Investigating Accuracy of Climate vs. Yearly Weather for Predicting the Spread of White-Nose Syndrome in the United States

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Introduction

Fig. 1 . Symptoms of WNS (source: *www.nwhc.usgs.gov*)

White-Nose Syndrome (WNS) is an epizootic fungal disease caused by *Pseudogymnoascus destructans* which has killed millions of Vespertilionidae bats. It was first recorded in 2006 in Schoharie county, NY, with *Myotis lucifugus* bearing the highest mortality rates across infected counties[3]. Studies have shown that WNS spreads by jump dispersal along cave-bearing geologic formations, as opposed to simple diffusion from an epicenter [4].

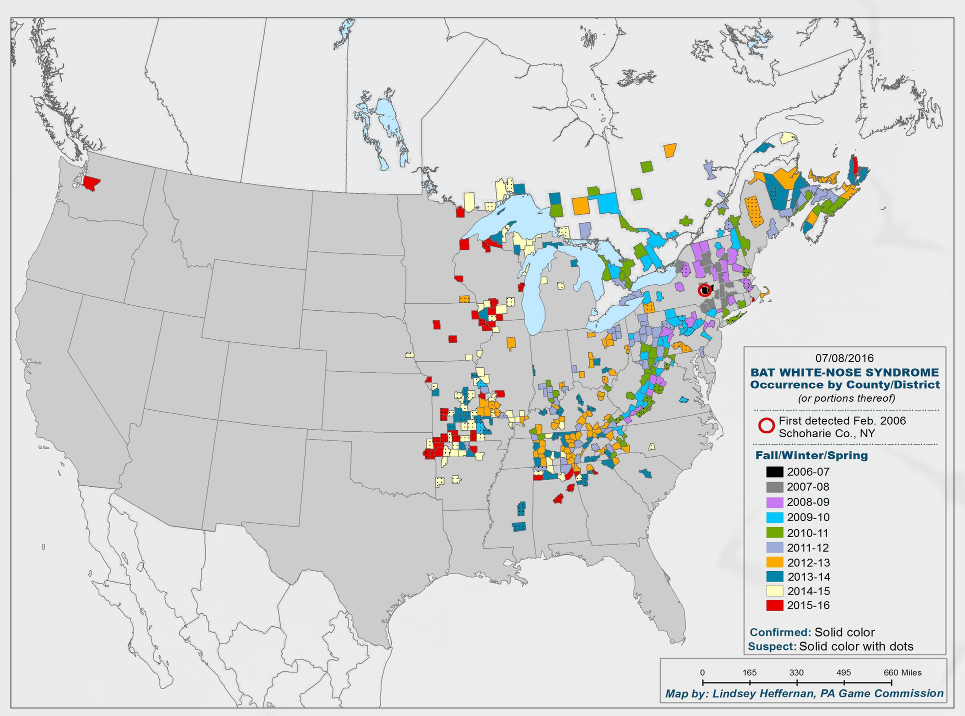

Fig .2: White-Nose Syndrome occurrence data as of July , 2016
Source: U.S. Fish and Wildlife Service

- Spatial spread depended on factors such as the density of caves, species richness and temperature [4].
- *P. destructans* produces conidia (infectious spores) at an optimal temperature range of 12.58°C and 15.8°C [5], coincides with the temperature of the hibernation period of most Vespertilionid bats [2].
- The data suggests that length of winter is directly proportional to the infection rate of WNS between counties with caves [4].

Based on the previous success of temperature in providing a good model for the spread of the disease, **we wanted to know whether yearly variations in temperature (weather) is a better environmental factor than climate (average, length of winter) in predicting the spread of White-Nose Syndrome in the contiguous United States.**

Hypothesis

Yearly weather is a better environmental factor than climate (average temperature or average length of winter) for predicting the spread of WNS between infected and susceptible caves.

Model

$$\beta_0 + \beta_1 \frac{d_{ij}}{(n_i n_j)^{\beta_2}} + \beta_3 \tau_i$$

Fig.3 Gravity$_{(caves)}$ + Winter hypothesis [3]

β_0: basic rate of infection
β_1: probability of infection (distance)
β_2: density/gravity of caves
β_3: climate (covariate)
τ: climate variable

Methods

1)Models (from Maher et. al 2012) were fitted with current WNS infection data to determine how their predictions held up with the addition of new data .

2) Values for monthly precipitation, maximum and minimum temperature from 2000 to 2014 were obtained from high resolution satellite data (30 arcseconds) and averages were derived from the mean of values per grid of a county polygon.

3) Data was sorted into year prior to first infection (2006) and year of infection to determine if the weather of year preceding infection had an impact on spread.

4)NLL and AIC were obtained from the MLE parameter sets and used to compare quality of fit.

5)Spatial spread of WNS was simulated based on climate (length of winter, average temperature) versus year-to-year weather to see whether patterns differed.

6) All coding and statistical analysis was done in R software.

Results

Table 1. Percent difference in WNS MLE parameter sets of best models from 2015 to 2016

Hypothesis	β_0	β_1	β_2	β_3	β_4
Gravity$_{(caves)}$ + Winter	2.64%	-4.58%	16.10%	10.82%	
Gravity$_{(caves)}$+ Winter+Species richness	2.43%	-2.52%	13.44%	9.41%	-1.29%

Table 2. MLE parameter estimates for top three models, comparing quality of fit

Model	β_0	β_1	β_2	β_3	NLL	AIC
beta.caves.temp.maher	7.8865	-0.016	0.0163	0.1931	924	1855.724
beta.caves.avgtmin1.maher	4.7344	0.0326	0.0161	0.1787	927	1861.333
beta.caves.tmin1.maher	4.6742	0.0246	0.0145	0.1677	932	1872.385

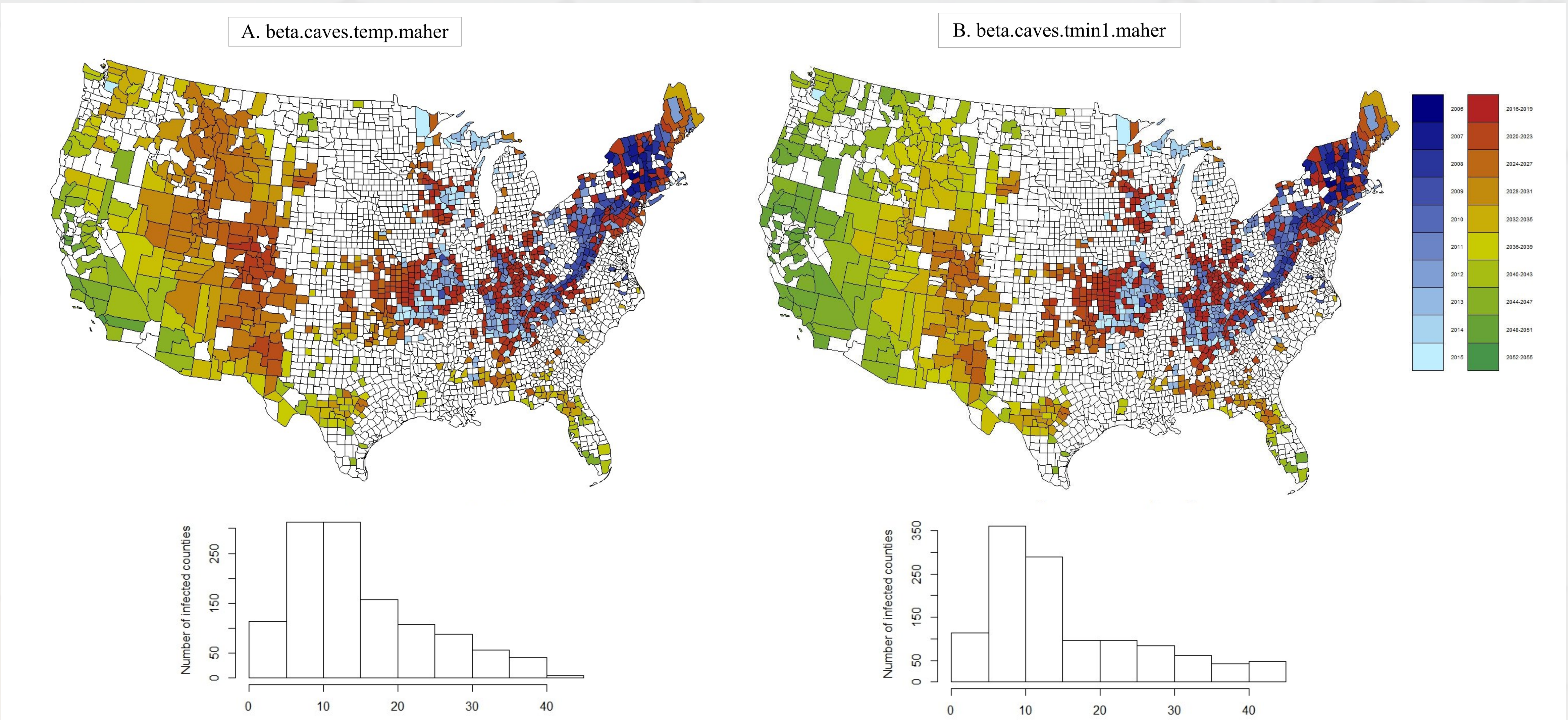

Figure 4. Maps of the contiguous United States showing current spread of WNS alongside 50 year forward simulations using:
A)Average length of winter
B) Yearly minimum temperature

Conclusion

1) Average length of winter had the best fit based on comparing NLL and AIC values of the models

2)Average temperature had a significantly lower NLL than the yearly weather models, reflecting higher accuracy.

3) All simulations showed distinct peaks in the second decade of infection. This could be attributed to the abundance of caves in the mid-eastern/mid United States.

4)Predicted spread of WNS was fastest in the Average length of winter model (beta.caves.temp.maher).

Future directions

1) Use yearly variation in length of winter to determine if variations may contribute to a closer model fit.

2) Investigate better methods to predict onset of hibernation based on minimum temperature and also note bat hibernation patterns in the various areas, and interspecific differences in hibernation periods and associated temperature.

3) Data on co-occurring species should be used to determine species diversity per county [1].

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