



# Forest and Woodland Management in the Era of White-nose Syndrome



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# Why do we care about bats?

- **Ecosystem services** and **keystone species**
- Contribute to overall **biodiversity** of ecosystems
- Primary **predators** of night flying insects
- **ESA** and **2012 planning rule** guidelines



M. Tuttle



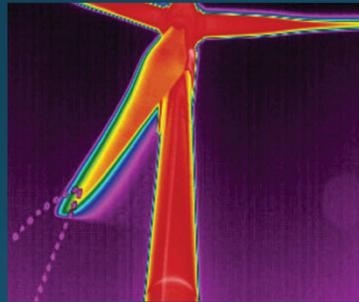
© Merlin D. Tuttle



# Threats

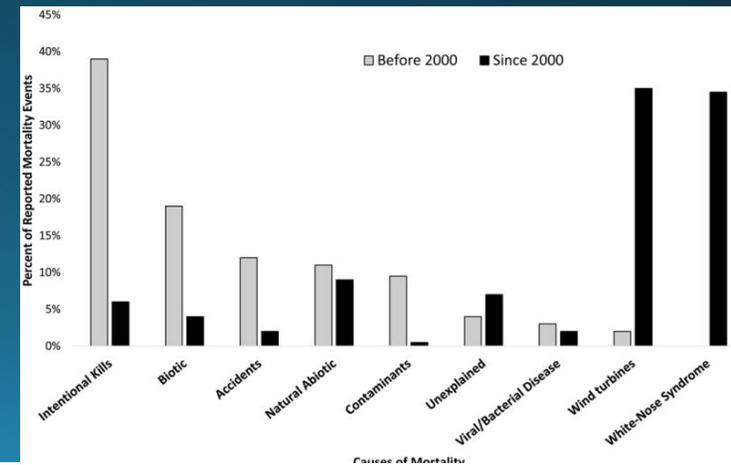
Prior to 2000:  
Intentional killing by humans

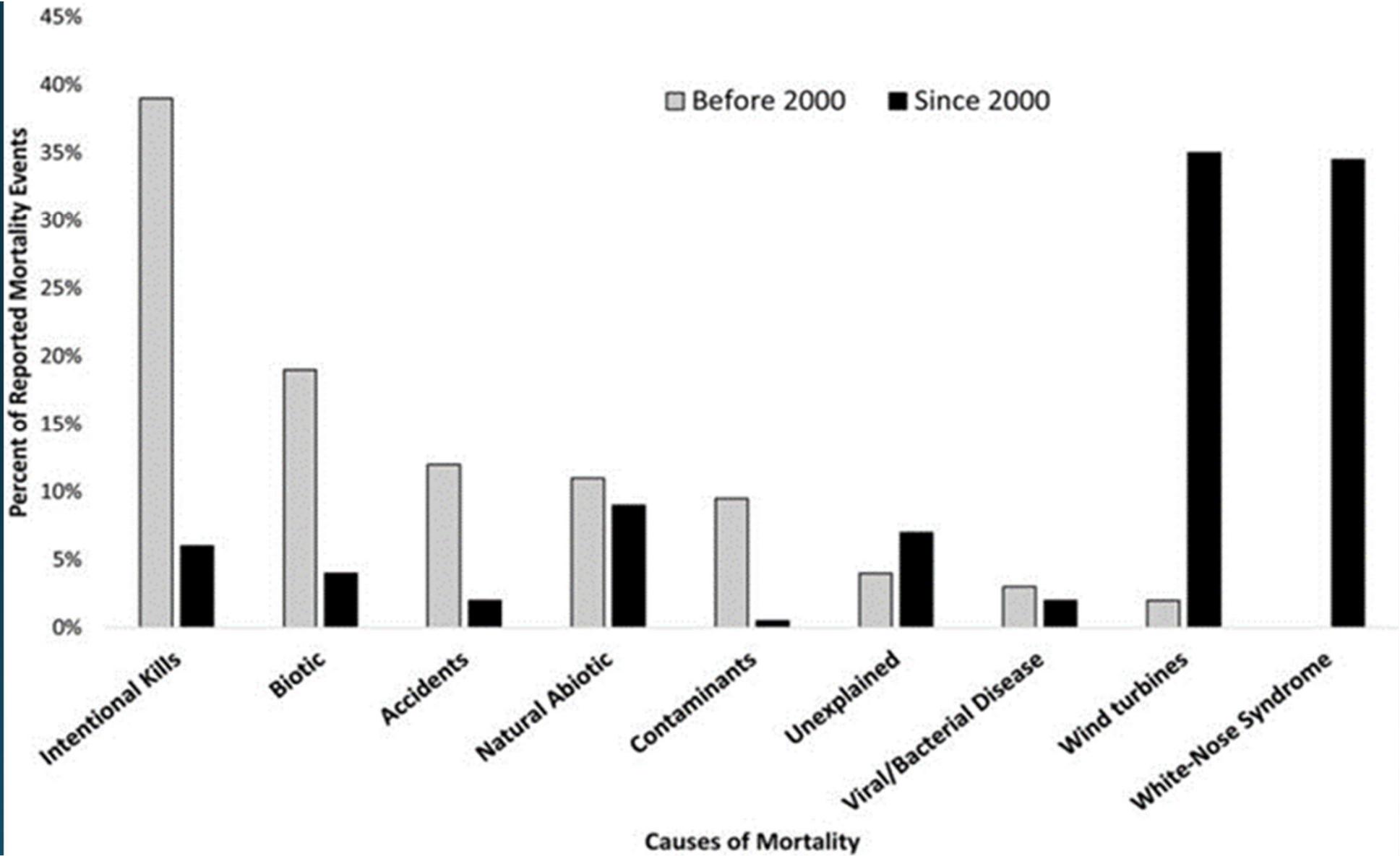
Since 2000:  
Wind Turbines &  
White-nose Syndrome

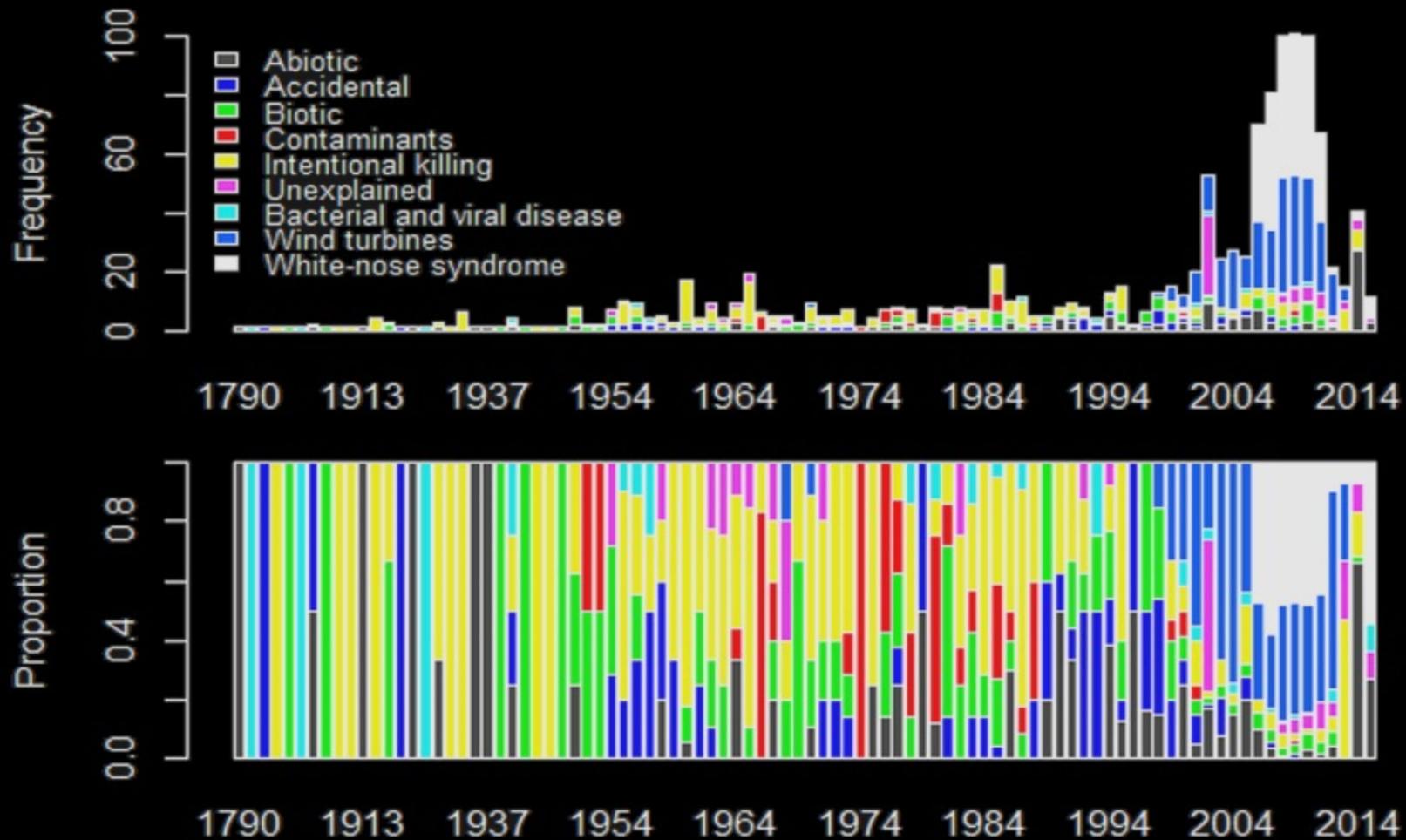


## Abiotic and Biotic

O'Shea, T. J., P. M. Cryan, D. T. S. Hayman, R. K. Plowright, and D. G. Streicker. 2016. Multiple mortality events in bats: a global review. *Mammal review* 46:175-190.







**Fig. 1.** Numbers and proportions of reported multiple mortality events in bats over time (1790–2015). All 1180 events included in this review are shown.

O'Shea, T. J., P. M. Cryan, D. T. S. Hayman, R. K. Plowright, and D. G. Streicker. 2016. Multiple mortality events in bats: a global review. *Mammal review* 46:175-190.

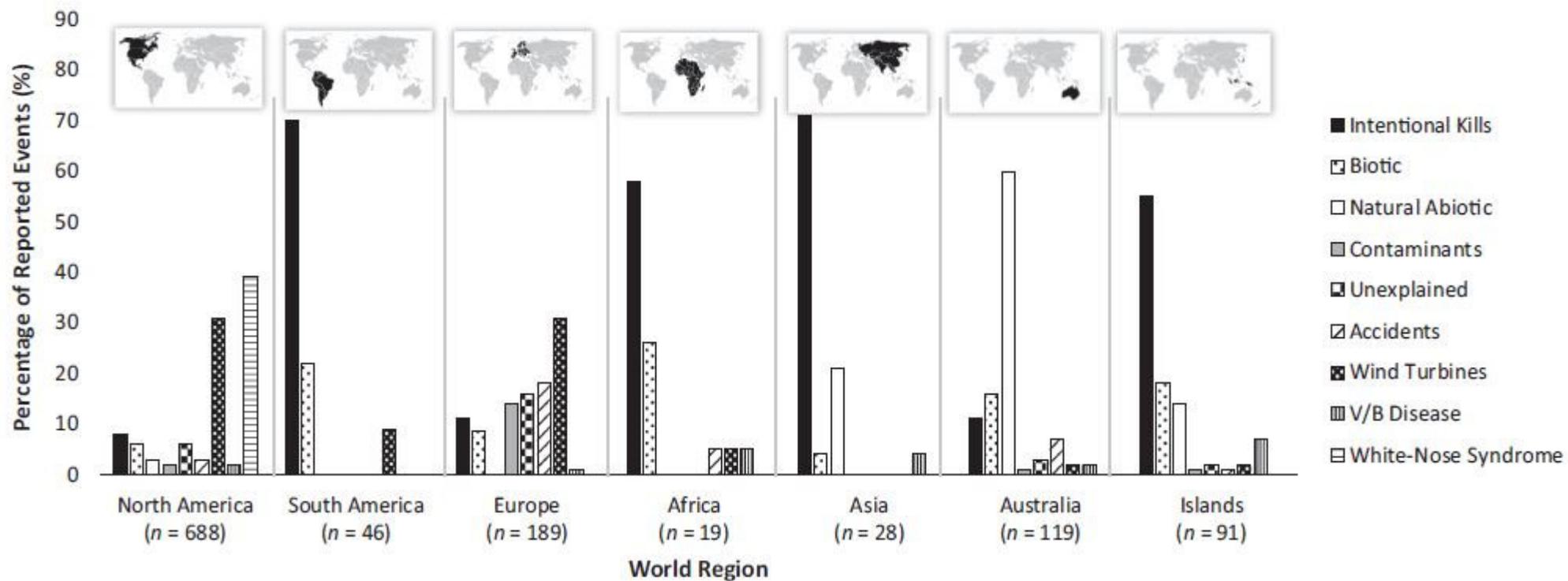
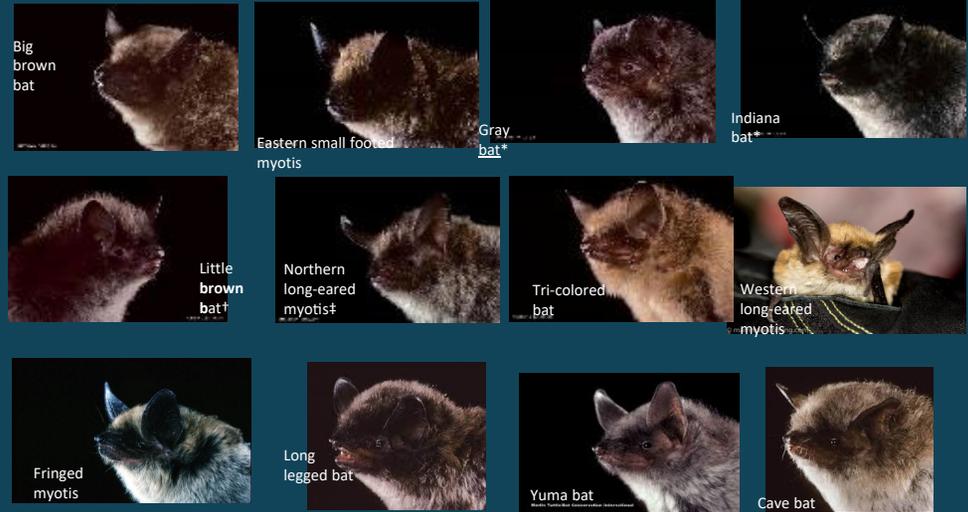


Fig. 4. Causes of multiple mortality events in bats, expressed as percentages of all events (*n*), for each geographic region.

# What is WNS?



White-nose syndrome is disease of hibernating bats caused by an invasive fungal pathogen *Pseudogymnoascus destructans*. WNS has been confirmed in 12 of 47 species of North American bats including two endangered species and one threatened species. Since the winter of 2007-2008, millions of insect-eating bats in at least 35 states and seven Canadian provinces have died from this devastating disease.

\*Endangered  
†Under internal listing review by the USFWS  
‡Threatened



# Disease triad

**Susceptible host**

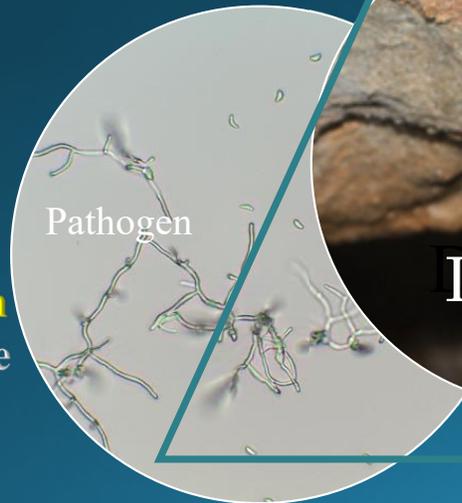
Naïve  
Stressed  
Immunocompromised



**Reservoir**  
Conducive to pathogen



**Pathogen**  
Virulence

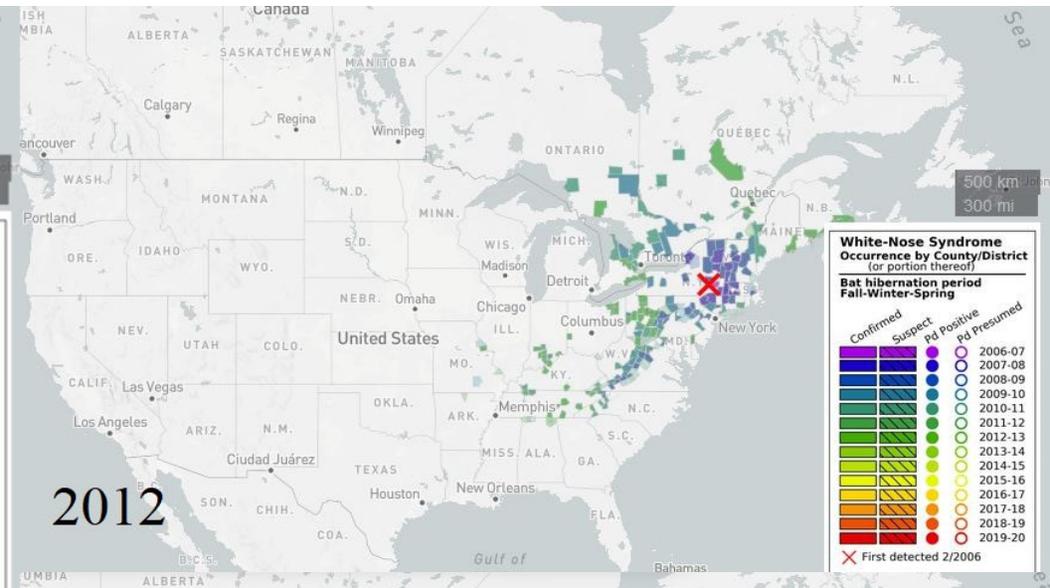


# Where is WNS?

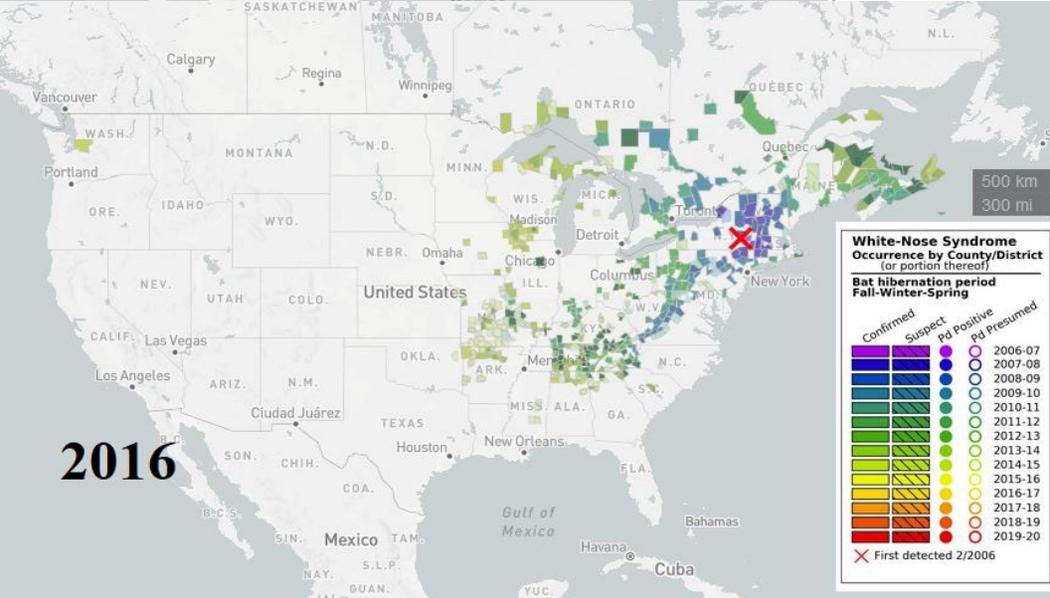
2008/09



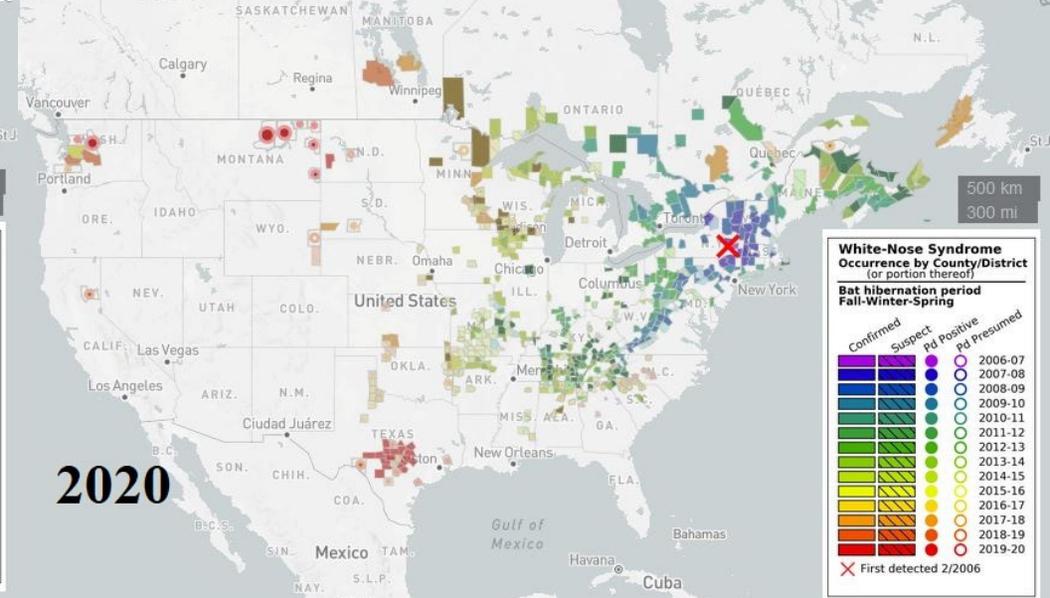
2012



2016

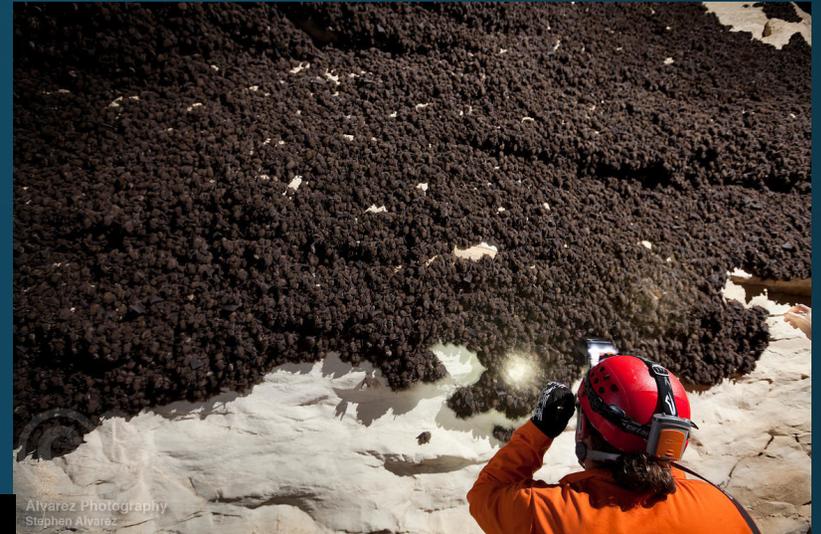


2020



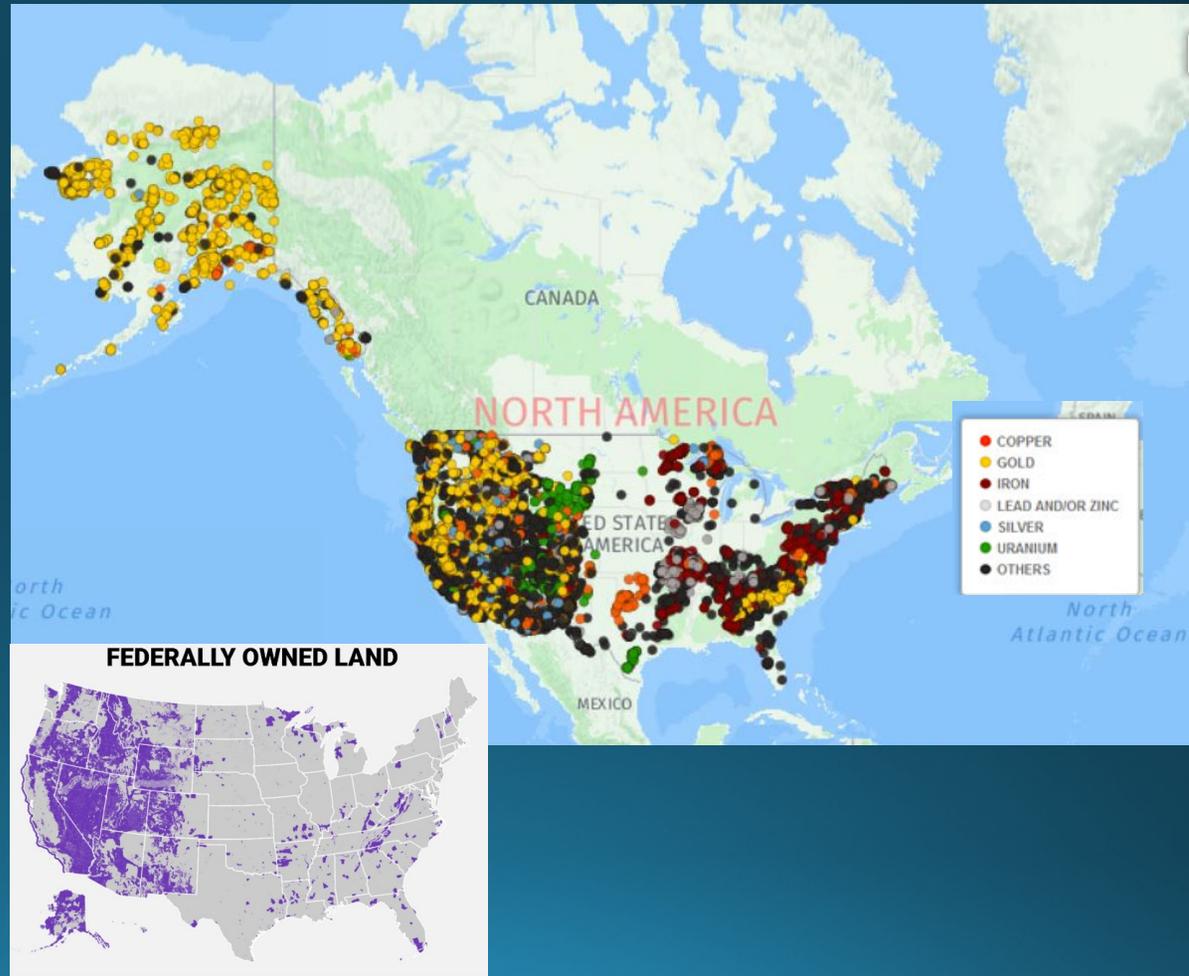
# Hibernating bat species east of the great plains –

- many form large clusters
- many protected by gates
- many hibernacula of all sizes have lost populations to WNS

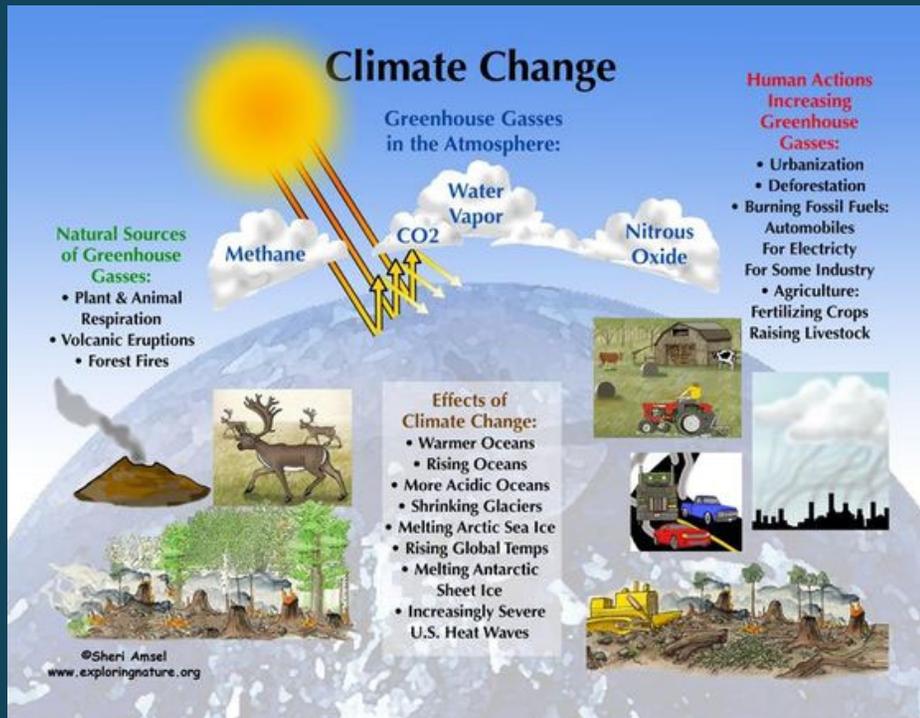


# Hibernating bat species west of the great plains –

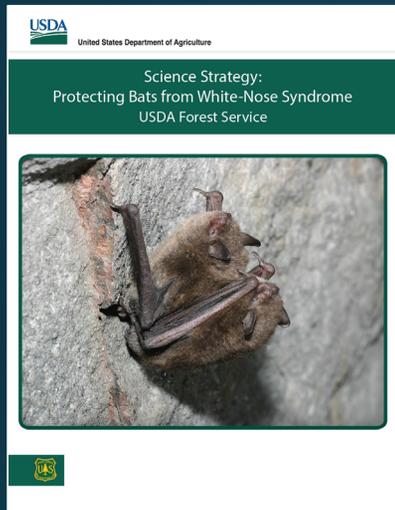
- very dispersed resources
- bats species hibernate in smaller clusters
- known locations of hibernacula relatively low due to large land areas and lower accessibility
- types of hibernacula used more variable



# Why is WNS?



# USFS R&D Science Strategy 2012 with updates 2015



Species	Pre-WNS Count	Post-WNS Count	Percent Decline
Little brown bat	348,277	30,260	-91%
Indiana bat	55,028	15,650	-72%
Northern long-eared bat	1,706	31	-98%
Eastern small footed myotis	1,303	1,142	-12%
Tri-colored bat	3,107	783	-75%
Big Brown bat	2,919	1,713	-41%
<i>P. destructans</i>	745/673	7</8 : <	0; ; (

Turner et. al, 2011  
 NY, PA, VT, VA, WV, 19 priority hibernacula

## Goals:

- Minimize WNS disease-induced population to provide the greatest potential for survival and recovery at the population level for each bat species affected, and
- Identify approaches that perpetuate long-term, stable and functional/viable bat populations in the presence of *P. destructans*.



# Host Goal: Increase survival and adaptive options

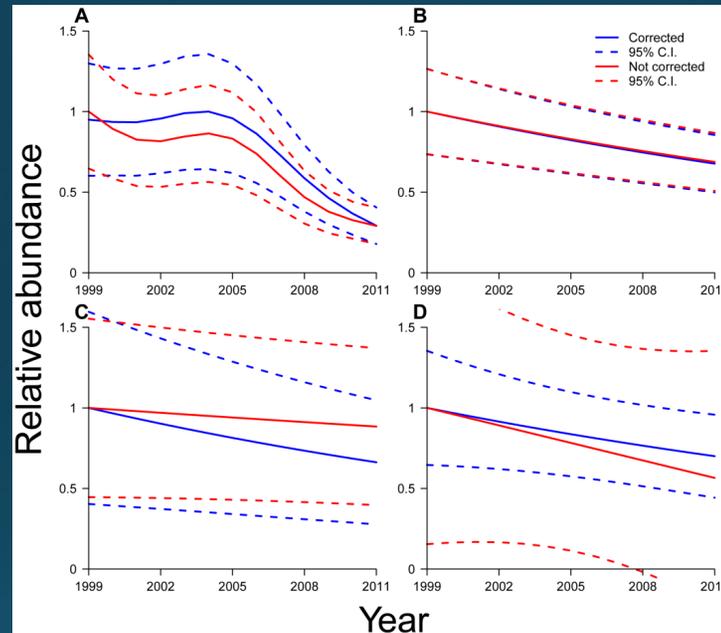
- Increase survival of individuals (slow reproducing species - 15 years per generation)
- Time to develop adaptive mechanisms
- Develop options to interrupt disease process ( natural inhibitors - immune enhancers)



# NLEB: 30% Decline Threshold of IUCN by 2011

**M. lucifugus,  
Little brown  
bat**

**M. sodalis,  
Indiana bat**



**P. subflavus  
Tricolor bat**

**M. septentrionalis  
Northern long-ear  
bat**

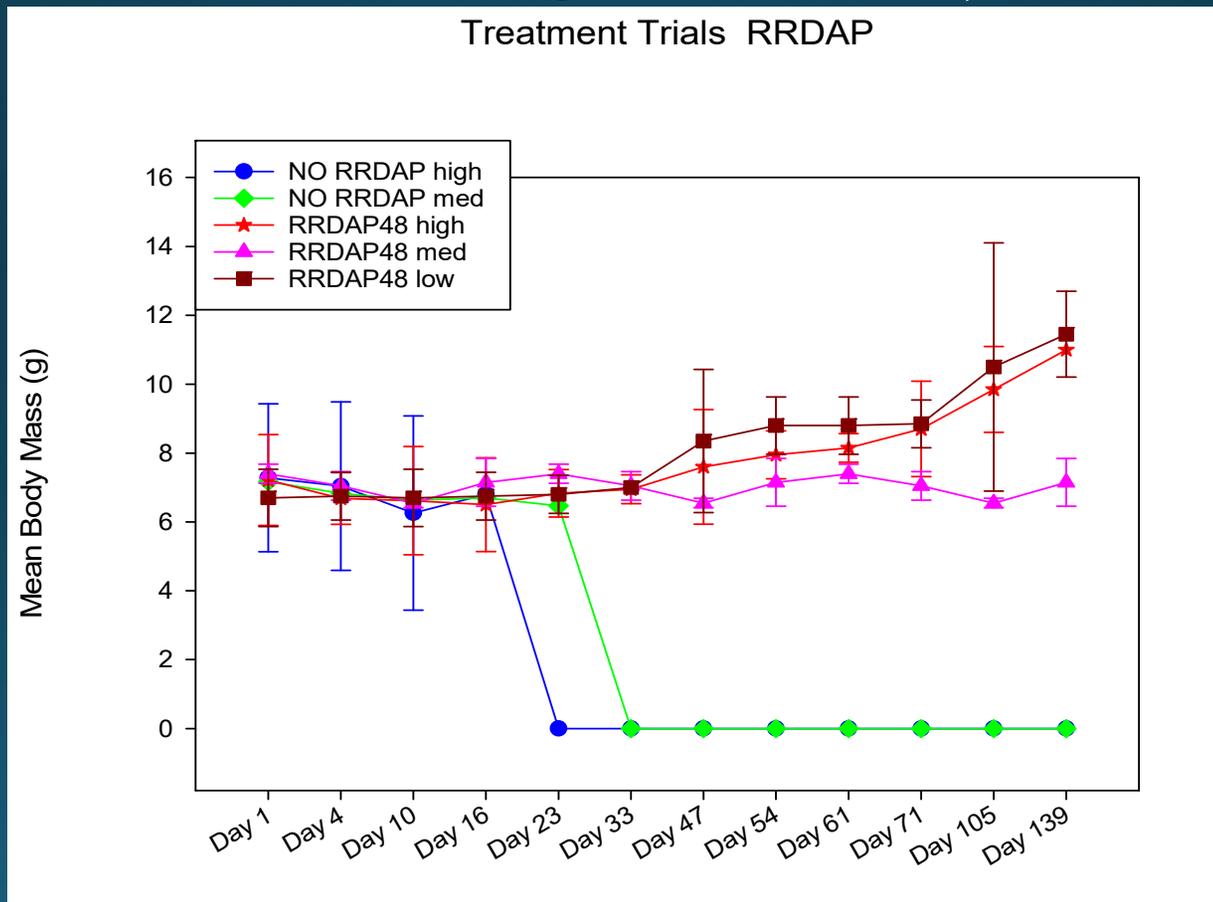
corrected for survey date of bat counts (in blue), and the uncorrected trajectory (red).

Ingersoll, T., B. Sewall and S. Amelon. 2013. Improved analysis of long-term monitoring data demonstrates marked regional declines of bat populations in the eastern United States. Plos One 8(6):e65907



# 2014 Exposure trials

VOC treated (reds and pinks) versus  
untreated bats (green and blue)





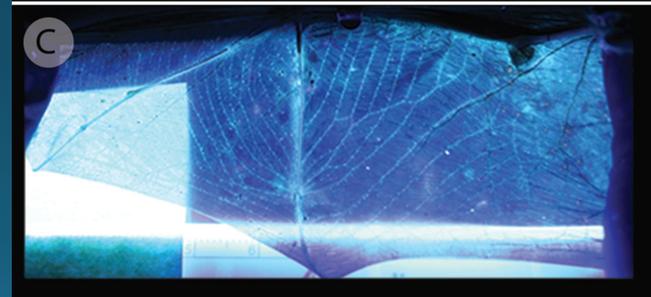
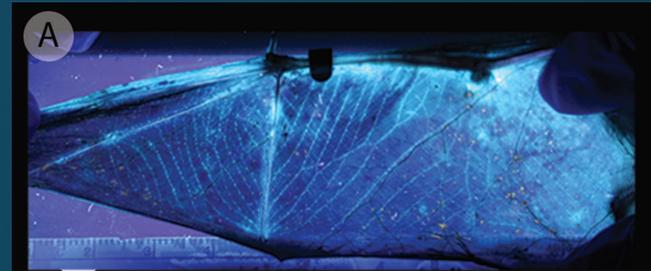
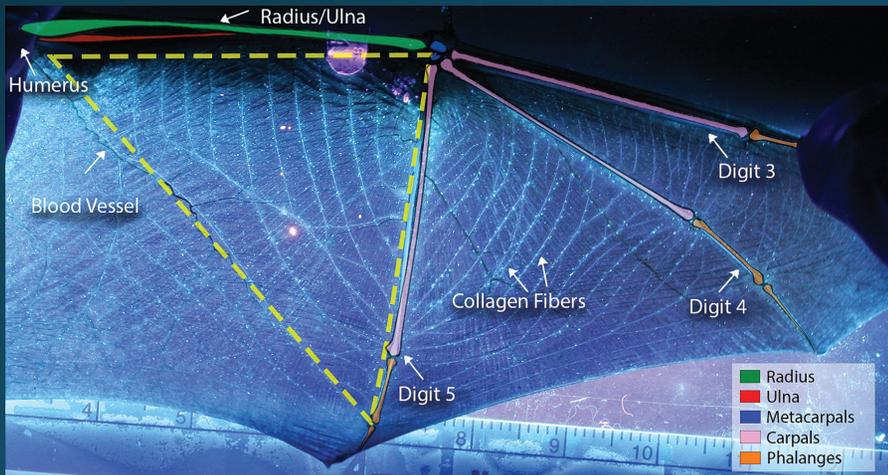
## Bat wing biometrics: using collagen–elastin bundles in bat wings as a unique individual identifier

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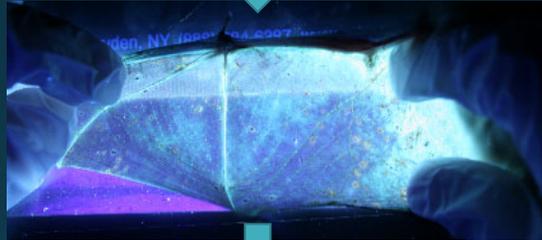
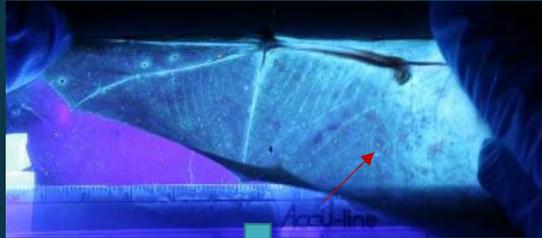
*College of Veterinary Medicine, University of Missouri, 4011 Discovery Drive S219, Columbia, MO 65211, USA (SEH)*

*School of Natural Resources, University of Missouri, 202 Anheuser-Busch Natural Resources Building, Columbia, MO 65211, USA (KMW)*

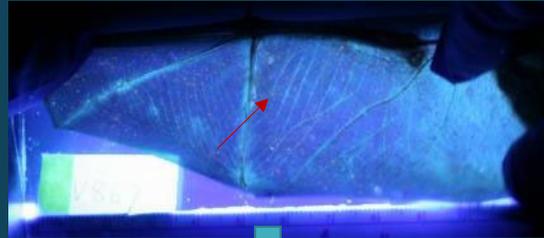


# Wing Healing Analysis

Treatment Group Bat



Control Group Bat



# Universal biopsy histological grading scheme

- Diagnostic tool for White-nose Syndrome
  - Study progression of disease



RESEARCH ARTICLE

## White-nose syndrome pathology grading in Nearctic and Palearctic bats

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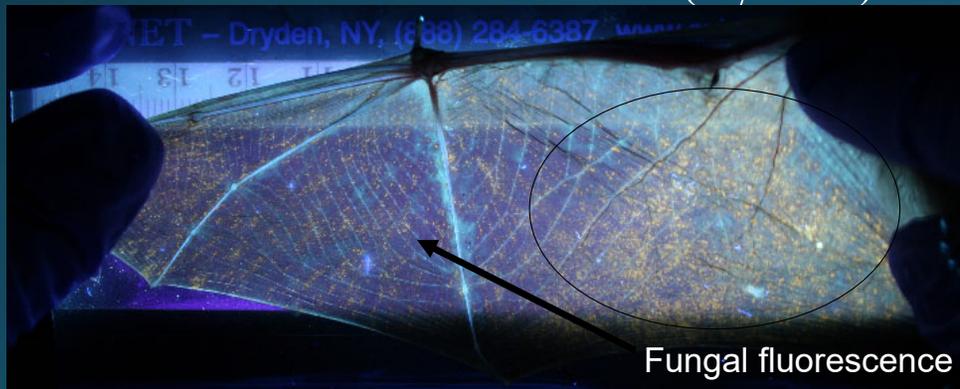
**1** Department of Ecology and Diseases of Game, Fish and Bees, University of Veterinary and Pharmaceutical Sciences Brno, Brno, Czech Republic, **2** CEITEC—Central European Institute of Technology, University of Veterinary and Pharmaceutical Sciences Brno, Brno, Czech Republic, **3** United States Department of Agriculture Forest Service, Northern Research Station, Columbia, Missouri, United States of America, **4** Department of Botany and Zoology, Masaryk University, Brno, Czech Republic, **5** Institute of Vertebrate Biology, Czech Academy of Sciences, Brno, Czech Republic, **6** Department of Veterinary Pathobiology, University of Missouri, Columbia, Missouri, United States of America, **7** Institute of Biology, Department of Vertebrate Ecology and Palaeontology, Wrocław University of Environmental and Life Sciences, Wrocław, Poland, **8** Laboratory of Fungal Genetics and Metabolism, Institute of Microbiology, Czech Academy of Sciences, Prague, Czech Republic, **9** Institute of Immunology, Friedrich-Loeffler-Institute, Federal Research Institute for Animal Health, Greifswald-Insel Riems, Germany, **10** Pennsylvania Game Commission, Harrisburg, Pennsylvania, United States of America, **11** Institute of Biostatistics and Analyses, Masaryk University, Brno, Czech Republic



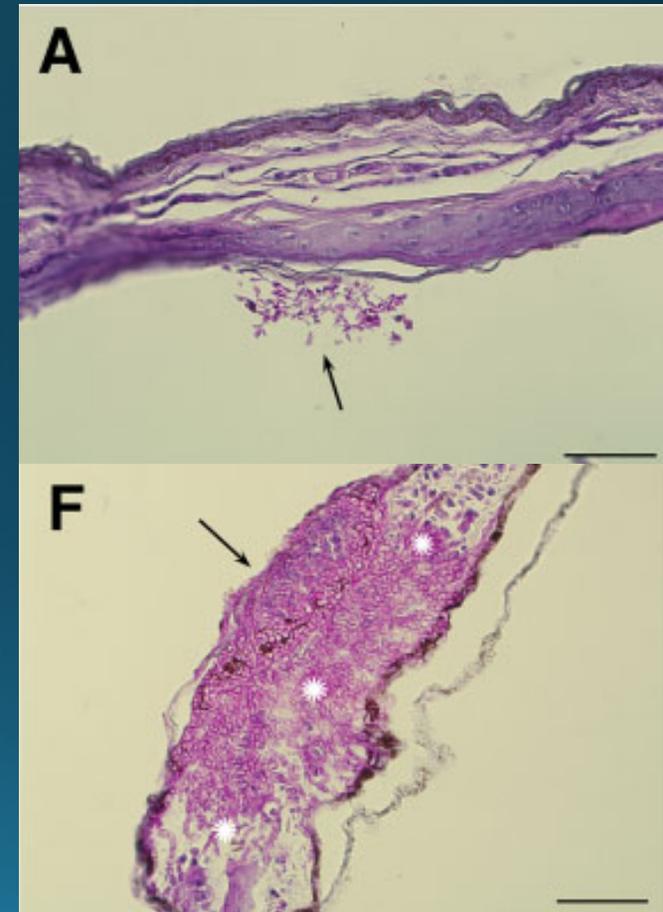
Europe

# Semi-quantitative grading system

- A single UV-light assisted biopsy punch
- To evaluate the severity of the infection
  - Fungal skin colonization ( $w_1 = 1$ )
  - Hair follicle ( $w_2 = 2$ )
  - Single ( $w_4 = 6$ ) or multiple ( $w_5 = 12$ ) cupping erosions
  - Full thickness infection ( $w_7 = 19$ )



**BIOPSY**



Pikula, Amelon, ..., Hooper et al. 2017 PLOS ONE

# Creation and Validation of the R-package Countcolor for Quantifying the Fluorescence Emitted by *Pseudogymnoascus destructans*

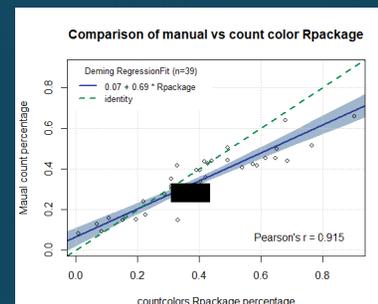
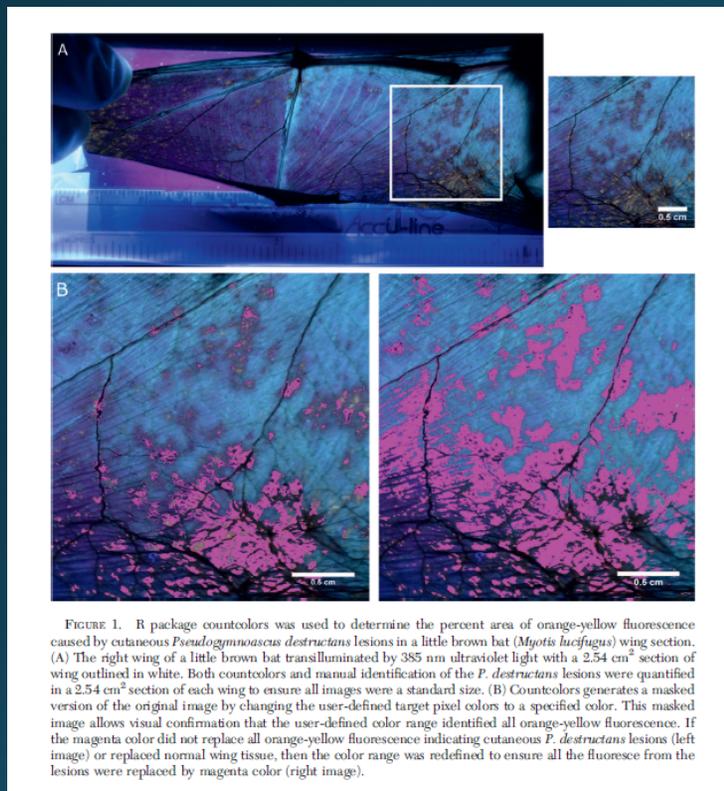


Figure 4: Regression analysis revealed that the two methods showed good agreement, Pearson's correlation = 0.915.

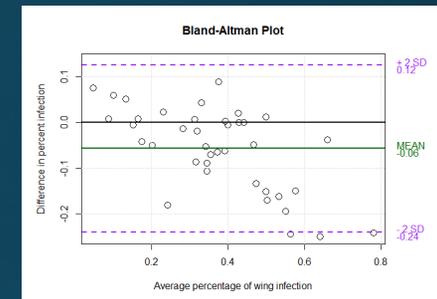


Figure 5: Bland-Altman plot comparing the manual and semi-automatic measurement methods.

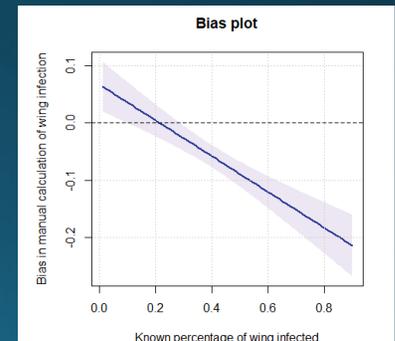


Figure 6: Bias plot clearly shows the manual calculations consistently underestimated the surface area of the fungal infection.

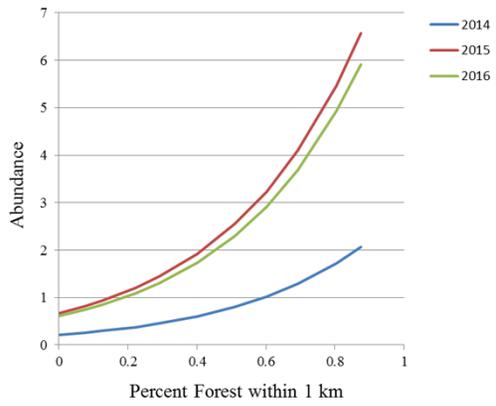
Hooper, Sarah E., Hannah Weller, and Sybill K. Amelon. "Countcolor, an R package for quantification of the fluorescence emitted by *Pseudogymnoascus destructans* lesions on the wing membranes of hibernating bats." *Journal of Wildlife Diseases* 56, no. 4 (2020): 759-767.

# Additional methodologies validated

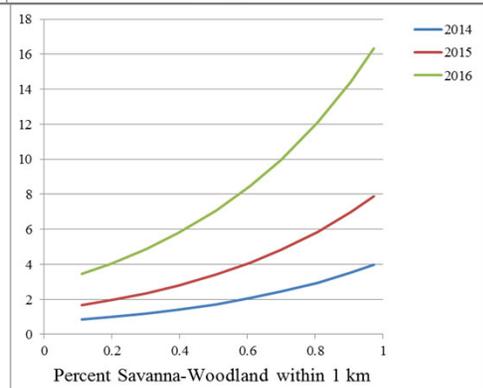
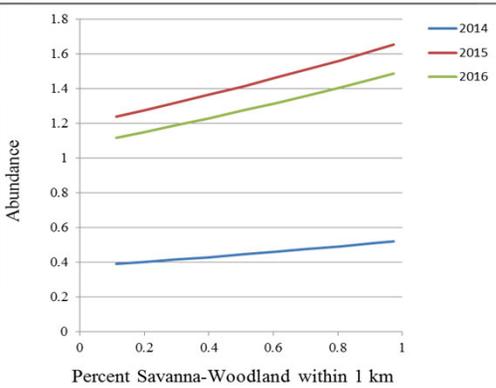
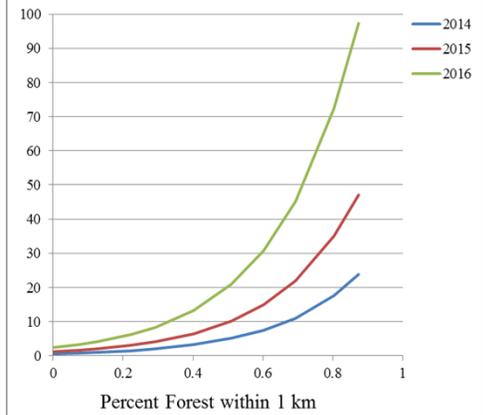
- Actual vs Relative Abundance and Density estimates for bats
- Baseline physiological characteristics for several species
- Development of non-invasive molecular approaches to look at changes in metabolites, other compounds and gene expression

## Crevice Roosting Species ie *Myotis* spp.

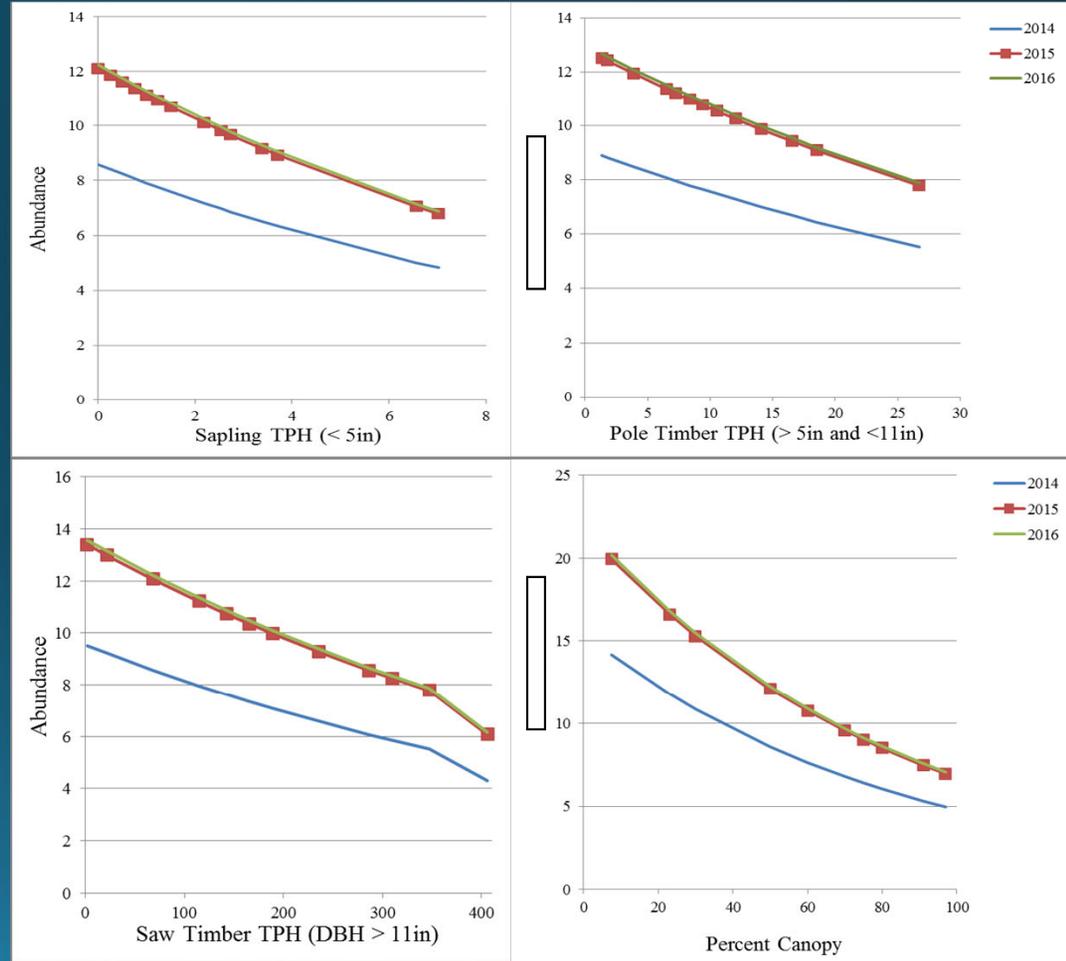
PESU



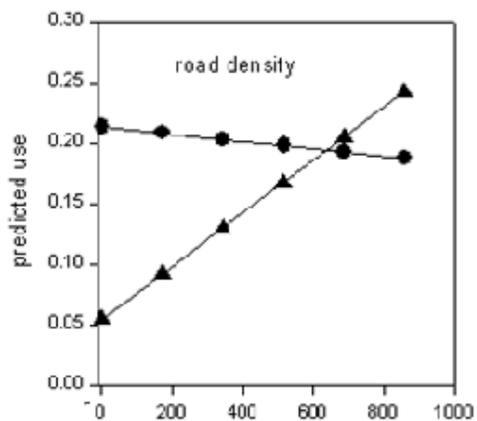
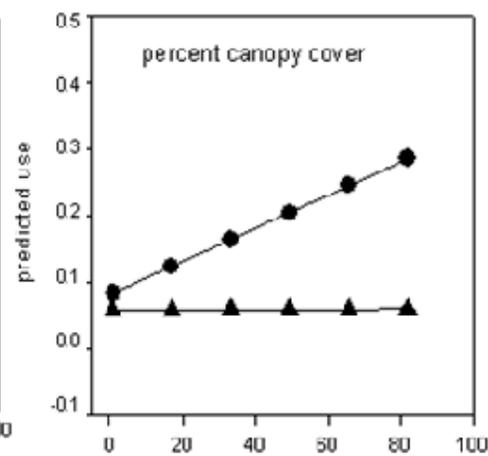
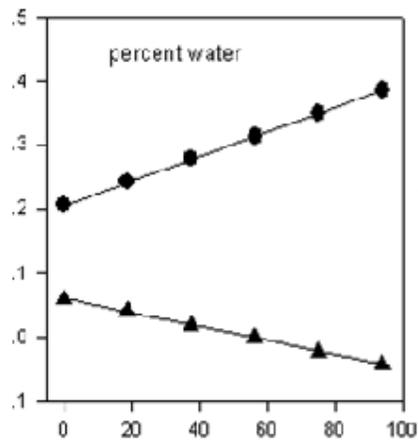
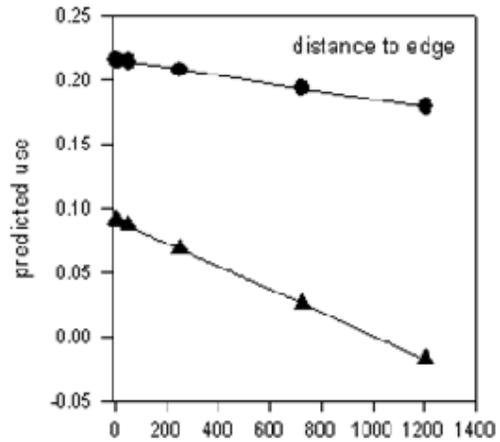
MYSE



## Foliage Roosting Species ie LABO

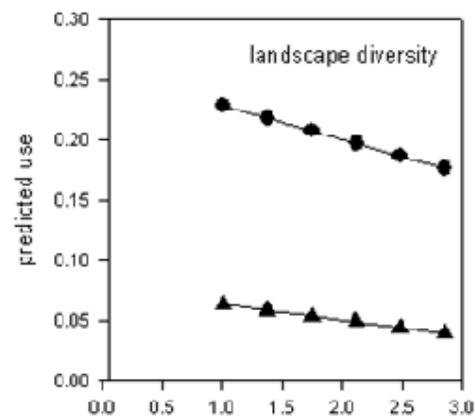


# Varies Geographically



Predicted use for RUF(foraging), by landscape factors for *L. borealis* by geographic unit in the Ozark Region of Missouri 2001-2003.

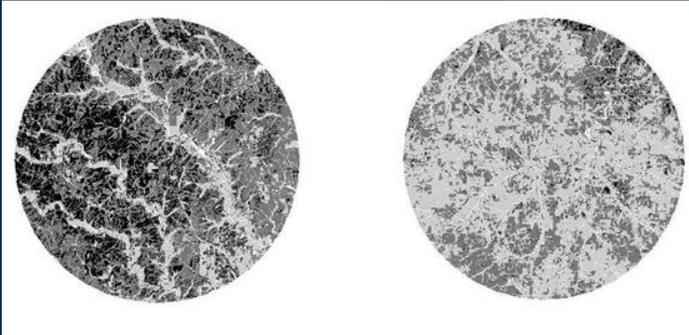
north = closed circles;  
south = closed triangles.



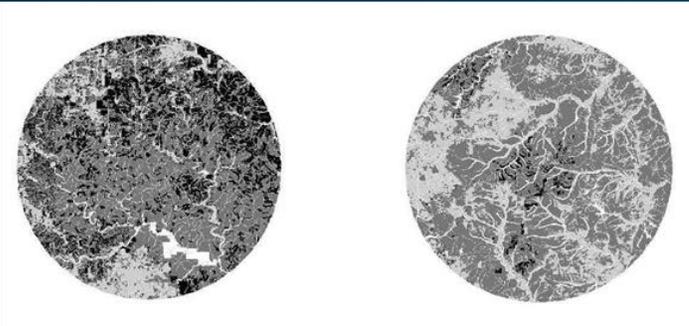
# Predicting Bat Species Use of Forest Landscapes

Higher Occurrence Lower Occurrence

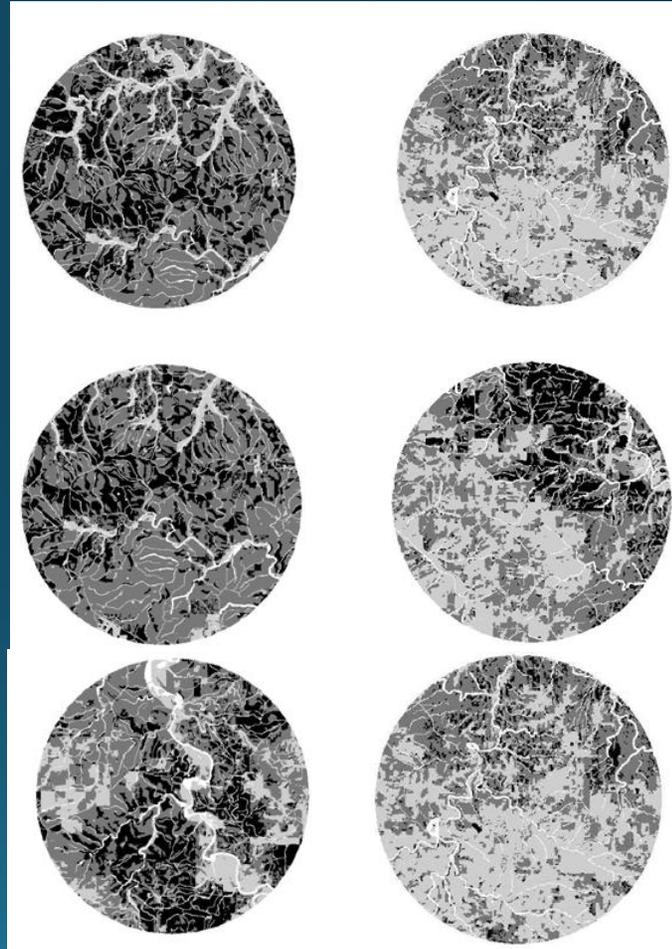
Higher Occurrence Lower Occurrence



Eastern Red Bat



Hoary Bat



Evening bat

Little Brown Bat

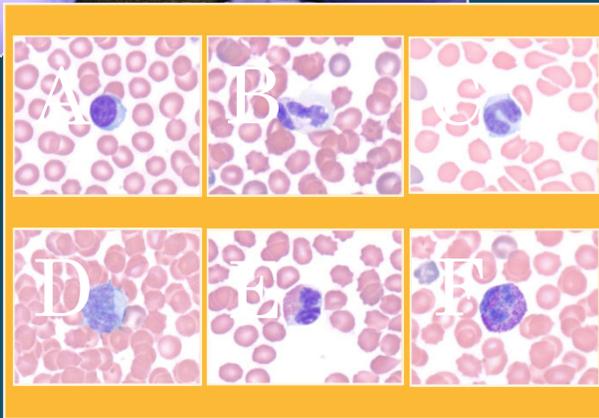
N. Long-eared Bat

# Biomarkers of Health and Fitness



## Other Parameters used in Wildlife Health Evaluations:

Parasite load, Glucose, Cholesterol, Fatty Acids, Leptin, Neutrophil ratios, Enzymes, Vitamins, etc.



Examples of (A) lymphocyte, (B) neutrophil, (C) band neutrophil, (D) monocyte, (E) eosinophil, and (F) basophil from a normal *Myotis lucifugus*.

A close-up photograph of bat fur, heavily infested with numerous small, dark, oval-shaped ticks and mites. The parasites are densely packed across the brown and grey fur, with some showing their mouthparts. A black rectangular box is overlaid on the center of the image, containing white text.

**Thank you for your attention.**

**QUESTIONS?**

# Northern Long-eared Bat

- Highest Canopy
- Landscape Scale -16 km
  - Generally older larger trees
- Any tree species available with cavities
- Social maternity groups 10-30 females
- High number of roost/stand
- Fission/Fusion
- Low intensity fire
- Ark/Mo Pine-Oak

