

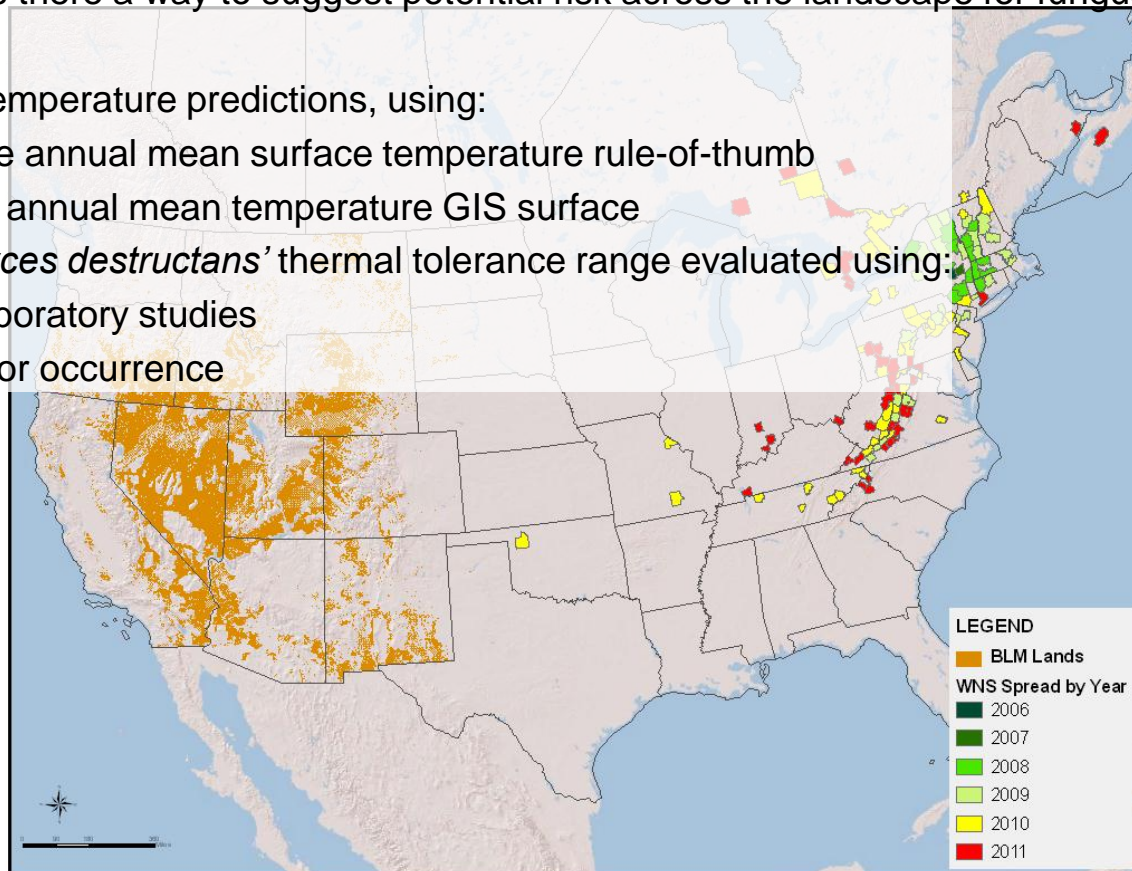
# A Temperature-Based GIS Model Suggesting Risk for White Nose Syndrome in the West



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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
  - *Geomyces 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),
  - Literature citations: Howarth 1983, Wigley and Brown 1976, Moore 1956



Boga, S. 1997. *Caving*. Stackpole, Mechanicsburg, Pennsylvania, USA.

Howarth, F.G. 1983. Ecology of Cave Arthropods. *Annual Review of Entomology*. 28: 365-389.

Moore, G.W., 1956. Aragonite speleothems as indicators of paleotemperature. *American Journal of Science*. 254: 746-753.

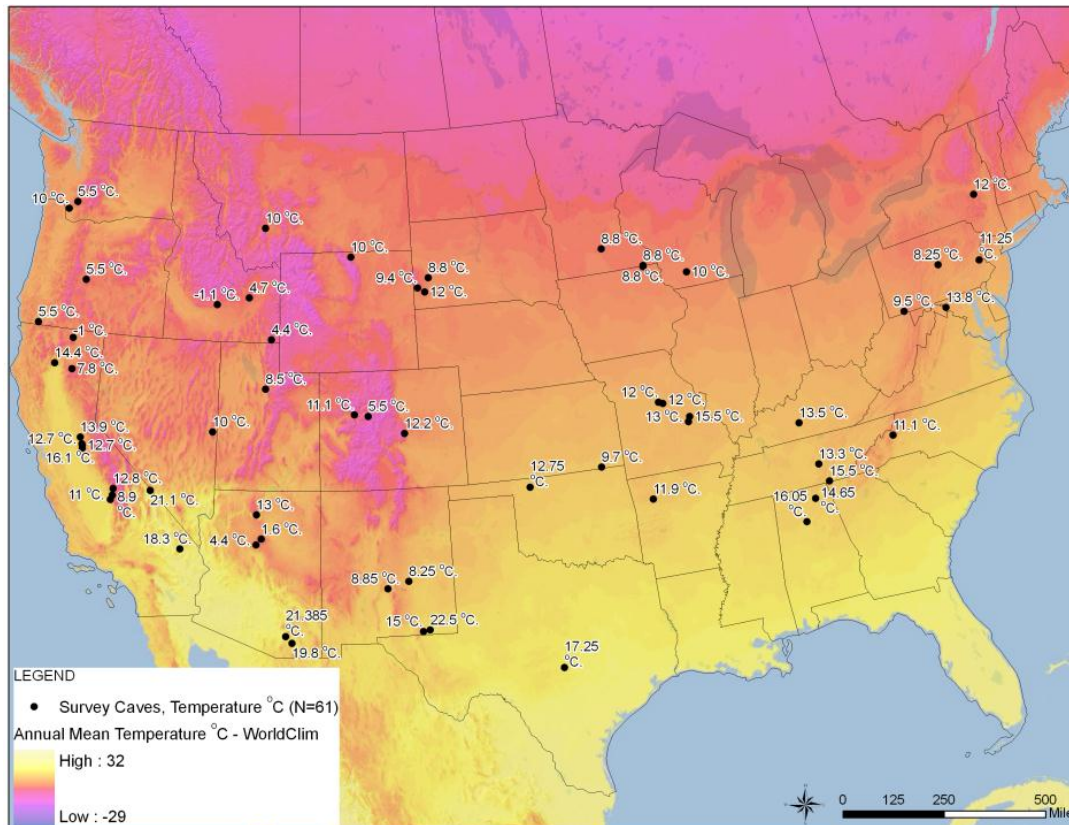
Wigley, T.M.L., and Brown, M.C., 1976. The physics of caves. *In: The Science of Speleology*, 329-358. Academic Press, NY.

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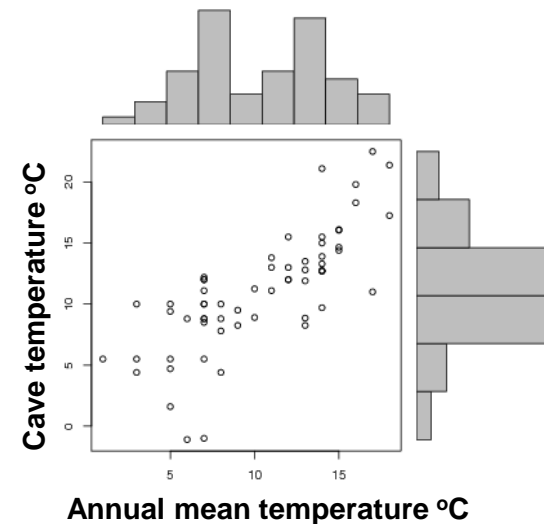


## • Cave Temperature Prediction

- 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



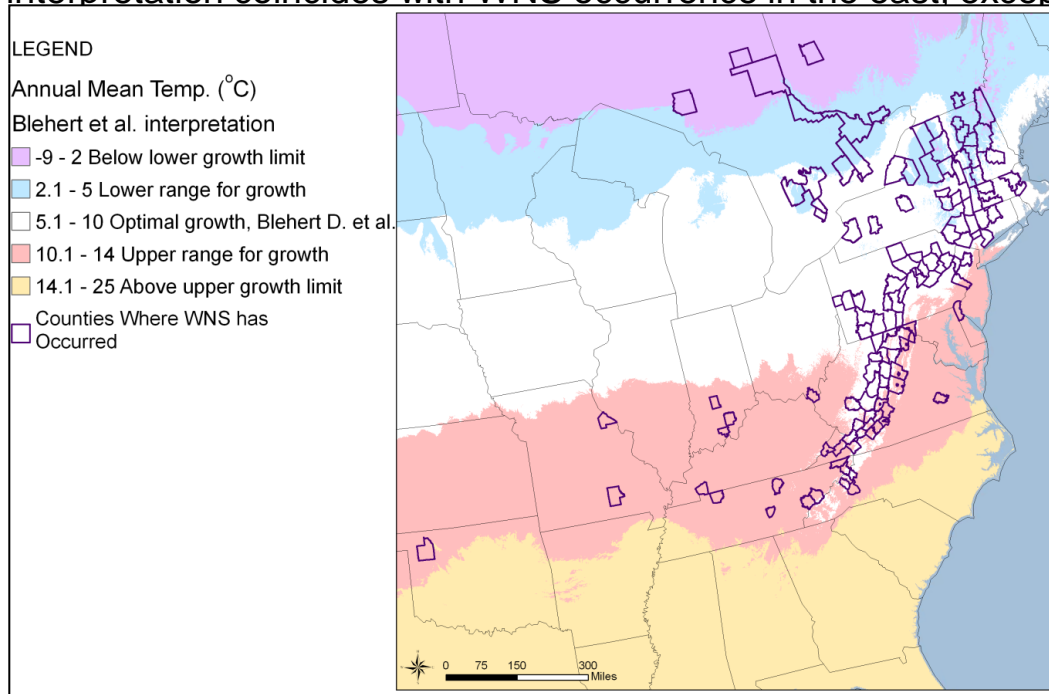
•Correlation analysis  
•  $r = 0.762$ ,  $r^2 = 0.580$   
(from Daymet surface data)



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



- *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



Gargas, A., M.T. Trest, M. Christensen, T.J. Volk, and D.S. Blehert. 2009. *Geomyces destructans* sp. nov. associated with bat white-nose syndrome. *Mycotaxon*. 08:147–154.

Blehert, D.S., A.C. Hicks, M. Behr, C.U. Meteyer, B.M. Berlowski-Zier, E.L. Buckles, J.T.H. Coleman, S.R. Darling, A. Gargas, R. Niver, J.C. Okoniewski, R.J. Rudd, and W.B. Stone. 2009. Bat white-nose syndrome: an emerging fungal pathogen? *Science*. 323:227.


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


## LEGEND


Annual Mean Temp. ( $^{\circ}\text{C}$ )


Blehert et al. interpretation


 -9 - 2 Below lower growth limit

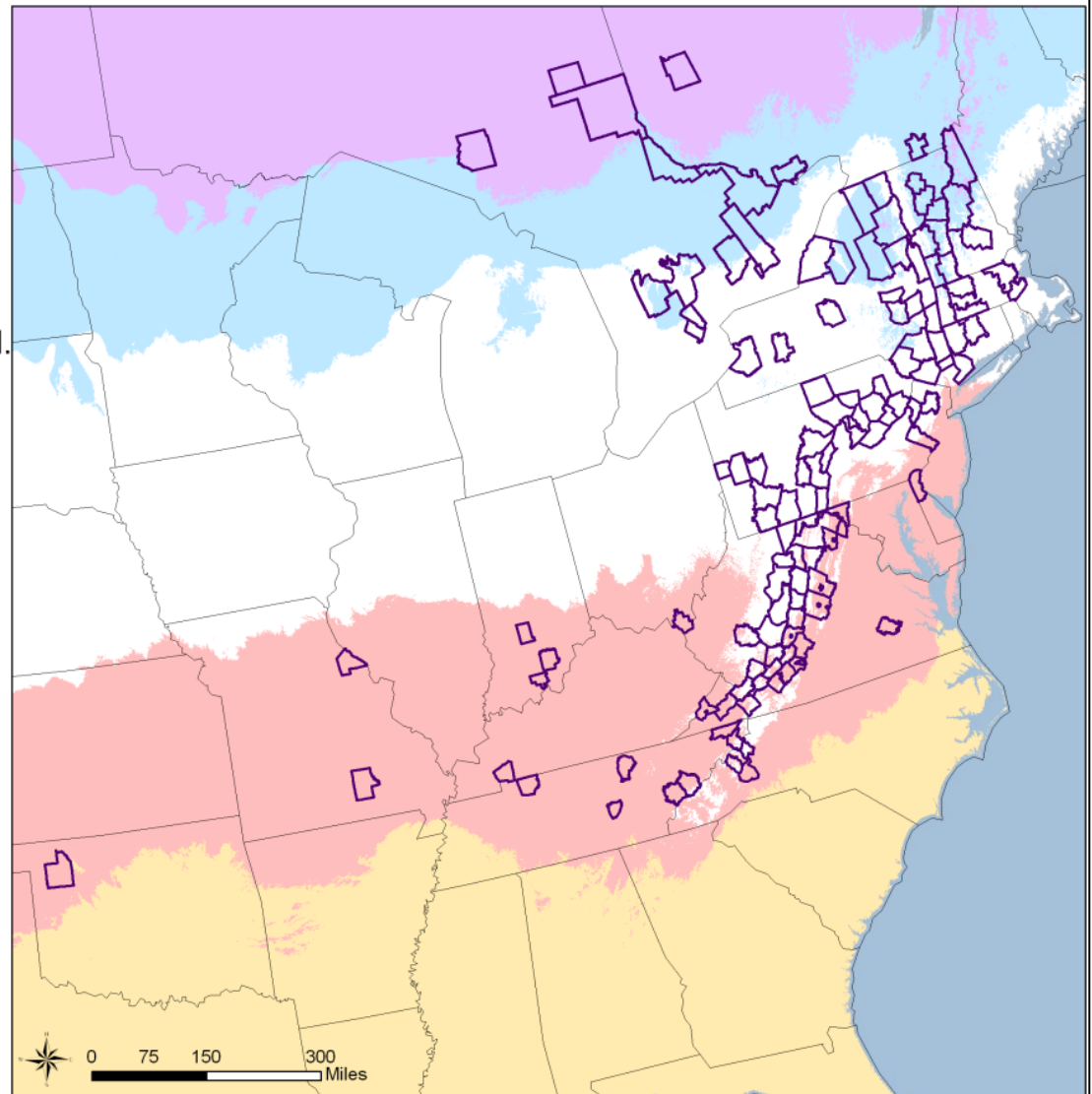
 2.1 - 5 Lower range for growth

 5.1 - 10 Optimal growth, Blehert D. et al.

 10.1 - 14 Upper range for growth

 14.1 - 25 Above upper growth limit

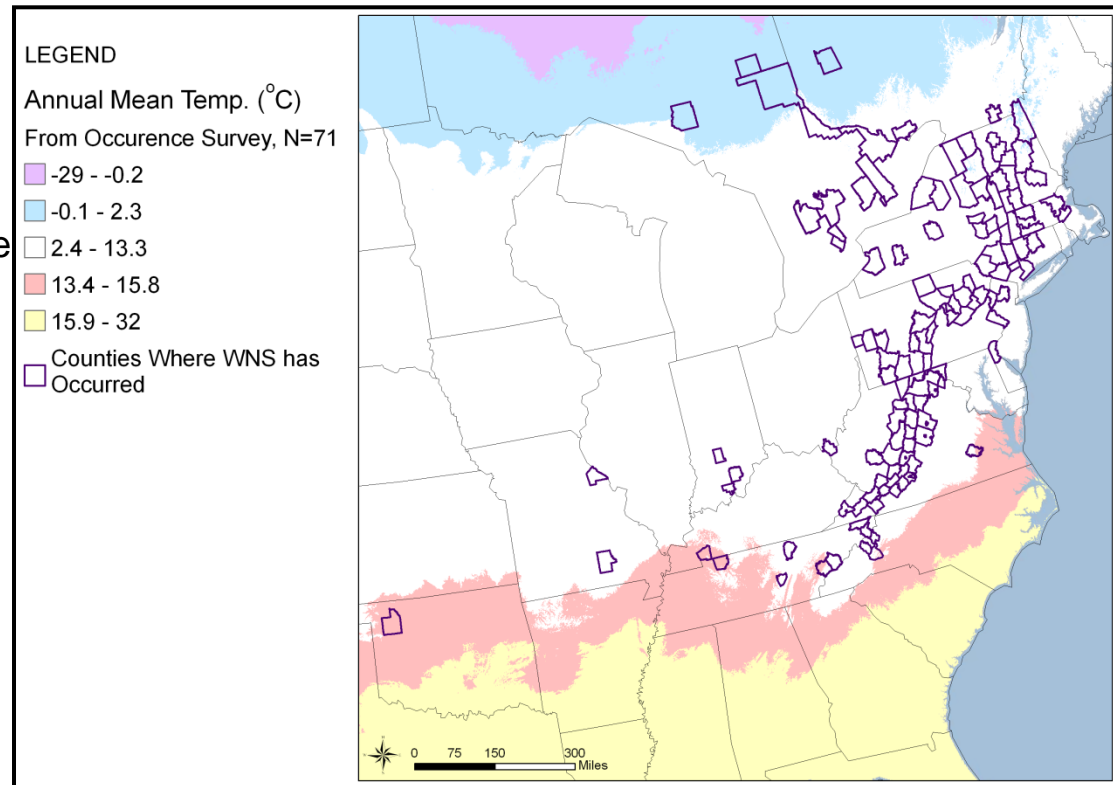
 Counties Where WNS has Occurred



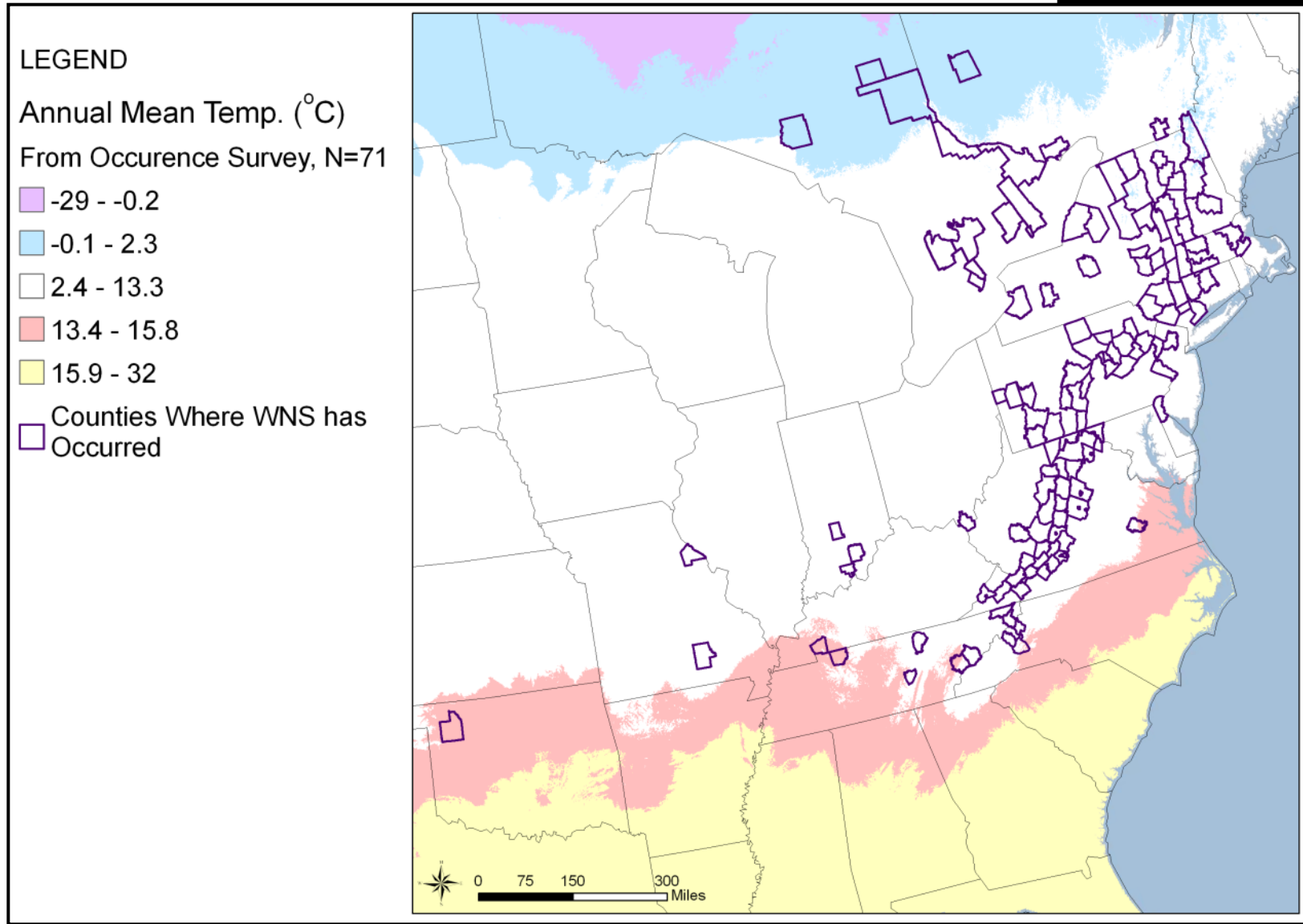
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- *Geomyces destructans*' thermal tolerance ranges –Prior Occurrence
  - Extract annual mean temperature in each county where WNS has occurred
  - Analyze results statistically
    - Counties, N=71 (collected from the Internet, Fall, 2010)
    - Mean = 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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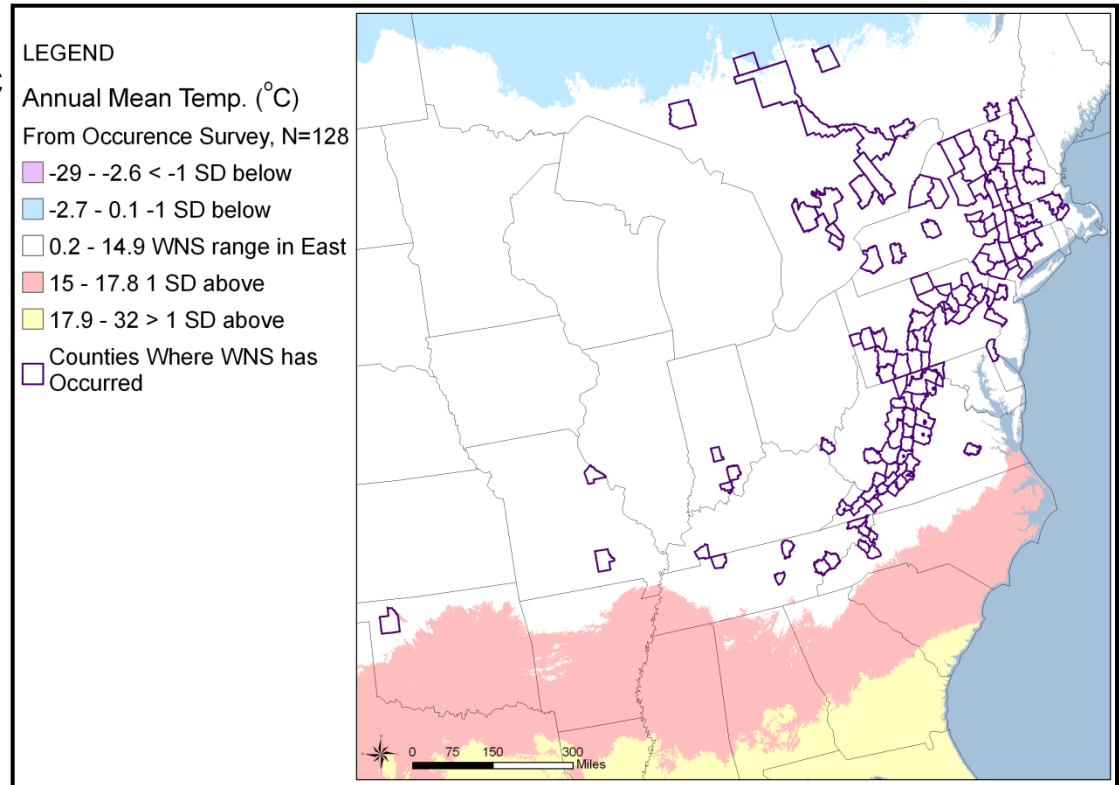


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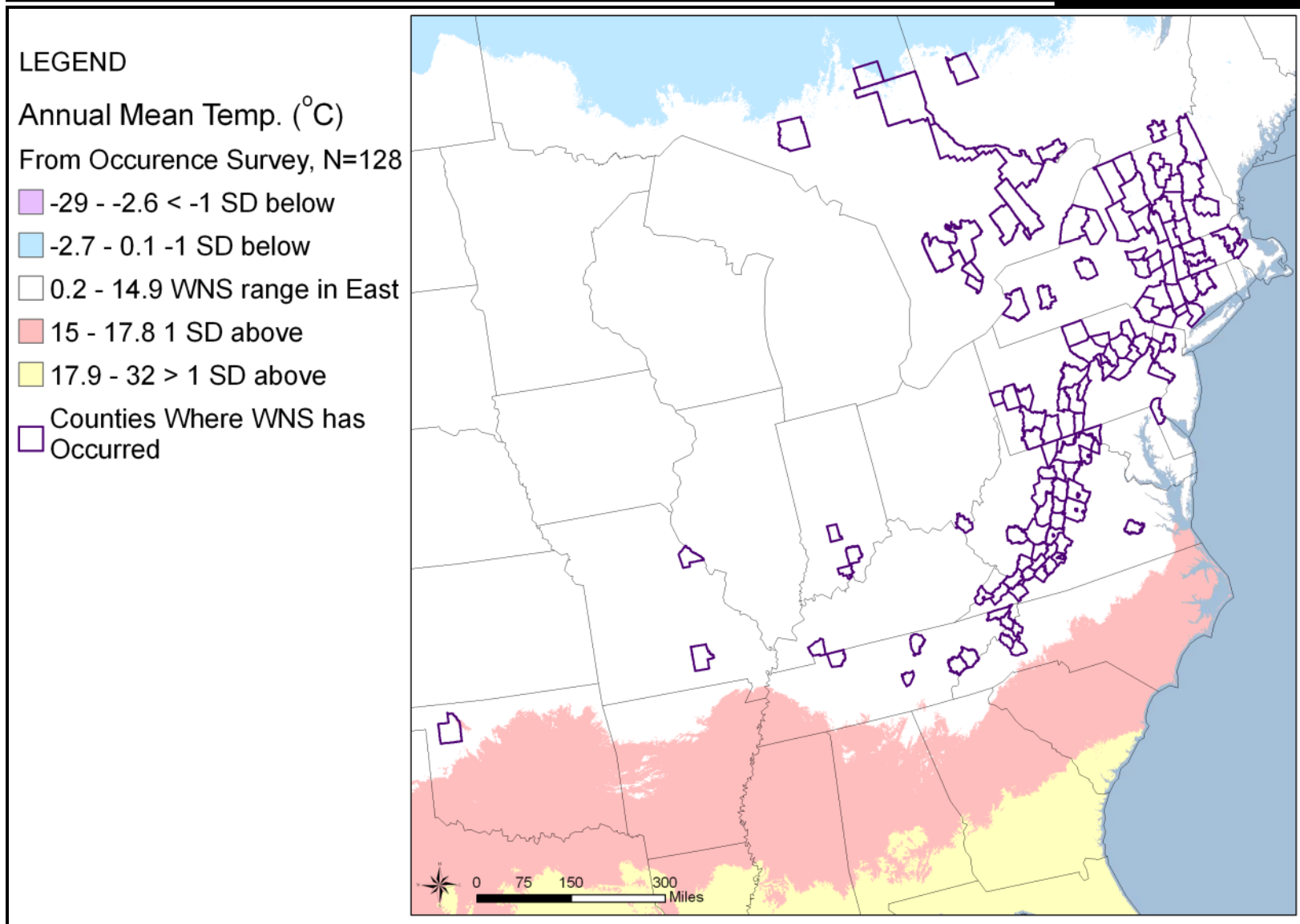
- *Geomyces destructans*' thermal tolerance ranges – Prior Occurrence
  - Recent county additions

- 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





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



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



- 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

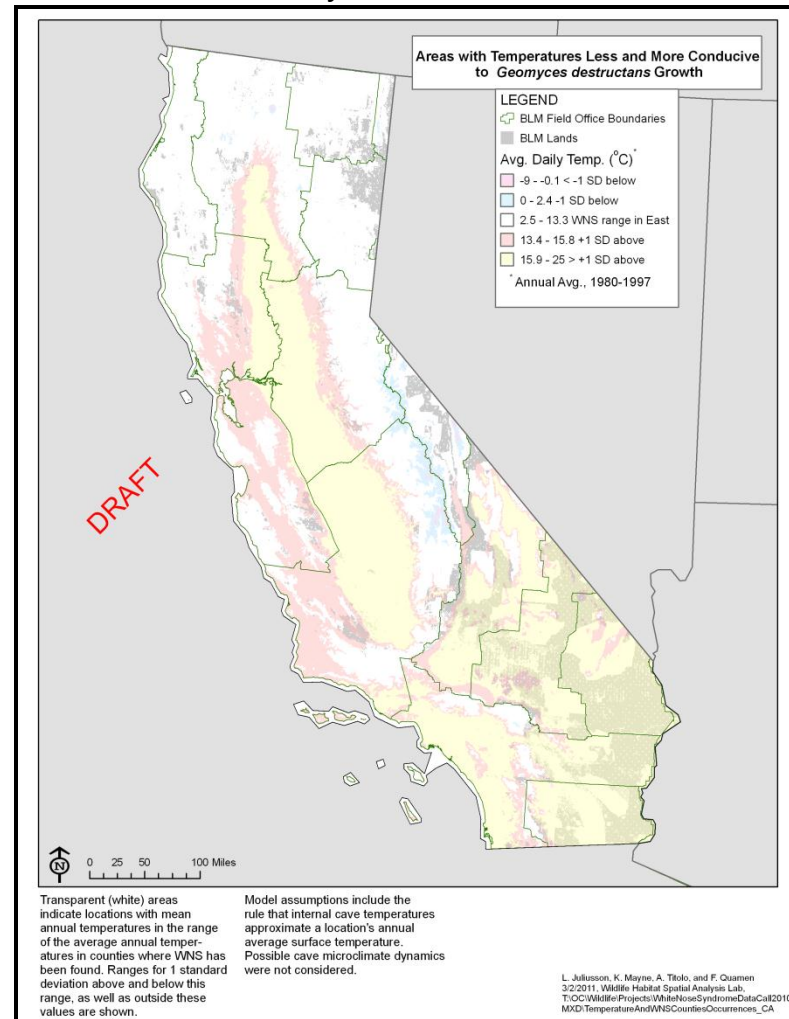
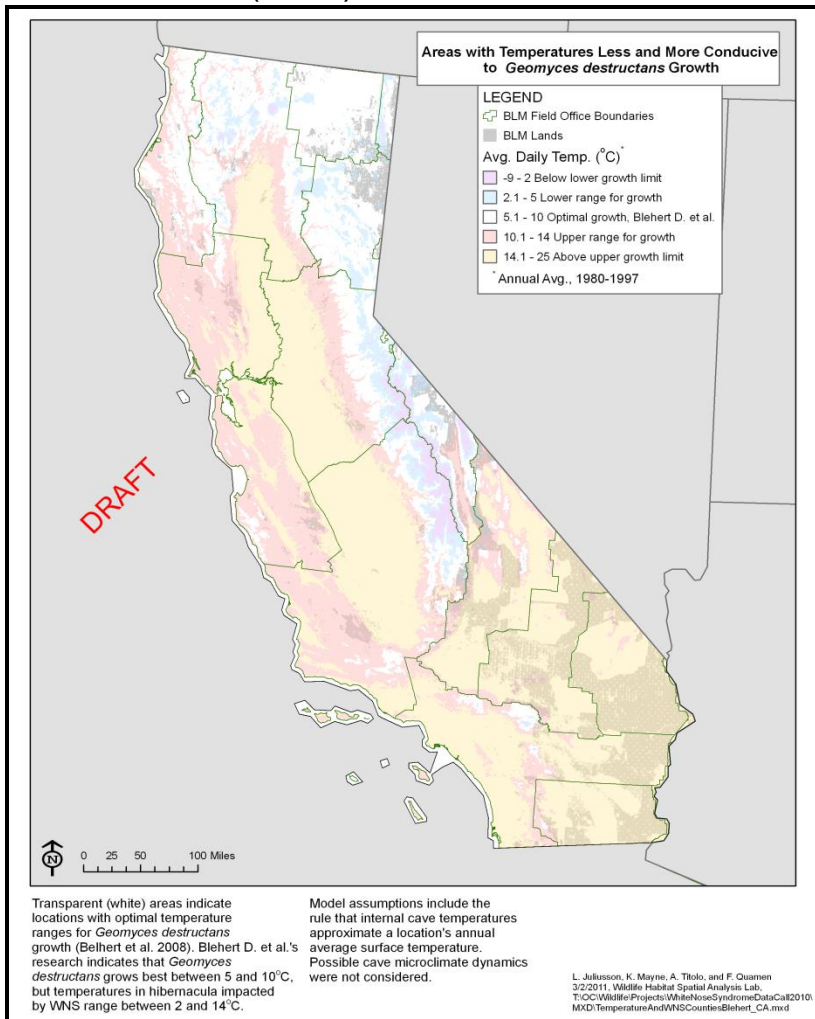
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- California Risk Scenarios: Maps

Bleher et al. (2009)

Occurrence survey, N=71



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



- California Risk Scenarios: Tabular

Model Scenarios: Acres of Land in California*					
Blehert et al.			Occurrence Survey		
Category	Acres	Percent	Category	Acres	Percent
Below lower growth limit	1,795,264	2.0%	Less than -1 SD below occurrence range	180,880	0.2%
Lower range for growth	4,688,818	5.3%	-1 SD below occurrence range	1,614,383	1.8%
Optimal growth	16,953,842	<b>19.1%</b>	Range where WNS has occurred	37,499,285	<b>42.2%</b>
Upper range for growth	24,071,610	27.1%	+1 SD above occurrence range	16,120,772	18.1%
Above upper growth limit	41,438,166	46.6%	More than +1 above occurrence range	33,532,380	37.7%

Model Scenario: Acres on BLM Managed Lands in California**					
Blehert et al.			Occurrence Survey		
Category	Acres	Percent	Category	Acres	Percent
Below lower growth limit	4,800	0.0%	Less than -1 SD below occurrence range	0	0.0%
Lower range for growth	231,398	2.2%	-1 SD below occurrence range	4,800	0.0%
Optimal growth	1,325,367	<b>12.5%</b>	Range where WNS has occurred	3,125,200	<b>29.5%</b>
Upper range for growth	2,319,544	21.9%	+1 SD above occurrence range	1,446,534	13.7%
Above upper growth limit	6,697,272	63.3%	More than +1 above occurrence range	6,001,847	56.7%

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

\*\* 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?

Flory, A.R., 2010. Thesis: Potential Environmental Factors Associated with the Newly Emerging Bat White-Nose Syndrome in the Northeastern United States: An Exploratory Modeling Approach and Case-Control Study. Colorado State University.