Seasonal variations in the incidence of pine wilt and infestation by its vector near the northern limit of the disease in Japan

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Recent spread of pine wilt disease damages

Spread to northern Japan (after 1970’s)
  - up north to Akita (1982-)
  to Aomori (2009)

- **Annual damages in cool climate regions**
  (i.e. northern and montaneous areas)
occupy **25% of national totals**.

→ Korea, China, Taiwan (1980’s)
→ Portugal (1999) → midwest Europe ?
Akita, the disease frontier

Now the northern most part of the continuous range of the disease

Large body of coastal pine forest (planted stands)

Disease has increased in the 2000’s.

Southern coast severely damaged
Common eradication practices in Japan

1. Cut-and-treat
   - Target: larvae of wood-boring insects
     - Fumigating insecticide
     - Chipping
     - Least costly, but depends on detection

2. Insecticide spraying
   - Target: adults of *M. alternatus*
     - Aerial and ground application
     - Requires expensive devices (e.g. helicopter)

3. Trunk injection
   - Target: pine wood nematode
     - Most effective
     - But also most costly
     - Few stand-level application
4? Charcoal burning: a public-participating practice ("Sumi-yaki")

(Hoshizaki et al. 2005)

A kind of cut-and-treat eradication
- No insecticide, very costless
- Damaged trees re-usable as various resources
- Collaboration with the public
  (>110 burning events since 2002)
- Detection of damaged trees also feasible
Distinct disease features in cool climate regions
(Zinno et al. 1987, Nakamura-Matori 2008)

Low temp. suppresses activities of *B. xylophilus* and *M. alternatus*.

1. Delay of disease development ⇒ Discolored tree occurs year round.
   ↔ peaked in summer in central Japan (e.g. Kishi 1995)

2. Shorter flight season ⇒ Infestation by *M. alternatus* should be limited to trees in which weakening time falls within oviposition period.
   ↔ Damaged trees were mostly infested in warmer regions.
To what extent these features are examined?

If true, we might adopt a selective eradication strategy, in which only necessary infectees are served for eradication, in cool climate regions. ("Akita system"; Kobayashi 2004, Hoshizaki et al. 2005)

However, findings remains collective and thus the supposed patterns have not been evidenced convincingly.

1. Investigation requires data for both seasonal damage occurrence and disease vector infestation.

2. Insufficient sample size, statistical power of analyses (e.g. data for not-throughout the year
Aims and questions of this study:

1) Need to confirm the pattern of year-round occurrence of pine wilt, based on a big dataset

2) What fraction of damaged trees is infested by *M. alternatus*?

3) Among damaged trees of various onset time of discoloration, which are more likely be infested?
60 km from the former northern limit
600-m inland from the shoreline
85 ha (forested in 60 ha), 60-90 yr old
Living trees: *Pinus thunbergii* + *P. densiflora*
  800-1200 trees/ha
Damage incidence: initial invasion in 1988, but remains approx. 0.1-2.4 %/yr

**Climate**
Annual temperature 11.4 °C
Precipitation 1700 mm/yr
July: rainy season
Seasonal incidence of diseased trees

(Ohta et al. in press)

June 2007–May 2009, once-a-month survey
Mapped all damaged trees (>5 cm diameter) in the 85-ha area
Keyed by:
  sign of early-stage foliage discoloration & cessation of oreoresin flow
Disease vector infestation

Presence/absence of oviposition scars
climbing & cutting for all damaged trees

Oviposition scar densities
counts at 1-2 m and 4.5-5.5 m high
with trunk surface area

Oviposition scar by *M. alternatus*
Results

Overall incidence of damage: 6.3 trees ha\(^{-1}\) yr\(^{-1}\)
For both species ...
Discoloration
- Occurs year-round
- Most frequently in June

Different patterns for autumn between the species

Seasonal incidence of damages (June 2007-May 2009)

Observation month

Tree with newly occurring discoloration
Akita: contrasting with general patterns in warmer regions (annu. temp. 13-15 °C).

e.g. Ibaraki (Kishi 1995), Ishikawa (Togashi 1989), Gunma (Yamaguchi & Tanaka 1985)

Kolmogorov-Smirnov test, P < 0.001
Vector infestation (1): proportion of oviposited trees

% oviposited trees
2007: 44.9% (n = 170 trees)
2008: 40.4% (n = 155 trees)

Canopy 58%
Suppressed 25%
(years pooled)

Summer-discolored trees: higher proportion of oviposited trees.
Vector infestation (2): oviposition intensity

Very large variation between samples

Higher density scars for July- to October-discolored

Lower density for June and November-discolored
Statistical analysis of oviposition risk

1) Logit generalized linear model

\[ \text{logit} \left( P_{\text{oviposited}} \right) = \exp \left( a + b \text{ month} \right) \]

Oviposition (0 or 1) assumed to follow binomial distribution.

→ Relative risk for a given month \( j \)

\[ = \exp(b_j) \text{, setting a specific month as the baseline.} \]

Relative risk = \( P_{\text{oviposited}} / P_{\text{no_oviposition}} \)

2) Negative binomial GLM

\[ \log \left( \text{No.Scars} \right) = \exp \left( a + b \text{month} \right) \]

Number of oviposition scars were assumed to follow negative binomial distribution.
### Pairwise relative risks of oviposition

Relative risk = \( \frac{P_{\text{oviposited}}}{P_{\text{no oviposition}}} \)

<table>
<thead>
<tr>
<th>Baseline month (( P_{\text{oviposited}} ))</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
</tr>
</thead>
<tbody>
<tr>
<td>June (0.38)</td>
<td>1</td>
<td>2.60**</td>
<td>14.61***</td>
<td>12.74***</td>
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<td>0.24*</td>
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<td>0.20***</td>
<td>1.15</td>
<td>1</td>
<td>0.40*</td>
<td>0.28*</td>
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<td>Oct (0.75)</td>
<td>0.21***</td>
<td>0.51*</td>
<td>2.89**</td>
<td>2.52*</td>
<td>1</td>
<td>0.70</td>
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<td>Nov (0.67)</td>
<td>0.30**</td>
<td>0.74</td>
<td>4.14*</td>
<td>3.61*</td>
<td>1.43</td>
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*\( P < 0.05 \)  **\( P < 0.01 \)  ***\( P < 0.001 \)

Trees with discoloration starting between August-September had high risk of being oviposited.
Which trees are important in eradication?

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** N.S.
Which trees are important in eradication?

June-discolored trees:
Lower risk, fewer oviposition scars than all other months.

“Safe” from the disease vector infestation.
Discoloration starting in June

Relative risk

- P < 0.05
- N.S.

Safe

Baseline month

Starting in July

95% C. I.

To be eradicated

Especially important

Starting in August

Relative scar density

To be eradicated
Especially important
To be eradicated
Safe

Relative risk
Relative scar density

Baseline month
Summary & discussion

In Aklita, cool climate region, • ••

- Damage occurred year-round, ca. 40% of which were infested by the disease vector. (highly contrasting pattern with warmer, central Japan)

- Analyses of relative oviposition risks and scar densities provides an effective tool in deciding eradication priority. (in this study, July-October discolored trees)

- Selective cutting for eradication is feasible as a cost- and labor-effective control, “Akita system”. (Kobayashi 2004, Hoshizaki et al. 2005)

→ Investment of resources can be toward a wider area.
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Have a look at our publication in *Journal of Forest Research*: