Predicting Severity and Periodicity of Mountain Pine Beetle Outbreaks

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**Abstract**

The relationship between the mountain pine beetle (Dendroctonus ponderosae) and spruce trees (Picea spp.) is one of the most destructive forest pests in Western North America. The beetle grows on the inner bark of trees and can spread rapidly through a forest. This phenomenon is known as an outbreak. We develop a structured forest demographic model for the mountain pine beetle outbreak in both the pre-outbreak and outbreak phases. The model is parameterized using data from Colorado and simulations are performed. From these simulations we see that outbreaks are at most 20 years from start to finish and that juvenile trees significantly decrease the spread of MPB by competing for resources with adult trees.

**Outbreak-Recovery Cycle**

1. **Phase 1: Outbreak**
   - The outbreak begins when a group of beetles enters a forest and starts to feed on the trees. The beetles produce eggs, which hatch into larvae that feed on the inner bark of the trees. This process continues until the larvae mature and emerge as adult beetles.
   - **Variables**: \( R_T \), \( n_T \), \( s \), \( t \), \( k \)
   - **Description**: The system has two fixed points: \( R_T = \) one outbreak and \( n_T = 0 \).

2. **Phase 2: Population Graduation**
   - During this phase, adult beetles start to die off and the population of susceptible trees decreases.
   - **Variables**: \( G_n \), \( J_n \), \( O_D \), \( F \)
   - **Description**: The next outbreak begins when the population of susceptible trees decreases to its minimum point.

3. **Phase 3: Factorization Graduation**
   - In this phase, the population of susceptible trees further decreases as the beetle population declines.
   - **Variables**: \( I_n \), \( n_I \), \( n_P \), \( n_K \)
   - **Description**: We see that footprint mortality is significantly decreased as the beetle population declines.

4. **Phase 4: Full Recovery**
   - The final phase of the outbreak begins with the release of new beetles into the forest.
   - **Variables**: \( n_T \), \( s_F \), \( k \)
   - **Description**: The next outbreak begins when the population of susceptible trees decreases to its minimum point.

**Approximations and Results**

- **Approximation of \( G_n \)**
  - Using our approximation model, we have \( G_n = 0 \)
  - This shows that outbreaks are at most 20 years from start to finish.

- **Approximation of \( J_n \)**
  - Using our approximation model, we have \( J_n = 0 \)
  - This shows that outbreaks are at most 20 years from start to finish.

**Footprint Graduation**

- **Footprint Graduation of juvenile trees**
  - After the start of the outbreak, juvenile trees that grew up in the spaces left by the outbreak leave the forest. The footprint of these trees decreases as the beetle population declines.
  - **Variables**: \( n_F \), \( s_F \)
  - **Description**: The next outbreak begins when the population of susceptible trees decreases to its minimum point.

- **Footprint Graduation of adult trees**
  - After the start of the outbreak, adult trees leave the forest. The footprint of these trees decreases as the beetle population declines.
  - **Variables**: \( n_A \), \( s_A \)
  - **Description**: The next outbreak begins when the population of susceptible trees decreases to its minimum point.

**References**


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