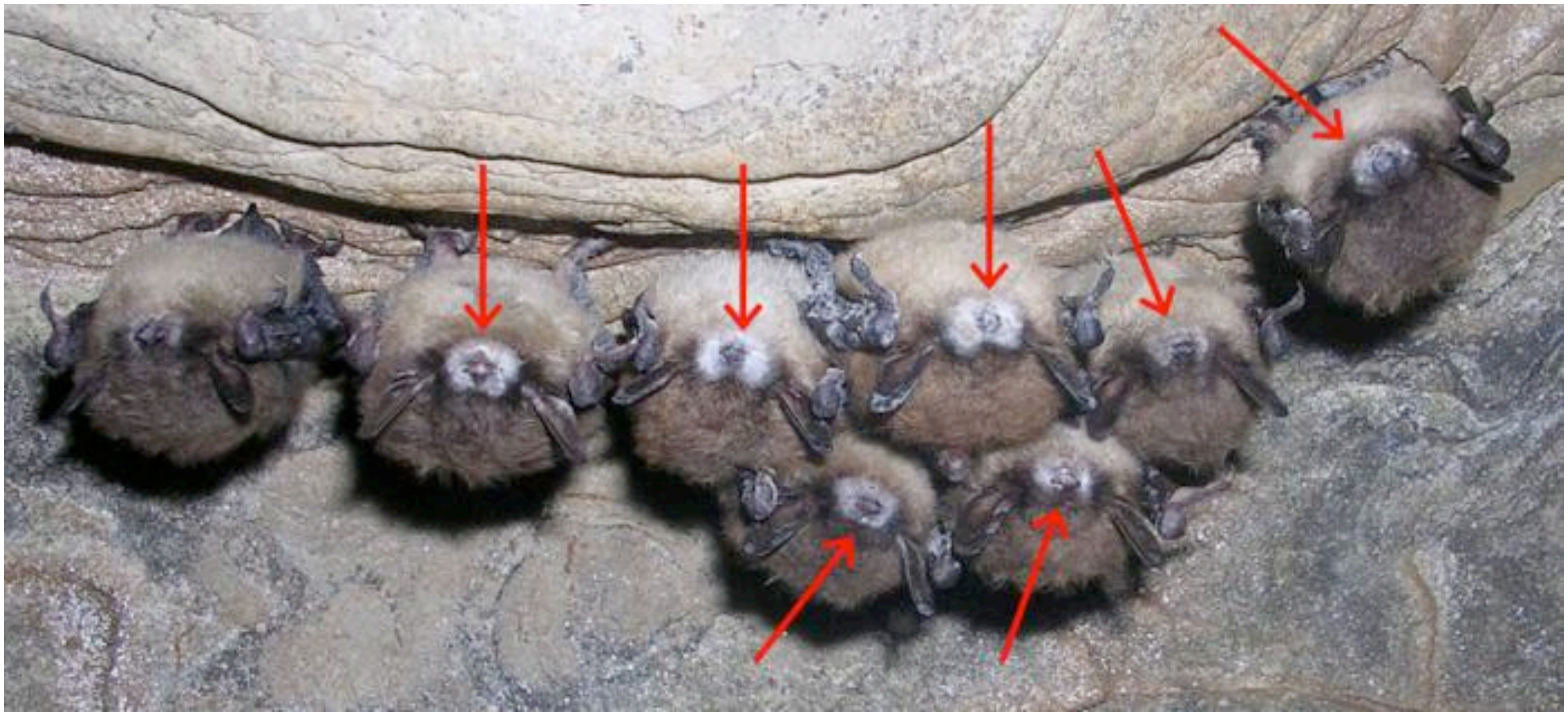
What We Know and Don't Know About White-Nose Syndrome



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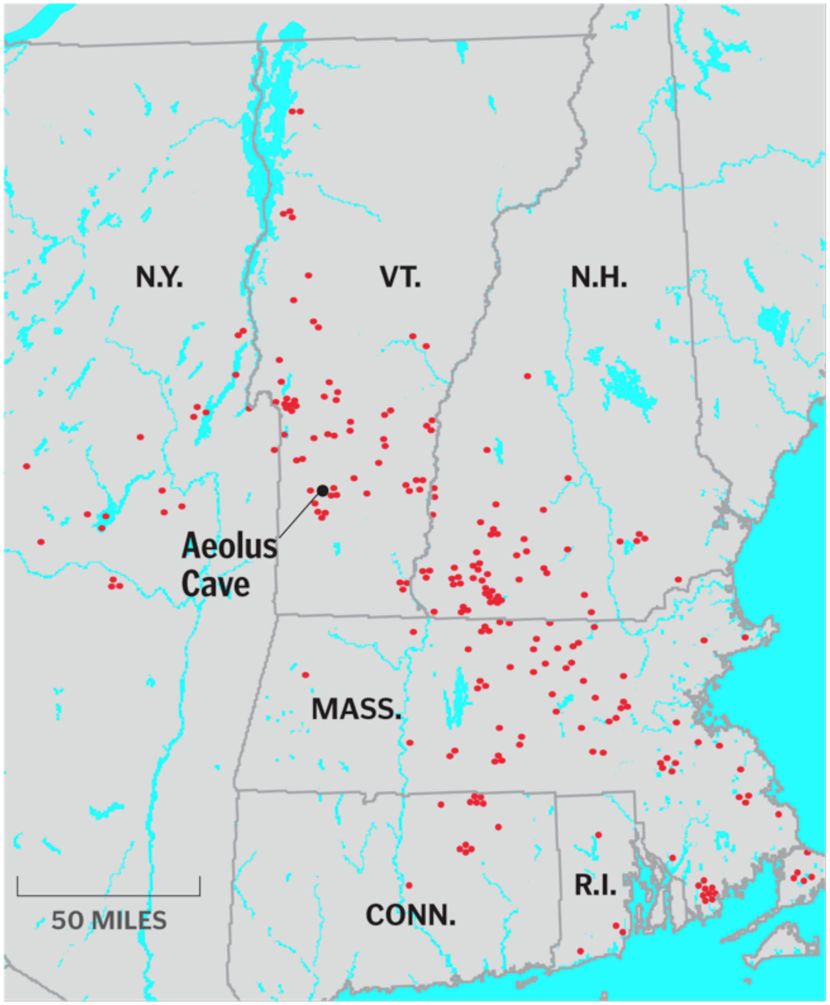
Unprecedented mortality observed in hibernating bats from the Northeastern United States (2008-2009)

Dead little brown myotis on the floor of Aeolus Cave, Vermont
(February 2009)

What did we know about little brown myotis before the appearance of WNS?

Summer distribution of little brown myotis that hibernate in Aeolus Cave

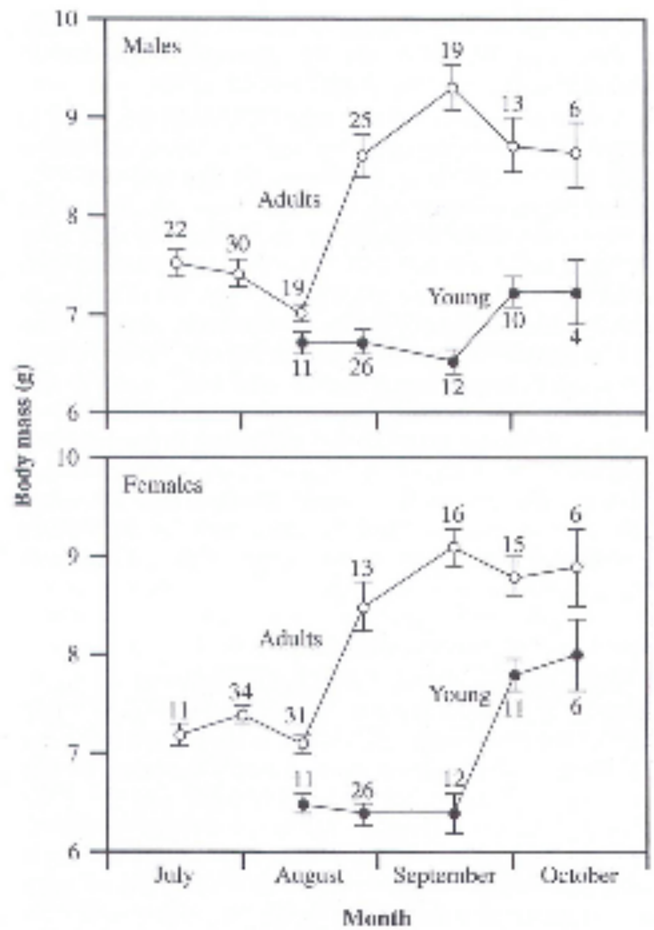


Map by David Butler, Boston Globe,modified from Davis and Hitchcock (1965). Journal of Mammalogy

Each fall, little brown myotis (*Myotis lucifugus*) migrate from maternity roosts to swarming sites that can also serve as hibernacula.

Each spring, females return to these same maternity roosts throughout the northeastern United States.

Pre-hibernation changes in body mass in little brown myotis (*Myotis lucifugus) at* Aeolis Cave



- Rapid gain in adult body mass begins in mid-August
- Rapid gain in juvenile body mass begins in mid-September
- Small loss of body mass in late September coincides with autumn mating

Kunz et al. (1998). Ecoscience, 5: 7-17.

Research on White Nose Syndrome

Overall Goals

- To identify causes and consequences of this emerging disease
- To provide science-based knowledge for making sound management decisions

Challenges

- Inadequate funding
- Slow response to funding requests
- Moving targets (uncertainty of what constitutes and unaffected site)
- Inadequate Coordination (too many cooks in the same kitchen)
- Small samples for analysis (in part, due to reduced colony sizes)

Some Basic Research Questions

- What is WNS?
- Where did WNS come from?
- How is WNS manifested?
- What is the underlying cause of WNS?
- Is the fungus associated with WNS pathogenic or is it a saprophytic opportunist?
- Are bats affected with WNS immunocompromised?
- What is the mode of transmission of the fungus associated with WNS?
- What is the geographic distribution of the fungus?
- Why do bats affected by WNS die in mid-winter?
- Do pre-hibernating bats fail to deposit adequate fat reserves in autumn?

More Basic Research Questions

- Do hibernating bats affected with WNS prematurely deplete their fat reserves?
- Why are the fat reserves of hibernating bats depleted by mid-winter?
- What other conditions are associated with WNS?
- Can bats survive exposure to the fungus associated with WNS??
- Can the transmission and spread of WNS be slowed or stopped?
- Can a fungicide be developed to treat bats affected with WNS?
- Should bats and or caves be treated with a fungicide to reduce its spread?
- Could a field test be developed to detect the fungus before external symptoms appear?
- Does WNS adversely affect summer bat populations? If so, how?
- Are some bats resistant to WNS?

What Do We Know?

A newly described psychrophilic fungus (*Geomyces destructans*)[1]

- This fungus grows optimally at temperatures ranging from 4-14 ^{o}C, typical of many hibernacula in North America/
- Microscopic images indicate that some fungal sampled from bats in Europe have the same unique morphology as *G. destructans* in the North America.
- Genetic analyses suggest that certain European fungal isolates from bats may also be *G. destructans*

Fungal hyphae and conidia from G. *destructans* in North America

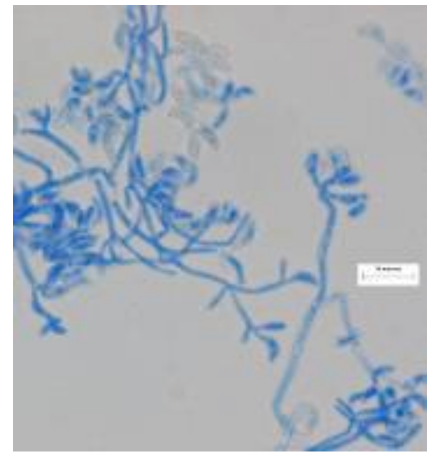


Photo courtesy of USGS
National Wildlife Health Center

Fungal hyphae and conidia from *Geomyces* sp. in Europe

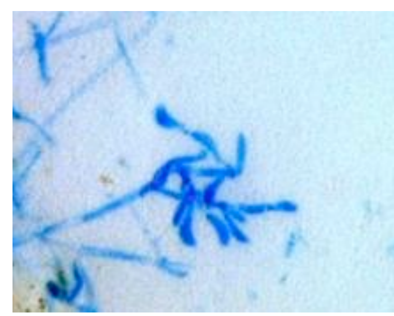
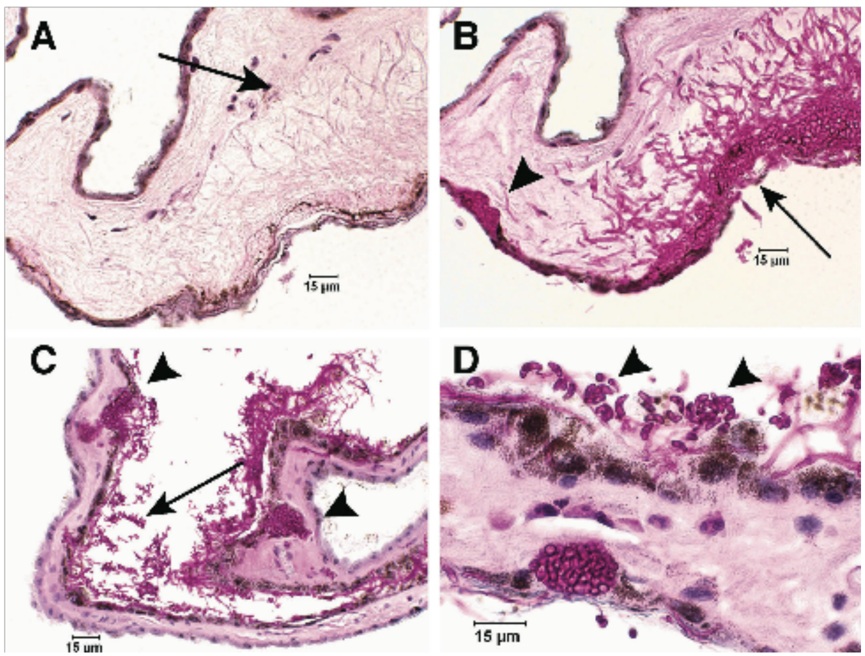


Photo courtesy of:Ludwig E. Hoelzle, University of Zurich, and Fabio Bontadina, Institute of Ecology and Evolution, Conservation Biology, Bern, Switzerland

[1]Gargas et al. (2009). Mycotaxon, 108: 147-154.

White-nose syndrome is a cutaneous fungal disease of hibernating bats associated with a novel fungus (*Geomyces destructans*)[1]



[1]Meteyer, et al. 2009. J. Vet. Diagn Invest. 21: 411-4141.

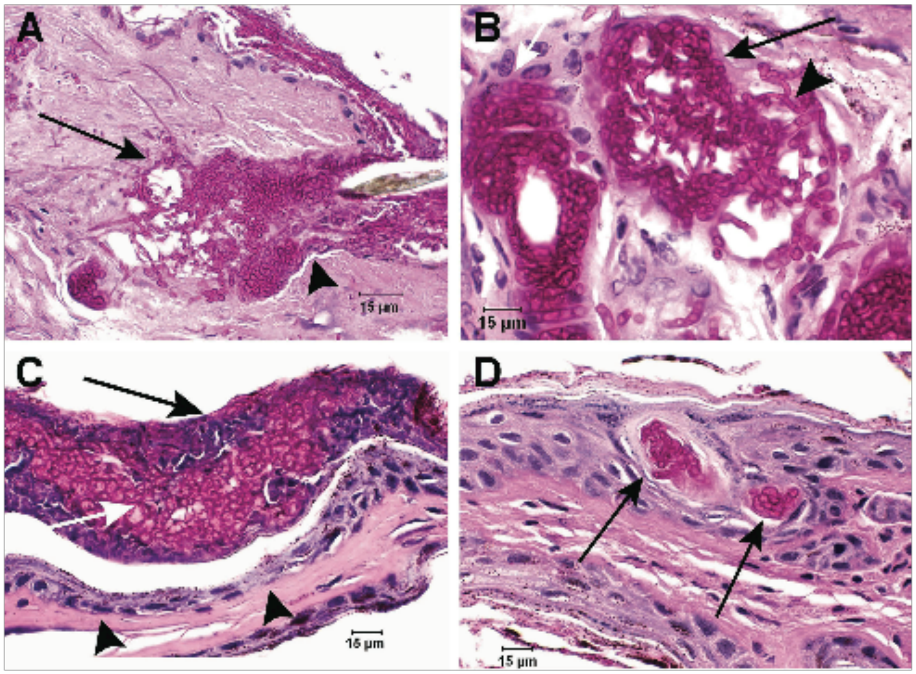
A. Invasive fungus (arrow) with no evidence of inflammation of wing membrane.

B. Fungal hyphae are associated with cup-shaped epidermal erosions (arrow head) and ulcers with invasion of underlying tissues (arrow).

C. Fungal growth is present on the surface of skin (arrow) and penetrates the wing membrane without associated inflammation.

D. Fungal conidia on the surface of a wing membrane (arrow heads).

Histological sections of the muzzle and wing membrane of little brown bats affected with white-nose syndrome[1]



[1]Meteyer, et al. 2009. J. Vet. Diagn Invest. 21: 411-414.

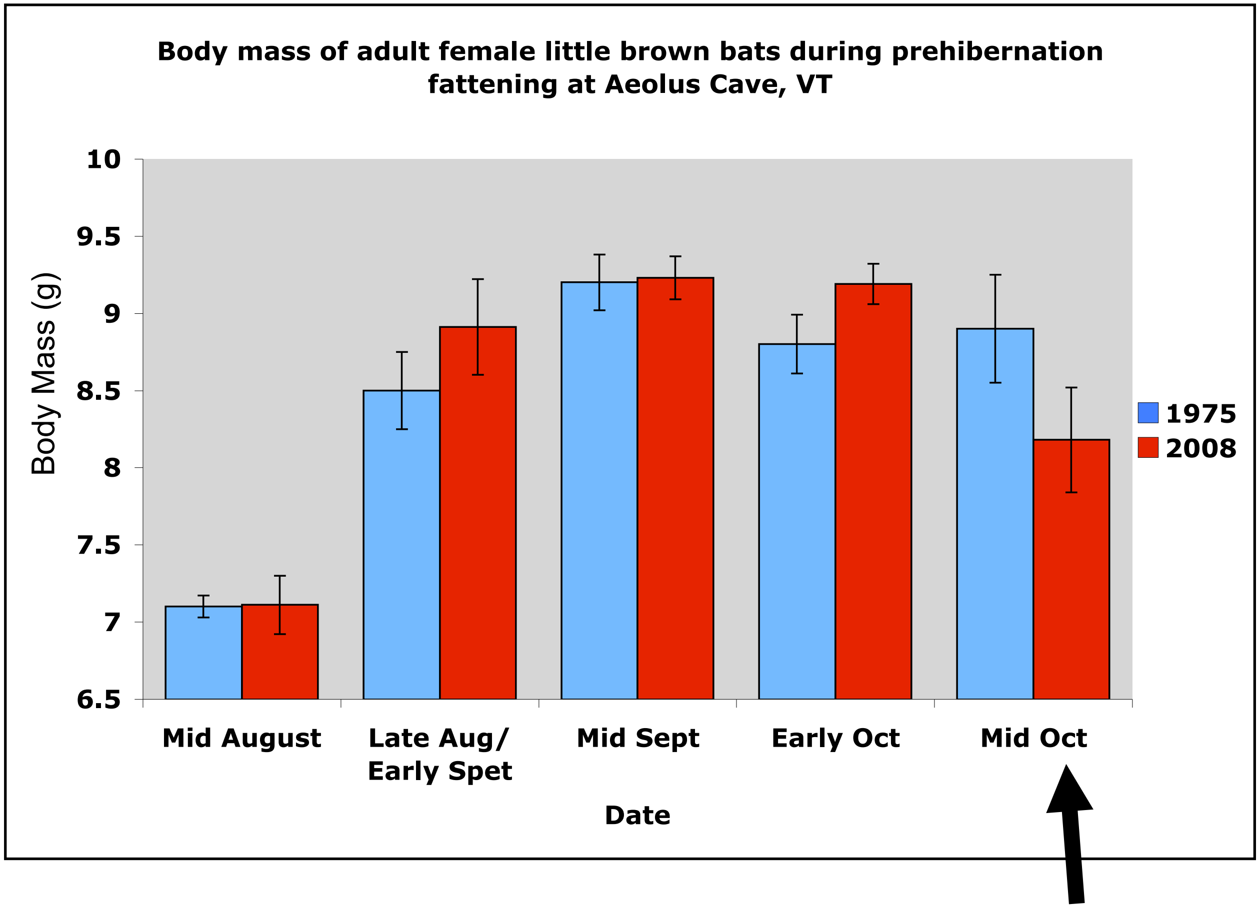
A. Section of bat muzzle showing fungal hyphae filling a hair follicle.

B. Section of a bat muzzle showing fungal hyphae in the hair follicle (arrow head) and filling a sebaceous gland (arrow).

C. Section of wing membrane showing inflammatory cells (arrow) surrounding fungal hyphae (white arrow), forming a cellular crust over epidermis (arrow heads)

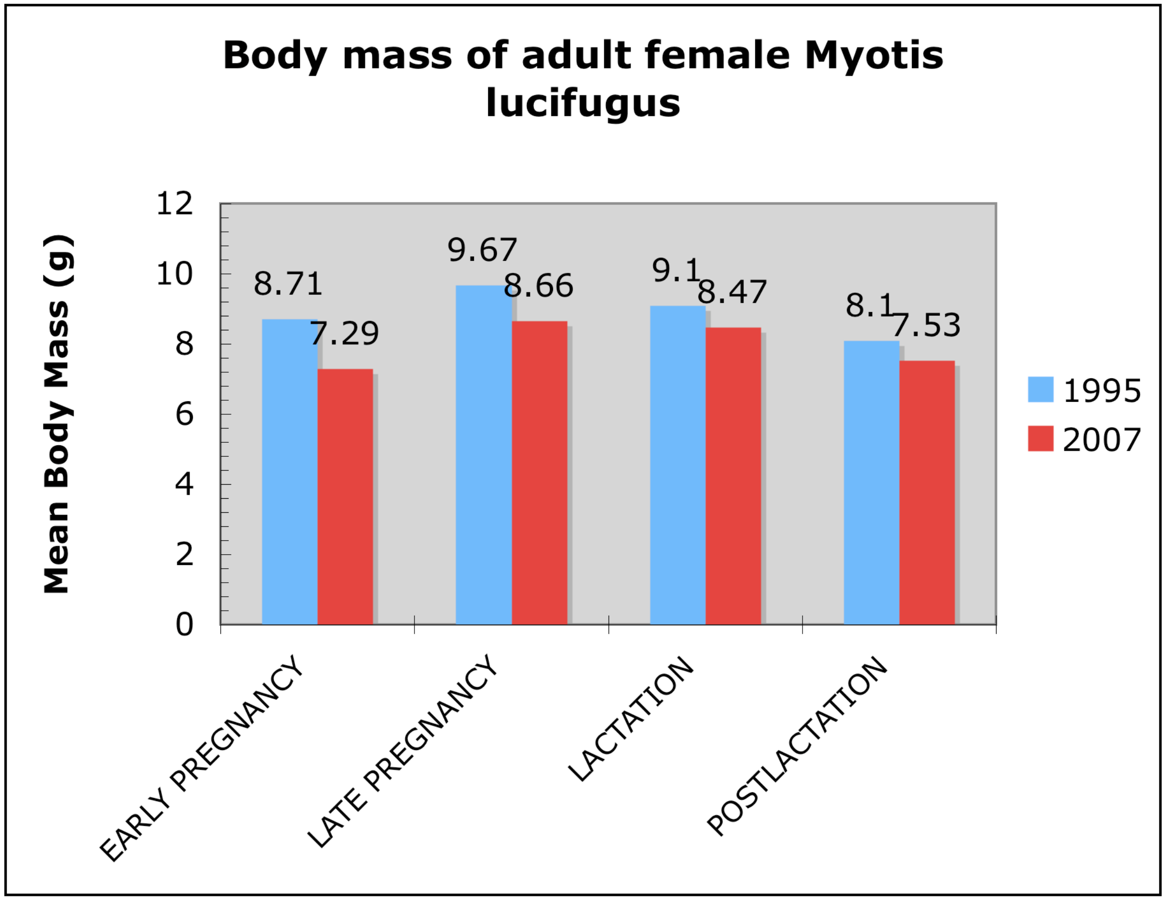
D. Quiescent clusters of fungus in the wing membrane (arrows)

Body masses of adult females entering hibernation (mid-October) were significantly less during the post-WNS period than during the pre-WNS period



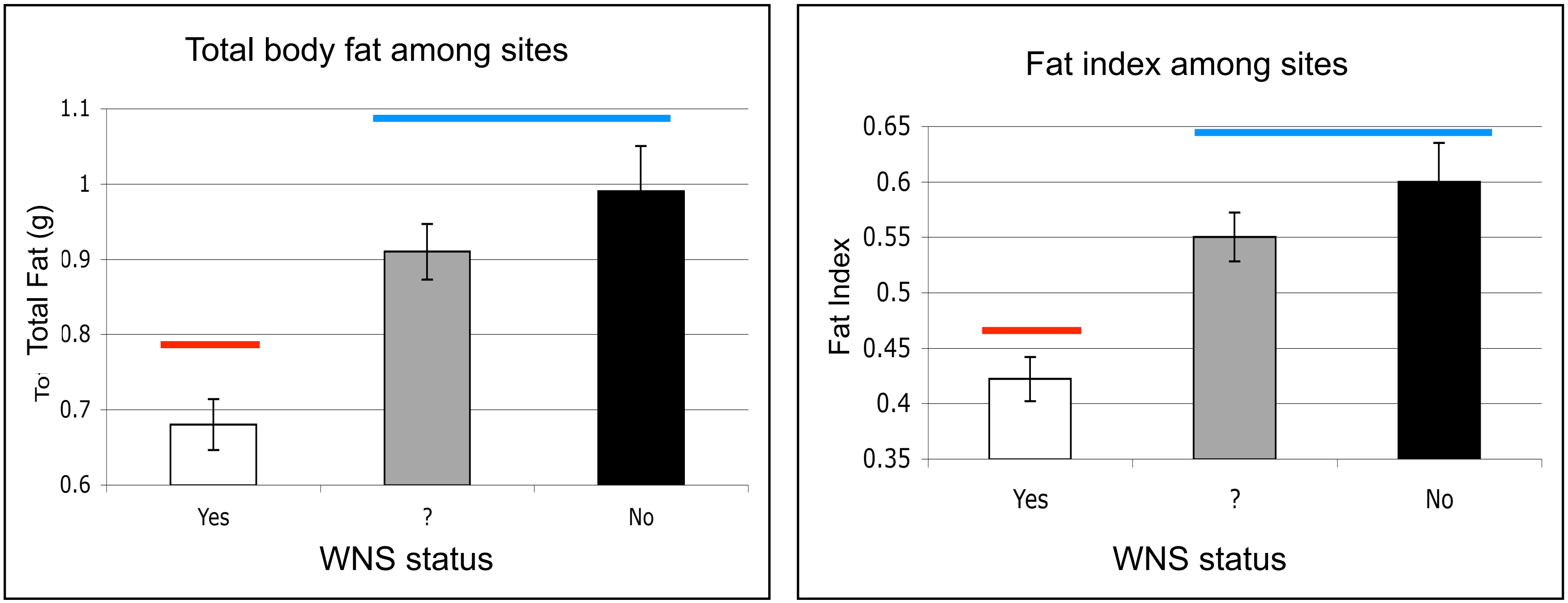
Prehibernation body masses of adult female little brown myotis during the Pre-WNS period (Kunz et al., 1998) and Post-WNS period (Reichard and Kunz, in prep.)

Mean body masses of adult females were significantly lower during each reproductive stage during the post-WNS period compared to the pre-WNS period



Body mass of female little brown myotis at maternity colonies during Pre-WNS (Blue) and Post-WNS (Red) periods (Reichard & Kunz, in prep., 1995 data from Reynolds and Kunz, 1999)

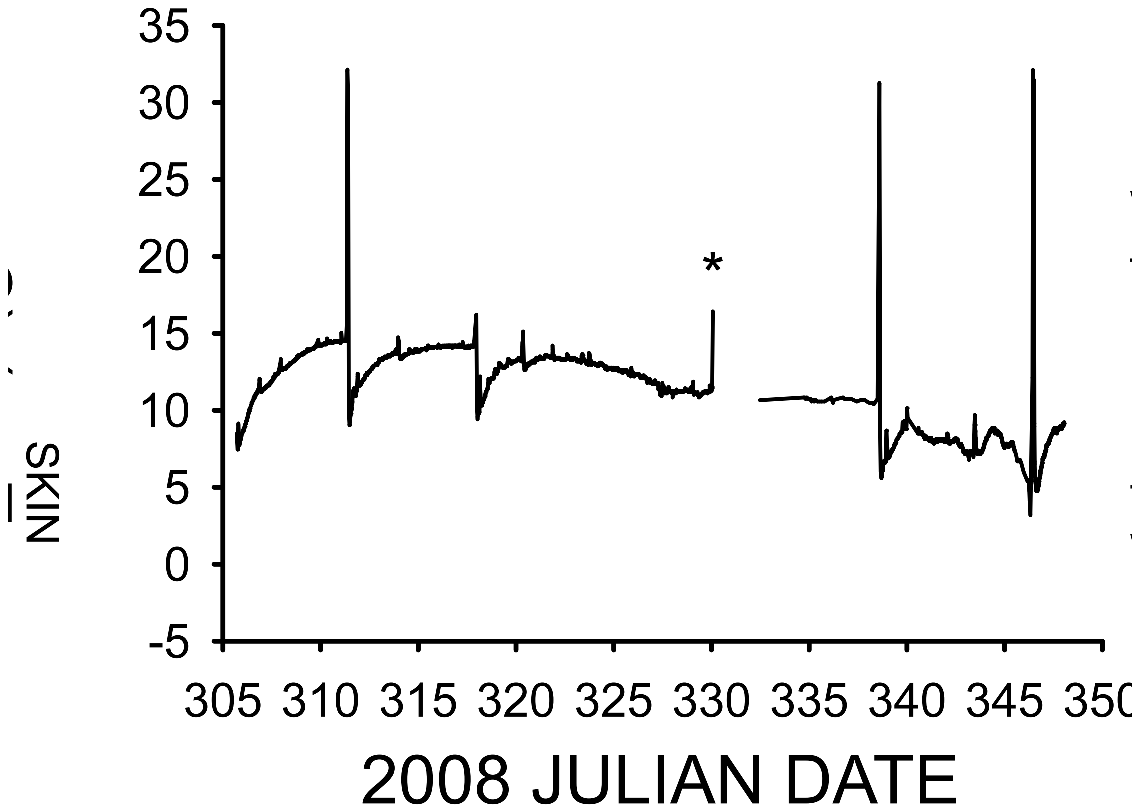
Adult females from WNS affected sites have significantly smaller body fat reserves and lower fat indices than bats from questionably unaffected and unaffected sites



Total Body Fat and Fat Index of Adult Female Little Brown Myotis Captured in February 2008 (Reichard and Kunz, in prep.)

Key: ☐ Affected sites ■ Unaffected sites but near affected sites ■ Unaffected site

Little brown bats with symptoms of WNS arouse more frequently than those without symptoms of WNS



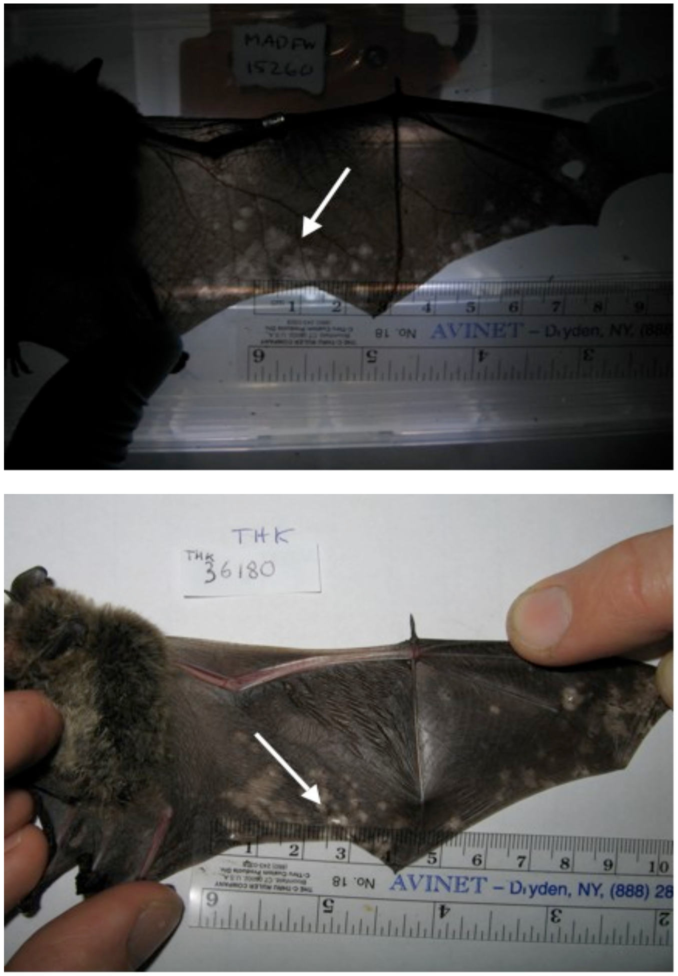
Bats with WNS have torpor bouts 38 to 60% shorter than What was previously reported from non-WNS affected bats.

Bats with WNS experience 1.7 to 2.6 times more arousals than bats that do not have WNS.

Frequency of arousals appear to be related to amount of polyunsaturated fatty acids present in white fat reserves (Craig Frank, pers. comm.)

Little Brown Myotis with Damaged Wings Captured Within the Affected Summer Range of WNS

WDI 2 (Moderate)

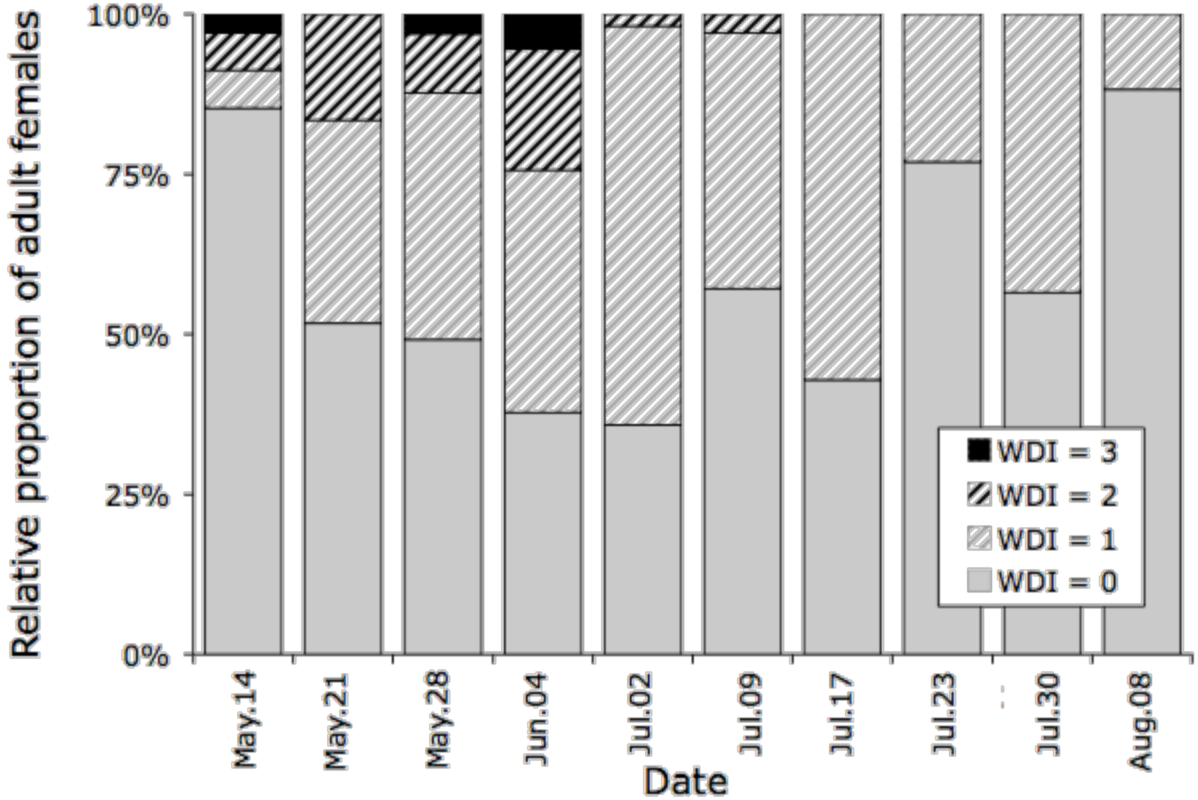


Scaring and heavy spotting

WDI 2 (Severe)

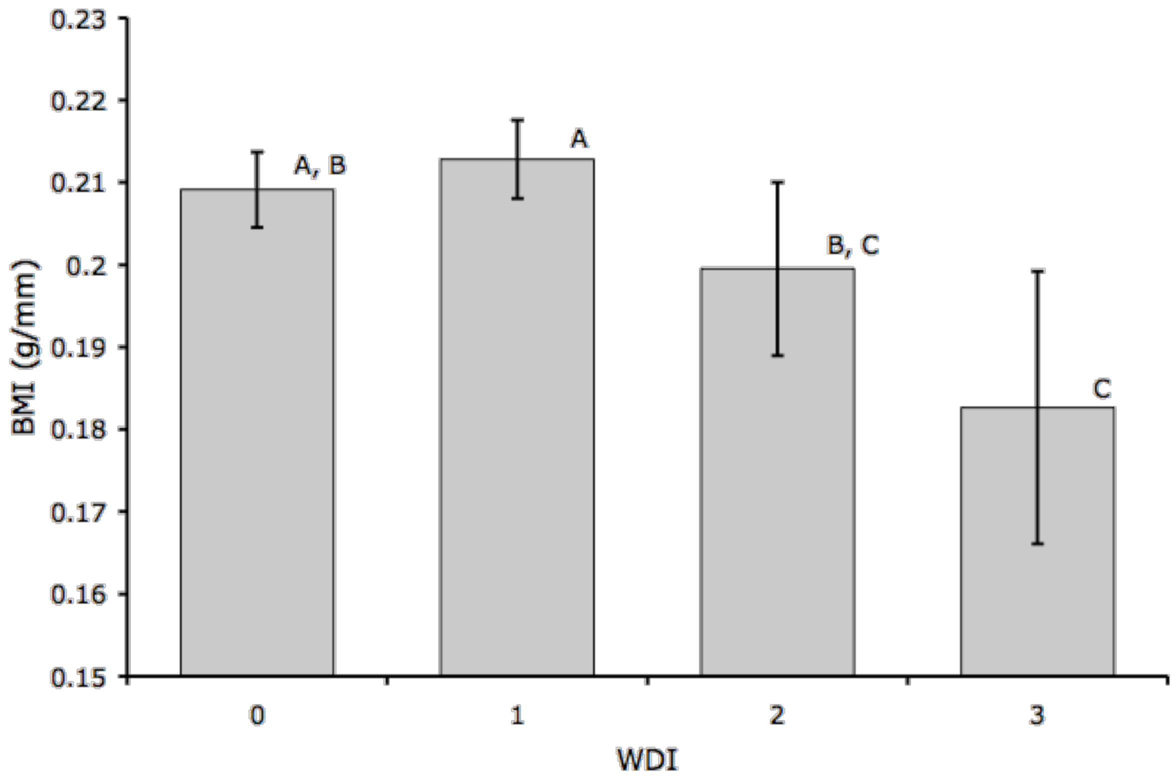
Necrosis and loss of membrane

The most severe wing damage was observed from mid- to late-May, and least in mid-summer



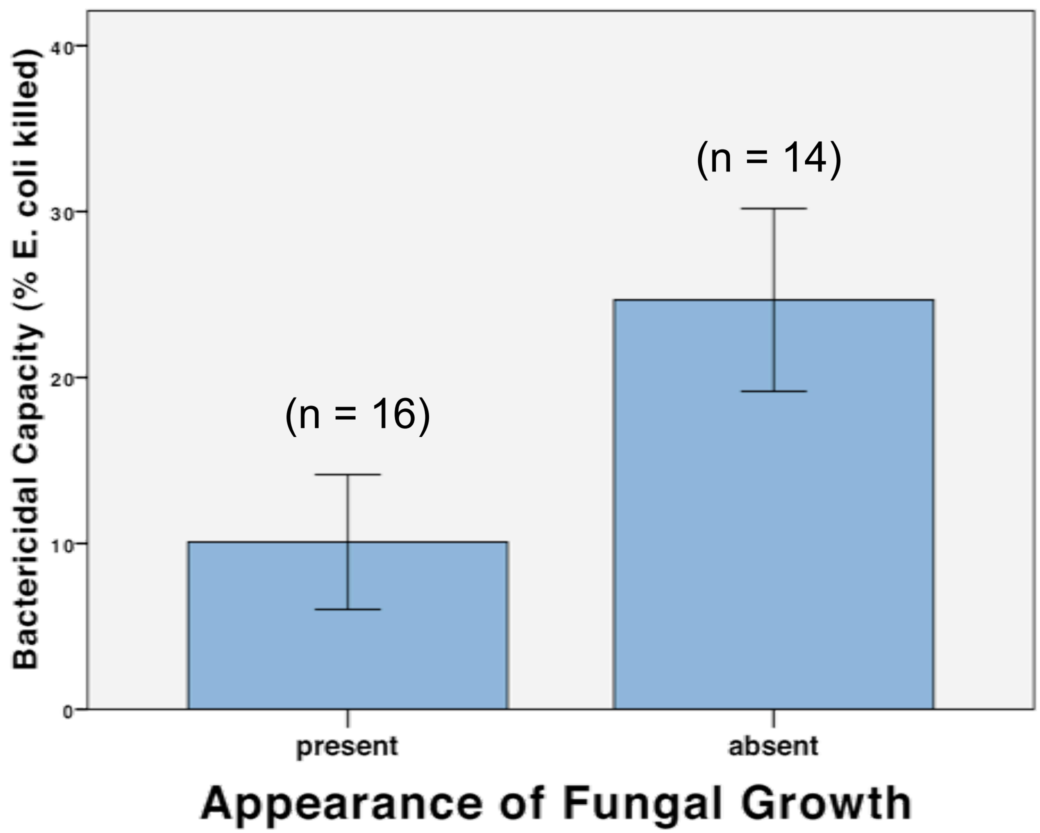
Prevalence of wing damage in adult female little brown Myotis from maternity colonies in New England

Bats with the most severe wing damage had the lowest body condition index



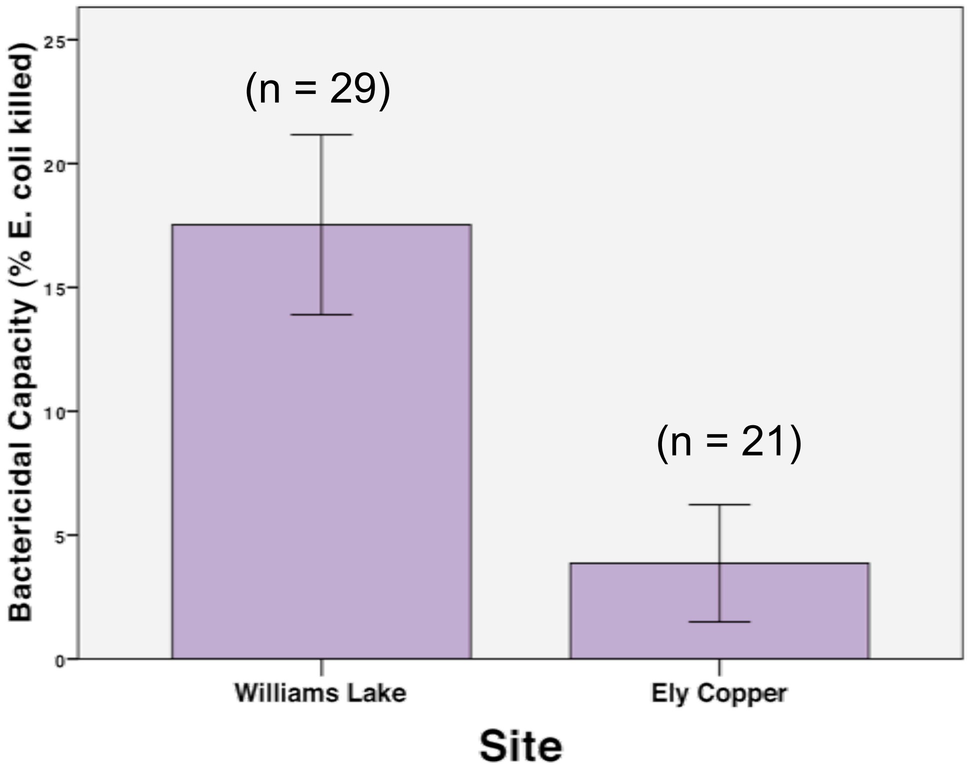
Body condition index of adult female little brown myotis with different levels of wing damage

Bats with fungal growth have a significantly lesser bactericidal ability compared to bats without visible fungal growth



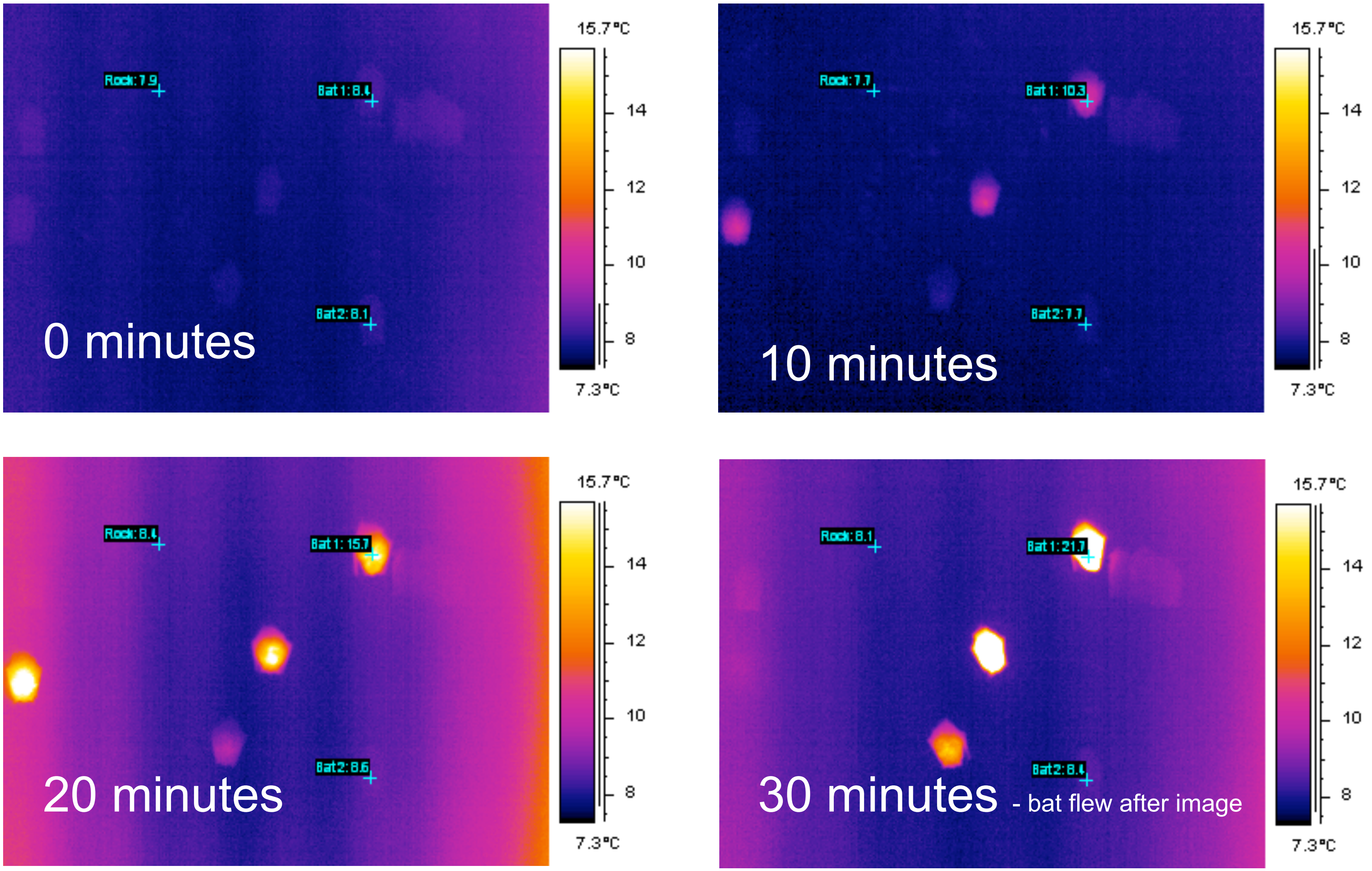
Bactericidal Capacity of Blood from Adult Female Little Brown Myotis During the Winter of 2007-2008 (Moore and Kunz, in prep.)

Bactericidal capacity of blood collected from adult little brown *Myotis* was higher at affected site Williams Lake Complex) compared to an unaffected site (Ely Copper Mine)

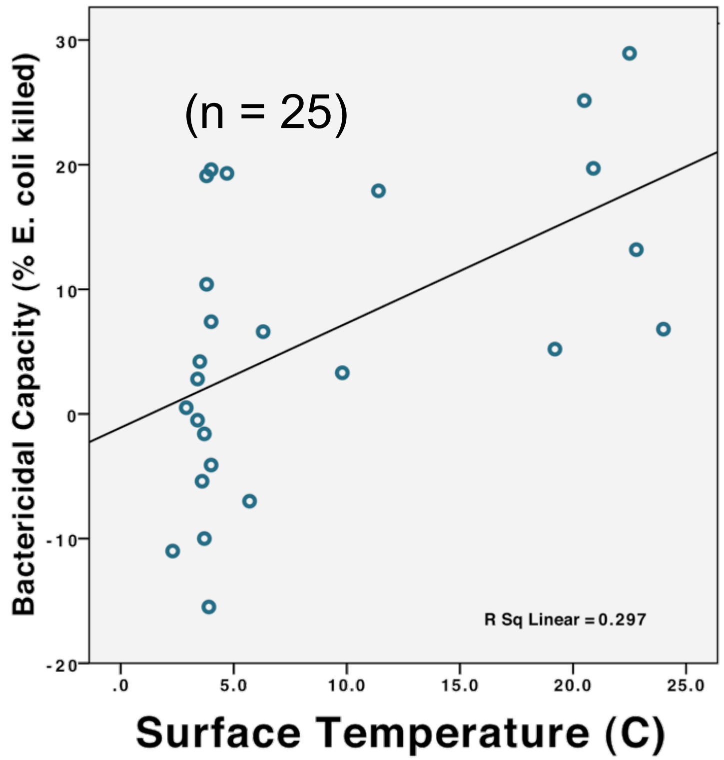


Blood from Williams Lake Complex (a site affected by WNS) was significantly better at killing bacteria that blood collected from bats at the Ely Copper Mine (a site that was presumed to be unaffected by WNS at the time bats were sampled)

Arousals of hibernating bats and assessment of immune responses can be quantified using thermal infrared imaging

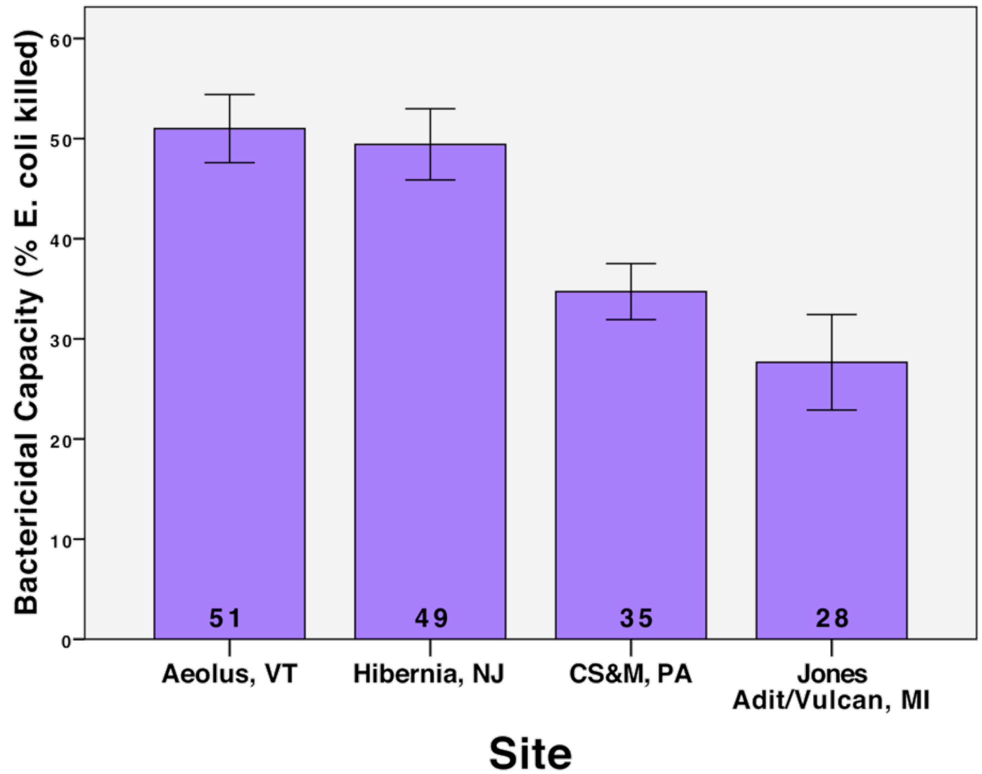


Bactericidal capacity of blood increases significantly with body surface temperature



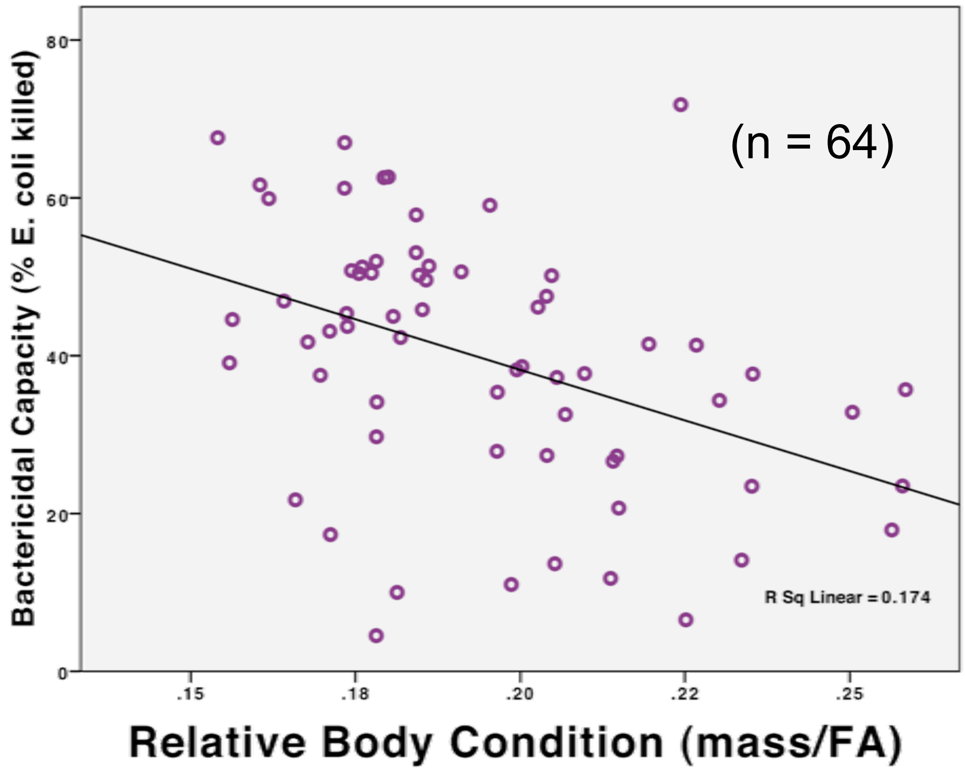
Bactericidal Capacity of Blood From Adult Female Little Brown Bats with Different Body Surface Temperatures Collected During the Winter of 2007-2008 (Moore and Kunz, in prep.)

Blood samples collected from bats at sites affected by WNS have higher bactericidal capacity compared to samples from sites unaffected by WNS



Bactericidal capacity of blood from adult female little brown myotis captured during the winter of 2008-2009 from two affected and two presumably unaffected sites (Moore & Kunz, in prep.)

Bactericidal capacity of blood decreases significantly with increasing body condition of bats



Relationship between bactericidal capacity and body condition in little brown myotis during the winter of 2008-2009 (Moore, Reichard, and Kunz, in prep.)

What We Know About WNS

- Body masses and fat indices of bats during the pre-hibernation period in 2008 were comparable to those collected during the pre-WNS period in 1975.
- Total body fat and fat indices of bats were lower during early hibernation in 2008 compared to those collected during the pre-WNS period in 1975.
- Bats with visible signs of WNS captured in hibernacula in mid-winter in 2008 had lower fat reserves and higher water content that those without signs of WNS.
- Body masses of bats captured at maternity colonies in the post-WNS period were lower than those captured in the pre-WNS period.
- Bats with WNS arouse more frequently than bats without WNS.
- Frequency of arousals appear to be related to amount of polyunsaturated fatty acids.
- Among bats that survived hibernation in 2007-2008, many bats showed signs of wing damage--ranging from 1-3 (using a scale from 0 (no damage) to 3 (severe damage).
- The most severe damage was observed soon after bats arrived at maternity sites. Fewer bats with wing damage were observed as the summer progressed.
- Wing damage observed in bats that occupy maternity roosts may have adverse consequences for successful foraging, reproductive success, and ultimately for survival.
- Bats collected from affected sites have greater bactericidal ability compared to bats collected from unaffected sites.
- Bats collected only from affected sites, but with conspicuous fungal growth show significantly reduced ability to kill bacteria than those without fungal infection.
- Bats with low body condition show increased bactericidal capacity.
- Bats with low body surface temperature show reduced bactericidal capacity.

What We Don't Know About WNS

- Is the newly described cold-loving fungus associated with WNS the primary cause of mortality in hibernating bats? If so, what is the mode of action of the fungus in killing bats?

- What is the geographic distribution of the fungus associated with WNS?

- If the fungus is not the cause of WNS, is this condition a secondary manifestation of other underlying factor or factors? If so, what are these factors?

- Are pathogens (bacteria or viruses) a direct or indirect cause of mortality in bats affected by WNS?

- Are contaminants a direct or indirect cause of WNS related bat mortality?

- What causes the premature depletion of fat reserves in bats affected by WNS?

- Can bats mount affective immune responses to the fungus associated with WNS or to other potential pathogens or contaminants?

- Are some bats genetically or immunologically resistant to WNS and thus can survive infection?

- How does WNS affect bats at maternity colonies?

- What is the mode of transmission of WNS?

- Can we predict geographic limits to the spread of WNS?

- Can we slow or stop the spread of WNS?

- Can we reduce the mortality of bats affected by WNS?

- Can some individuals survive WNS, followed by a subsequent population recovery? If so, can population recovery be facilitated?

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