Mountain pine beetle outbreak dynamics in high elevation forests: Influence of climate change and tree chemistry

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1925. Mountain pine beetle-killed lodgepole pine in Yosemite National Park

1981. Mountain pine beetle-killed lodgepole pine in Glacier National Park

2009. > 2 million acres affected by mountain pine beetle in Colorado
Two major factors driving recent mountain pine beetle (MPB) outbreak dynamics in lodgepole pine forests

- Large expanses of susceptible aged & homogenous forests
- Climate Change - increasing temperature & decreasing precipitation

From Mike Dettinger & Dan Cayan:
http://geochange.er.usgs.gov/program/workshop/Dettinger.ppt
“In most stands throughout the West, MPB populations have increased dramatically within the past 8-10 years, infesting more than 1.2 million acres and killing as many as six million five-needle pines. “ Gibson et al. 2008. FHP Report R1-08-020.
Are similar factors driving MPB outbreak dynamics in low and high elevation forests?

- Direct effects of climate on MPB
  - Shifts in lifecycle timing
  - Increased survival

- Host tree differences
  - Reproductive capacity of MPB
  - Host defense response to MPB
  - Host response to decreasing precipitation

- Stand conditions
  - Increased density and reduced diversity across high elevation landscapes
Research Sites

Greater Yellowstone Ecosystem

MPB development was monitored on 10 trees at each site each year.
Approach 2: Quantified MPB attacks and reproductive capacity in mixed whitebark & lodgepole pine stands (2007).
Approach 3: Quantified terpene composition in lodgepole & whitebark pine prior to MPB attack. Phloem samples were taken again within 3 days of attack to measure the induction response (e.g., defense response) of each host tree species (2007).
RESULTS - MPB Developmental Timing

Low elevation – univoltine (1 generation per year)

MPB emergence from lodgepole pine, Sawtooth National Recreation Area, ID

~ 125 caged trees
RESULTS - MPB Developmental Timing

High elevation – semivoltine (1 generation every 2 years)
RESULTS - MPB Developmental Timing

High elevation – mix of semivoltine & univoltine

Trees attacked in 2004.
27 to 33% of MPB developed in 1 year (univoltine).
RESULTS - MPB Developmental Timing

Pheromone trap catch at 3 high elevation whitebark sites in 2005.

Multiple cohorts are emerging and flying to attack new trees throughout a summer.
Lifestage specific development $= f(\text{temperature})$

Bentz, Logan & Amman 1991
Logan & Bentz 1999
Powell, Jenkins, Logan, & Bentz 2000
Logan & Powell 2001
Jenkins, Powell, Logan, & Bentz 2001
Gilbert, Powell, Logan & Bentz 2004

Temperature to drive the Model:

SNOTEL Data & Products
1970 - present

Long-Term Daily and Monthly Climate Records from Stations Across the Contiguous United States
1915 - 2005

UNITED STATES HISTORICAL CLIMATOLOGY NETWORK
Field collected
Predicted temperatures at Togwotee whitebark pine site.

Mean annual and minimum temperatures have risen over the 86 yr. period, in particular since the 1980’s.
Temperature the summer following the attack year influence MPB voltinism.
RESULTS - MPB Attack Timing & Reproductive Capacity

No significant differences in emergence timing between lodgepole (LPP) and whitebark pine (WBP).
RESULTS - MPB Attack Timing & Reproductive Capacity

Whitebark pine were attacked first, and a greater proportion of available whitebark attacked.

Trees mass attacked by parents from the previous generation

- **Fish**
  - WBP $> 3''$ = 40% attacked
  - LPP $> 3''$ = 44% attacked
  - WBP $> 5''$ = 56%
  - LPP $> 5''$ = 48%

- **Union**
  - WBP $> 3''$ = 30%
  - LPP $> 3''$ = 9%
  - WBP $> 5''$ = 42%
  - LPP $> 5''$ = 10%
At both sites significantly more MPB attacks were observed on whitebark pine.
RESULTS - MPB Attack Timing & Reproductive Capacity

Significantly more MPB gallery starts on whitebark pine.
RESULTS - MPB Attack Timing & Reproductive Capacity

Number MPB emerging was greater from lodgepole pine.
RESULTS - MPB Attack Timing & Reproductive Capacity

MPB Reproductive Capacity was greatest in lodgepole pine.
RESULTS – Host Tree Defense Response

Whitebark pine had a greater proportion (than lodgepole pine) of several terpenes in both constituitive & induced resin:

- α-pinene
- borneol
- β-ocimene
- 3-carene
- limonene
- myrcene
- nerolidol
- nonyl acetate
- trans-caryophyllene
- Unk3

Terpenes with greater concentration in lodgepole pine:

- β-phellandrene
- β-pinene
- α-terpinene
- p-cymene
- Unk2
Both lodgepole and whitebark pine responded to MPB attack with greater total amount of terpenes (induced) relative to pre-attack levels (constitutive). Induced response in lodgepole was greater. Relationships were not significant.

Greater total quantity of terpenes suggests greater defense.
In 2004 – 2006, MPB lifecycle timing at high elevation sites was a mix of univoltine and semivoltine beetles. 100% univoltinism not necessary for outbreaks to occur.

Multiple and overlapping cohorts from different generations occur throughout a summer.

Model predictions suggest that some proportion of univoltinism has occurred in the past 100 years, particularly in the late 1920-30’s.

In a mixed stand, whitebark pine was attacked first, and also had more attacks per tree than lodgepole pine.

Reproductive capacity in lodgepole pine was greater.
Our results suggest that WBP terpene composition could be potentially more favorable to MPB communication (and hence attack success) than LPP. Also, LPP had a greater induced response, although not significant.

Phenological strategies expressed at high elevations reflect range of flexibility in mountain pine beetle life histories.
Genetic differences in MPB populations across latitudes.
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Palmer Drought Severity Index (PDSI)
Yellowstone Drainage WY