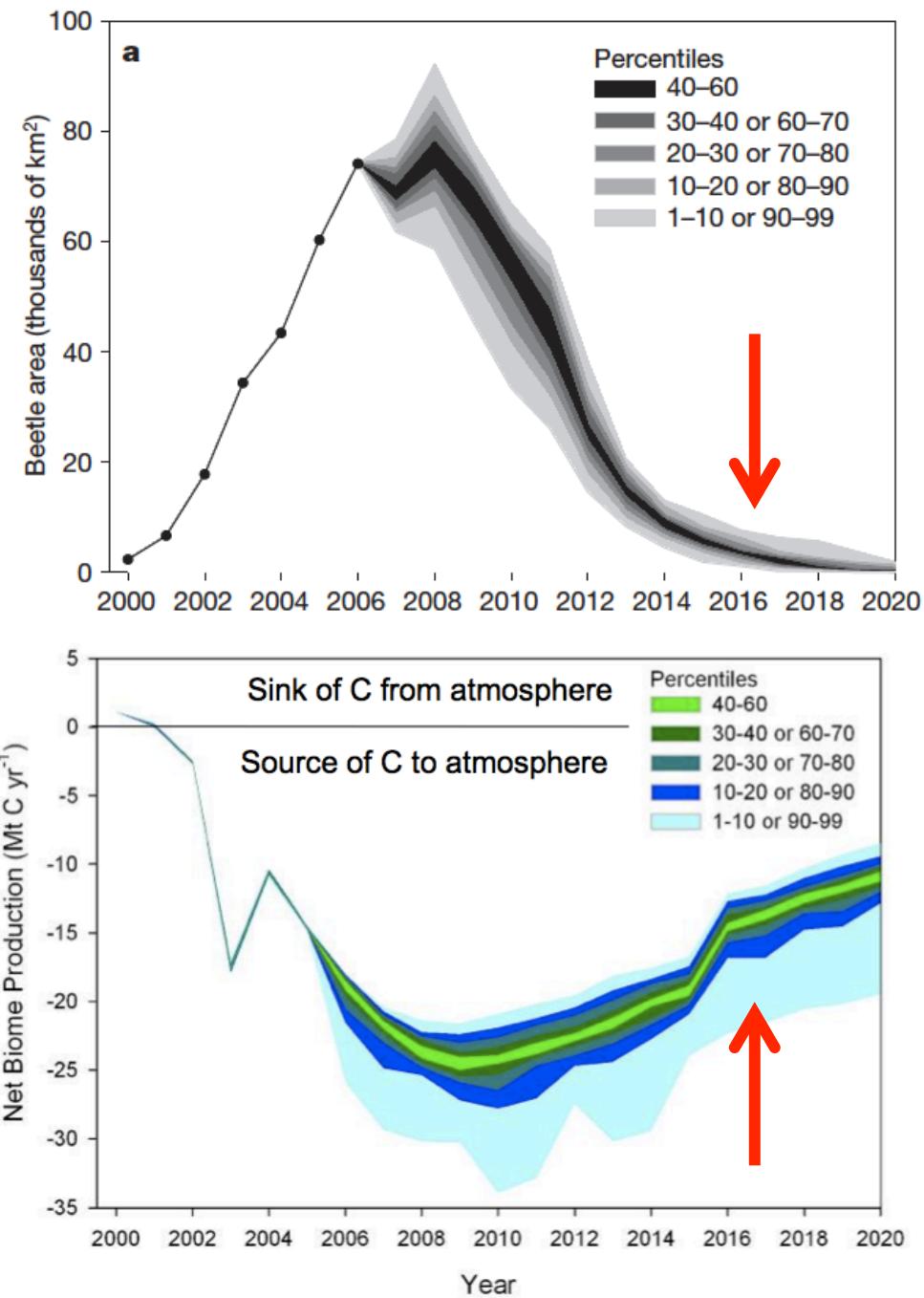
# Effects of transient defoliation



Forest tent caterpillar



Cook et al., *Ecosystems*, 2008



# Long legacy of bark beetle outbreak

Kurz et al., *Nature*, 2008

### 3. Host preferences and variability in mortality

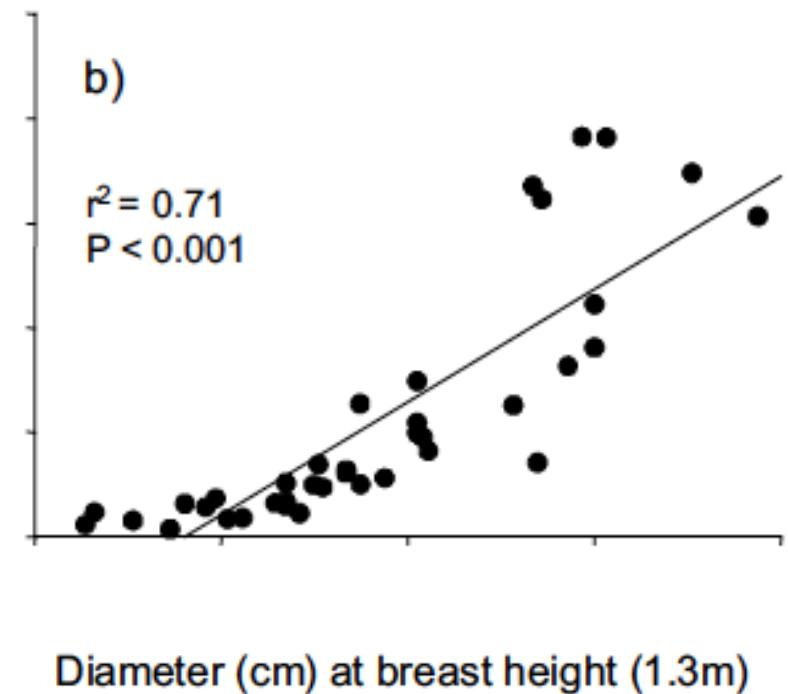
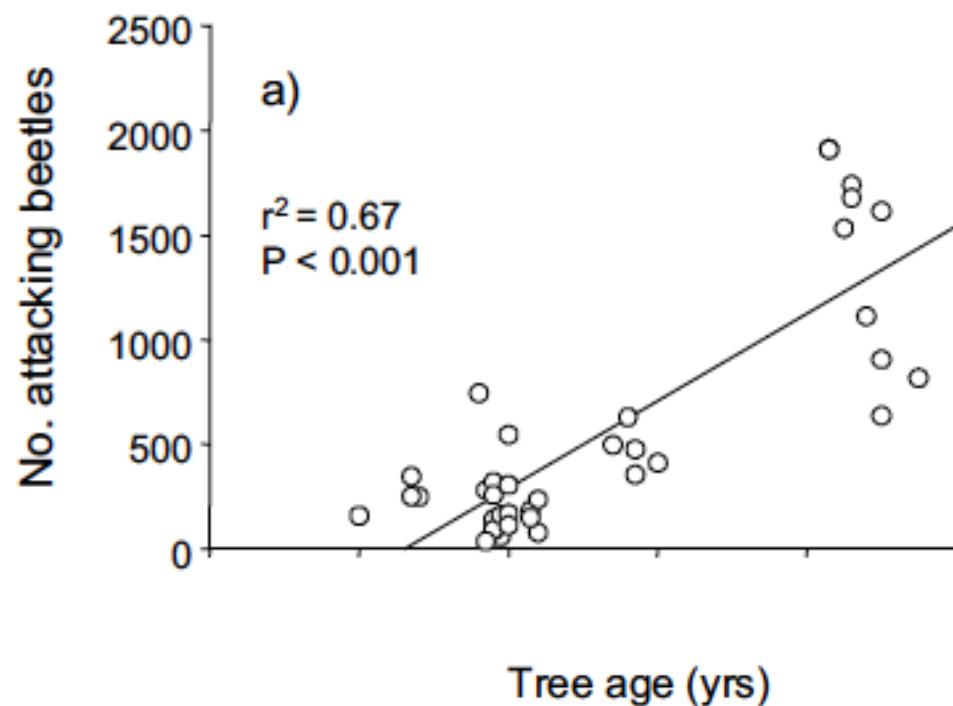
#### Preferred host species

**Table 1.** Bark beetle species that have the capacity to cause landscape-scale tree mortality in the western United States and Canada.

Common name	Scientific name	Major host species
Arizona fivespined ips	<i>Ips lecontei</i>	<i>Pinus ponderosa</i> , and others
California fivespined ips	<i>Ips paraconfusus</i>	<i>Pinus attenuata</i> , <i>Pinus contorta</i> , <i>Pinus coulteri</i> , <i>Pinus jeffreyi</i> , <i>Pinus lambertiana</i> , <i>P. ponderosa</i> , <i>Pinus radiata</i> , <i>Pinus torreyana</i> , and others
Douglas-fir beetle	<i>Dendroctonus pseudotsugae</i>	<i>Pseudotsuga menziesii</i>
Eastern larch beetle	<i>Dendroctonus simplex</i>	<i>Larix laricina</i>
Fir engraver	<i>Scolytus ventralis</i>	<i>Abies concolor</i> , <i>Abies grandis</i> , <i>Abies magnifica</i>
Jeffrey pine beetle	<i>Dendroctonus jeffreyi</i>	<i>P. jeffreyi</i>
Mountain pine beetle	<i>Dendroctonus ponderosae</i>	<i>Pinus albicaulis</i> , <i>Pinus aristata</i> , <i>Pinus balfouriana</i> , <i>P. contorta</i> , <i>Pinus flexilis</i> , <i>P. lambertiana</i> , <i>Pinus monticola</i> , <i>P. ponderosa</i> , and others
Northern spruce engraver	<i>Ips perturbatus</i>	<i>Picea engelmannii</i> , <i>Picea glauca</i> , <i>Picea × lutzii</i> , <i>Picea mariana</i> , <i>Picea sitchensis</i>
Pine engraver	<i>Ips pini</i>	<i>P. contorta</i> , <i>P. jeffreyi</i> , <i>P. ponderosa</i> , and others
Piñon ips	<i>Ips confusus</i>	<i>Pinus edulis</i> , <i>Pinus monophylla</i>
Roundheaded pine beetle	<i>Dendroctonus adjunctus</i>	<i>Pinus arizonica</i> , <i>Pinus engelmannii</i> , <i>P. flexilis</i> , <i>Pinus leiophylla</i> , <i>P. ponderosa</i> , <i>Pinus strobus</i>
Southern pine beetle	<i>Dendroctonus frontalis</i>	<i>Pinus engelmannii</i> , <i>P. leiophylla</i> , <i>P. ponderosa</i>
Spruce beetle	<i>Dendroctonus rufipennis</i>	<i>Picea engelmannii</i> , <i>Pi. glauca</i> , <i>Pi. sitchensis</i>
Western balsam bark beetle	<i>Dryocoetes confusus</i>	<i>Abies lasiocarpa</i> , and others
Western pine beetle	<i>Dendroctonus brevicomis</i>	<i>P. coulteri</i> , <i>P. ponderosa</i>

### 3. Host preferences and variability in mortality

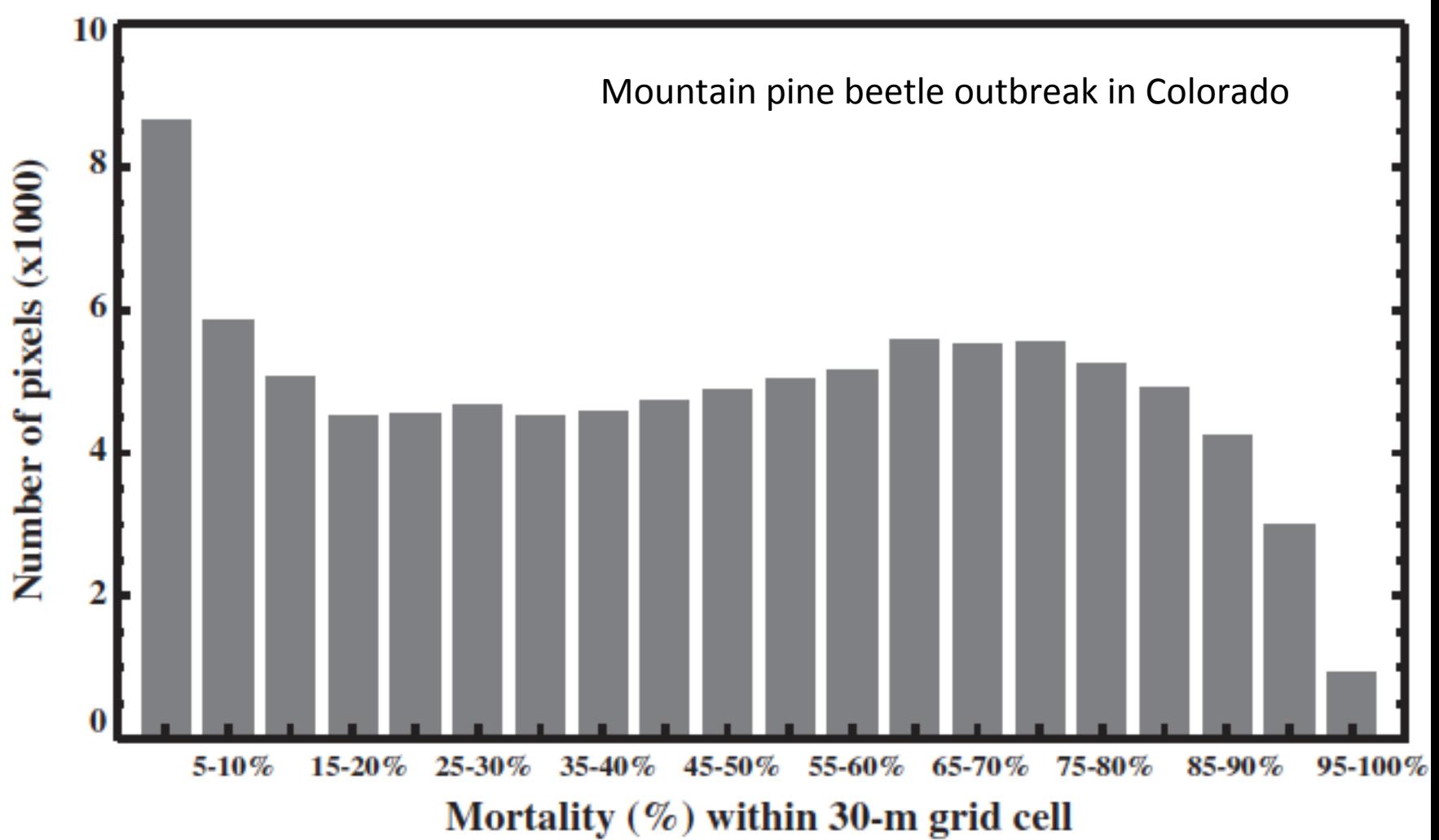
Beetles prefer older, larger hosts



*Safranyik and Carroll, 2006*

### 3. Host preferences and variability in mortality

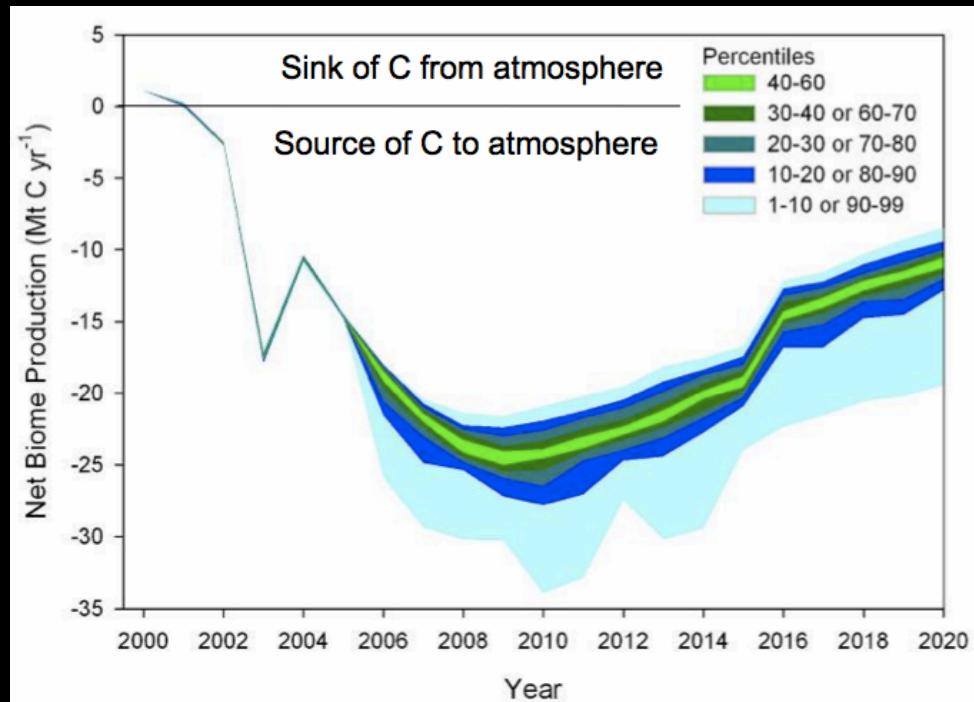
#### Variability in tree mortality within an outbreak



### 3. Host preferences and variability in mortality

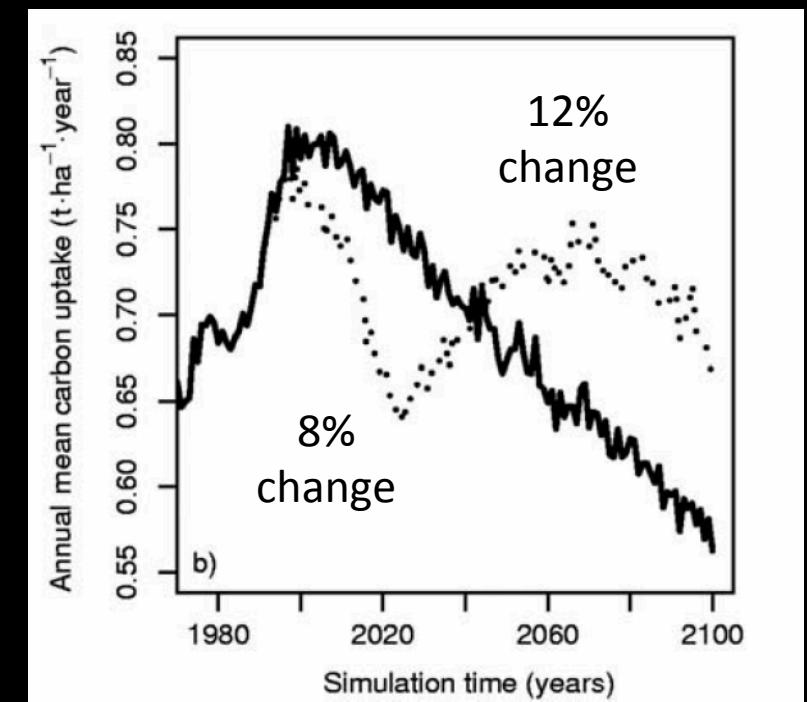
#### Variability in tree mortality within a region

Major impacts to regional NEP  
by mountain pine beetle



Kurz *et al.*, *Nature*, 2008

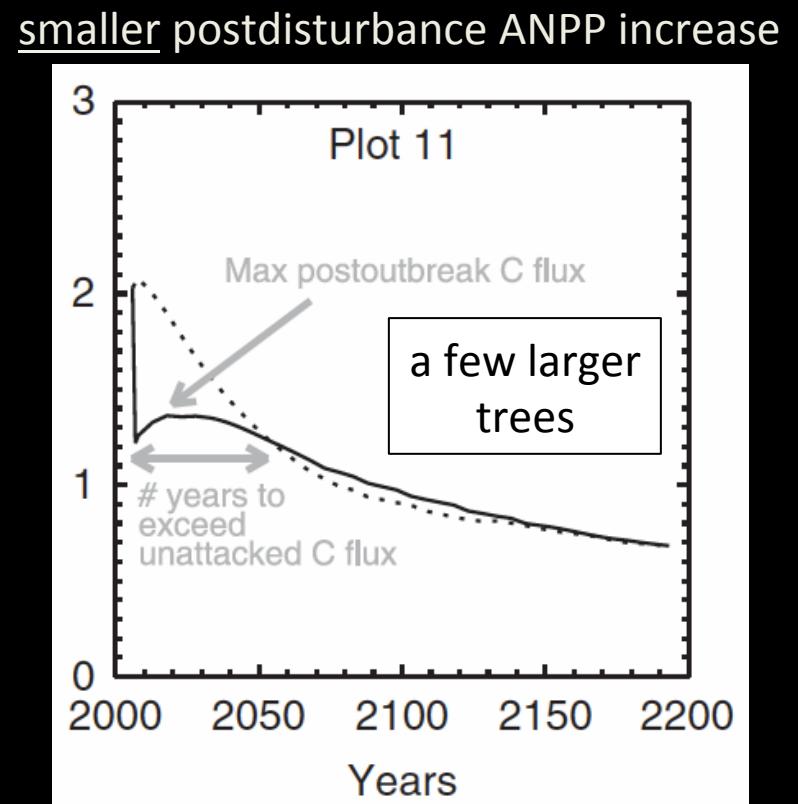
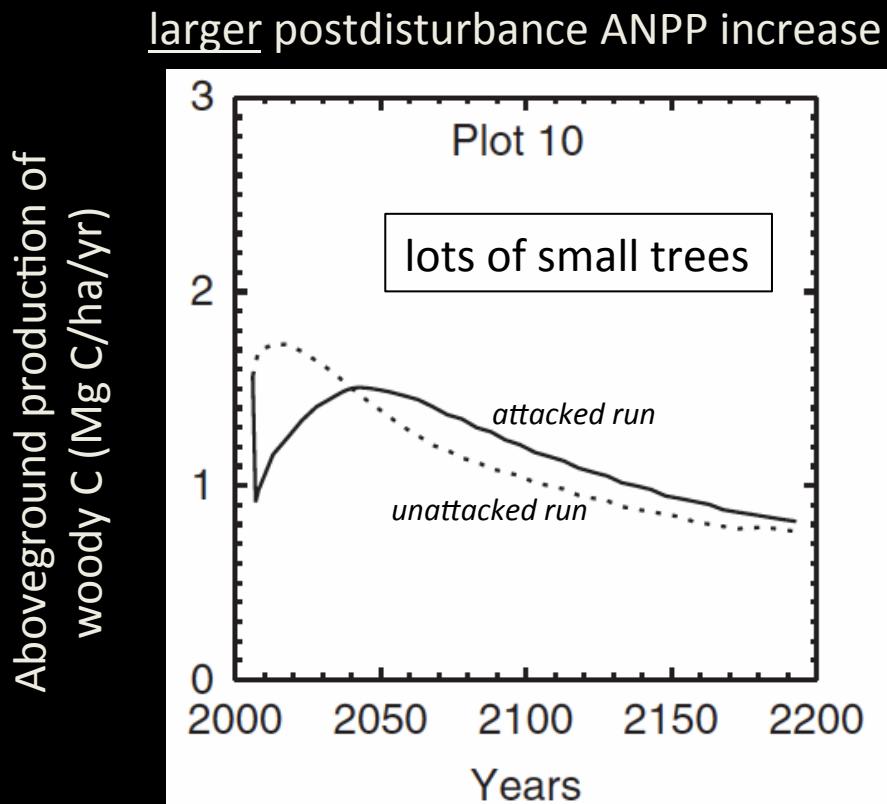
Minor impacts to regional NEP  
by hemlock woolly adelgid



Albani *et al.*, *CJFR*, 2010

### 3. Host preferences and variability in mortality

Postoutbreak stand characteristics affect regrowth



# Questions

- Are biotic disturbances important in C cycling?
- What are the impacts of outbreaks on C stocks and fluxes?
- Can we predict future outbreaks?



# Bad news:

## Lots of different insects/pathogens

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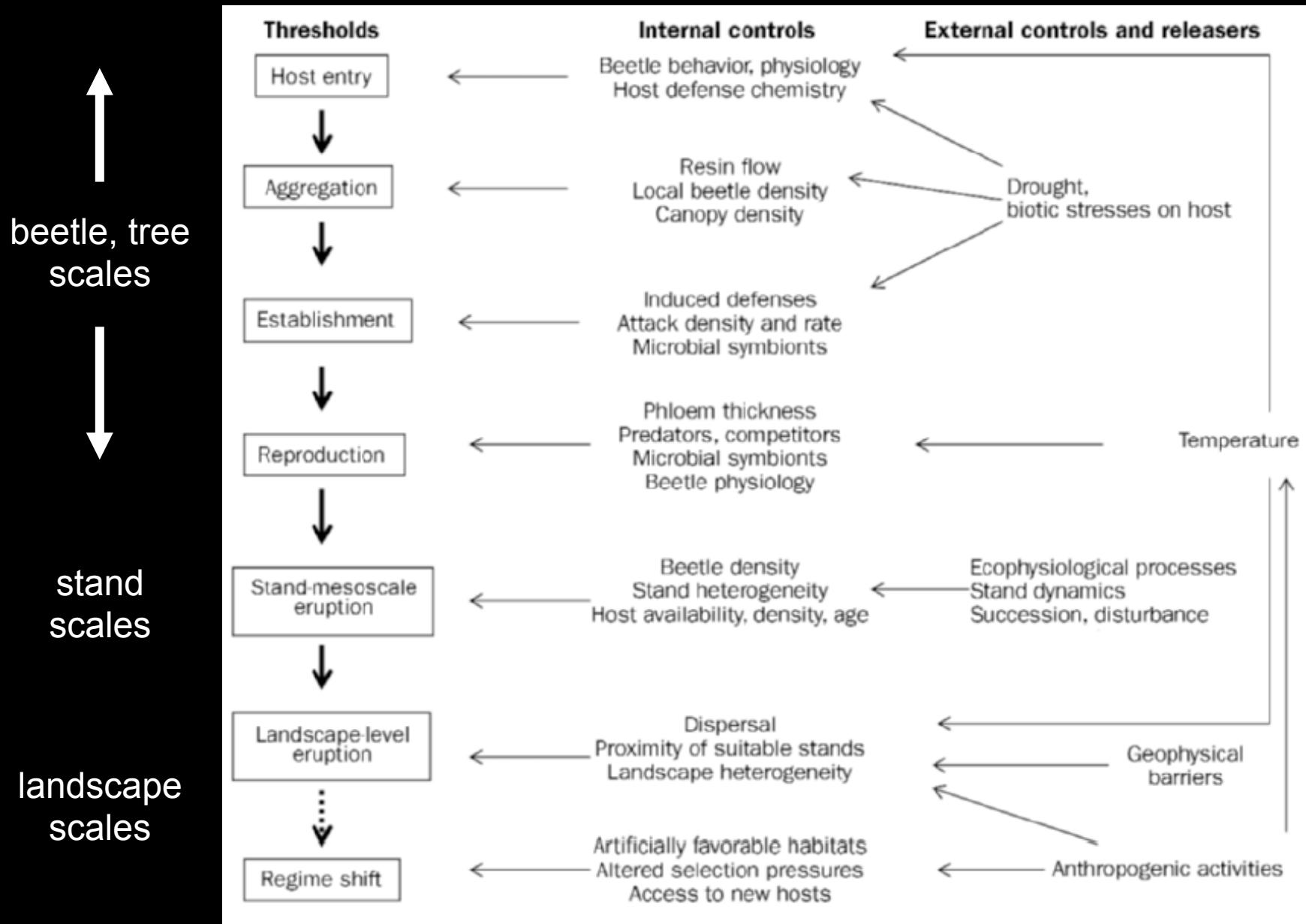
## Good news:

- only a few major species
- commonality in drivers (?)

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# Complexity in drivers, interactions



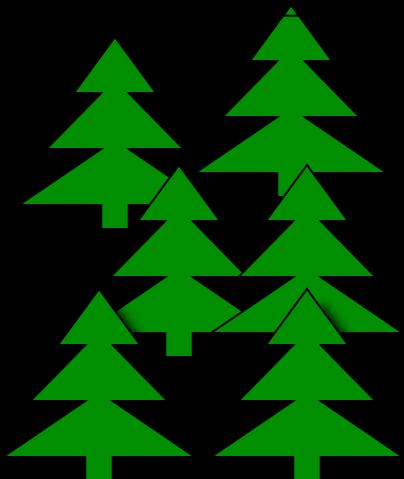
# Limited understanding of most insects/pathogens

## Factors influencing mountain pine beetle epidemics

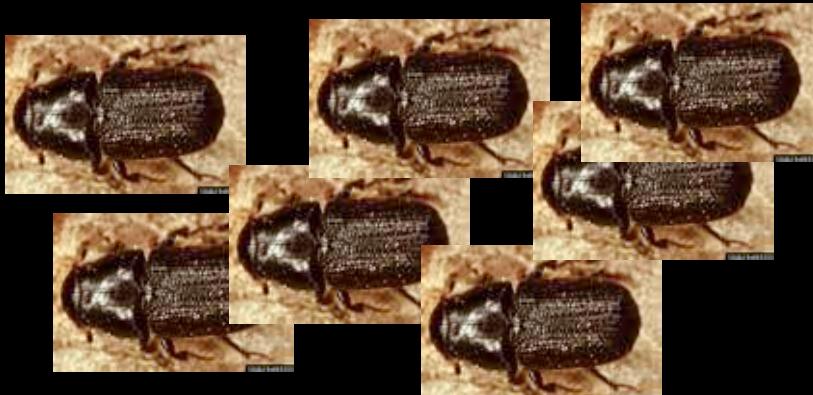
### Factors related to trees:

- presence of host tree species
- stem density
- stand age
- drought stress on trees

*density dependent*



*climate*

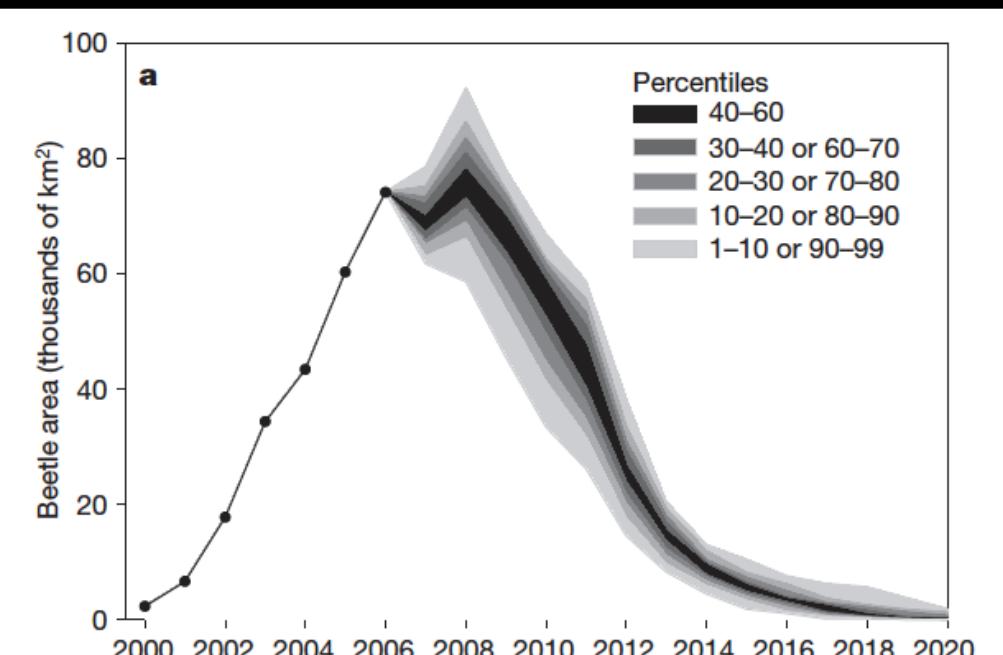


*Photo courtesy USDA Forest Service, [www.forestryimages.org](http://www.forestryimages.org)*

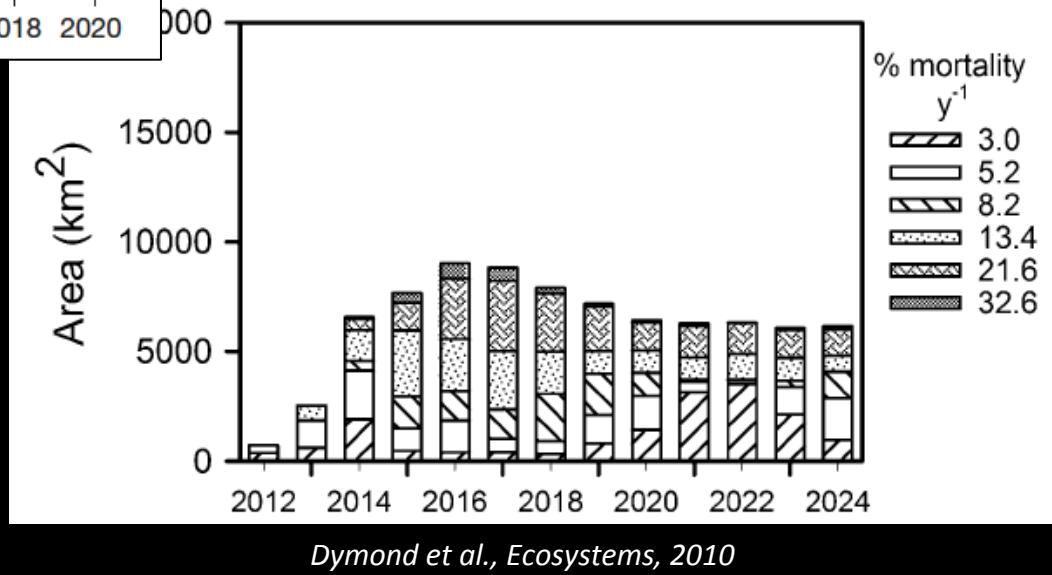
*Safranyik et al. 1975; Shore and Safranyik 1992; Carroll et al. 2004; Logan and Powell 2001*

# Use of scenarios

## Expected decline of beetle outbreak



## Expected outbreak of spruce budworm

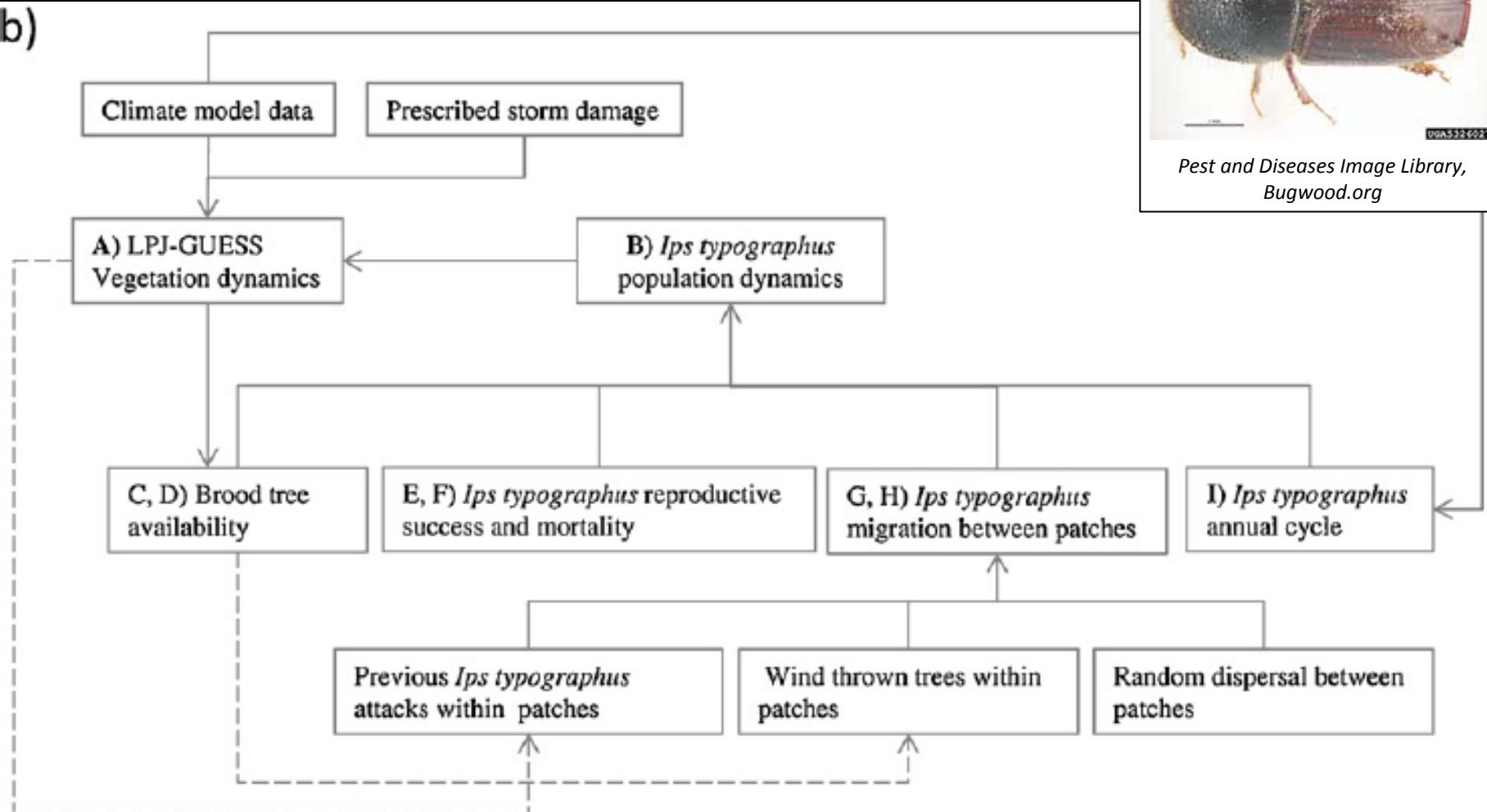


# More complete insect model

# European spruce bark beetle

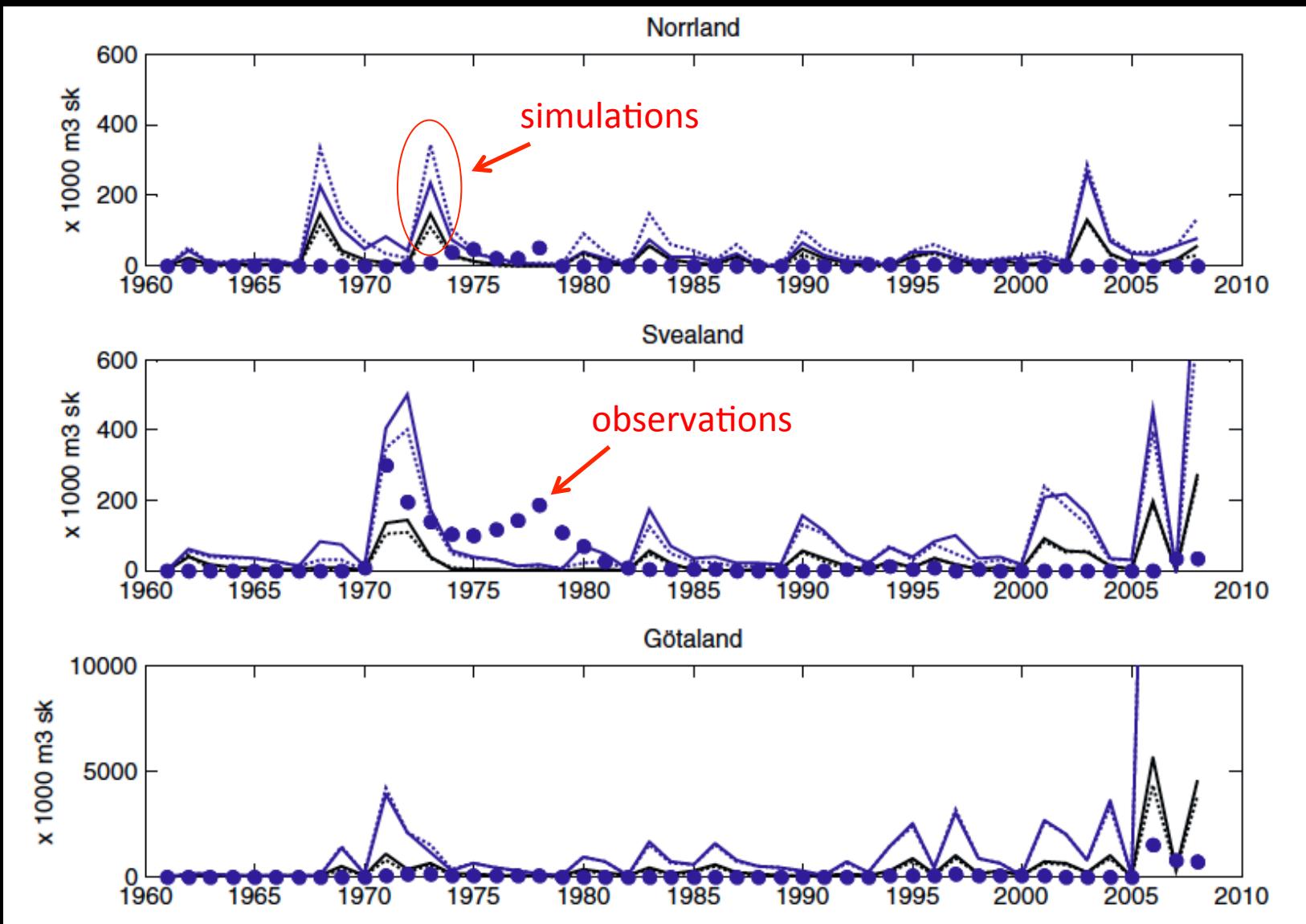


Pest and Diseases Image Library,  
Bugwood.org



*Jonsson et al., Ag. For. Met., 2013*

# More complete insect model



*Jonsson et al., Ag. For. Met., 2013*

## on bad days

- complex situations
- range of agents and drivers
- limited scientific understanding
- limited observations
- variation in C responses
- prognostic modeling is challenging



## on good days

- impacts of insects, pathogens important regionally
- beginning to understand historical impacts
- enough (?) is known about a few significant species
- any advance is progress
- interesting, challenging research

