Big Brown Bat (*Eptesicus fuscus*) Post Hibernation Mass Changes During White-Nose Syndrome Invasion

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Today's Presentation

- Introduction/Background

- Methods

- Results

- Discussion

Background/Introduction:

What is White Nose Syndrome?

- White Nose Syndrome (WNS) is a disease impacting hibernating bat species caused by the fungal pathogen:
  - *Pseudogymnoascus destructans* (Pd)
- *Pd* grows in temperatures between 12-16°C, allowing Pd to thrive in bat winter hibernacula conditions
- as *Heterothermic mammals*, bat species are vulnerable to WNS when they undergo periods of suppressed immune functioning during torpor/hibernation.

Little Brown Bat with WNS fungus (New York, Oct. 2008.)

WNS and Mass Changes

Little Brown Bat with WNS fungus (New York, Oct. 2008.)

- *Pd* impacts the epithelial tissues of the bats, leaving an uncomfortable white fuzz and fissions on their muzzles and wings (pictured).

- The arousal of Pd infection wakes them up and prematurely burns their brown fat and water, **leading to associated losses in mass.**

Seasonal Cycles:

Little Brown Bat with WNS fungus (New York, Oct. 2008.)

Adult males
Adult females (reproductive)
Juveniles (young of year)

Emergence
Hibernation
Gestation
Birth/Growth
Summer Activity
Lactation
Late Swarming
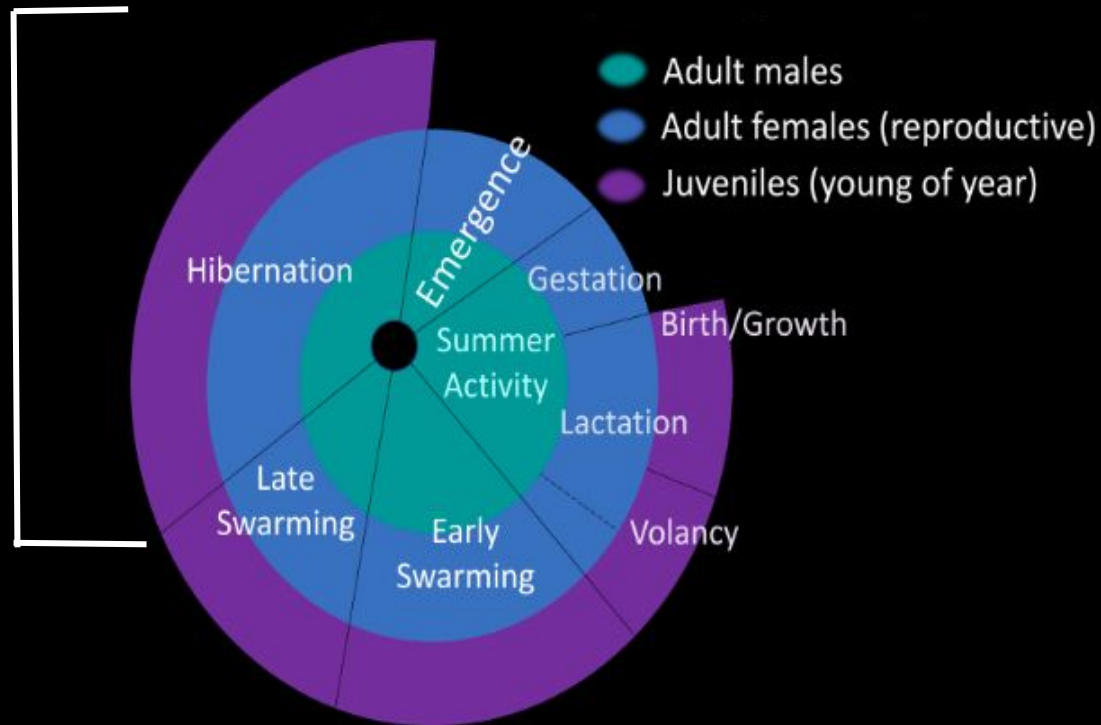Early Swarming
Volancy

Chart by: Dr. Davy (2020)

Seasonal Cycles:

Pd exposure has physiological carry-over effects in the mass of recovered individuals, where:

- Energy expenditure of *Pd* immune responses/stress decreases available energy for emergent seasonal behaviors such as **migration to summer hibernacula** and **initiation of reproduction;** w/ differing energy necessities between adult and juvenile **male** and **female** bats.
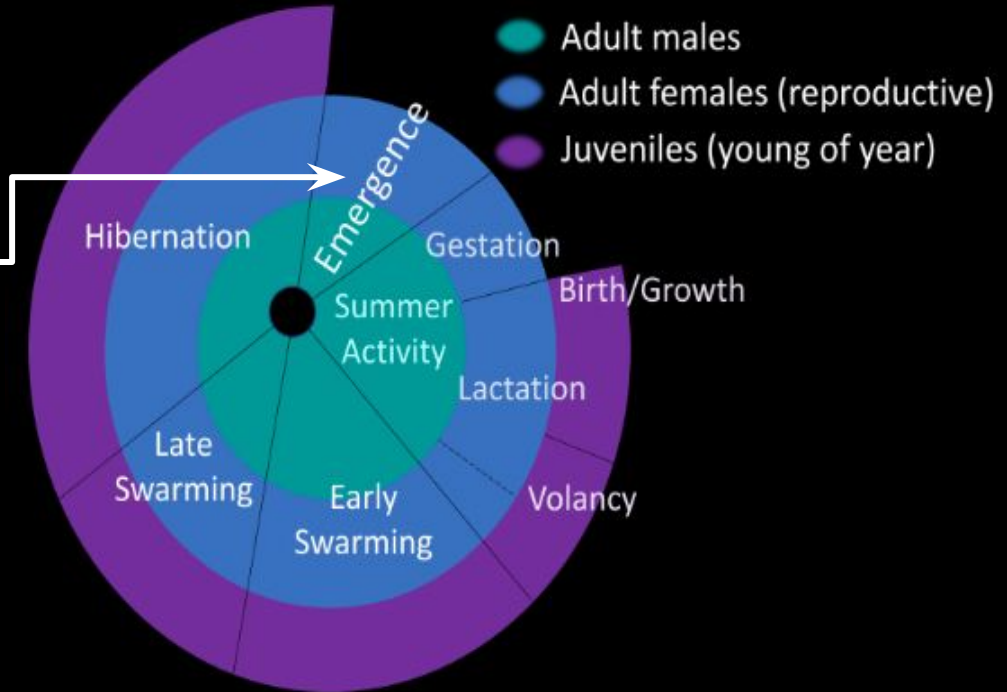

Adult males
Adult females (reproductive)
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Hibernation
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Late Swarming
Early Swarming
Volancy

Chart by: Dr. Davy (2020)

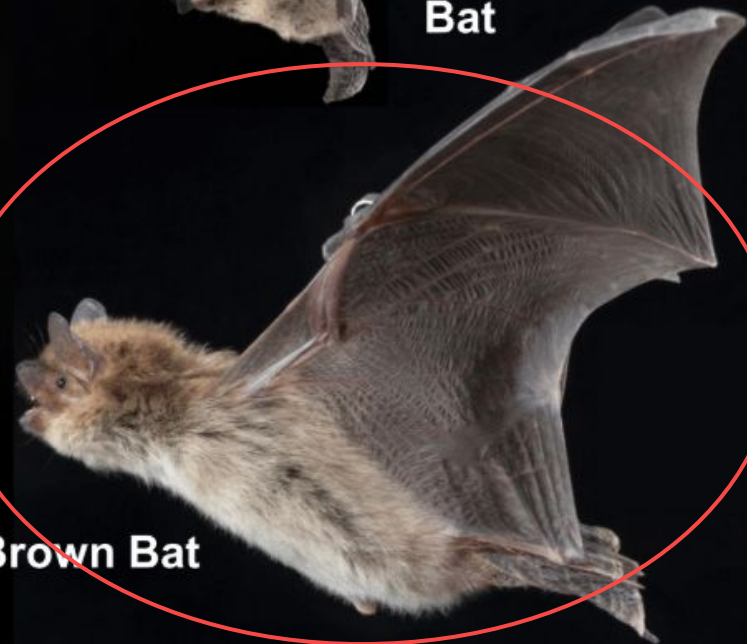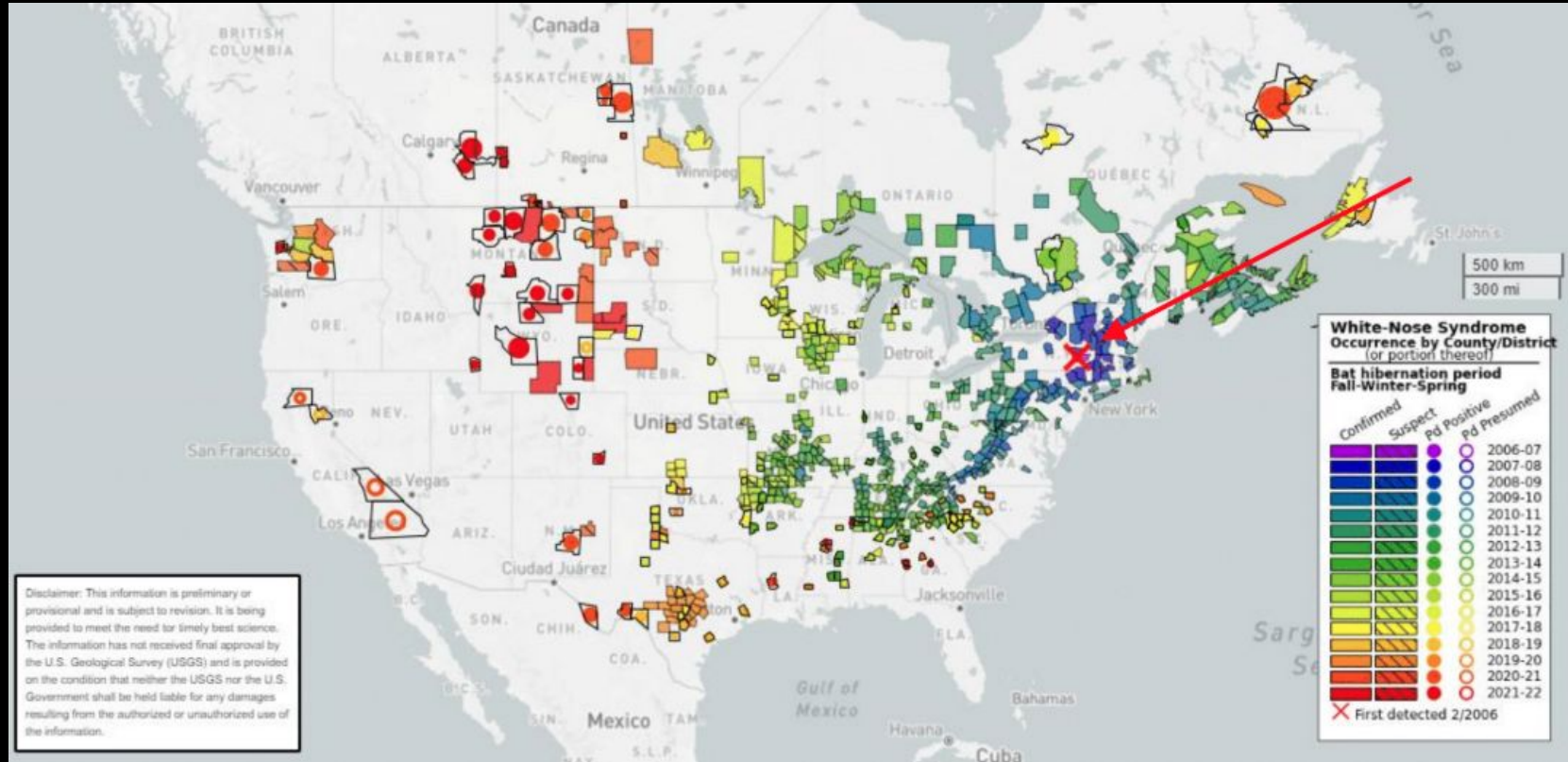# Bats of Ontario – local hibernators

Little Brown Bat

Northern Myotis

Eastern Small-footed Bat

Big Brown Bat

Tricolored Bat

Photos: Charles Francis / Brock and Sherri Fentor

Spread of Fungus/Disease Over Time

White-Nose Syndrome
Occurrence by County/District
(or portion thereof)

Bat hibernation period
Fall-Winter-Spring

Confirmed	Suspect	Pd Positive	Pd Presumed	
				2006-07
				2007-08
				2008-09
				2009-10
				2010-11
				2011-12
				2012-13
				2013-14
				2014-15
				2015-16
				2016-17
				2017-18
				2018-19
				2019-20
				2020-21
				2021-22

X First detected 2/2006

500 km
300 mi

Disclaimer: This information is preliminary or provisional and is subject to revision. It is being provided to meet the need for timely best science. The information has not received final approval by the U.S. Geological Survey (USGS) and is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

Methodology:
Process/Methods

About Our Data:

- Big brown bat (EPFU) captured & recorded from 1990-2010
- 30,497 individual records across 3,797 unique capture sites across eastern United States
- Age, sex, reproductive status, mass, forearm length, etc.
- Focus on mass (more directly impacted by WNS)
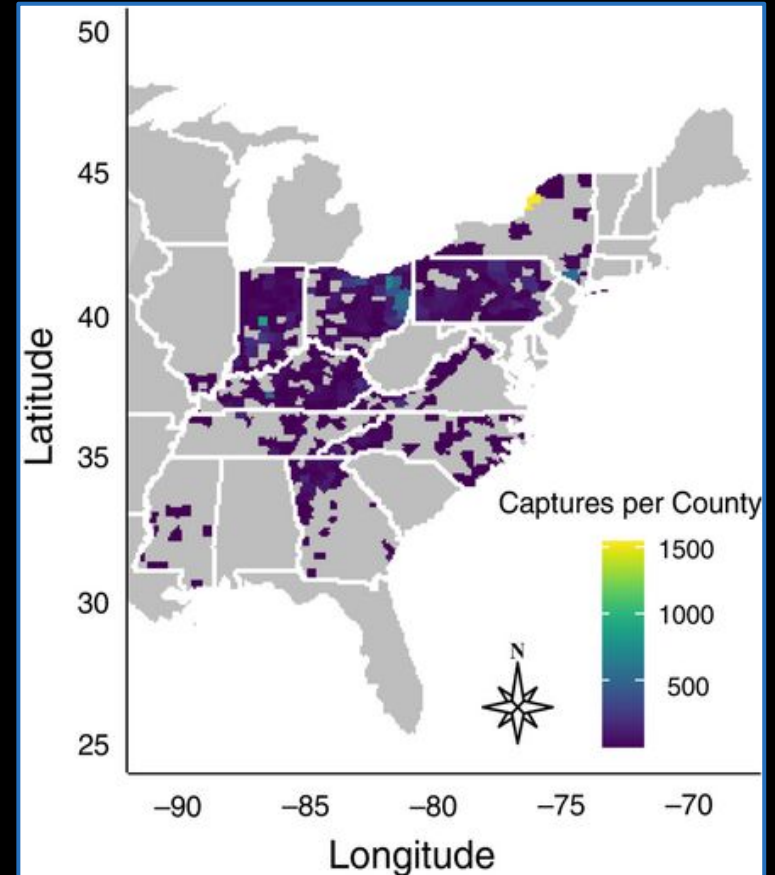
Process:

- Attempt 1
  - Gamma distribution. Attempted to find MLE, where parameters are maximized (shape, scale)
  - Mean = shape * scale
  - Variance = shape * scale^2
  - CI: lower shape * lower scale – upper shape * upper scale
- Attempt 2
  - Try to model using different types of distributions
- Attempt 3
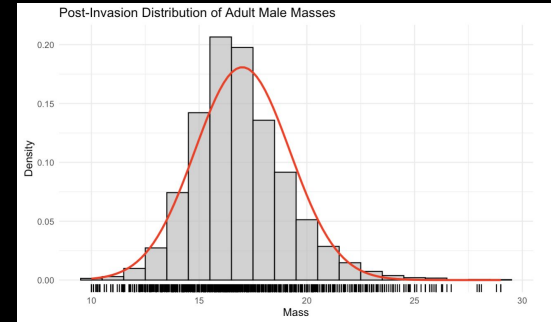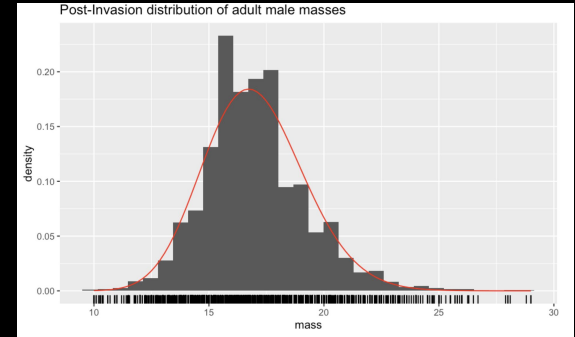 - GLMMs using gamma distribution

Model Section: Gamma vs Normal distribution

- **Gamma distribution** AIC = 155189

- **Normal distribution** AIC = 156321

- Gamma distribution more appropriate than normal **(lower AIC)**

Figure x: Distribution modeled using a **normal distribution** for Post-Invasion Adult Male Masses.

Figure x: Distribution modeled using a **gamma distribution** for Post-Invasion Adult Male Masses.

Hypotheses:

- Null hypothesis
  - Age and sex are not correlated with the effect of *Pd* on mass of EPFU
- Alternative hypothesis
  - Age and sex are correlated with the effect of *Pd* on mass of EPFU
- Prediction:
  - Mass and mass variation fitted on a Gamma distribution will decrease over Pd exposure time

Methods of Analysis:

- Original study fit linear mixed models with normal distributions

- Generalized Linear Mixed Model using Gamma distribution → glmer()

- Link function: "log"
  - multiplicative effects → additive on log scale
  - better than others

- Trying different fixed and random effects, looking at coefficients for effects on mass

- Elevation as a fixed effect → unable to obtain elevation data

Photo by: J. Scott Altenbach

Results/Discussion

Comparison of Random Effects

Random Effects Tested:

1. **Model 1**: Random intercept for year
2. **Model 2**: Random intercept for site_mask.
3. **Model 3**: Random intercept for state

Model	Random Effect	AIC
Model 1	year	138844.5
Model 2	site_mask	132567.2
Model 3	state	137431.1

Figure x: Model Comparison: Site_mask model fits bat mass data best.

Model 2 (Random Effect: site_mask) has the lowest AIC, indicating it provides the **best fit for the data.**

Results: Gamma GLMM with Random Effects

```
Family: Gamma  ( log )
Formula: mass ~ disease_group * sex * pregnancy_status * age + (1 | site_mask)
   Data: data_new

     AIC      BIC   logLik deviance df.resid
132567.2 132667.1 -66271.6 132543.2    30484

Scaled residuals:
    Min     1Q  Median      3Q     Max
-4.7955 -0.6163 -0.0102  0.5994  6.4132

Random effects:
 Groups    Name        Variance Std.Dev.
 site_mask (Intercept) 0.003297 0.05742
 Residual              0.013525 0.11630
Number of obs: 30496, groups:  site_mask, 3797

Fixed effects:
                                                  Estimate Std. Error  t value Pr(>|z|)
(Intercept)                                       2.967439   0.002390 1241.774  < 2e-16 ***
disease_groupPre-Invasion                         0.015950   0.004951    3.222  0.00128 **
sexmale                                          -0.138996   0.001839  -75.570  < 2e-16 ***
pregnancy_statusPregnant                          0.151456   0.003565   42.486  < 2e-16 ***
agejuvenile                                      -0.194312   0.002675  -72.630  < 2e-16 ***
disease_groupPre-Invasion:sexmale                -0.001418   0.005010   -0.283  0.77723
disease_groupPre-Invasion:pregnancy_statusPregnant -0.028060 0.009989   -2.809  0.00497 **
disease_groupPre-Invasion:agejuvenile             0.021801   0.007604    2.867  0.00415 **
sexmale:agejuvenile                               0.072712   0.003635   20.005  < 2e-16 ***
disease_groupPre-Invasion:sexmale:agejuvenile     0.003845   0.010337    0.372  0.70988
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure x: GLMM Summary: Key predictors and variances for bat mass.

Data Overview

- **Focus:** Pre- and Post-Invasion Bat Mass Differences with **different fixed effects**
- **Predictors:** disease_group, sex, pregnancy_status, age
- **Random Effects: site_mask**
- **Key Fixed Effects:**
    - disease_group Pre-Invasion:
    - pregnancy_status Pregnant:
    - age juvenile:

GLMM captures the skewed distribution of bat mass better than LMM.
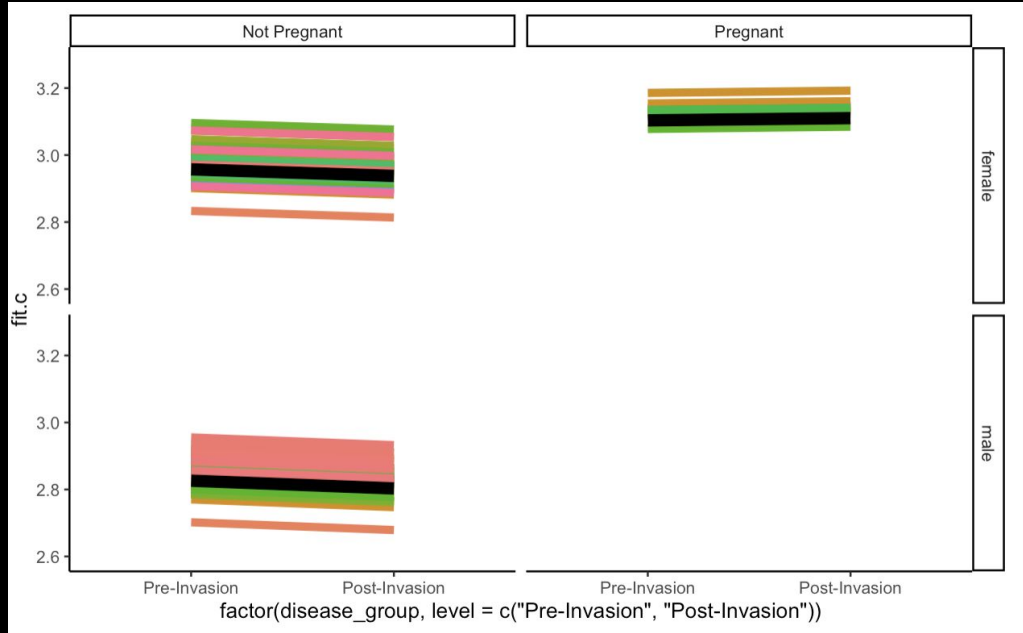
Results: Interaction Plot

Figure x: Predicted log-mass by disease group, sex, and pregnancy status.

Key Takeaways

- Gamma GLMM captures positively skewed mass data for pregnant bats.

- Significant predictors include **disease_group**, **pregnancy_status**, and **age**.

- Random effect for site_mask accounts for spatial variability.

Conclusion:

- Alt hypothesis/prediction accepted:
  - Age and sex are correlated with the effect of *Pd* on mass of EPFU, with the Gamma as the best fit to account for the skewed distribution of mass compared to the Normal Distribution (i.e. for pregnant status)
- Gamma GLMM highlights the ecological implications of WNS, where disease introduction (by year), sex, and reproductive status, highlight the understanding of bat mass dynamics across geographic regions during invasion periods.

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Thank you!
Questions?

I HAVE HAD A VERY LONG DAY.... I AM VERY SMALL
AND I HAVE NO MONEY SO YOU CAN IMAGINE
THE KIND OF STRESS I AM UNDER

Image by Traer Scott
https://socialbat.org/videos