A Temperature-Based GIS Model Suggesting Risk for White Nose Syndrome in the West

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- The issue: White Nose Syndrome is spreading westward
- Land managers are planning for monitoring and response
- We asked: is there a way to suggest potential risk across the landscape for fungus development?
- Combine:
  - Cave temperature predictions, using:
    - The annual mean surface temperature rule-of-thumb
    - An annual mean temperature GIS surface
  - *Geomycetes destructans*’ thermal tolerance range evaluated using:
    - Laboratory studies
    - Prior occurrence
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• Cave Temperature Prediction
  – The average annual temperature rule-of-thumb: Cave “air temperature is greatly determined by wall temperature, which is approximately equal to the mean annual temperature outside the cave.” (Boga 1997),

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• Cave Temperature Prediction
  – Test this empirically. Does the mean annual surface temperature predict known average cave temperatures?
  – Compare:
    • Annual mean temperature GIS surface: Daymet model (18-year mean)
    • N=61 caves with locations and average temperature gathered from publications and the Internet

• Correlation analysis
  • $r = 0.762$, $r^2 = 0.580$
    (from Daymet surface data)
• Geomyces destructans’ thermal tolerance ranges – Lab Studies
  – Temperature is one environmental variable affecting fungus growth
  – Gargas et al. (2009) first to culture G. destructans in the lab
  – Blehert et al. (2009) interpret these lab experiments,
    • “isolates were initially cultured at 3 °C, grew optimally between 5 ° and 10 °C, but grew marginally above 15 °C. The upper growth limit was approximately 20 °C.”
  – Their interpretation coincides with WNS occurrence in the east, except in Canada

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LEGEND

Annual Mean Temp. (°C)

Blehert et al. interpretation

-9 - 2 Below lower growth limit
2.1 - 5 Lower range for growth
5.1 - 10 Optimal growth, Blehert D. et al.
10.1 - 14 Upper range for growth
14.1 - 25 Above upper growth limit
Counties Where WNS has Occurred
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- Geomyces destructans’ thermal tolerance ranges – Prior Occurrence
  - Extract annual mean temperature in each county where WNS has occurred
  - Analyze results statistically
    - Counties, N=71 (collected from the Internet, Fall, 2010)
    - Mean = 8.04 °C
    - Range = 2.4 °C to 13.3 °C
    - Standard deviation = 2.5 °C
    - +1 SD = 13.4 - 15.8 °C
    - -1 SD = -0.1 - 2.3 °C
  - Results on a new map
  - Canadian cases within SD range
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Annual Mean Temp. (°C)
From Occurrence Survey, N=71
- -29 - 0.2
- 0.1 - 2.3
- 2.4 - 13.3
- 13.4 - 15.8
- 15.9 - 32

Boxes Where WNS has Occurred
• **Geomyces destructans’** thermal tolerance ranges – Prior Occurrence
  – Recent county additions
    • Counties, N=128 (collected from the Internet, Spring, 2011)
    • Mean = 7.87 °C
    • Range = 0.2 °C to 14.9 °C
    • Standard deviation = 2.9 °C
    • +1 SD = 15.0 - 17.8 °C
    • -1 SD = -2.7 - 0.1 °C
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LEGEND

Annual Mean Temp. (°C)
From Occurrence Survey, N=128

-29 - -2.6 < -1 SD below
-2.7 - 0.1 -1 SD below
0.2 - 14.9 WNS range in East
15 - 17.8 1 SD above
17.9 - 32 > 1 SD above

Counties Where WNS has Occurred
- Model Weaknesses and Assumptions
  - Cave temperature prediction – Annual Mean Temperature rule-of-thumb
    - Correlation Analysis: How reliable are the cave average temperature and annual mean surface temp. data?
    - Cave configuration and microclimate: Unique by cave, unable to be modeled
    - Geothermal gradient: May be able to be modeled as an additional variable
    - Human alterations
    - Water presence
    - Annual mean temperature surface (1950-2000 annual mean): climate change effects?
    - Annual mean temperature surface: Unit of measurement 1 °C
  - *Geomyces destructans*’ thermal tolerance and growth
    - Other environmental variables influence fungal growth: humidity, pH
    - Differences seen in laboratory experiments versus environmental conditions
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• California Risk Scenarios: Maps

Blehert et al. (2009)

Areas with Temperatures Less and More Conducive to Geomyces destructans Growth

LENGEND
- BLM Field Office Boundaries
- BLM Lands
- Avg. Daily Temp. (°C)
- 0 - 1 Below lower growth limit
- 1 - 5 Lower range for growth
- 5.1 - 10 Optimal growth, Blehert D. et al.
- 10.1 - 14 Upper range for growth
- 14.1 - 29 Above upper growth limit
- Annual Avg., 1980-1997

Transparent (white) areas indicate locations with optimal temperature ranges for Geomyces destructans growth (Blehert et al. 2009). Blehert D. et al.’s research indicates that Geomyces destructans grows best between 5 and 10°C, but temperature in hibernacula impacted by WNS range between 2 and 14°C.

Model assumptions include the rule that internal cave temperatures approximate a location’s annual average surface temperature. Possible cave microclimate dynamics were not considered.
**California Risk Scenarios: Tabular**

### Model Scenarios: Acres of Land in California*

<table>
<thead>
<tr>
<th>Category</th>
<th>Acres</th>
<th>Percent</th>
<th>Occurrence Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below lower growth limit</td>
<td>1,795,264</td>
<td>2.0%</td>
<td>Less than -1 SD below occurrence range 180,880</td>
</tr>
<tr>
<td>Lower range for growth</td>
<td>4,688,818</td>
<td>5.3%</td>
<td>-1 SD below occurrence range 1,614,383</td>
</tr>
<tr>
<td>Optimal growth</td>
<td>16,953,842</td>
<td><strong>19.1%</strong></td>
<td>Range where WNS has occurred 37,499,285</td>
</tr>
<tr>
<td>Upper range for growth</td>
<td>24,071,610</td>
<td>27.1%</td>
<td>+1 SD above occurrence range 16,120,772</td>
</tr>
<tr>
<td>Above upper growth limit</td>
<td>41,438,166</td>
<td>46.6%</td>
<td>More than +1 above occurrence range 33,532,380</td>
</tr>
</tbody>
</table>

* Based on GIS layers from ESRI and Daymet. Inconsistencies may exist with official surveyed acreages.

### Model Scenario: Acres on BLM Managed Lands in California**

<table>
<thead>
<tr>
<th>Category</th>
<th>Acres</th>
<th>Percent</th>
<th>Occurrence Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below lower growth limit</td>
<td>4,800</td>
<td>0.0%</td>
<td>Less than -1 SD below occurrence range 0</td>
</tr>
<tr>
<td>Lower range for growth</td>
<td>231,398</td>
<td>2.2%</td>
<td>-1 SD below occurrence range 4,800</td>
</tr>
<tr>
<td>Optimal growth</td>
<td>1,325,367</td>
<td><strong>12.5%</strong></td>
<td>Range where WNS has occurred 3,125,200</td>
</tr>
<tr>
<td>Upper range for growth</td>
<td>2,319,544</td>
<td>21.9%</td>
<td>+1 SD above occurrence range 1,446,534</td>
</tr>
<tr>
<td>Above upper growth limit</td>
<td>6,697,272</td>
<td>63.3%</td>
<td>More than +1 above occurrence range 6,001,847</td>
</tr>
</tbody>
</table>

** Based on GIS layers from BLM SMA, 11/2010 and Daymet. Inconsistencies may exist with official surveyed acreages.
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• Future Directions
  – Alaska-specific map
  – Incorporate geothermal gradient
  – Evaluate model with WNS westward movement
  – Evaluate and incorporate other research (Flory, 2010 thesis)

• Questions?