Thank you for signing in early

The webinar will begin promptly at
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SERDP and ESTCP Webinar Series

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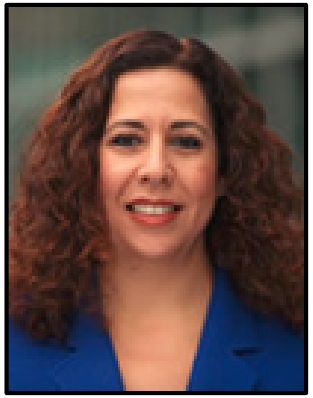
Assessing White-Nose Syndrome Threats to Western Bat Species

November 5, 2020

SERDP DOD • EPA • DOE | ESTCP

Welcome and Introductions



Rula A. Deeb, Ph.D.
Webinar Coordinator

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Webinar Agenda

- **Webinar Logistics** (5 minutes)
  Dr. Rula A. Deeb, Geosyntec Consultants
- **Overview of SERDP and ESTCP** (5 minutes)
  Dr. Kurt Preston, SERDP and ESTCP
- **Assessing White-Nose Syndrome Threats to Western Bat Species** (55 minutes + Q&A)
  Dr. Sarah Olson, Wildlife Conservation Society
- **Final Q&A session**

Zoom Instructions

- Download Zoom
  - https://zoom.us/download
- If you cannot download Zoom, you can view the slides using an internet browser
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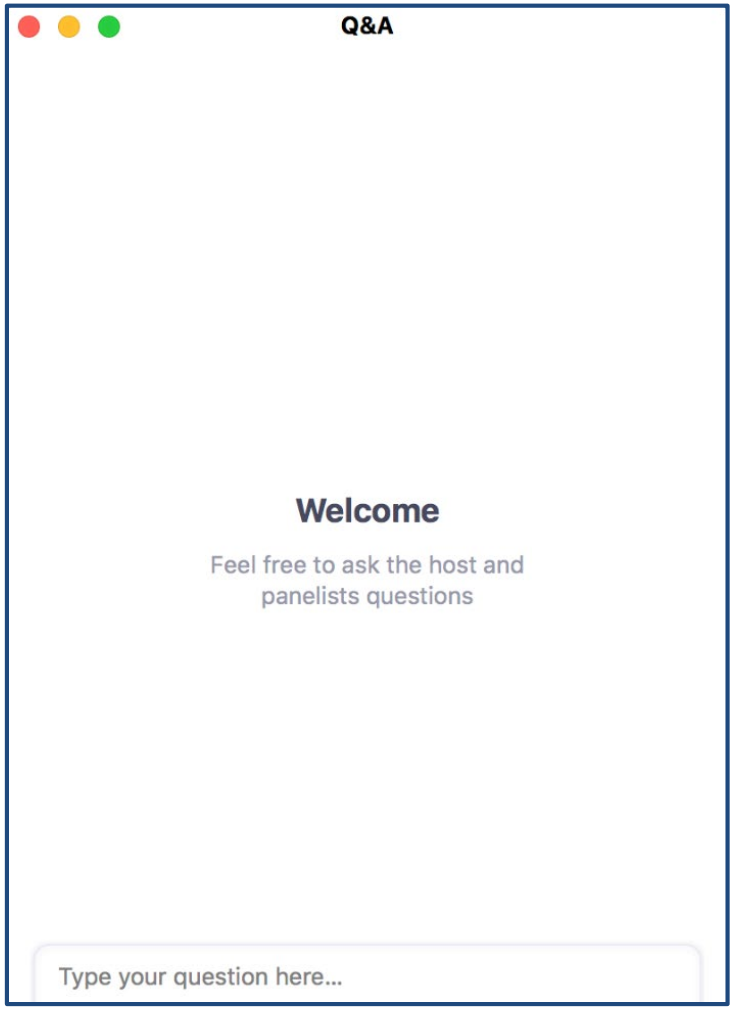
How to Ask Questions

- Find the Q&A button on your control bar and type in your question(s)
- Make sure to add your organization name at the end of your question so that we can identify you during the Q&A sessions



SERDP and ESTCP Overview

Kurt Preston, Ph.D.
SERDP and ESTCP

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SERDP

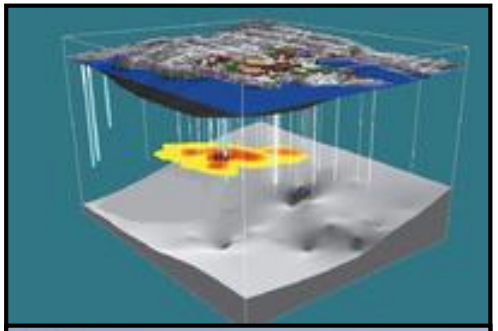
- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
  - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
  - Advanced technology development to address near term needs
  - Fundamental research to impact real world environmental management

ESTCP

- Environmental Security Technology Certification Program
- Demonstrate innovative cost-effective environmental and energy technologies
  - Capitalize on past investments
  - Transition technology out of the lab
- Promote implementation
  - Facilitate regulatory acceptance

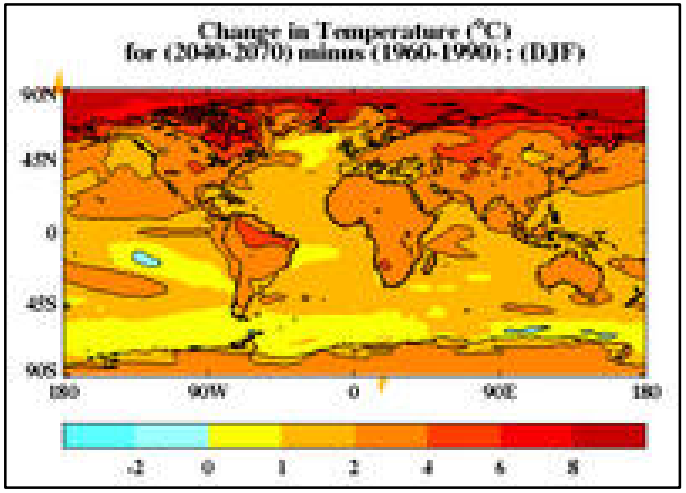
Program Areas

- Environmental Restoration
- Installation Energy and Water
- Munitions Response
- Resource Conservation and Resiliency
- Weapons Systems and Platforms



Resource Conservation and Resiliency

- Natural resources
  - Ecological forestry
  - Arid lands ecology and management
  - Cold regions ecology and management
  - Pacific island ecology and management
  - Coastal and estuarine ecology and management
  - Living marine resources ecology and management
  - Species ecology and management
  - Watershed processes and management
- Resilience
  - Vulnerability and impact assessment
  - Adaptation science
  - Land use and carbon management
- Air quality
  - Wildland fire dynamics
  - Fugitive dust



SERDP and ESTCP Webinar Series

Date	Topic
November 19, 2020	Abiotic Degradation of Chlorinated Solvents in Subsurface Environments
December 10, 2020	Approaches for Managing Contaminated Sediments
January 14, 2021	Improving Energy Efficiency through Advanced Building Controls
January 28, 2021	Improved Approaches for PFAS Sampling and Treatment
February 11, 2021	Advances in the Detection of Submerged Unexploded Ordnance in Marine Environments
February 25, 2021	Managing Chlorinated Solvents in Groundwater Using Biological Treatment
March 11, 2021	New Resource Conservation Paradigms on DoD Lands

For upcoming webinars, please visit

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Save the Date

SERDP • ESTCP
SYMPOSIUM

A three-day symposium showcasing the latest technologies that enhance DoD's mission through improved environmental and energy performance

November 30 - December 4, 2020

Registration for virtual event is open!

Assessing White-Nose Syndrome Threats to Western Bat Species

Sarah H. Olson, Ph.D.
Wildlife Conservation Society

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Agenda

- What is white-nose syndrome (WNS)?
- The need to support western bats
- Data collection and empirical evaluation
  - Results, conclusions, benefits
- Q&A session 1
- Data modeling
  - Results, conclusions, benefits
- Q&A session 2

Threatened Bats and DoD's Mission

- Mission to maintain military readiness
- Requires access to diverse training environments
- DoD is committed to effective and sustainable management practices as stewards of DoD lands
- Need knowledge of ecological factors to manage disease threats to species of concern

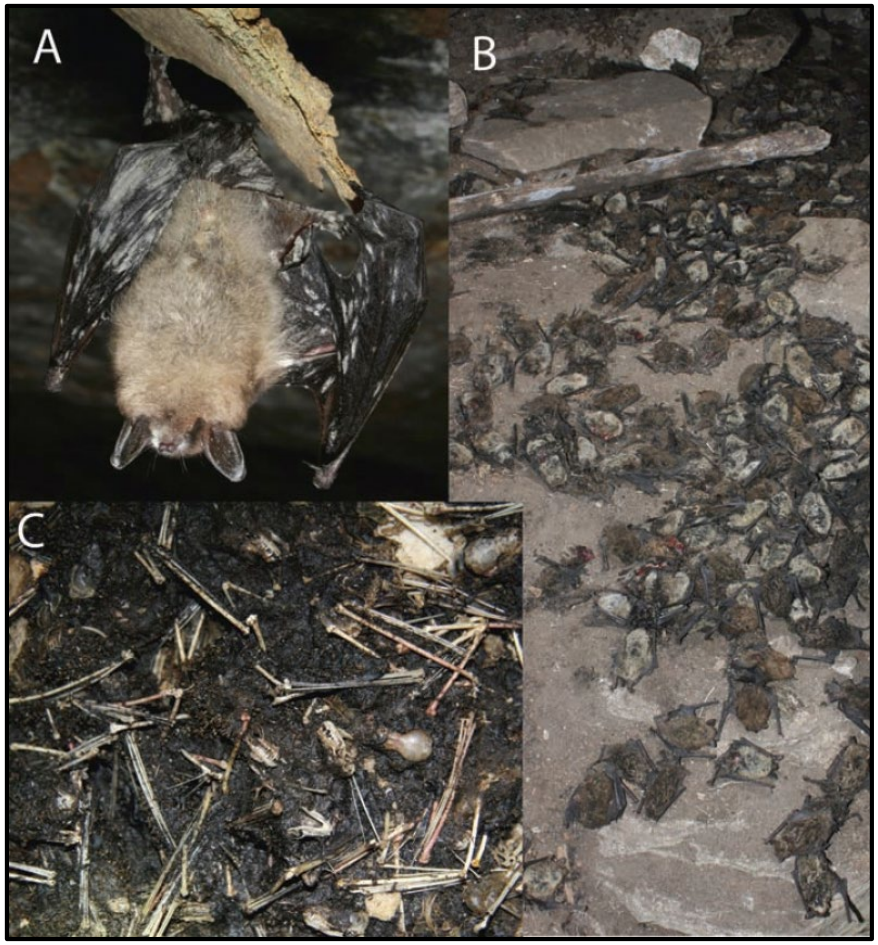
Why Bats?

- Ecological role
- Scientific insights
  - Immunology, physiology
- Insect predators and economic importance
  - Save pesticide costs – U.S. agricultural industry
    - $22 billion/year
  - One *E. fuscus* colony consumes 1.3 million pest insects/year
  - 8 Texas counties
    - *T. brasilienses* brings $750k/year of benefits to cotton industry

Sources: Boyles et al. 2011; Whitaker et al. 1995; Cleaveland et al. 2006

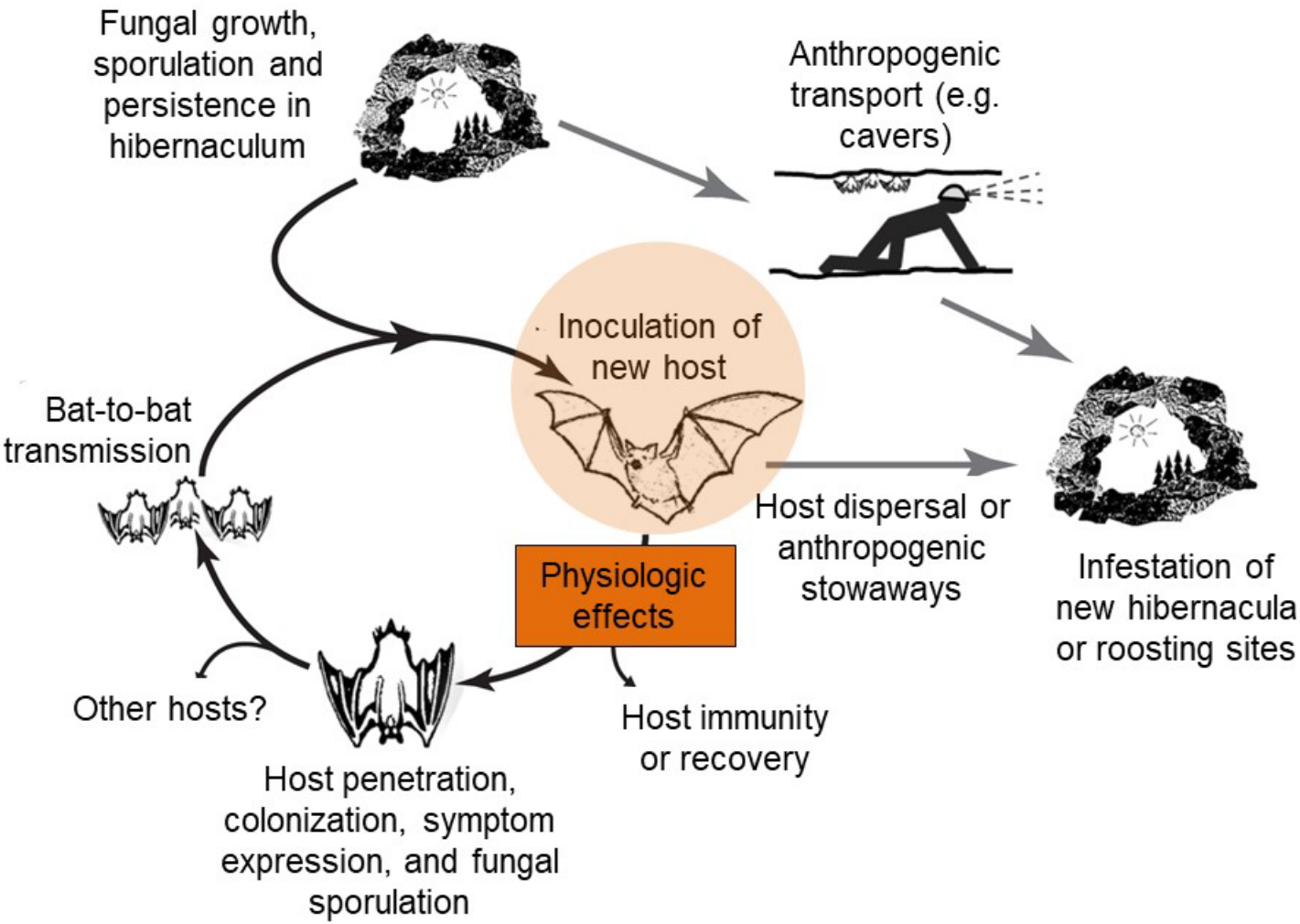
What is WNS?

- Fungal pathogen *Pseudogymnoascus destructans*
  - Killed ~6-7 million bats 2006-2012 in eastern North America
  - 30-99% mortality at infected hibernacula
- *Myotis lucifugus* (little brown bat)
  - Regional extinction predicted by 2026
- *M. septentrionalis* (Northern long-eared)
  - Threatened
- Mixed mortality rates observed in eastern species



Source: Frick et al. 2010

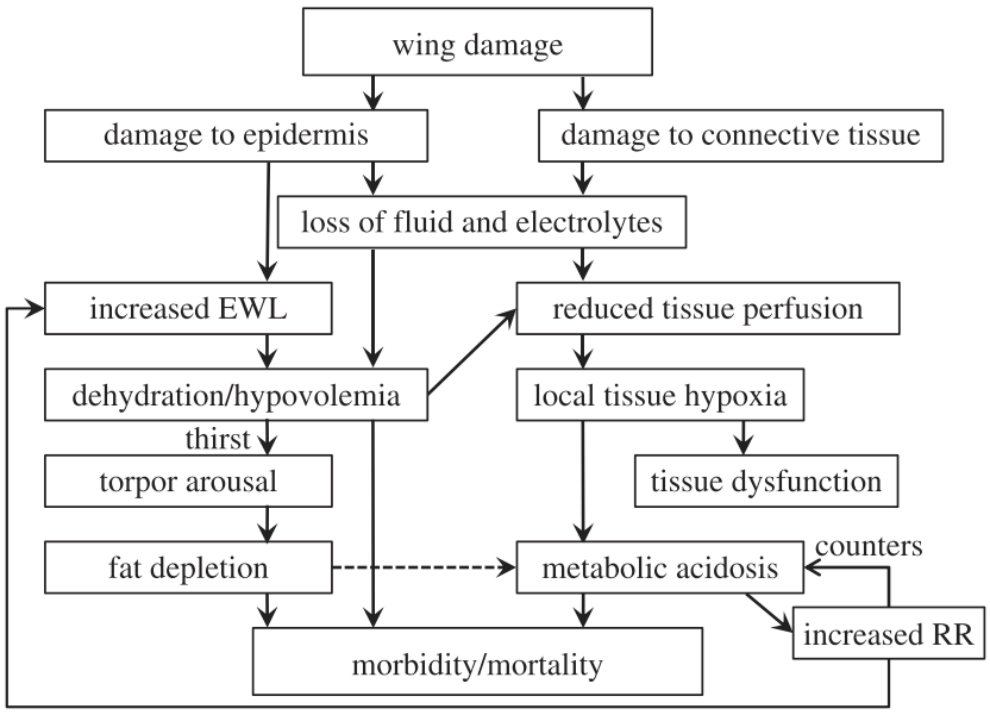
How Does WNS Spread?



Note: Adapted from Knudsen et al. 2013

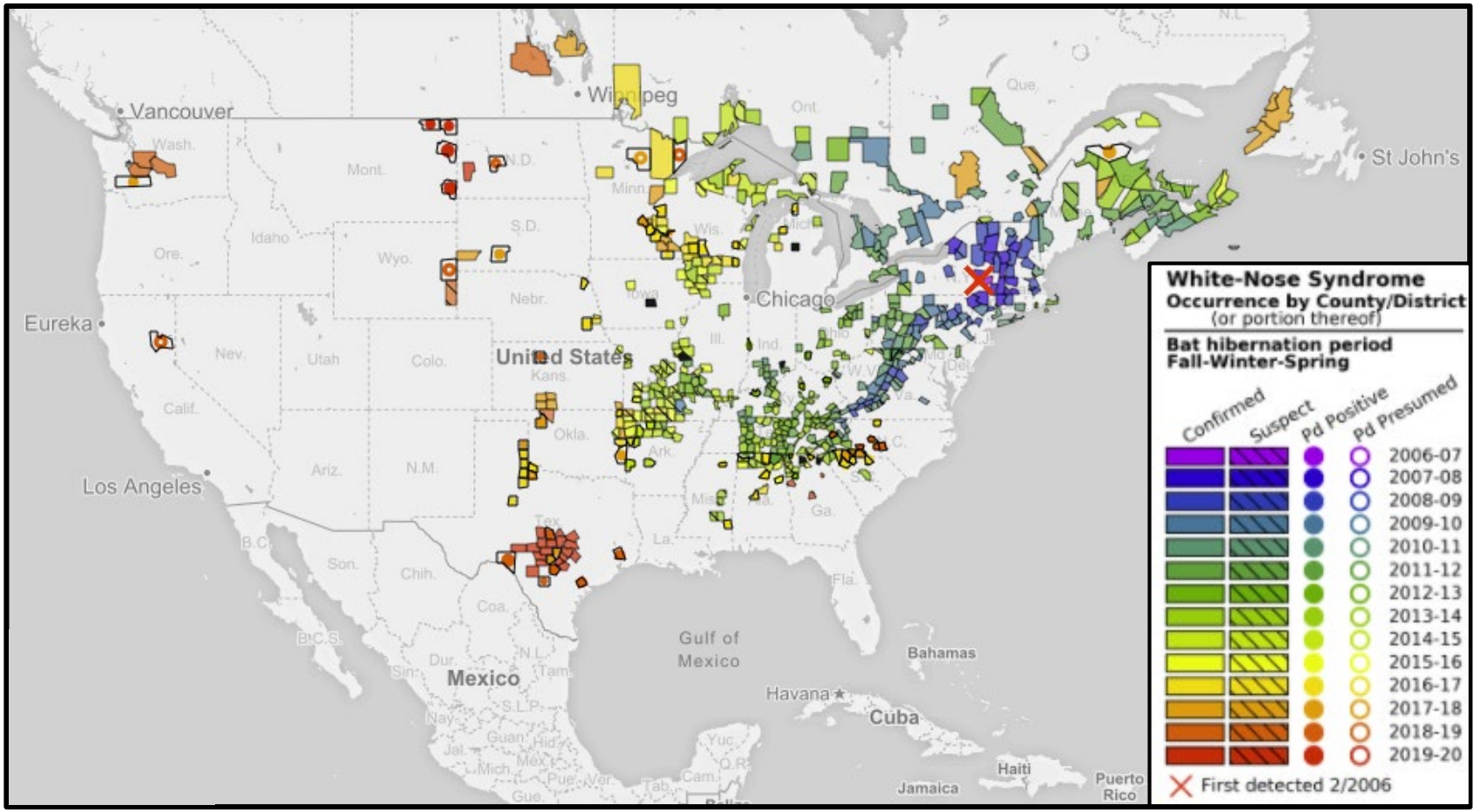
How Does WNS Kill Infected Bats?

- Bats use torpor and arousals during hibernation
- Limited amount of stored fat for the whole winter
- Infected bats have
  - Greater evaporative water loss
  - More frequent arousals
  - Increased energy expenditure
- Dead bats are emaciated and emerge too early



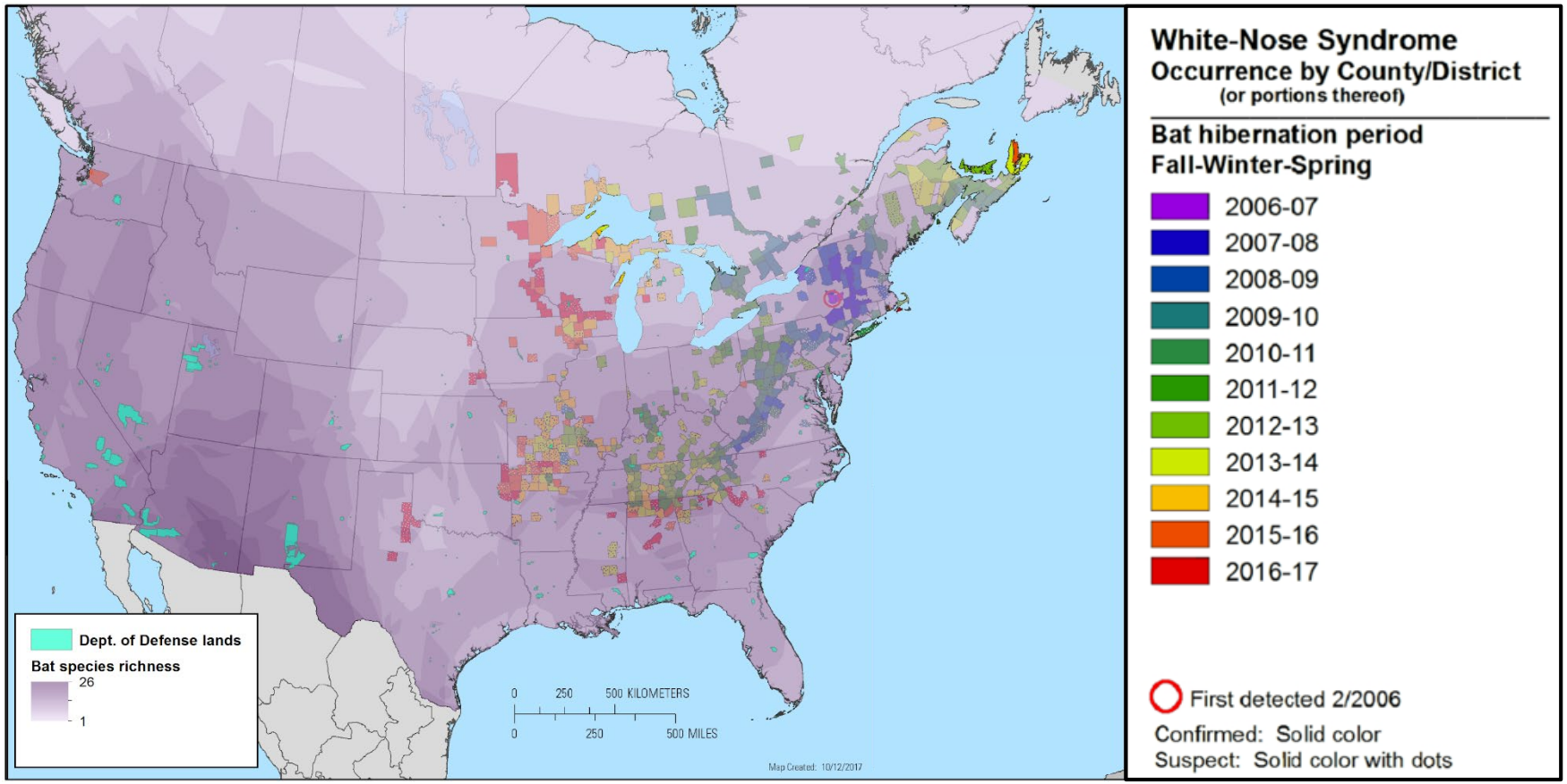
Source: Warnecke et al. 2013

Where is WNS Now?



Source: whitenosesyndrome.org

Why is the West Important?



High species diversity and big WNS challenges

Source: whitenosesyndrome.org

Which Species are Affected?

- 3 species known to be highly impacted in the east
  - *M. lucifugus* (little brown bat)
  - *M. septentrionalis* (Northern long-eared)
  - *Perimyotis subflavus* (tri-colored bat)
- ~13 species known to have diagnostic symptoms of WNS
- 6 species with the fungus but no diagnostic symptoms

Source: Karen Vanderwolf (with permission) New Brunswick 2011

Source: whitenosesyndrome.org

Objectives

- Collect data on western bats
- Conduct empirical analyses
- Model the bioenergetics of hibernation and WNS
- Integrate the bioenergetics model with species distribution models

Hibernacula Environments

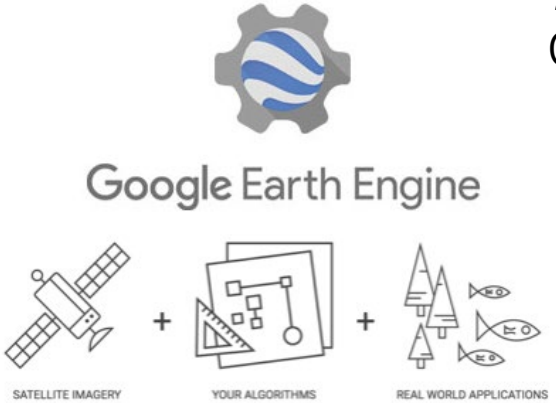
Literature reviews: access existing attribute data sets of hibernacula temperature and humidity, geo-spatial landscape attributes

iButton temperature loggers for microclimate adjacent to bats

6-10 for each site

HOBO temperature and humidity loggers for microclimate inside the hibernacula

~4 for each site



2050 climate scenarios: NA-CORDEX frost-free period and mean annual surface temperature

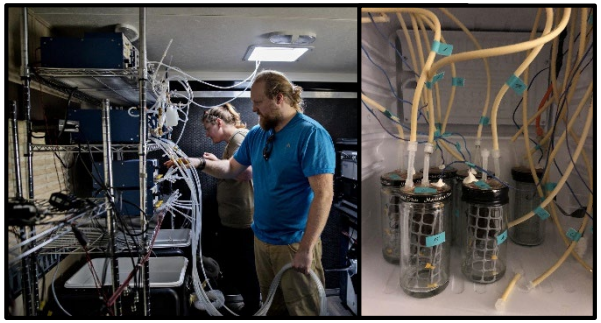
Utilize available local weather station data and other climate products for weather data outside the hibernacula

Statistics: Linear mixed effects models with multi-model inference, model averaging and Akaike Information Criterion (AIC) weighting

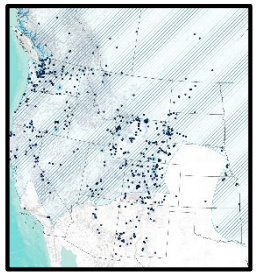
Bioenergetics of Hibernation

Noninvasive: mobile onsite lab, ~1.5 hrs from bat capture

Acoustic loggers: winter duration



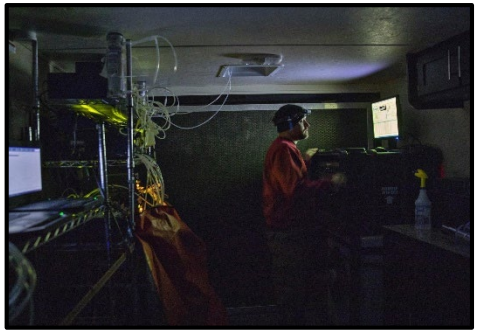
Respirometry measurements: torpid metabolic rates and evaporative water loss



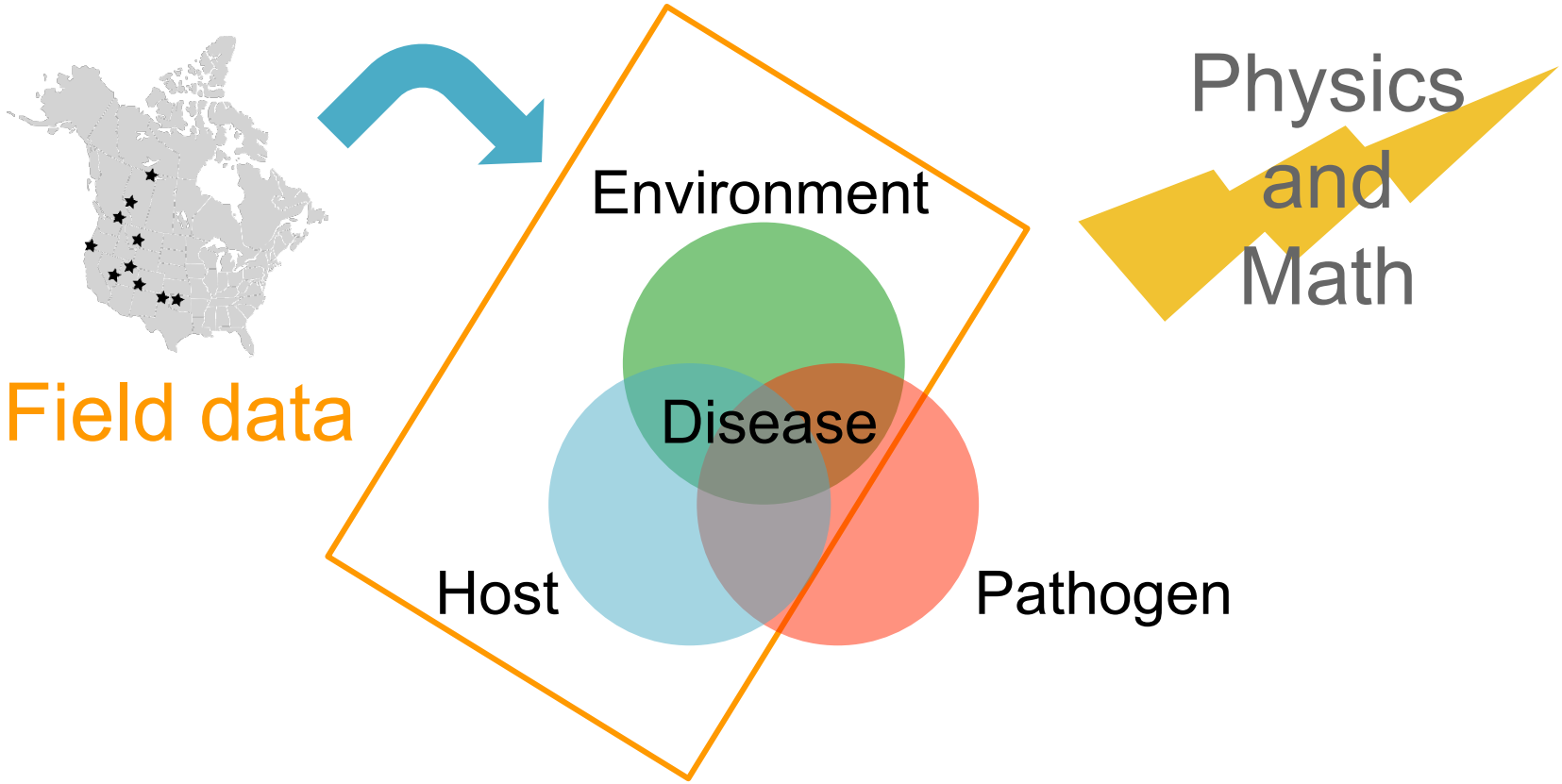
Existing baseline data: bat occurrence, winter duration

Statistics: general linear models, post-hoc pairwise comparison tests, cluster analysis, AIC model selection, boosted regression trees, hybrid correlative-mechanistic models

Quantitative magnetic resonance (QMR): fat mass, lean mass, and total body water

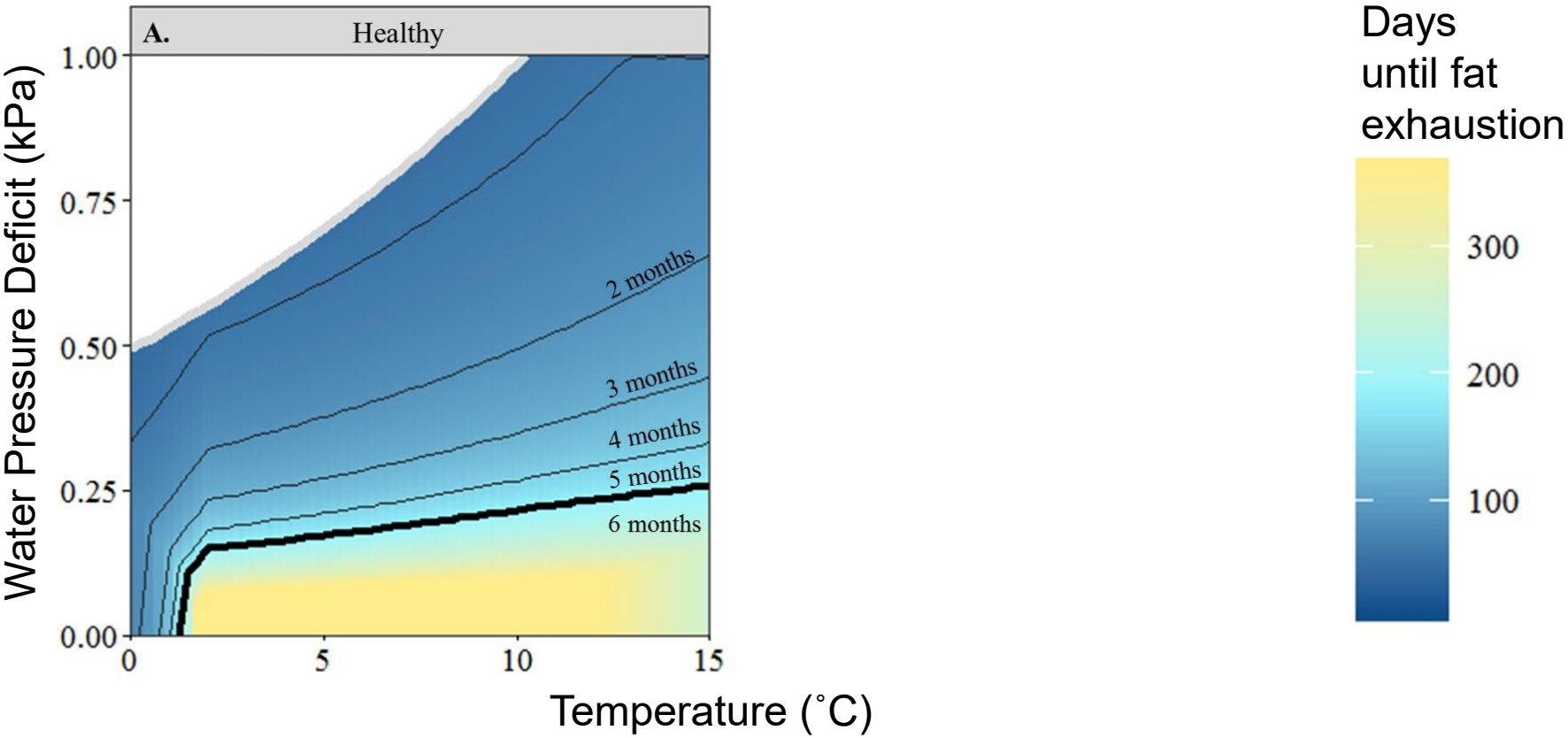


Mechanistic Model of Hibernation



Mechanistic Model of Hibernation

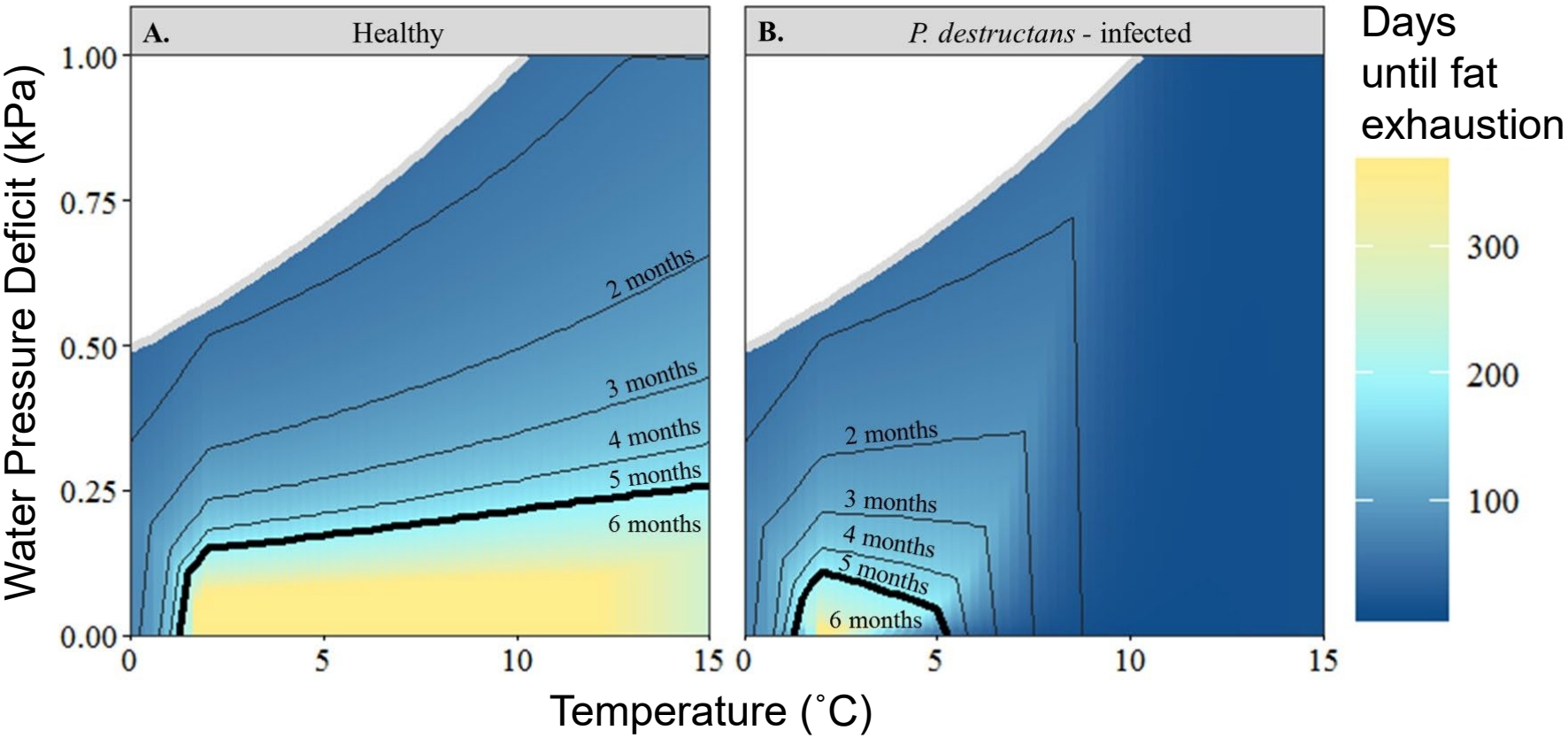
Bat survival (days until no fat) from the bioenergetic model



Growth of the fungus increases EWL, causing more frequent arousals and greater fat consumption

Mechanistic Model of Hibernation

Bat survival (days until no fat) from the bioenergetic model

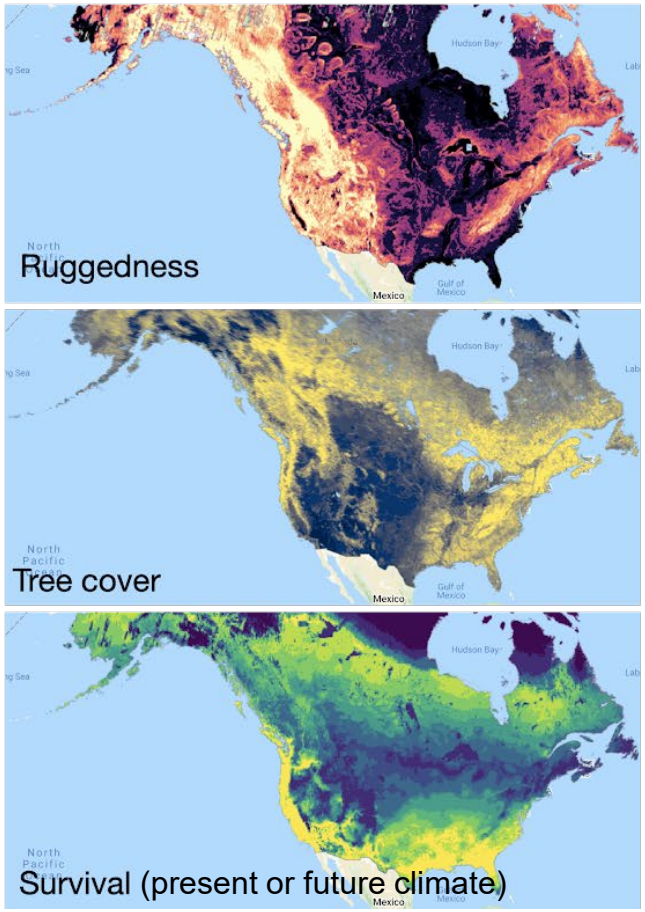


Growth of the fungus increases EWL, causing more frequent arousals and greater fat consumption

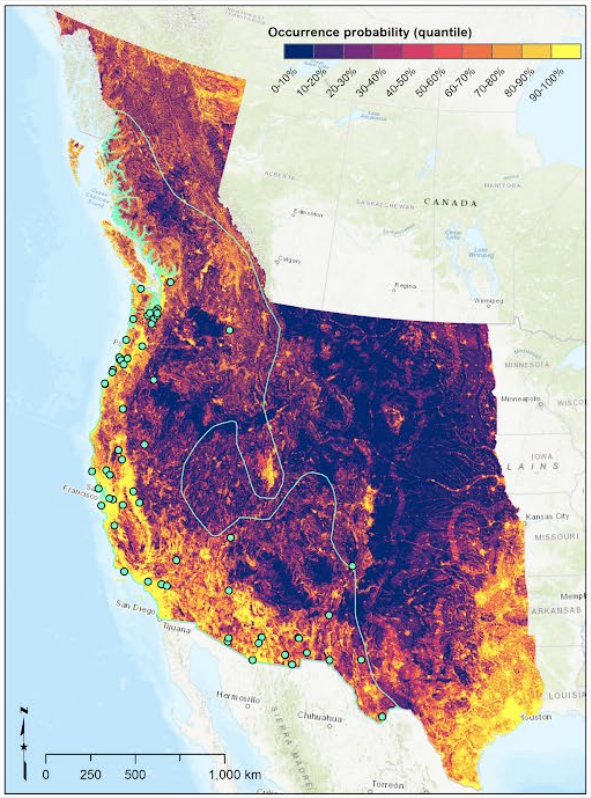
Integrated Modeling

1. Sample occurrence data

2. Model relationship with landscape attributes, including spatial maps of survival



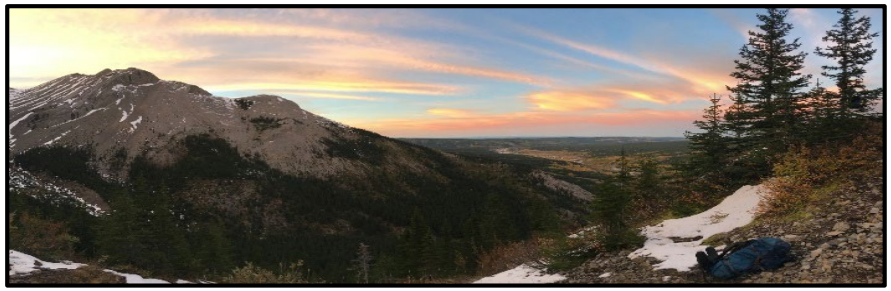
3. Estimate probability of occurrence; update with future conditions to project future probability of occurrence



Approach Summary

- Swarming and hibernation captures:
  - Morphometric data
    - Body mass, size
  - Physiological data
    - Torpid metabolic rate
    - Water loss
    - Microclimate data
    - Temperature, humidity

- Bioenergetic survivorship model
- Integrated spatial modeling present/future conditions



Overall Bat Counts

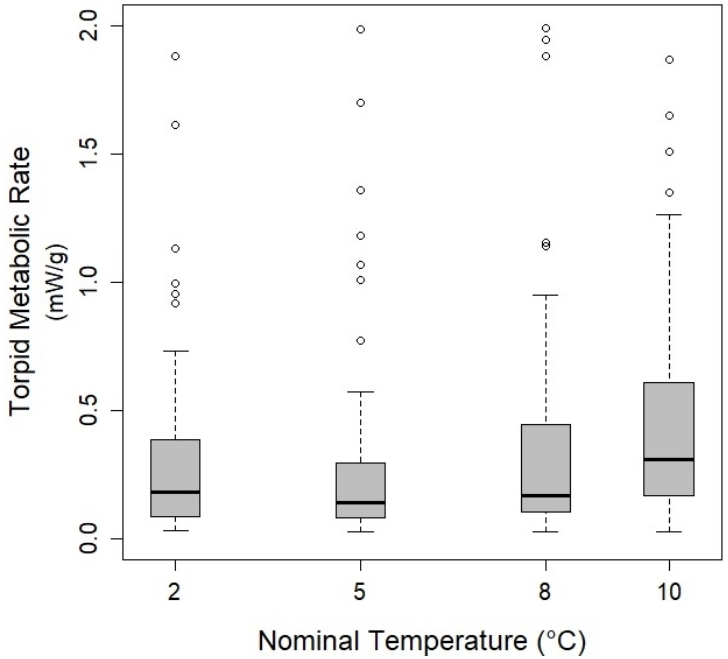
Species	Abbreviation	All bats	Respirometry
*Corynorhinus townsendii**	COTO	627	152
*Perimyotis subflavus**	PESU	141	34
*Myotis lucifugus**	MYLU	504	99
Myotis velifer	MYVE	418	33
*Eptesicus fuscus**	EPFU	37	7
Myotis evotis	MYEV	217	13
*Myotis volans**	MYVO	121	12
*Myotis ciliolabrum**	MYCI	86	23
Myotis thysanodes	MYTH	52	11
*Myotis yumanensis**	MYYU	337	27
*Tadarida brasiliensis**	TABA	228	27
Myotis californicus	MYCA	148	45
Lasionycteris noctivagans	LANO	146	23
Myotis septentrionalis	MYSE	11	0

** Known to be found on DoD installations (acoustic/capture)*

- 3073 total bats; 506 bat respirometry measurements
- *Corynorhinus townsendii* (Townsend's big-eared bat) at 6 sites across different biomes
- *M. lucifugus* (little brown bat) targeted at 3 latitudes

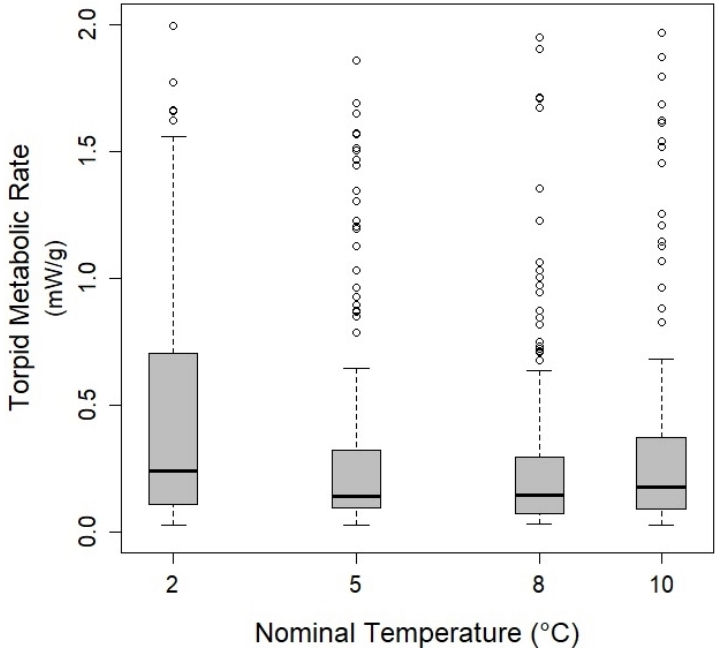
Torpid Metabolic Rate Variability within Species
M. lucifugus (little brown bat)

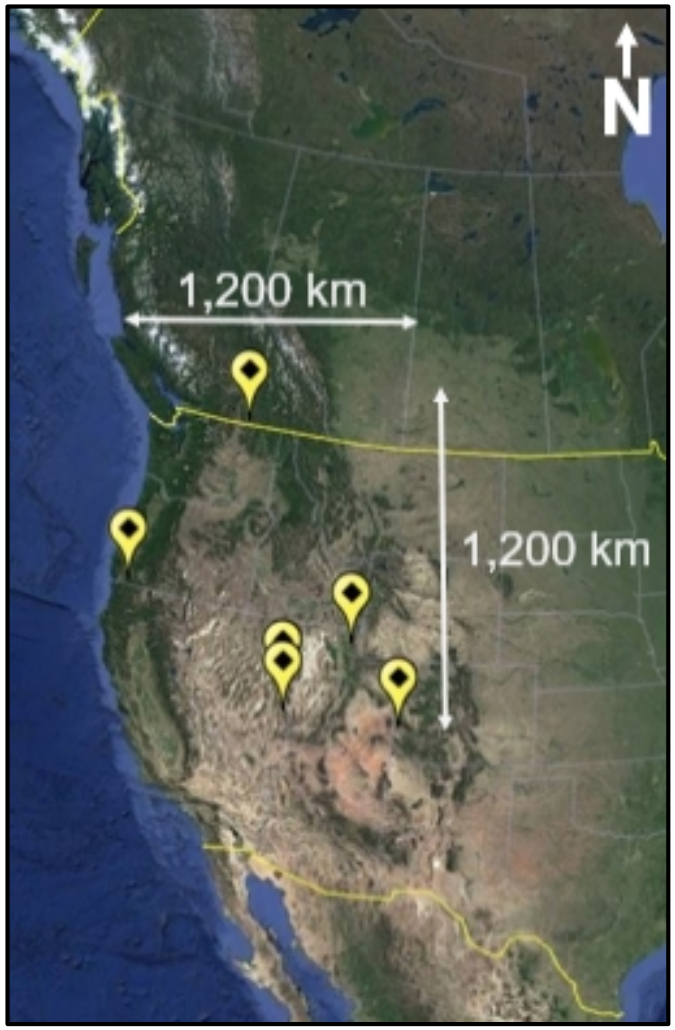
- No effect of latitude on a 1,500 km gradient
- p-value = 0.14 for site specific differences)



Torpid Metabolic Rate Variability within Species
C. townsendii (Townsend's big-eared bat)

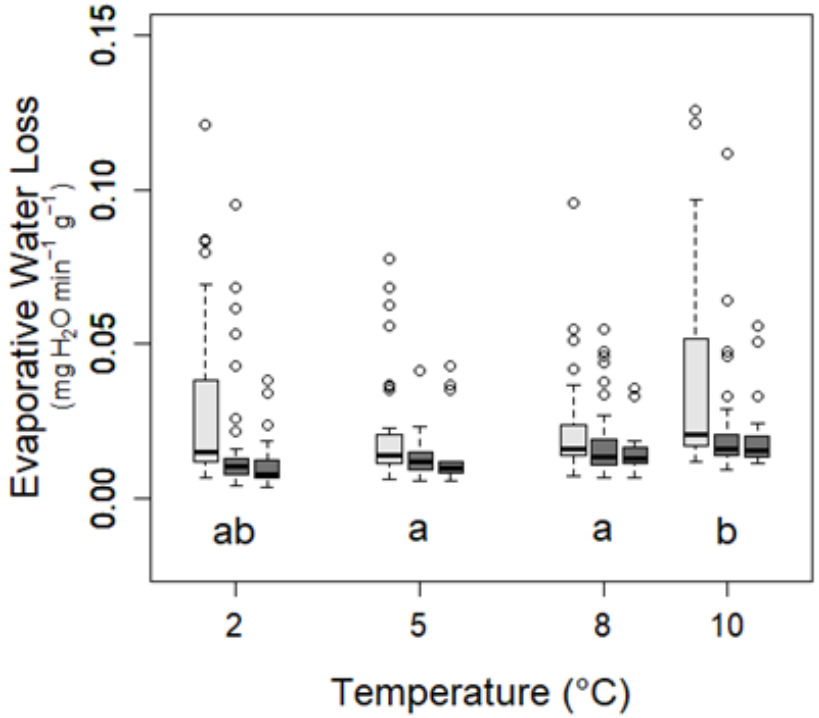
- No effect of different environments
- p-value = 0.20 for site specific differences





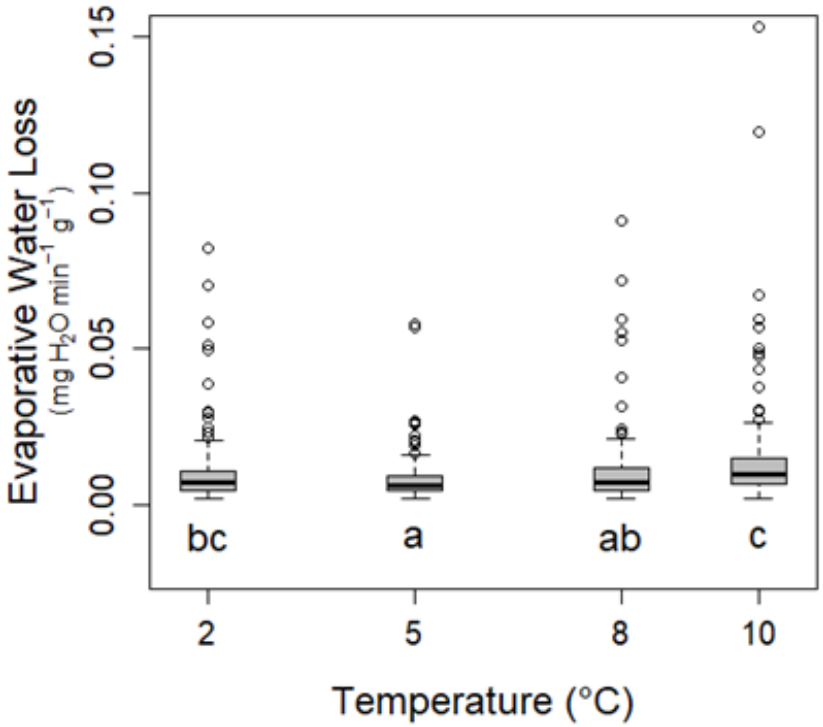
Evaporative Water Loss Variability within Species *M. lucifugus* (little brown bat)

- Montana bats (light grey) had slightly greater evaporative water loss

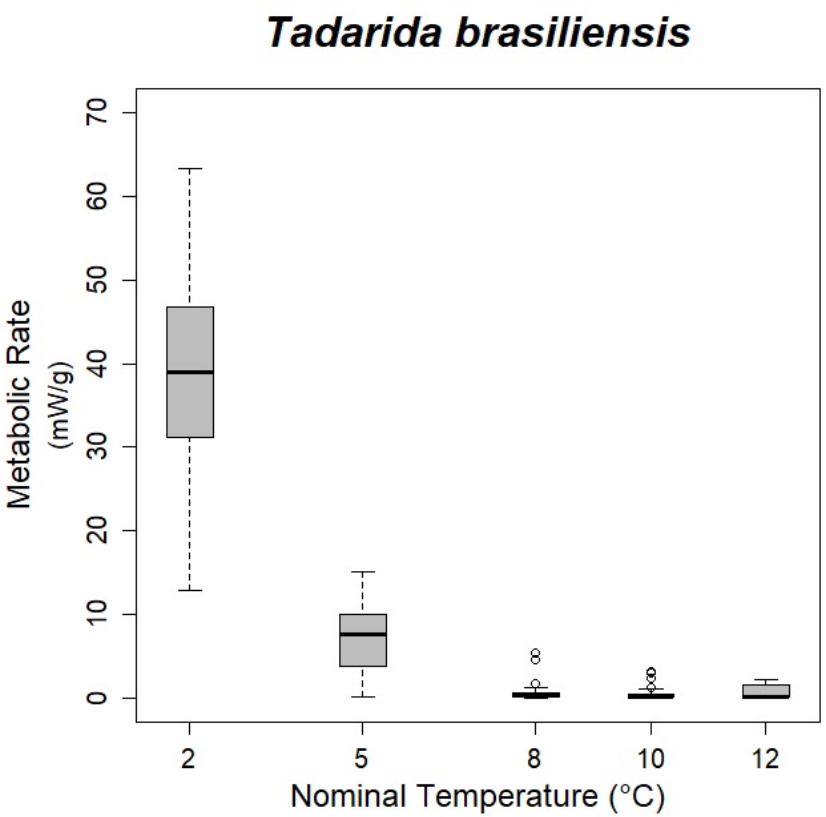


Evaporative Water Loss Variability within Species
C. townsendii (Townsend's big-eared bat)

- Only one pairwise difference between the 6 sites (British Columbia and Colorado)

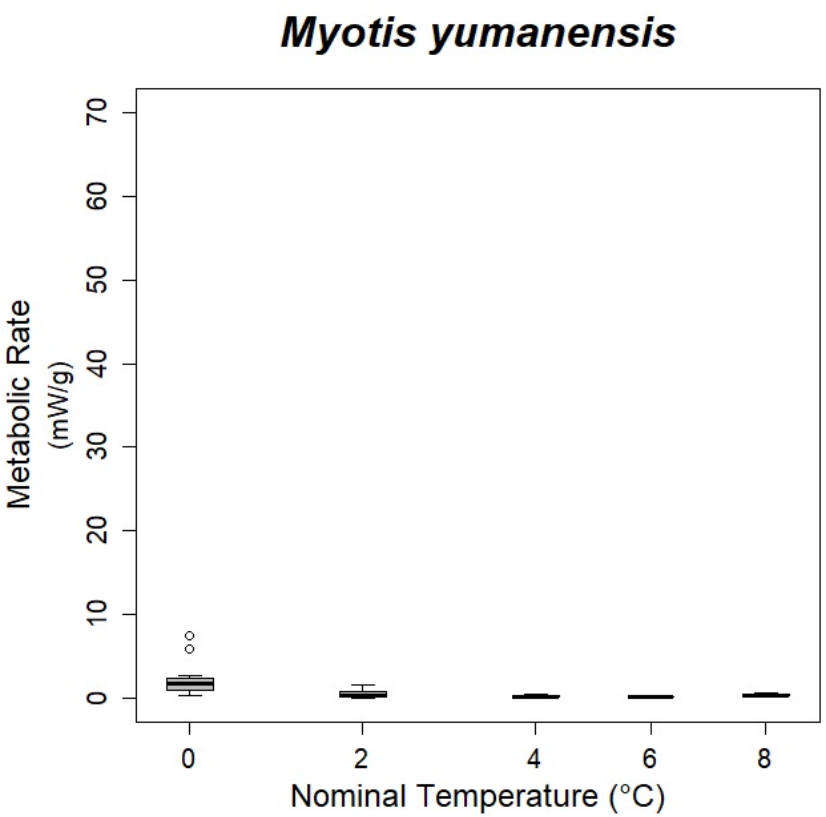


Hibernation Physiology Variability Among Species



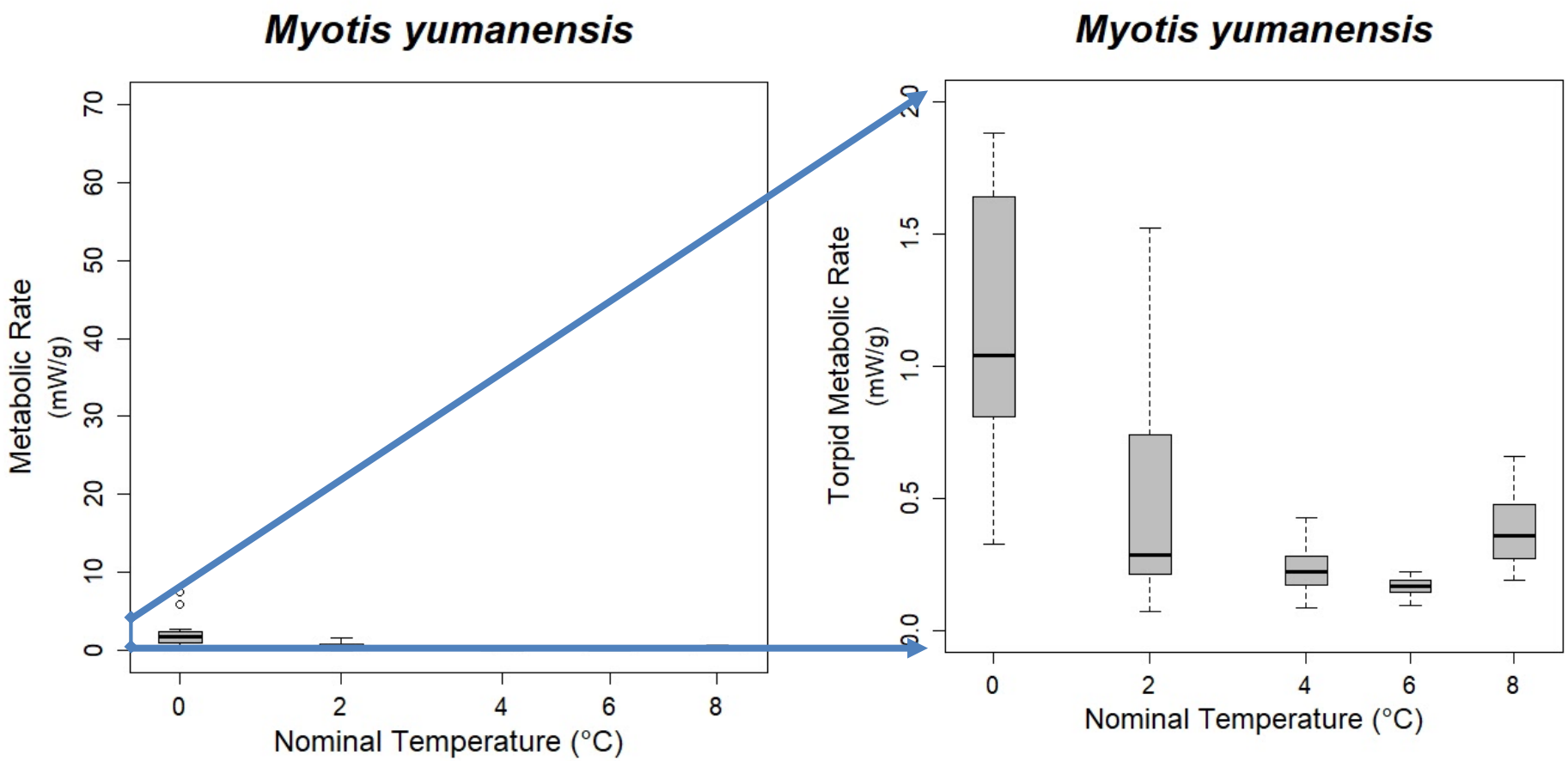
- Similar dramatic metabolic rate increase at cold temperatures
  - *M. evotis*
  - *M. thysanodes*
  - *M. volans*

Hibernation Physiology Variability Among Species

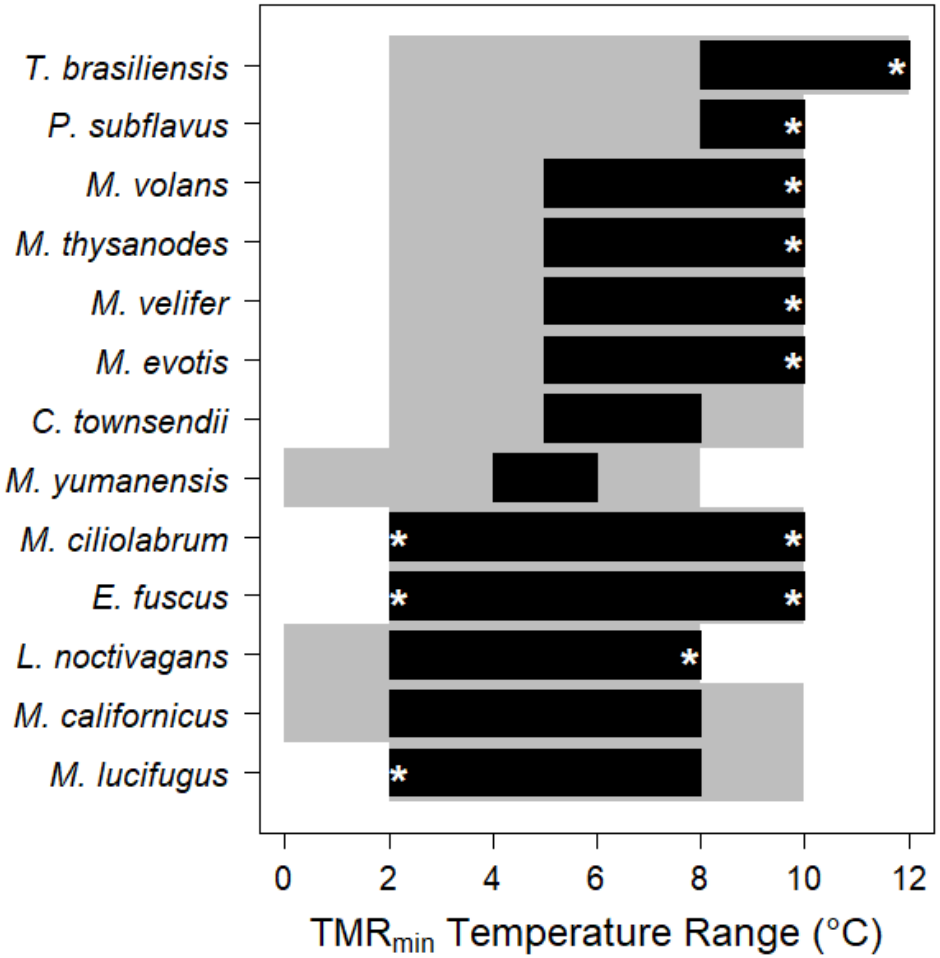


- Similar tolerance of broad temperature range
  - *C. townsendii*
  - *E. fuscus*
  - *M. ciliolabrum*
  - *M. lucifugus*
  - *M. velifer*
  - *M. yumanensis*
  - *M. californicus*
  - *L. noctivagans*
  - *P. subflavus*

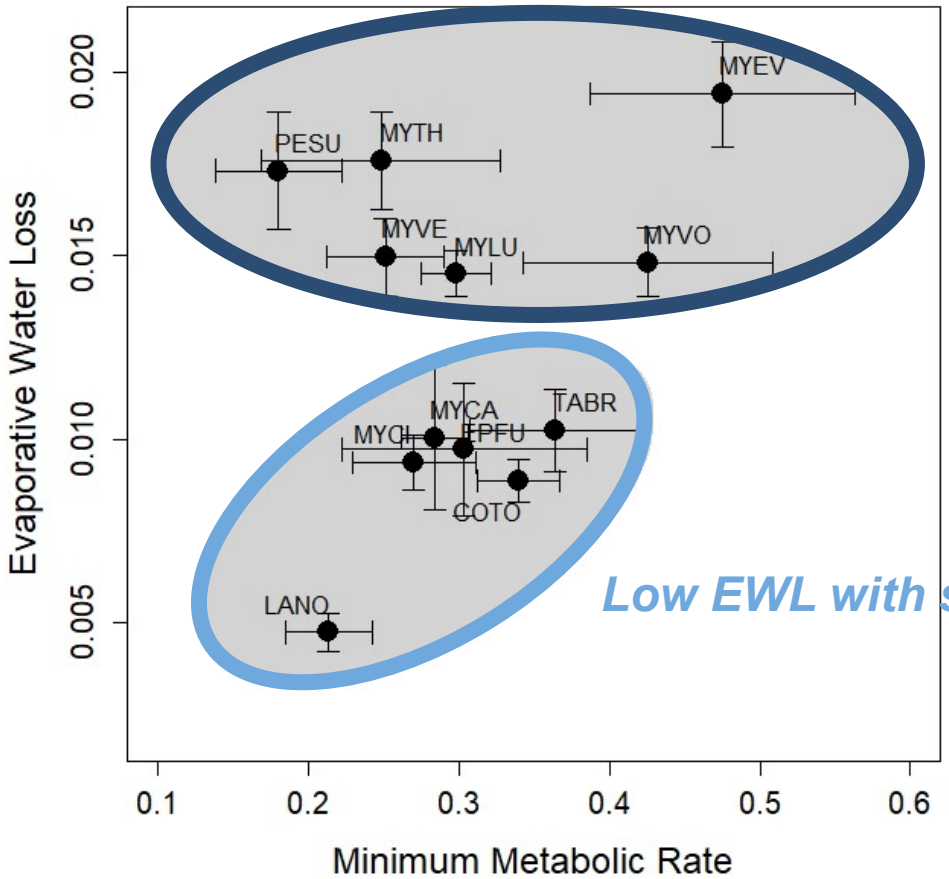
Hibernation Physiology Variability Among Species



Minimum Torpid Metabolic Rate Usage Temperatures by Species



EWL Rates by Bat Group



High EWL with species highly impacted by WNS

Low EWL with species less impacted by WNS

Note: EWL = evaporative water loss

Conclusions (Part I)

- No evidence of intraspecific variation
  - Torpid metabolic rate
  - Evaporative water loss (some exceptions)
- Interspecific
  - Differences
    - Rate of evaporative water loss (~2 groups aligned with known WNS mortality)
    - Temp range of minimum torpid metabolic rate
  - Similarities
    - Minimum torpid metabolic rate

Note: Intraspecific = within species; interspecific = among species

Benefits to DoD (Part I)

- Baseline pre-WNS data
  - 13 species with little prior research
- No evidence of local bioenergetic adaptations
- Established hibernation conditions likely preferred by each species
- Rate of evaporative water loss
  - Potential WNS risk indicator
- Parameterize bioenergetic models
  - Assess WNS survivorship and climate change

Q&A Session 1

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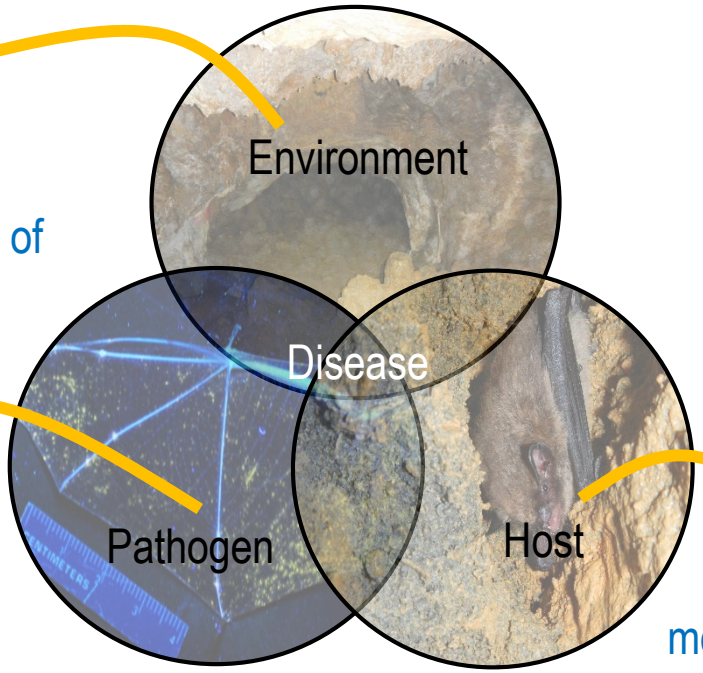
Part II: Modeling Results

- Survivorship model (non-spatial)
  - Improved cooling sub-model
  - Adding fungal growth + evaporative water loss
  - Interspecies WNS survivorship
- Generating spatial input parameters
  - Cave and mine temperatures
  - Winter duration
  - *M. lucifugus*: body mass, fat mass
  - Western species winter distributions
- Spatial predictions of WNS survival
  - *M. lucifugus* survival estimates
  - Climate change and multi-species impacts

Bioenergetic WNS Survivorship Model

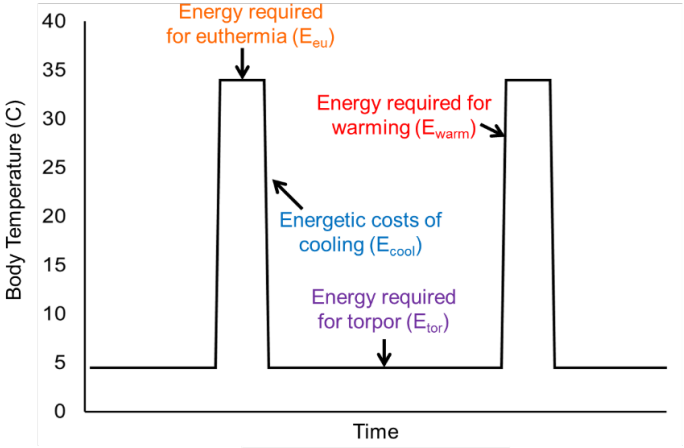
Predicts fat loss over time as a function of bat characteristics, fungal growth rate, and hibernaculum microclimate

Hibernaculum microclimate: temperature, humidity, duration of winter



Fungal traits: growth rate in response to hibernaculum microclimate

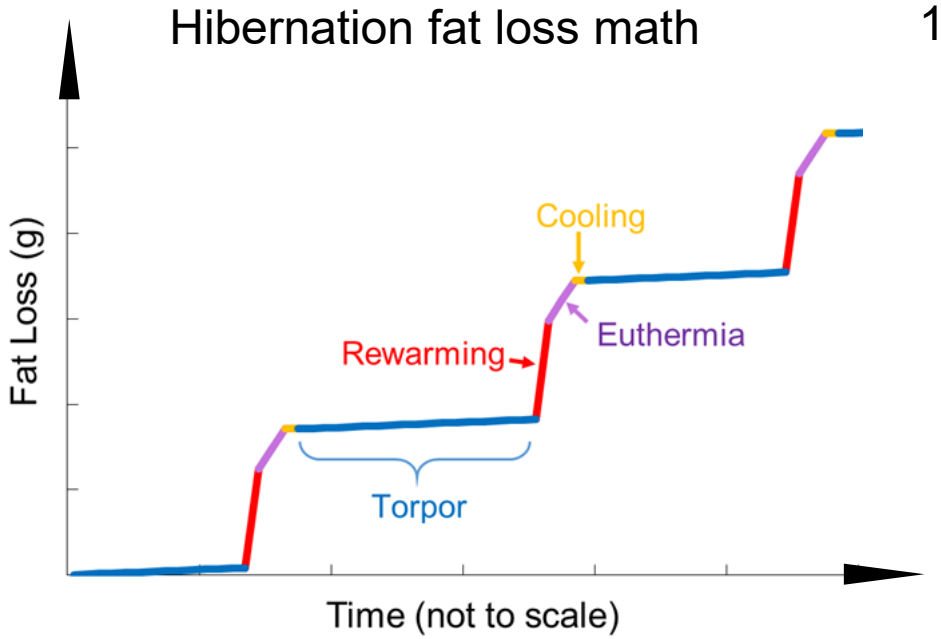
Bat traits: metabolic rate, body temperature, body mass, rate of evaporative water loss



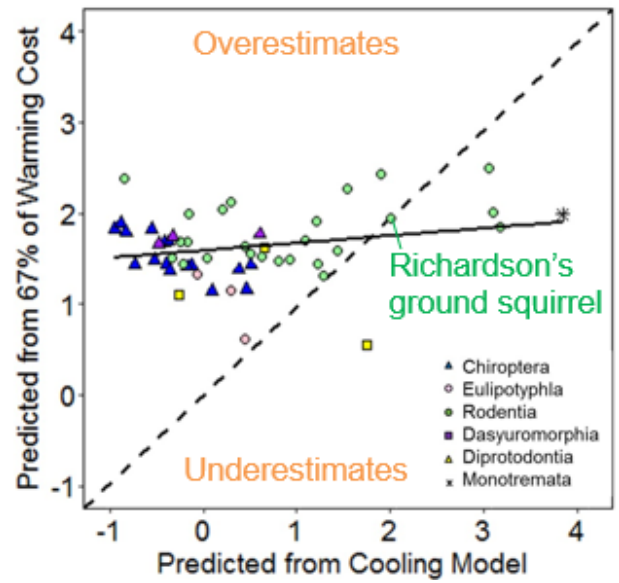
Better Bioenergetic Model of Hibernation: Cooling

- Refined an existing model
- Derived a new cooling costs sub-model using first principles
- Corrected a highly referenced sub-model that over-estimated costs of cooling in bats

Hibernation fat loss math



1st principles cooling model (ln[ml O_2 g^{-1}])

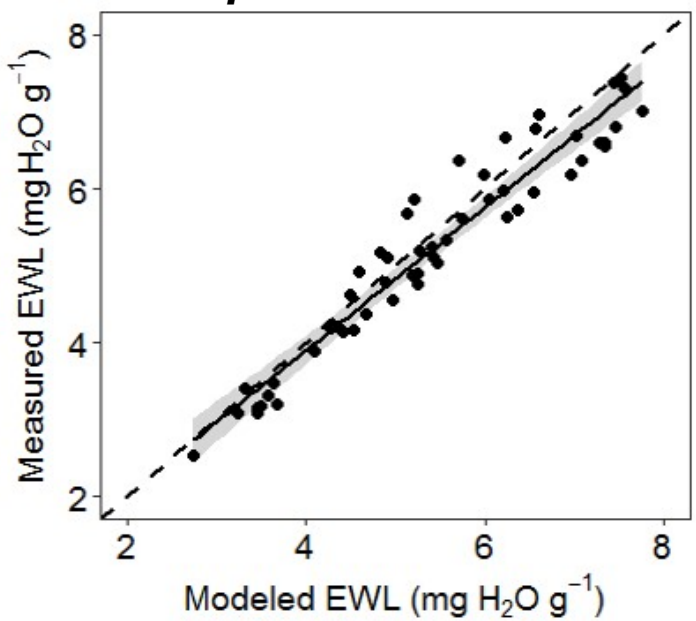


Source: Hayman et al. 2016; Thomas et al. 1990, Haase et al. 2019

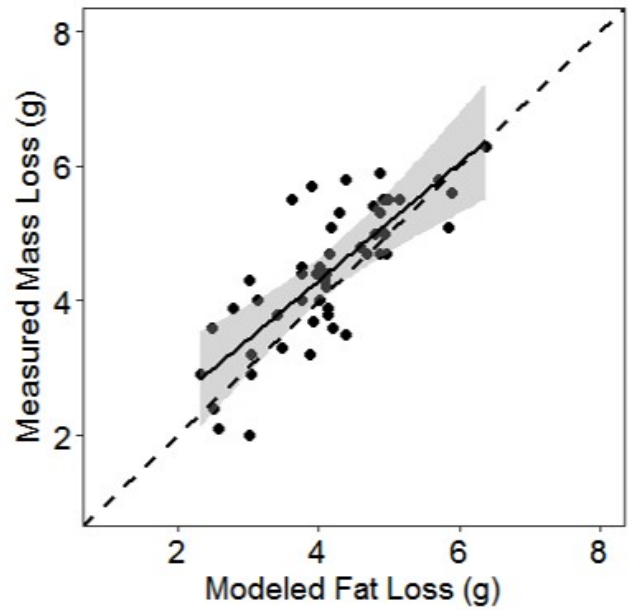
Better Bioenergetic Model of Hibernation: Fungal Growth and EWL

- Validation of the bioenergetic model with measured values for *M. lucifugus*
- Compared modeled vs. measured values of evaporative water loss (EWL), fat loss, and torpor bout duration (not shown)
- No significant difference, sensitivity analysis shows host factors (e.g. mass, body fat, EWL) most influential

Evaporative water loss



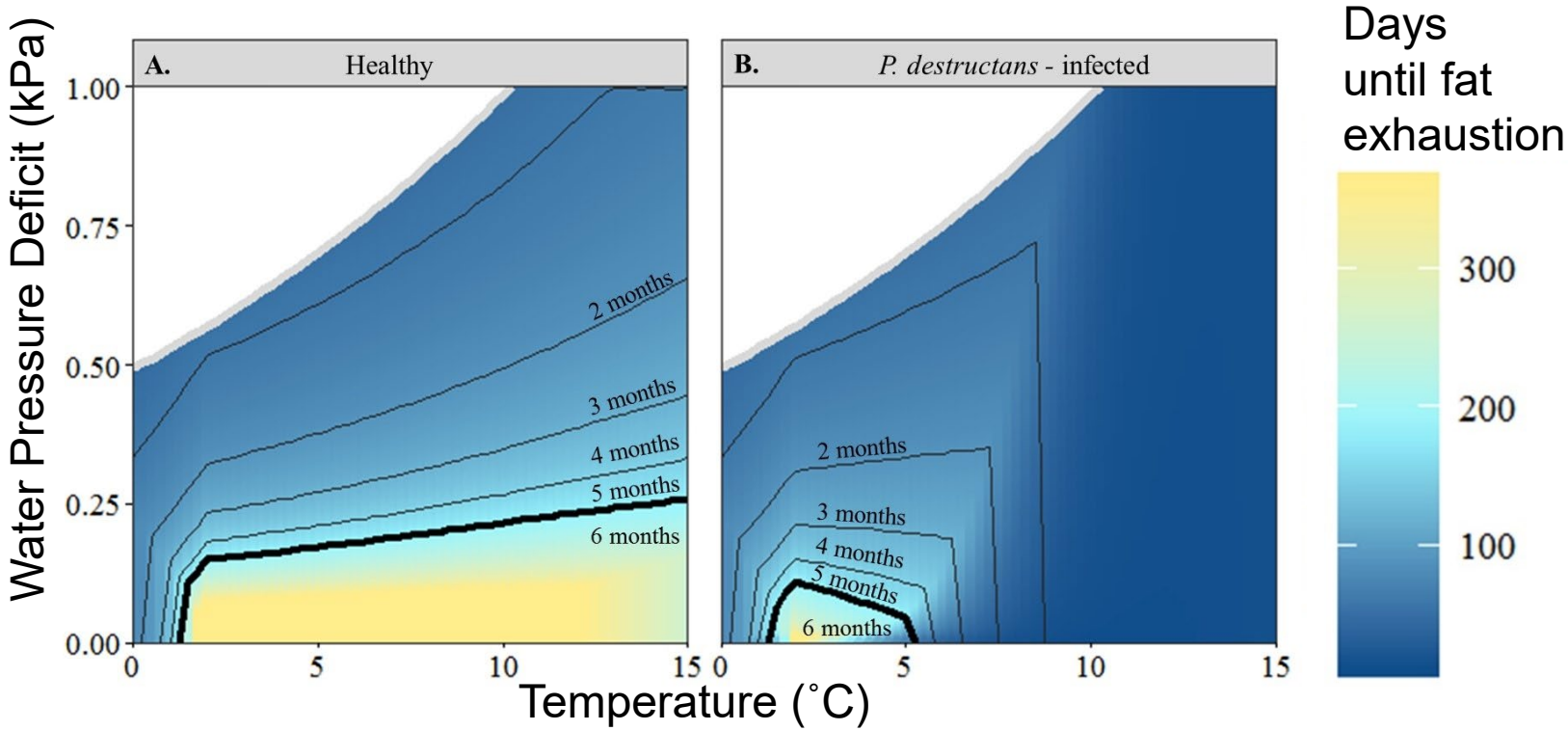
Fat loss



Predicted Time until Fat Exhaustion

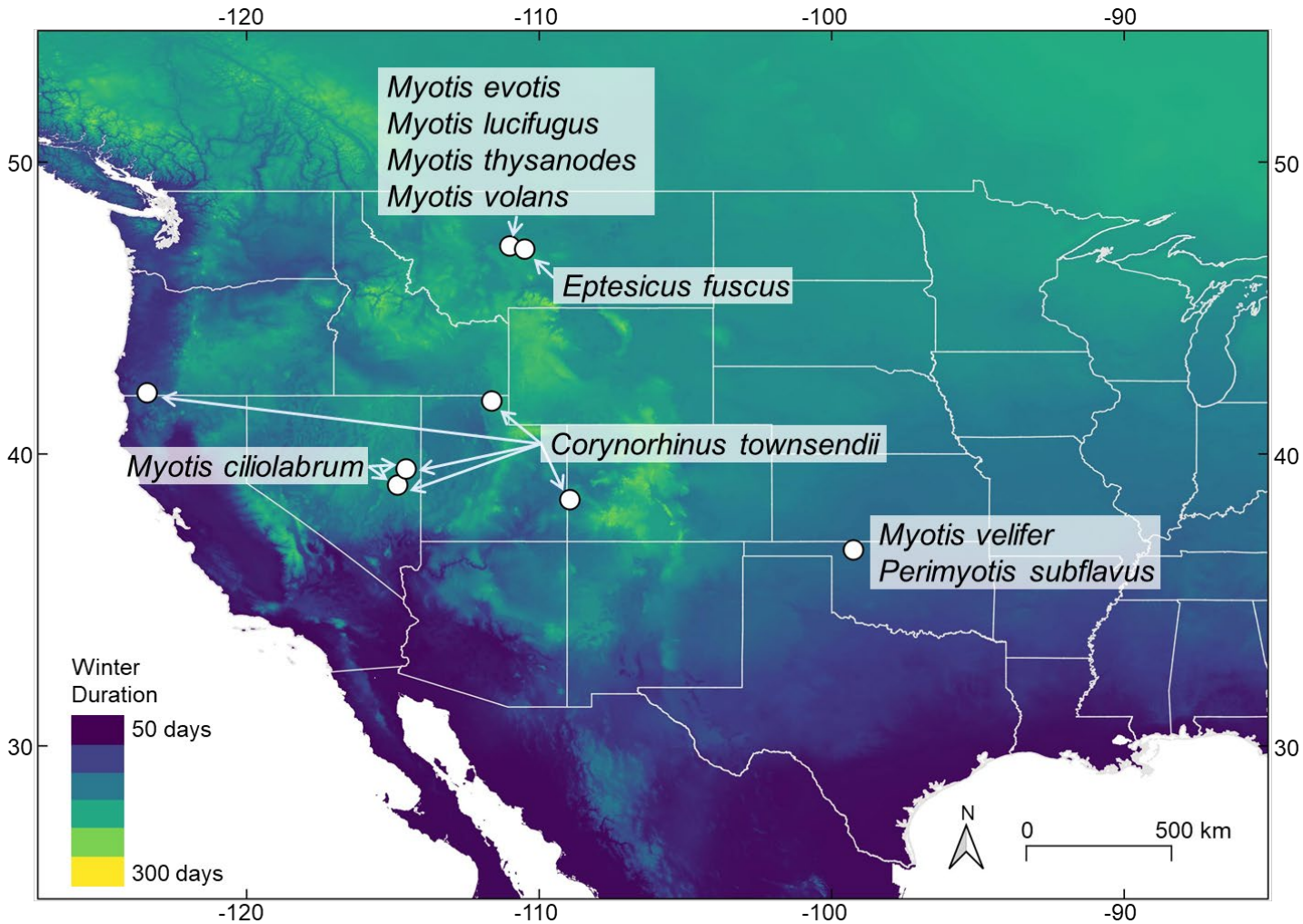
M. lucifugus (Little Brown Bats), Montana

- Almost all available microclimate conditions → mortality
- Microclimate conditions that permitted survival
  - Lowest temperatures (2-3˚C), highest humidity (96-100%)



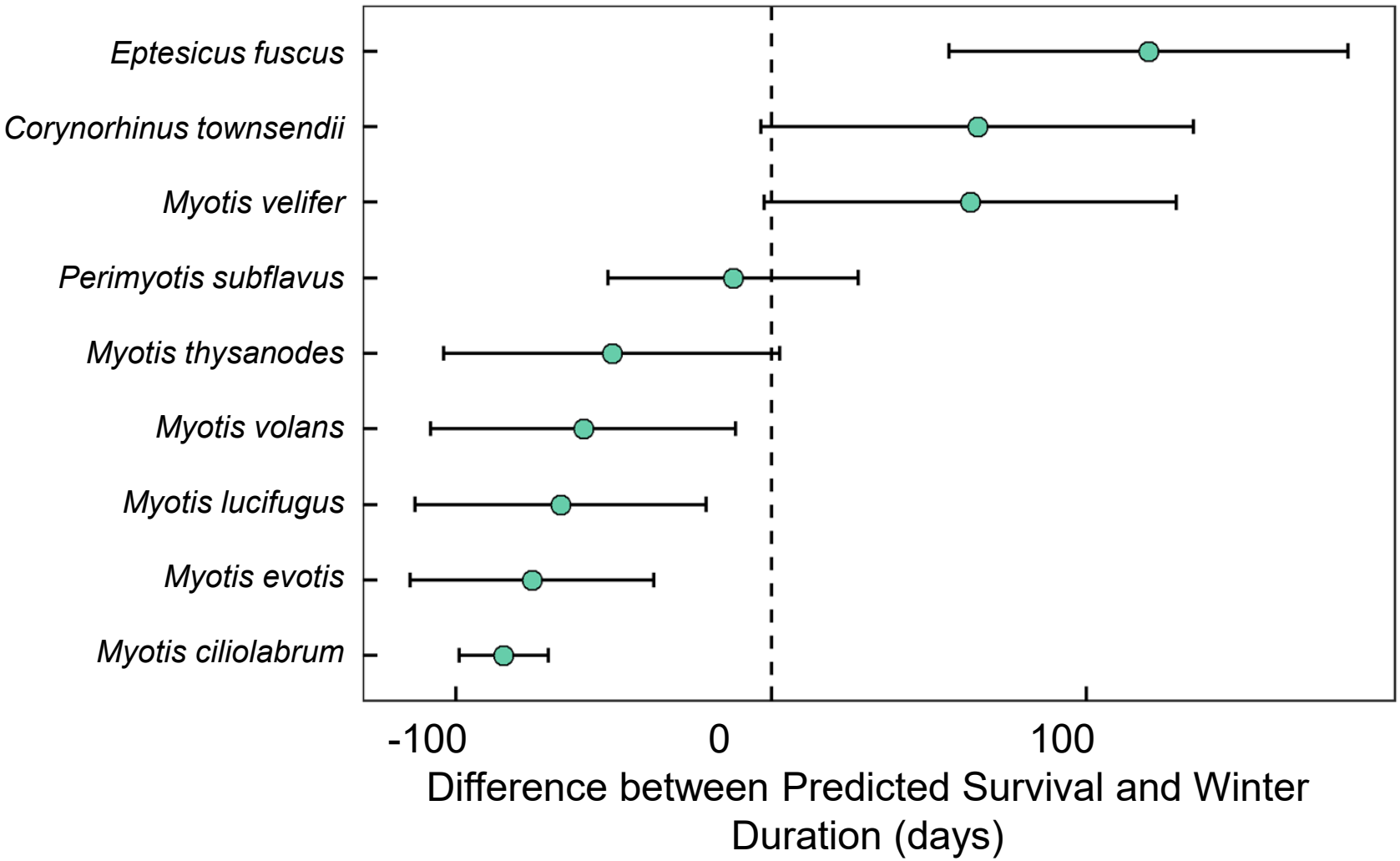
Interspecies WNS Survivorship

Data Sources



Interspecies WNS Survivorship

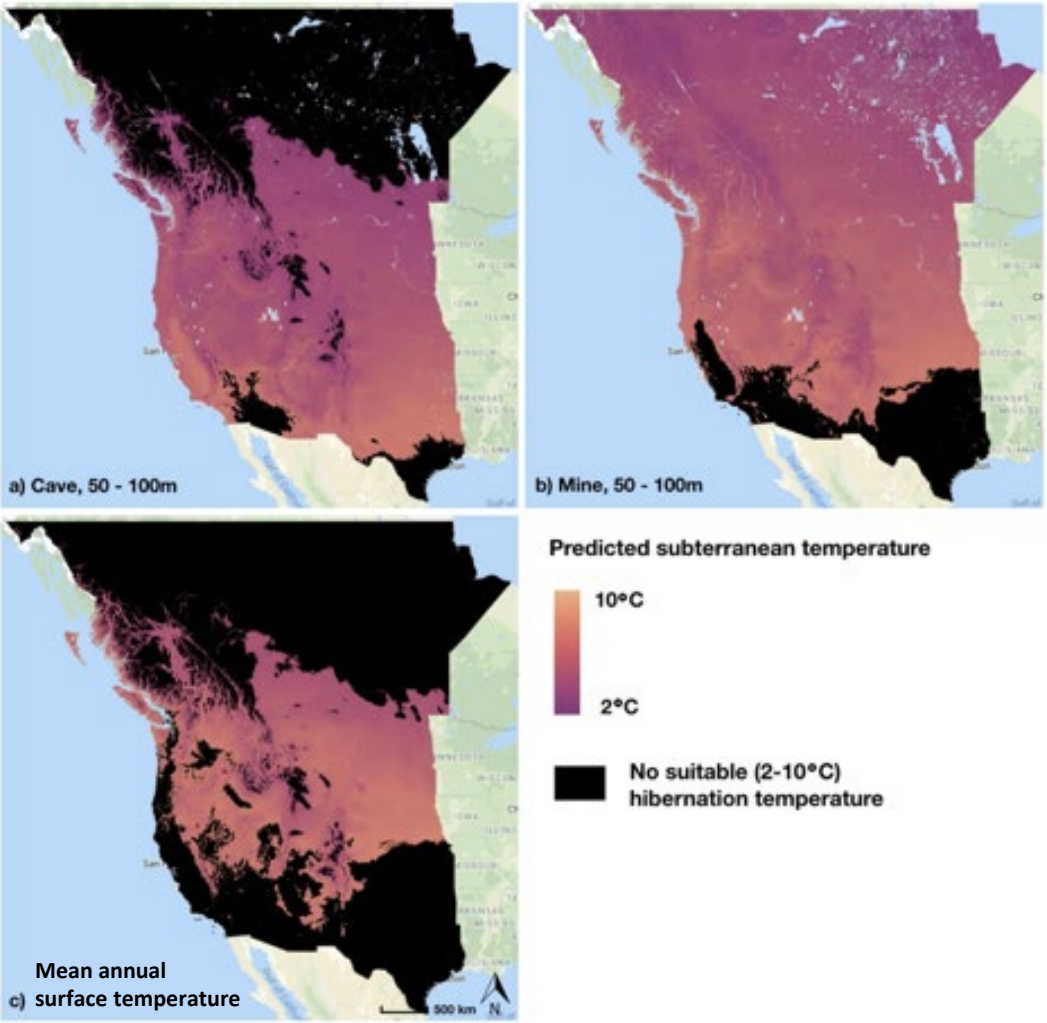
Estimates



Improved Spatial Estimates

Available Temperatures in Caves and Mines

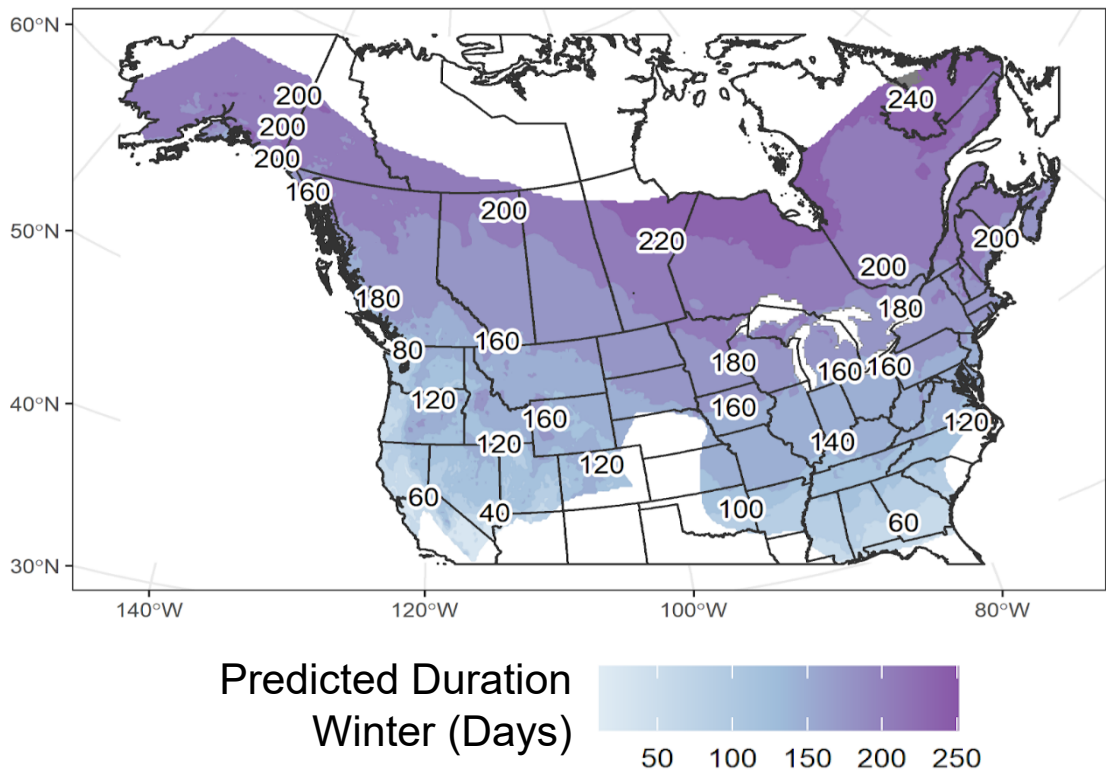
- Top predictors for temperature
  - Mean annual surface temperature
  - Distance from entrance
  - Site type (mine vs. cave)
- Can be adapted to species preferred hibernation temp
- Not enough data to do the same for humidity



Predicting Hibernation Duration

M. lucifugus (little brown bat)

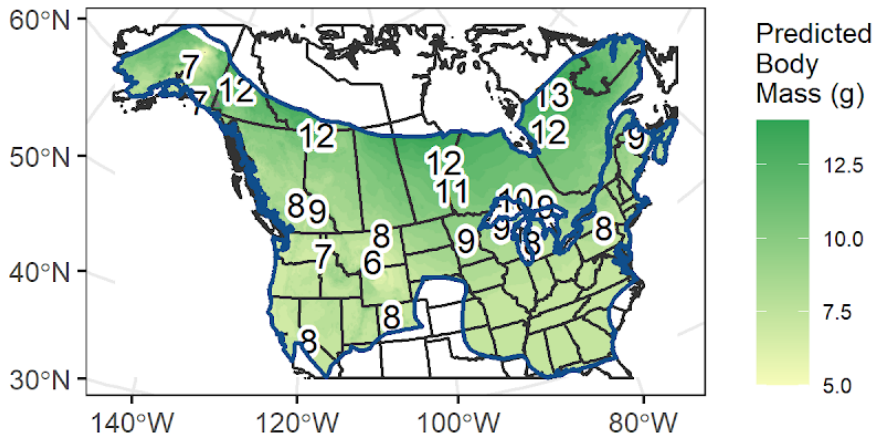
- Top linear model predictors
  - Elevation
  - Number of days of frost
  - Latitude
- Significant improvement
- Based on 49 observations

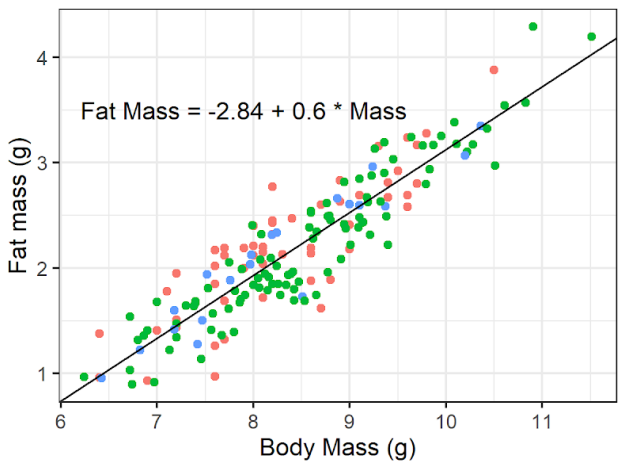


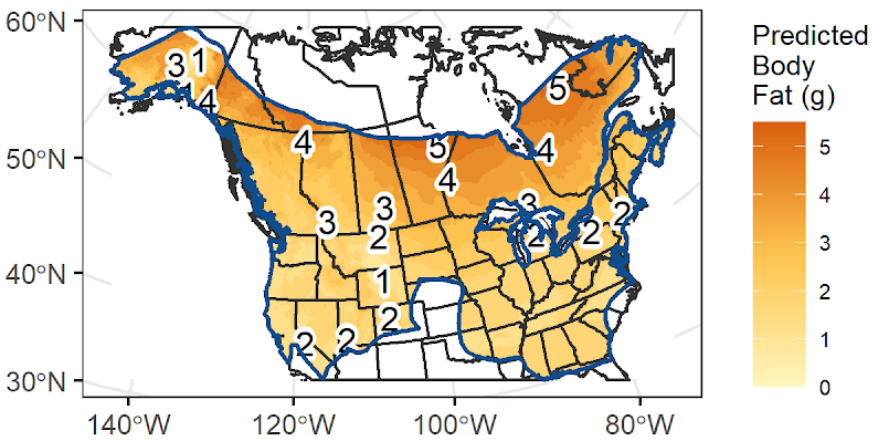
Predicting Spatial Body Mass and Fat

M. lucifugus (little brown bat)

- Top predictors for body mass
  - Latitude
  - Number of days below freezing
- Established relationship of body and fat mass



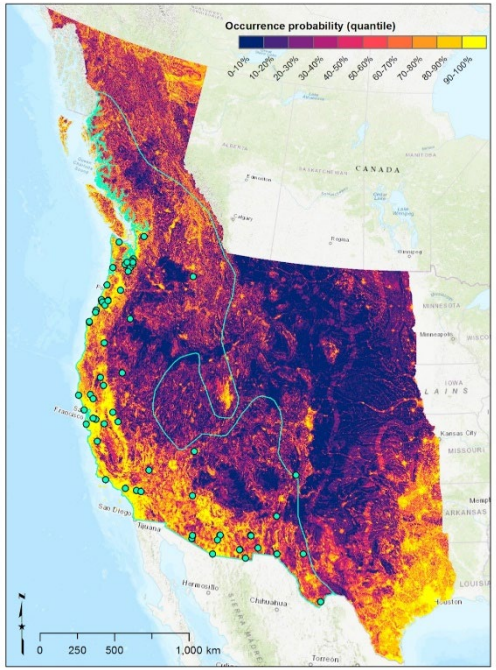




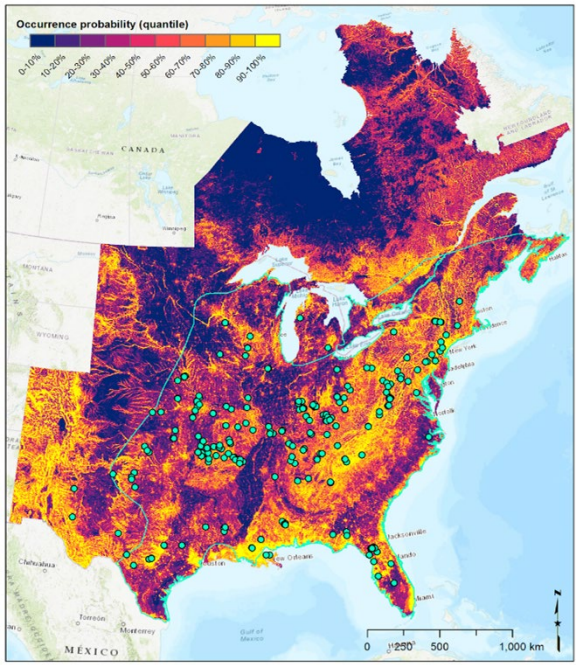
Mapping Western Species Distributions Relative Occurrence Probability

Corynorhinus townsendii

Myotis californicus

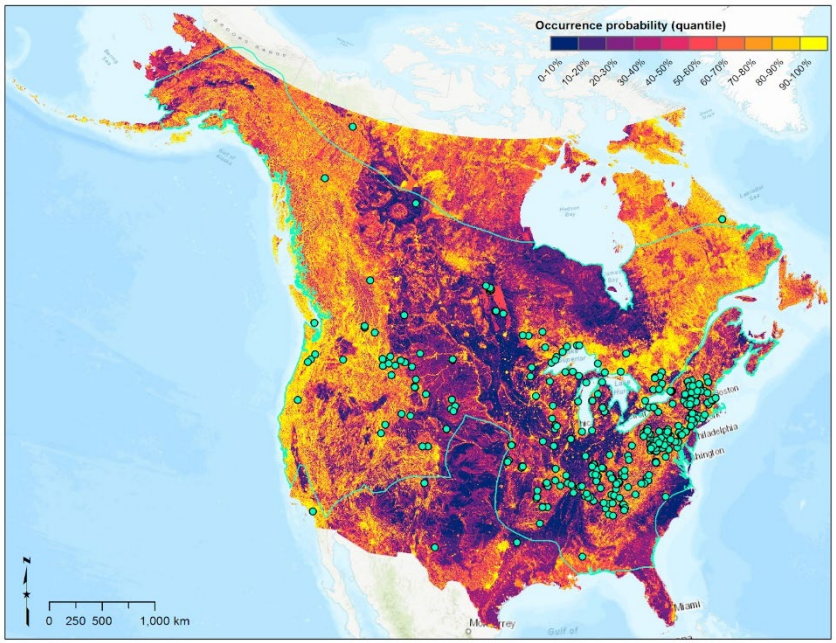


Perimyotis subflavus

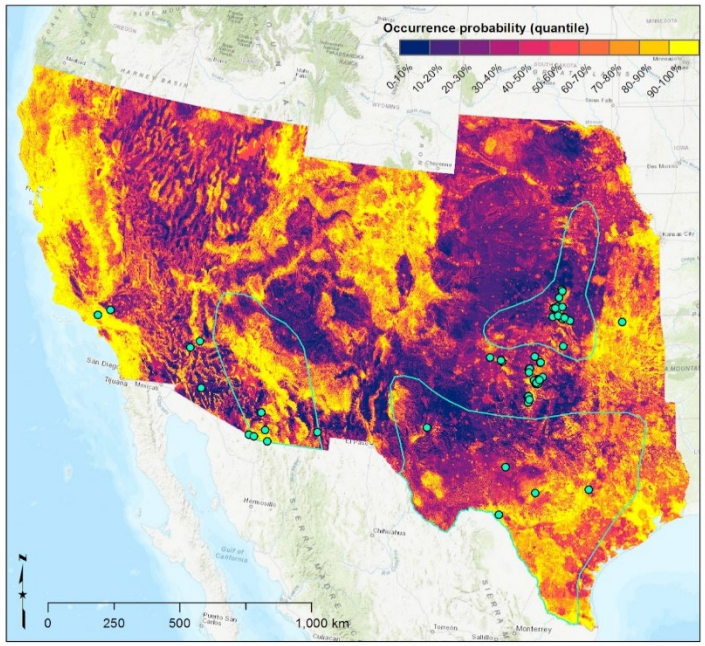


Mapping Western Species Distributions Relative Occurrence Probability

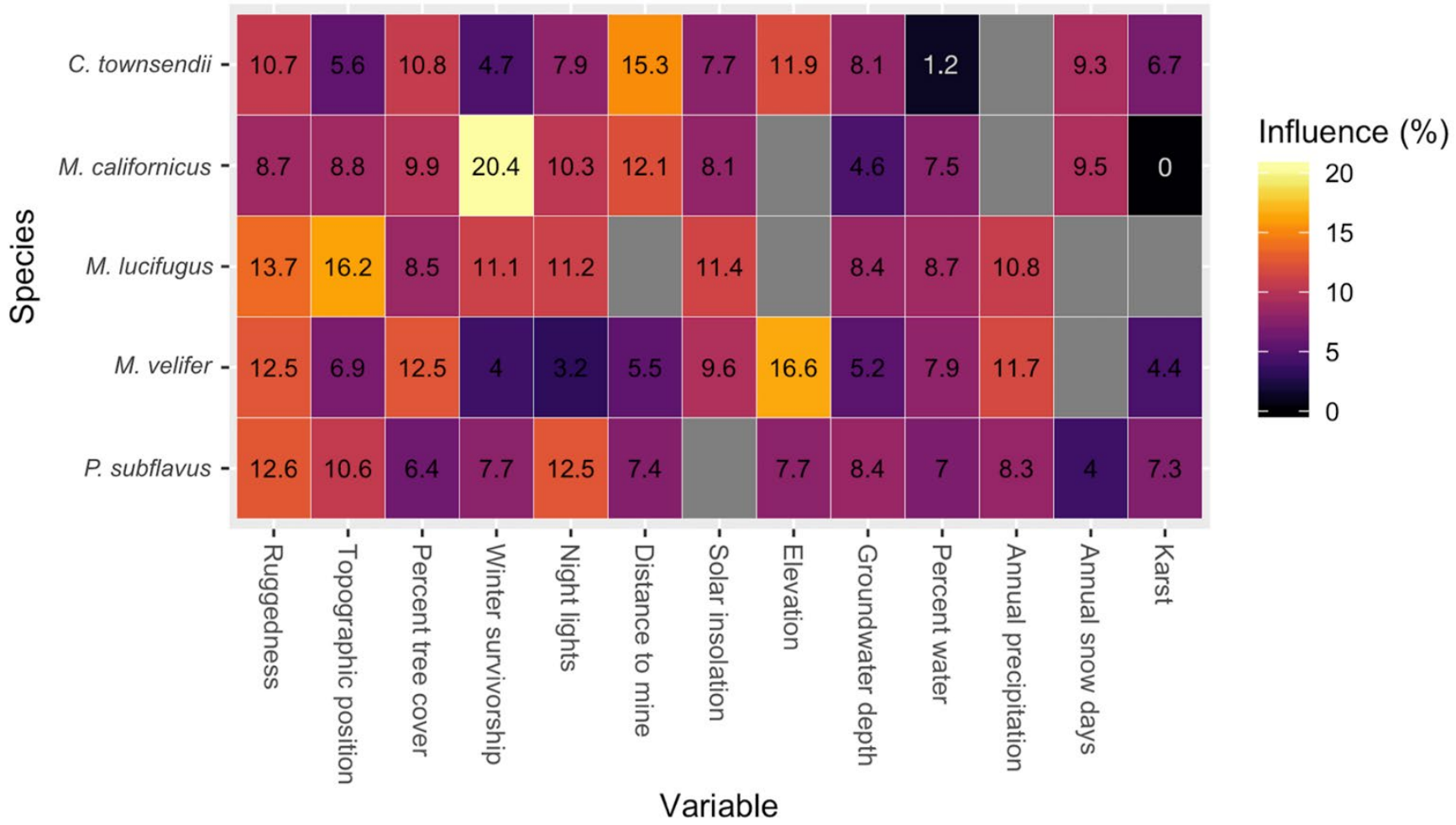
Myotis lucifugus



Myotis velifer

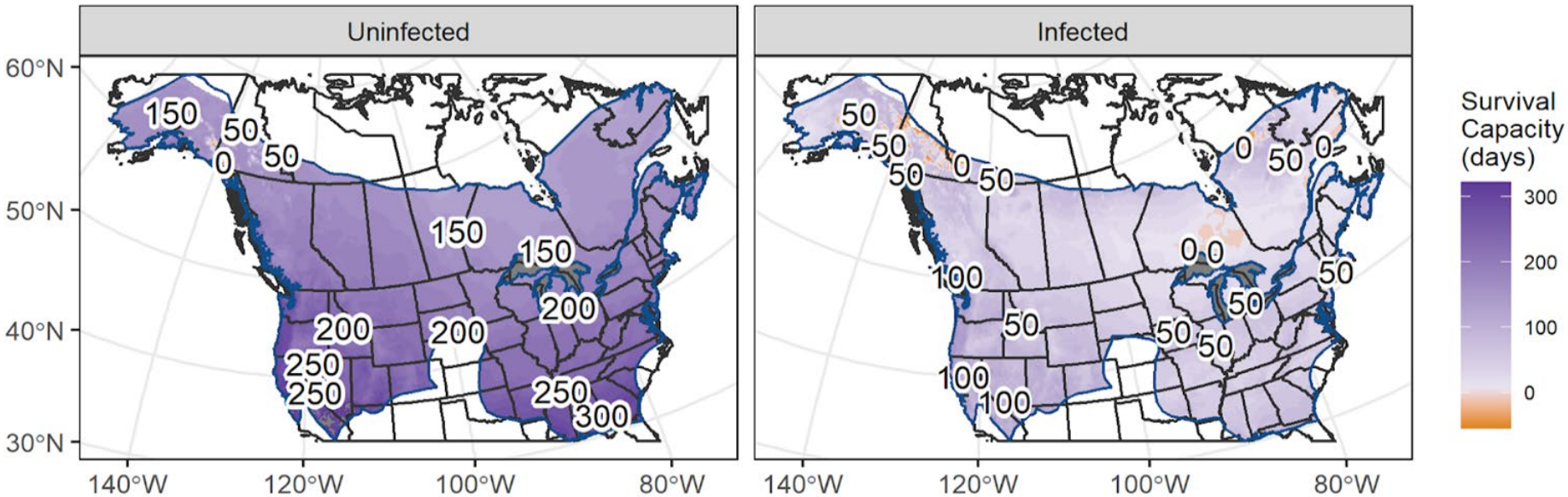


Mapping Western Species Distributions



Predicting Survivorship

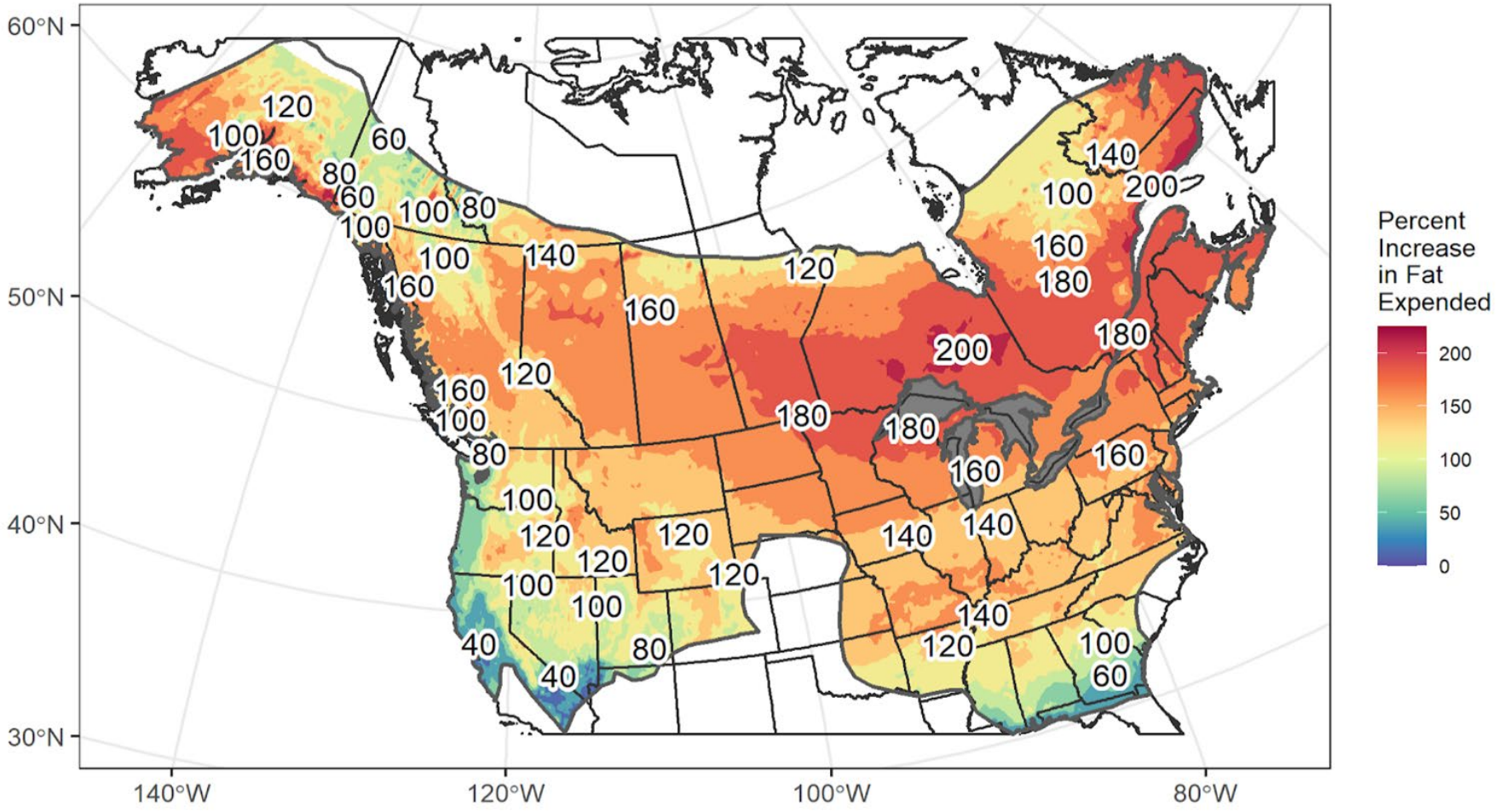
M. lucifugus (little brown bat)



- Ideal conditions
- Survival capacity = max days hibernation - predicted winter duration
- Declines for WNS infected bats
- Bats need to use best available temperature
  - (Which may be colder)

WNS Survivorship Fat Requirements

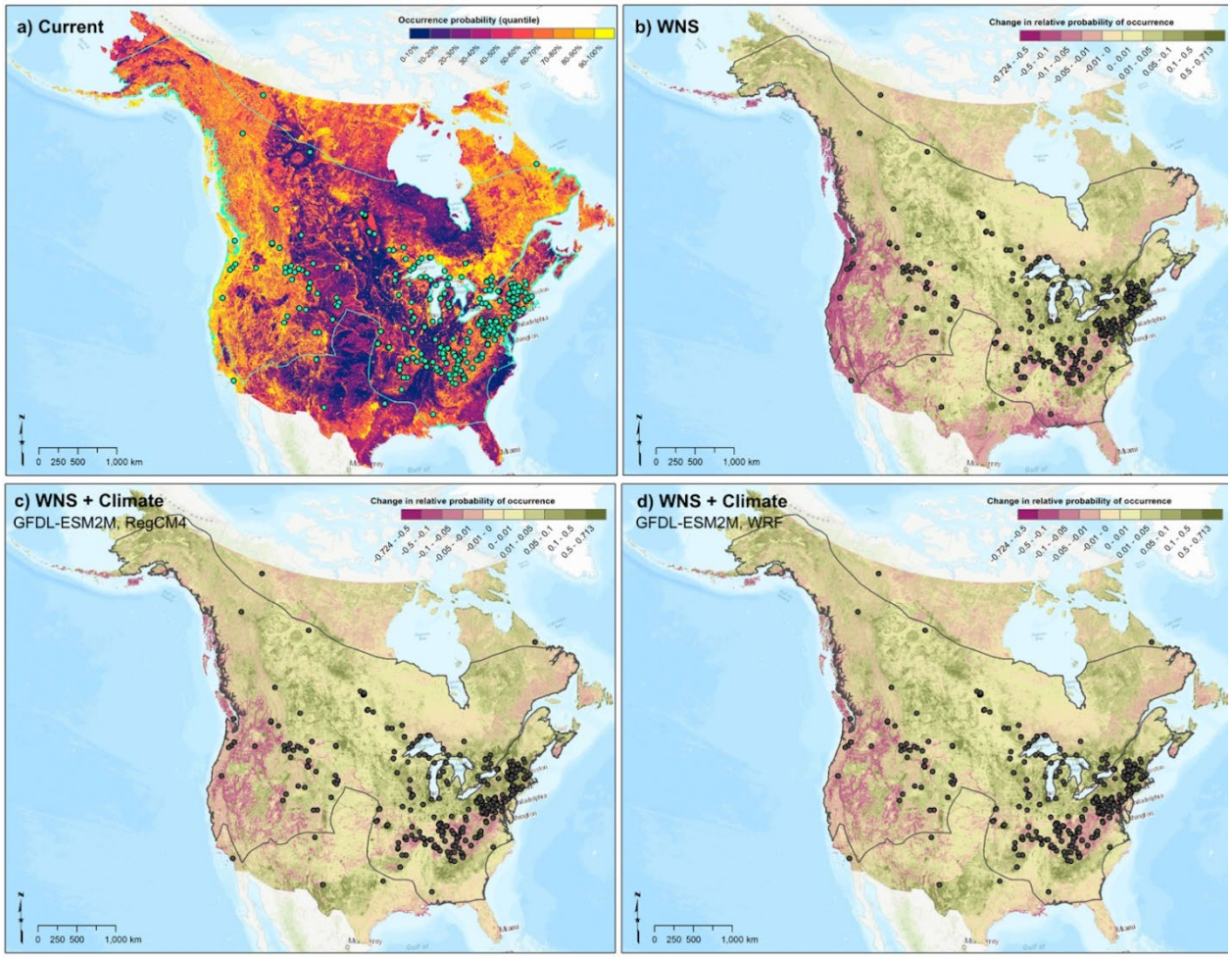
M. lucifugus (little brown bat)



Climate Change Impacts

Bats and WNS – *M. lucifugus*

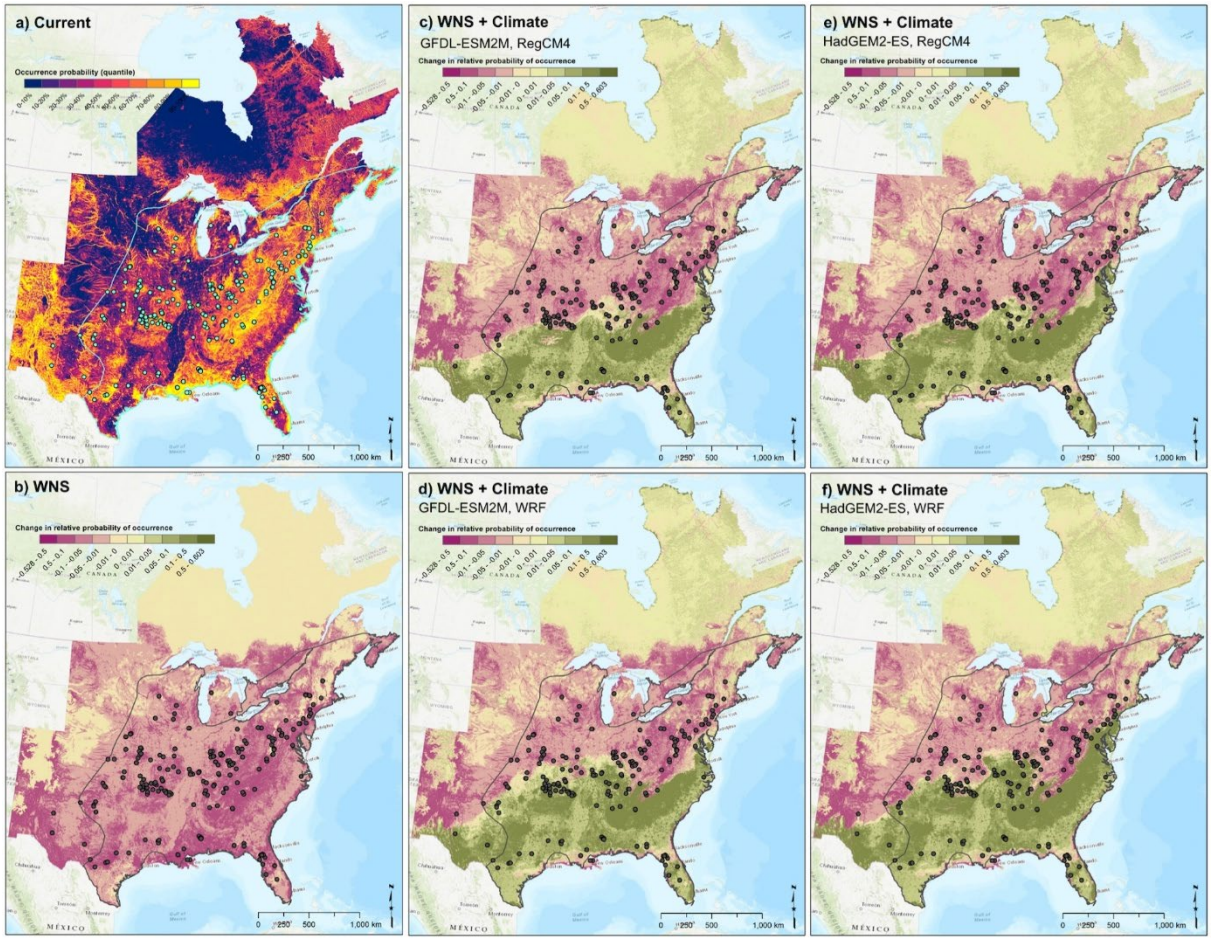
Probability of occurrence declines with WNS, but some rescue effect due to climate change



Climate Change Impacts

Bats and WNS – *P. subflavus*

There are species-level differences: note the strong threshold effect here, likely driven by patterns of frost-free period



Conclusions

- Bioenergetic baseline for assessing potential species-level impacts
  - WNS, climate change
- Winter distribution of bats occurring from surface attributes
- Derived parameters to understand how combined stressors impact species at risk
- Help allocate monitoring, research and management resources to high risk species to minimize impacts

Benefits to DoD

- Advanced bioenergetic modeling of hibernation
  - Characterize species at risk from WNS
  - Online github package
- Identified at risk surveillance targets
- Evidence supports protecting existing hibernacula and populations on installations
- Potential for climate thresholds
  - Frost-free period

Additional Resources

Haase et al. 2019. Bats are not squirrels. J. Thermal Bio.

Haase et al. 2019. Incorporating evaporative water loss into bioenergetic models of hibernation to test for relative influence of host and pathogen traits on white-nose syndrome. PLoS ONE.

McClure et al. 2020. Linking surface and subterranean climate: implications for the study of hibernating bats and other cave dwellers. Ecosphere.

Haase et al. In Review. Body mass and hibernation microclimate may predict bat susceptibility to white-nose syndrome.

Hranac et al. In Review. What is winter? Modelling spatial variation in bat host traits and hibernation and their implications for overwintering energetics.

McClure et al. In Review. A hybrid correlative-mechanistic approach for modeling and mapping winter distributions of western bat species.

McClure et al. In Review. Modeling and mapping western bat hibernaculum suitability before and after Pd exposure.

McGuire et al. In Review. Lean mass dynamics in hibernating bats and implications for energy and water budgets.

McGuire et al. In Review. Similar physiology in hibernating bats across broad geographic ranges.

McGuire et al. In Review. Interspecific variation in evaporative water loss, and not metabolic rate, among hibernating bats.

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Acknowledgements

The project would like to thank those who helped with field work and the collection of existing data. We deeply appreciate the assistance and support from the following individuals:

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For additional information, please visit

https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency/Natural-Resources/Species-Ecology-and-Management/RC-2633

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Q&A Session 2

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The next webinar is on November 19, 2020

Abiotic Degradation of Chlorinated Solvents in Subsurface Environments

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Survey Reminder

Please take a moment to complete the survey that will pop up on your screen when the webinar ends

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