Ecology of southern pine beetle: a smokeless wildfire in the Pinelands?

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Southern pine beetle
*Dendroctonus frontalis*
e.g., *Dendroctonus* in North America
Episodic outbreaks

![Graph showing the number of infestations in Texas from 1960 to 2000. The graph displays a pattern of episodic outbreaks with peaks in 1970, 1980, and 1990, followed by a decline.](image-url)
Standardized pheromone trapping survey
Ronald Billings, Texas Forest Service
Bankhead National Forest, AL: 80 km² infested during 1998-2000
Bankhead National Forest, AL

80 km² infested during 1998-2000

~10,000 truckloads of finished lumber worth $50-80 million

Smokeless wildfires?
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\[ C_6H_{12}O_6 + 6O_2 \rightleftharpoons 6CO_2 + 6H_2O \]
Smokeless wildfires?

\[ C_6H_{12}O_6 + 6O_2 \rightleftharpoons 6CO_2 + 6H_2O \]

- Episodic and contagious.
- Kills small to very large tracts of trees.
- Reduces extent of mature forest.
- Alters biodiversity.
- Creates hazard trees.
- Lowers property values.
- Reduces recreational opportunities.
- Destabilizes hydrology.
- Alters N cycling.
- Releases stored carbon from ecosystem.
- Can change forest type (e.g., pines to hardwoods; forest to scrub).
Relevant to:
biodiversity, wildlife, recreation
aesthetics, conservation biology,
fire management, water quality,
economics, carbon storage …
Aggregation pheromones -> Mass attack
$N = \text{beetle abundance}$

$R = \text{per capita population change}$
Link to dynamic visualization of spot growth

Site 39: 07-17
Growth
Photosynthesis
Secondary metabolism
Water or nutrient availability

Growth-differentiation balance hypothesis

Pete Lorio
Predation

Oviposition and inoculation
Mycangium of *D. frontalis*

Photomicrographs by Stan Barras
Mycangium

Mutualistic fungus
Insect – fungal interactions

Ophiostoma minus & Dendroctonus frontalis

Ayres et al. 2000. *Ecology*
Lombardero et al. 2000 *Ag. & For. Entomol*
Klepzig et al. 2000. *Symbiosis*
Lombardero et al. 2002 *Oikos*
Hofstetter et al., *Oecologia*, in press
O. minus is an antagonist of D. frontalis
Tarsonemus mites are mutualists with *O. minus*
Tarsonemus mites

Link to video
Tarsonemus krantzi

Sporotheca
Ascospores of *O. minus*
Other phoretic micro-associates

Link to video
An interaction chain

**Tarsonemus** mites

+↑↓+

**Ophiostoma minus**

-↑↓-

Mycangial fungi

+↑↓+

**D. frontalisis**

+↑↓-

Pine tree
Lower lethal temperatures

Temperature (°C)

Time (min)

SCP = -12 °C = LLT
Tran, Ylioja, Regniere, Billings, and Ayres. *Ecological Applications*, 2007
Recent epidemics in the north:

- Ohio 2000-2001
- Kentucky 1999-2000
- New Jersey 2001-2010
Minimum winter temperature in southeastern U.S. has increased ≈3.3 °C in 40 years

Tran, Ylioja, Regniere, Billings, and Ayres. *Ecological Applications*, 2007
Southern pine beetle
New Jersey
Hightstown: $\uparrow 4.1 \, ^\circ C$

Atlantic City: $\uparrow 4.4 \, ^\circ C$

- ~50% SPB mortality
- ~90% SPB mortality
Average annual temperature (°C)

Hightstown

↑ 0.5 °C

Atlantic City

↑ 1.0 °C
Dendroica caerulescens

Dendroctonus frontalis

Richard Holmes et al., Dartmouth, Hubbard Brook Forest

TEXAS

No. of infestations

Year


16000 14000 12000 10000 8000 6000 4000 2000 0

0 10000 20000 30000 40000 50000 60000


Birds / 64 ha

No. of infestations
\[ R_t = f(N_t) + \varepsilon_t \]

\[ N_{t+1} = N_t \cdot \exp(R_t) \]
Multiple equilibria model

Per capita growth rate

Population size
Multiple equilibria model

Per capita growth rate

- Stable equilibrium

Population size

- Stable equilibrium

$K_{\text{endemic}}$

$K_{\text{epidemic}}$
Multiple equilibria model

Per capita growth rate

Population size

Stable equilibrium
Unstable equilibrium
Escape threshold
Stable equilibrium

$K_{\text{endemic}}$
$K_{\text{epidemic}}$
\[
\ln (\text{Beetles \cdot trap}^{-1} \cdot 14 \text{ d}^{-1} + 1)
\]

Expected frequencies:
- Log normal
- Log normal, detection limits
- Bimodal log normal

\[
\ln (\text{infestations} / 100 \text{ km}^2 + 0.1)
\]
And Ron Billings, Tiina Ylioja, Brian Sullivan
$R$, per capita growth

$N$, Abundance
High basal area stand

Low basal area stand

Windspeed (km / h)

Date

Julian Day
Becky Niemiec: ecological economics of SPB in The Pinelands

Advised by Professor Richard Howarth, Environmental Studies, Dartmouth. Rich’s homepage
Charlie Governali: predators of southern pine beetle
Environment affects strength and domain of alternate attractors.
Adaptive management

Theoretical model, uncertainty

Management challenge → Management response → System response

Repeat as needed
Beetle abundance at time $t$

Climate
Bluestain fungus
Predators
Tree defenses
Forest structure

Monitoring
Suppression
Prevention

Beetle abundance at time $t+1$
Duhamel de Monceau
"Traité complet des bois et forests" 1755-1768.