Overview of Issues Related to Bats and Wind Energy

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Web Version of Presentation to the
Wind Turbine Guidelines Advisory Committee
Technical Workshop & Federal Advisory Committee Meeting
Washington, D.C., 26 February 2008

(talk script included—see upper left of each slide)

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Photo: P. Cryan


Lesser long-nosed bat feeding on flower of Agave
© J. Scott Altenbach


Fishing bat gaffing fish from water
© J. Scott Altenbach

- Long-lived and high survival
- Reproduction low and slow
- Limited population fluctuation
- Slow to recover from pop. impacts
- Seasonal torpor
- Ecological dimorphism

Extent of Impacts to Bat Species

- Available information on bats and turbines
- Species known to be impacted
  - Geographic distribution and movements
  - Similarities of affected bat species
- Protected species - unknown impact
  - Available evidence of risk
  - Geographic distribution

Species of bats in U.S.

	Species name	Common name
1	*Mormoops megalophylla*	Ghost-faced bat
2	*Choeronycteris mexicana*	Mexican long-tongued bat
3	*Leptonycteris nivalis*	Greater long-nosed bat
4	*Leptonycteris yerbabuanae*	Lesser long-nosed bat
5	*Macrotus californicus*	California leaf-nosed bat
6	*Antrozous pallidus*	Pallid bat
7	*Corynorhinus townsendii*	Townsend's big-eared bat
8	*Corynorhinus rafinesquii*	Rafinesque's big-eared bat
9	*Eptesicus fuscus*	Big brown bat
10	*Euderma maculatum*	Spotted bat
11	*Idionycteris phyllotis*	Allen's big-eared bat
12	*Lasionycteris noctivagans*	Silver-haired bat
13	*Lasiurus blossevillii*	Western red bat
14	*Lasiurus borealis*	Eastern red bat
15	*Lasiurus cinereus*	Hoary bat
16	*Lasiurus ega*	Southern yellow bat
17	*Lasiurus intermedius*	Northern yellow bat
18	*Lasiurus seminolus*	Seminole bat
19	*Lasiurus xanthinus*	Western yellow bat
20	*Myotis auriculus*	Mexican long-eared myotis
21	*Myotis austroriparius*	Southeastern myotis
22	*Myotis californicus*	California myotis
23	*Myotis ciliolabrum*	Western small-footed
24	*Myotis evotis*	Western long-eared myotis
25	*Myotis grisescens*	Gray myotis
26	*Myotis keenii*	Keen's myotis
27	*Myotis leibii*	Eastern small-footed myotis
28	*Myotis lucifugus*	Little brown bat
29	*Myotis occultus*	Occult myotis
30	*Myotis septentrionalis*	Eastern long-eared myotis
31	*Myotis sodalis*	Indiana myotis
32	*Myotis thysanodes*	Fringed myotis
33	*Myotis velifer*	Cave myotis
34	*Myotis volans*	Long-legged myotis
35	*Myotis yumanensis*	Yuma myotis
36	*Nycticeius humeralis*	Evening bat
37	*Parastrellus hesperus*	Canyon bat
38	*Perimyotis subflavus*	Eastern pipistrelle
39	*Eumops floridanus*	Florida bonneted bat
40	*Eumops perotis*	Greater mastiff bat
41	*Eumops underwoodi*	Underwood's mastiff bat
42	*Molossus molossus*	Pallas' mastiff bat
43	*Nyctinomops femorosacca*	Pocketed free-tailed bat
44	*Nyctinomops macrotis*	Big free-tailed bat
45	*Tadarida brasiliensis*	Brazilian free-tailed bat

U.S. Endangered Species

	Species name	Common name
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	Species name	Common name
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U.S. Species of Concern

	Species name	Common name
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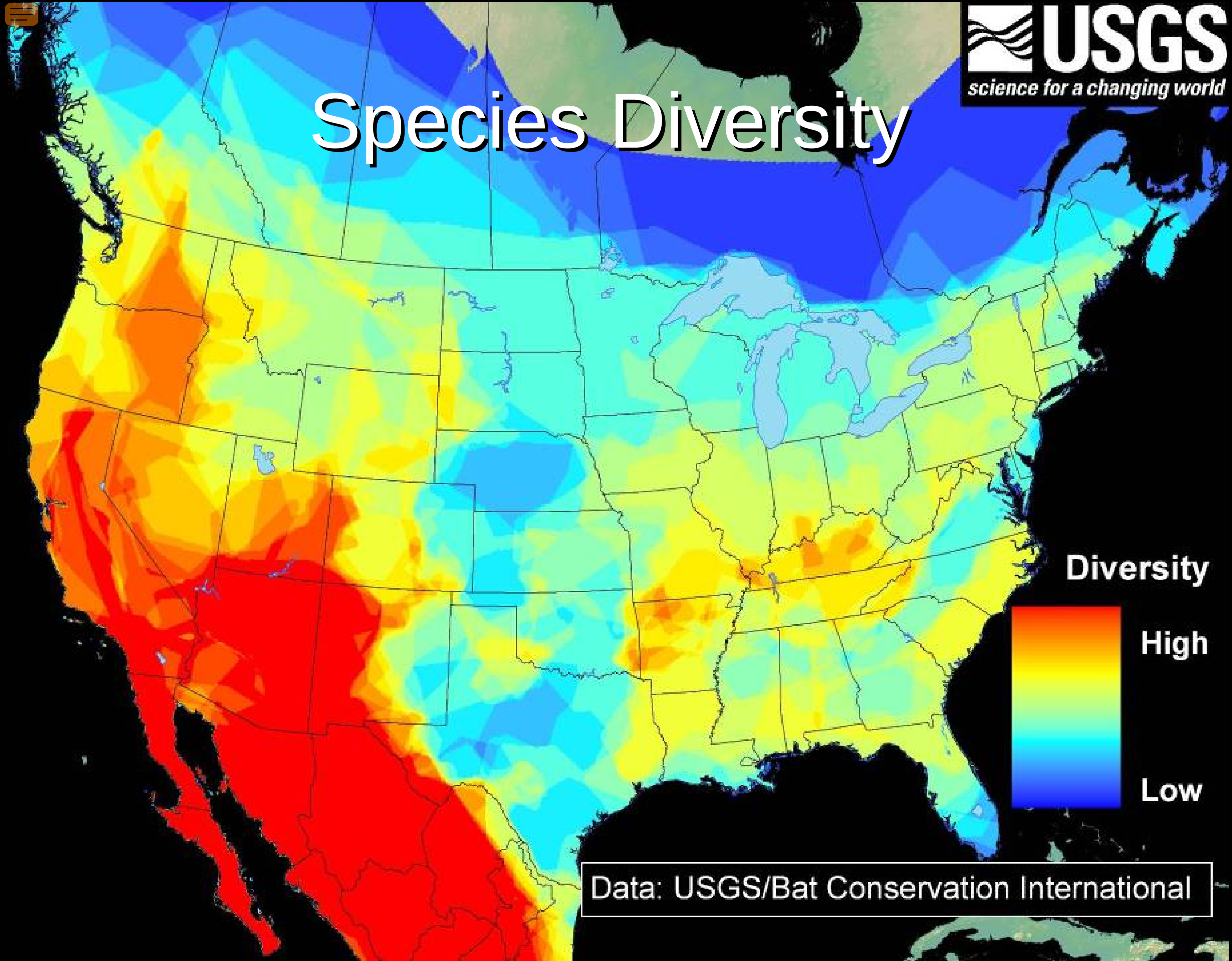
Federal Register 61(235):64481-64485

Species Diversity



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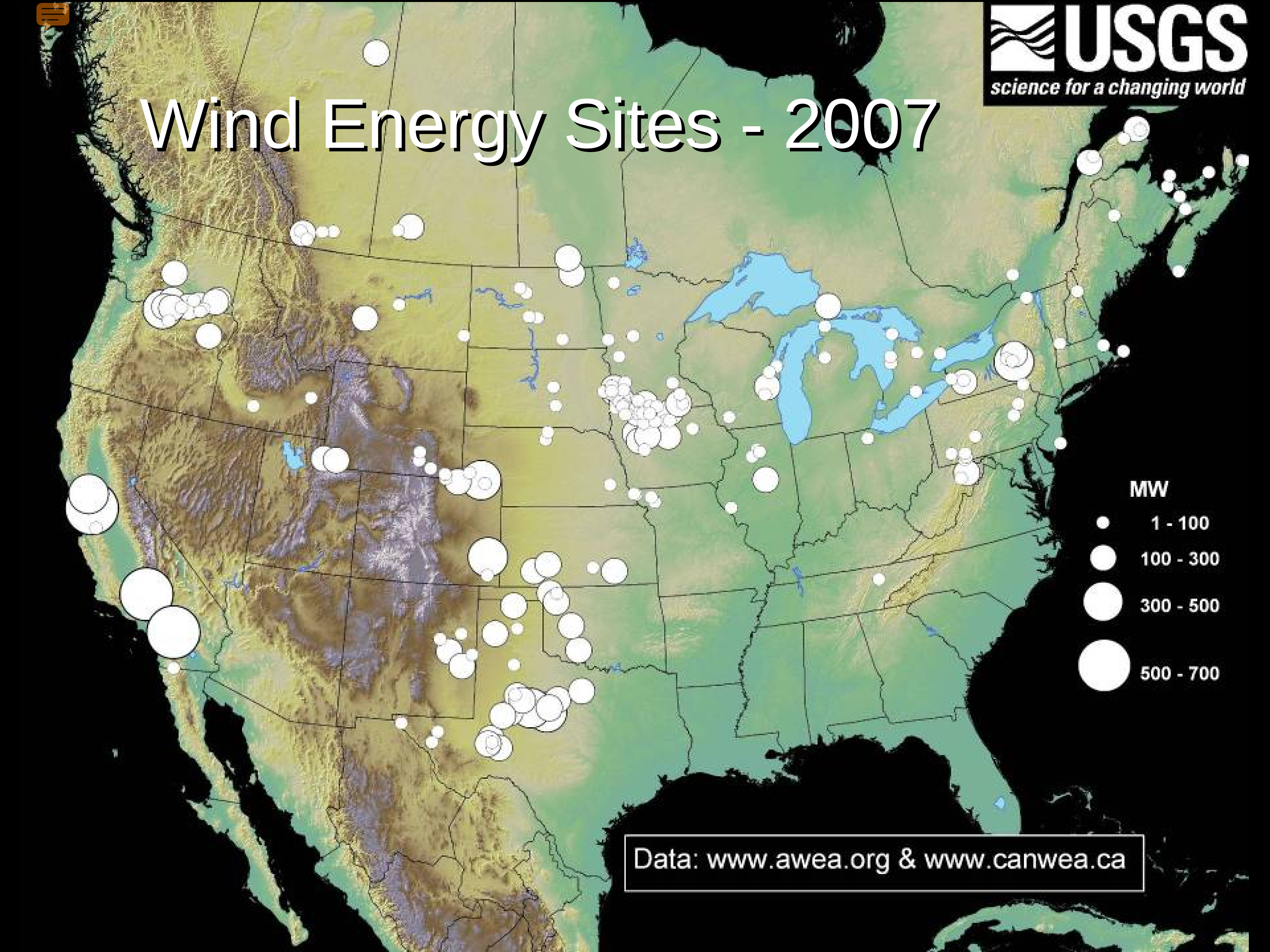
Bats and Wind Energy Cooperative (BWEC)

Bat Conservation International
U.S. Fish & Wildlife Service
American Wind Energy Association
National Renewable Energy Laboratory

AES Wind Generation
Binary Acoustic Technology
Boston University
BP Alternative Energy
California Dept. Fish and Game
FPL Energy
Freilandforschung
Humboldt State University
Illinois Natural History Survey
Leibniz Universität Hannover
Northeast Ecological Services
NY Dept. of Env. Conservation
Oregon State University
Pandion Systems
Pennsylvania Game and Fish
PPM Energy

Swedish University of Ag. Sci.
Tennessee Valley Authority
TransAlta Wind
U.S. Bureau of Land Management
U.S. Forest Service
U.S. Geological Survey
University of Bristol
University of Calgary
University of California
University of Erlangen-Nuremberg
University of Florida
VA Dept. of Game and Inland Fisheries
WEST, Inc.
Western Michigan University
WV Div. Natural Resources

Wind Energy Sites - 2007



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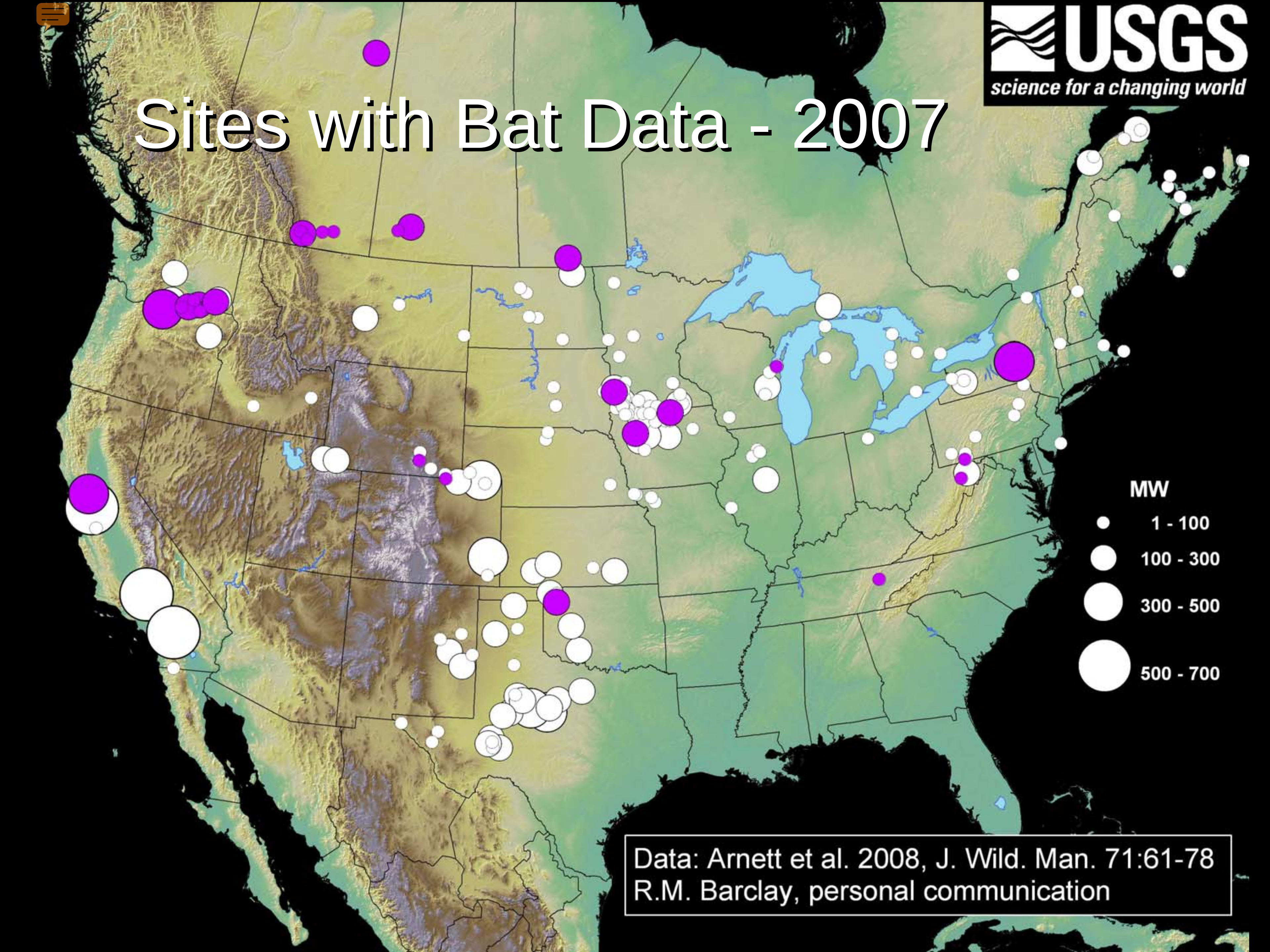
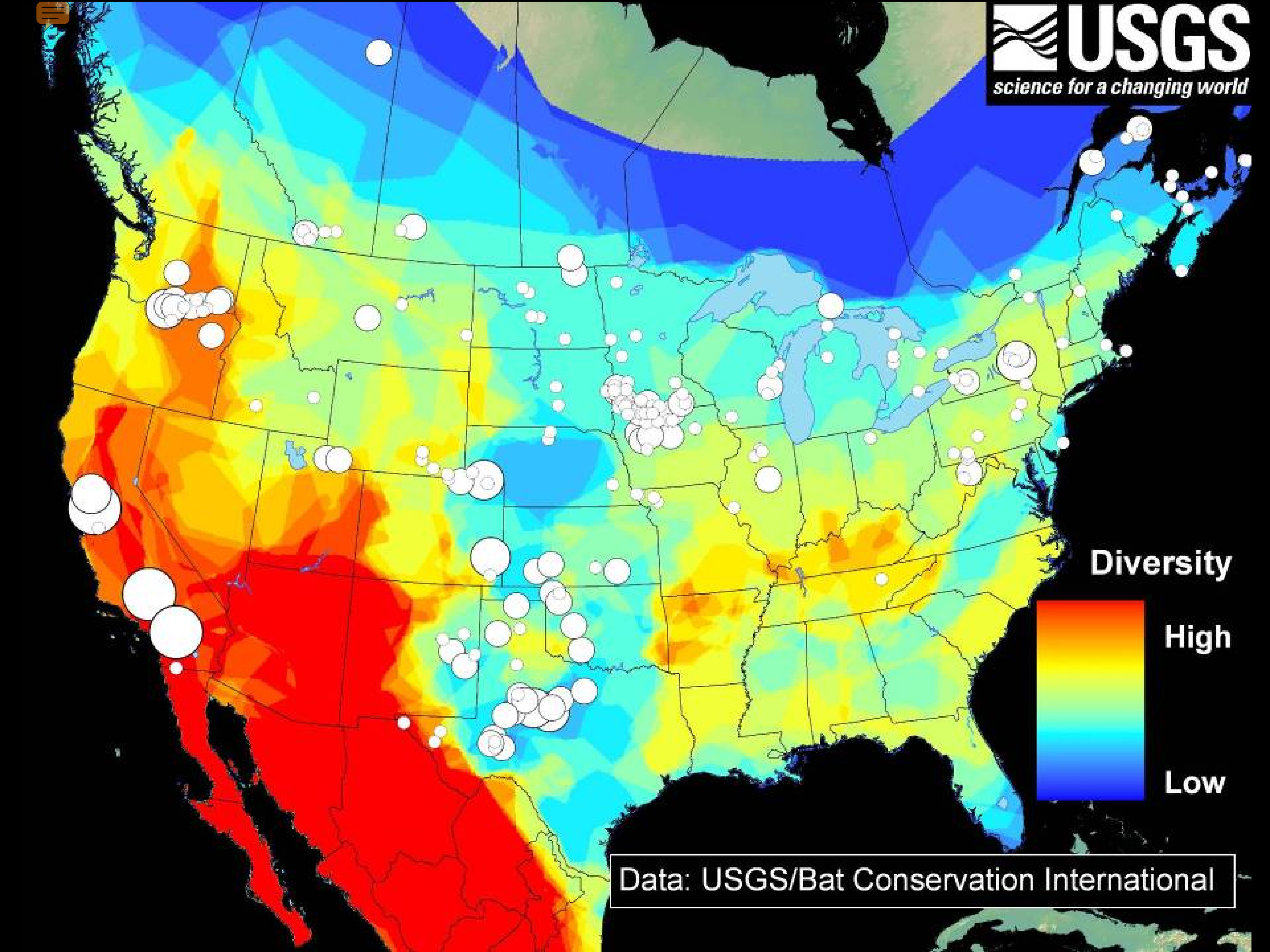
Sites with Bat Data - 2007



Data: Arnett et al. 2008, J. Wild. Man. 71:61-78
R.M. Barclay, personal communication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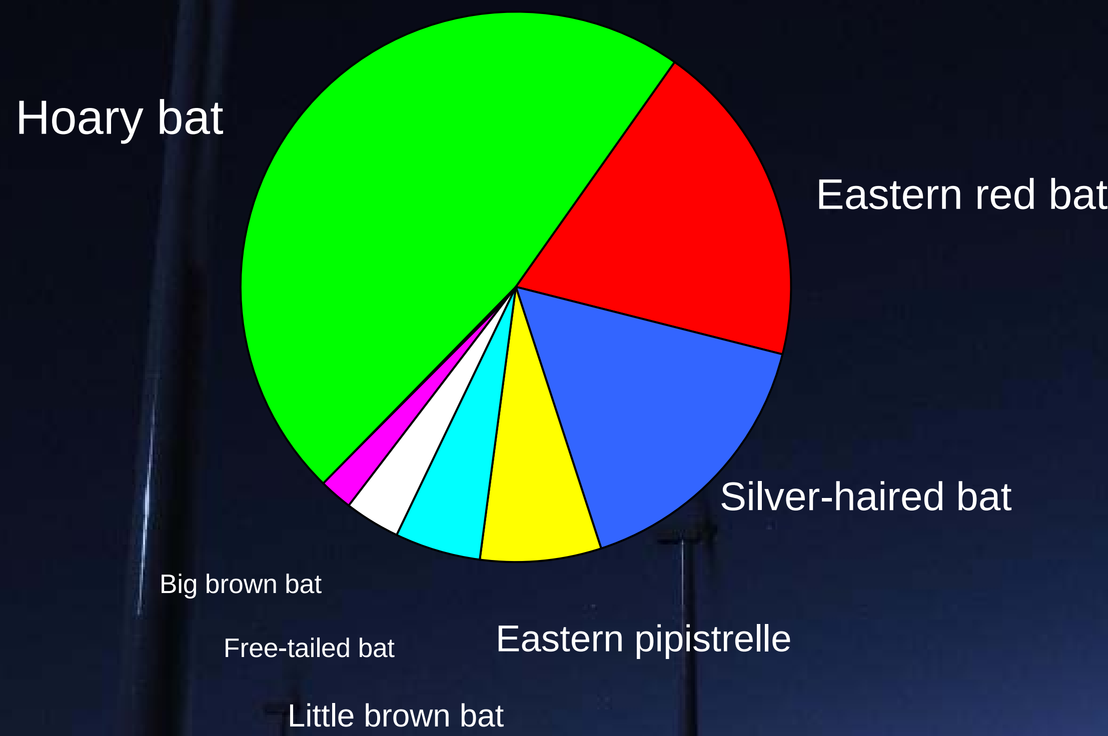
Diversity
High
Low
Data: USGS/Bat Conservation International

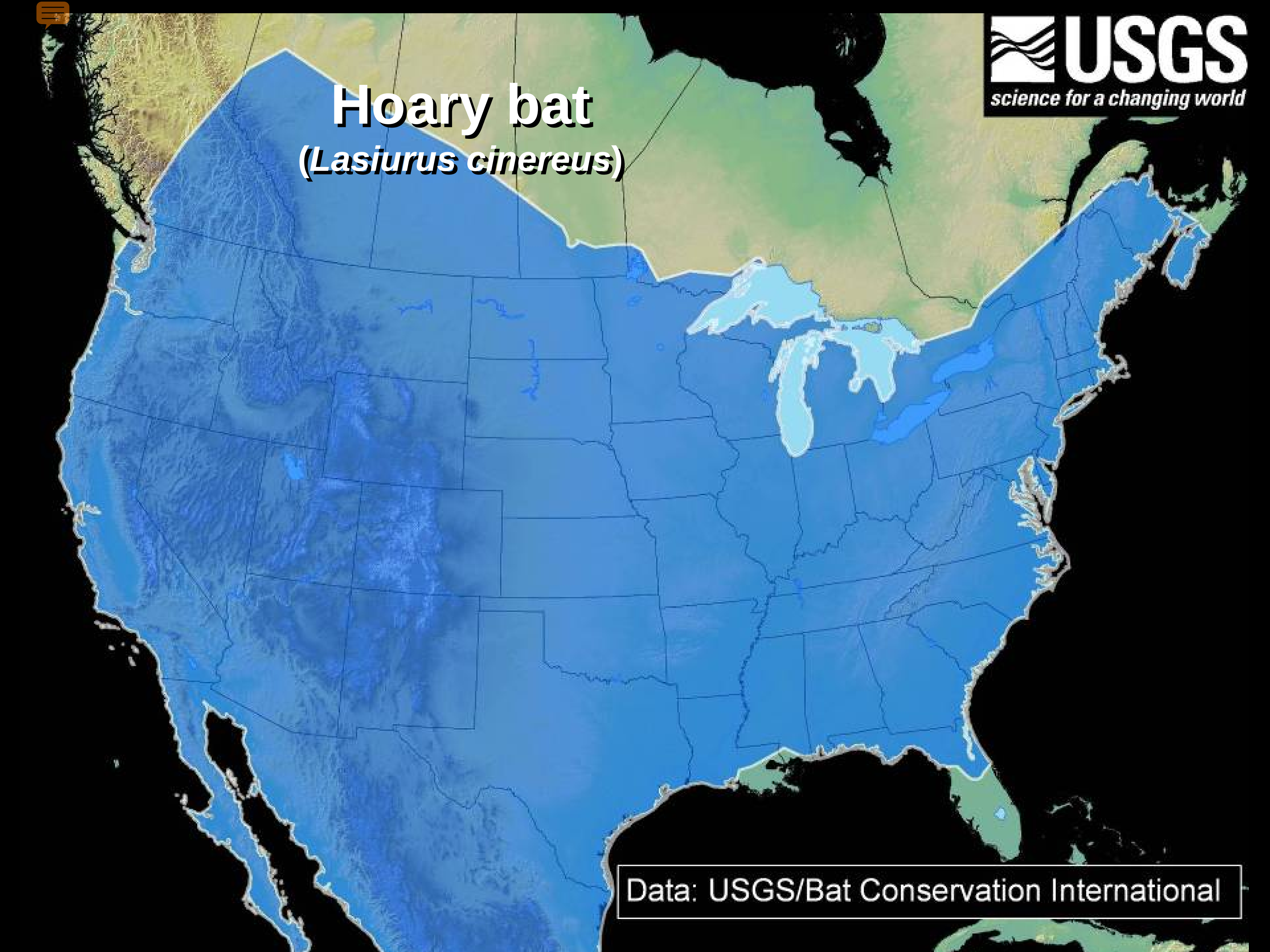
Species involved in North America

***n* = 3,974**



[copyrighted photos removed]

Data: Arnett et al. 2008; J. Wild. Man. 72:61-78


Hoary bat
(*Lasiurus cinereus*)
USGS
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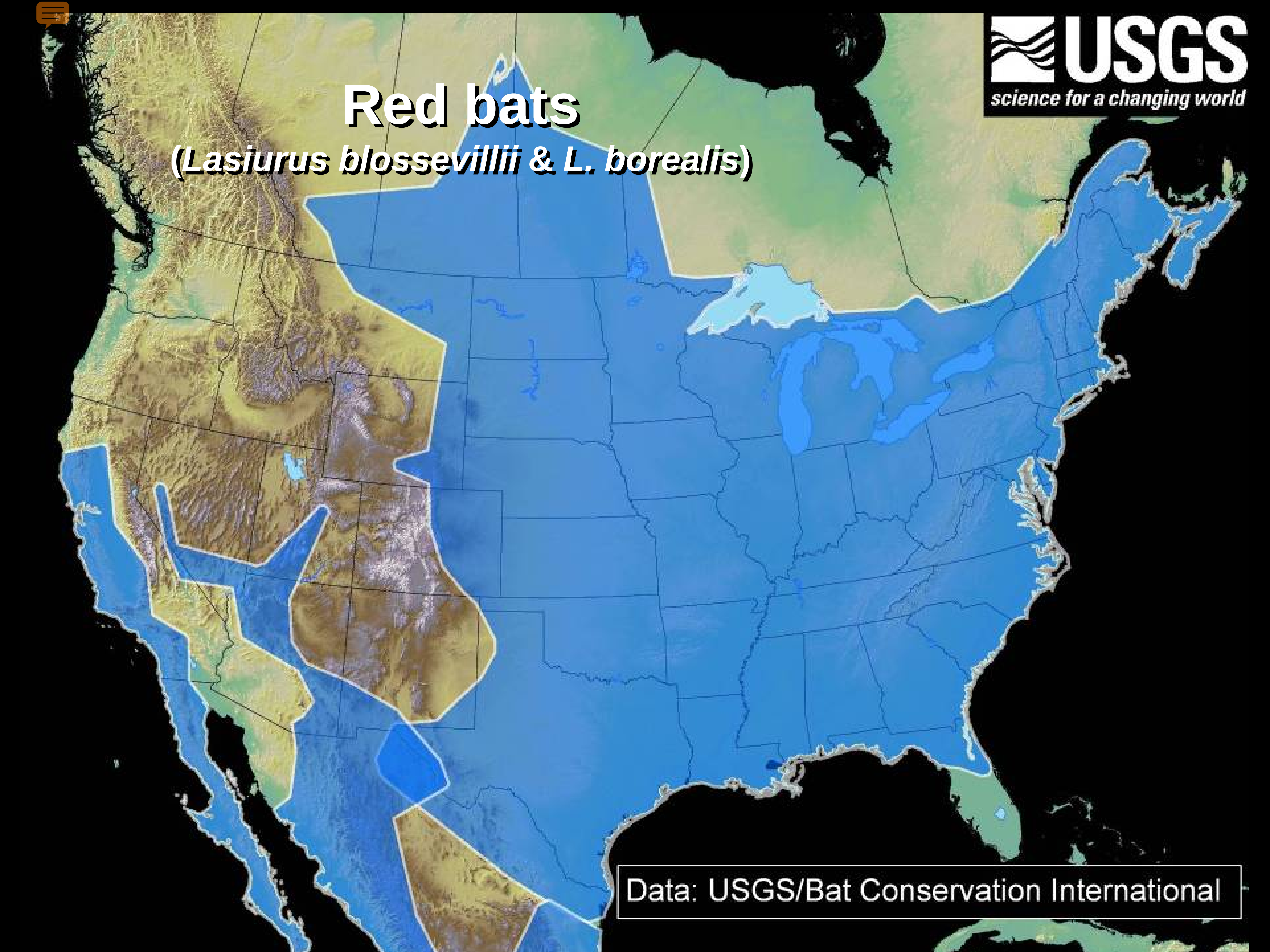
Data: USGS/Bat Conservation International

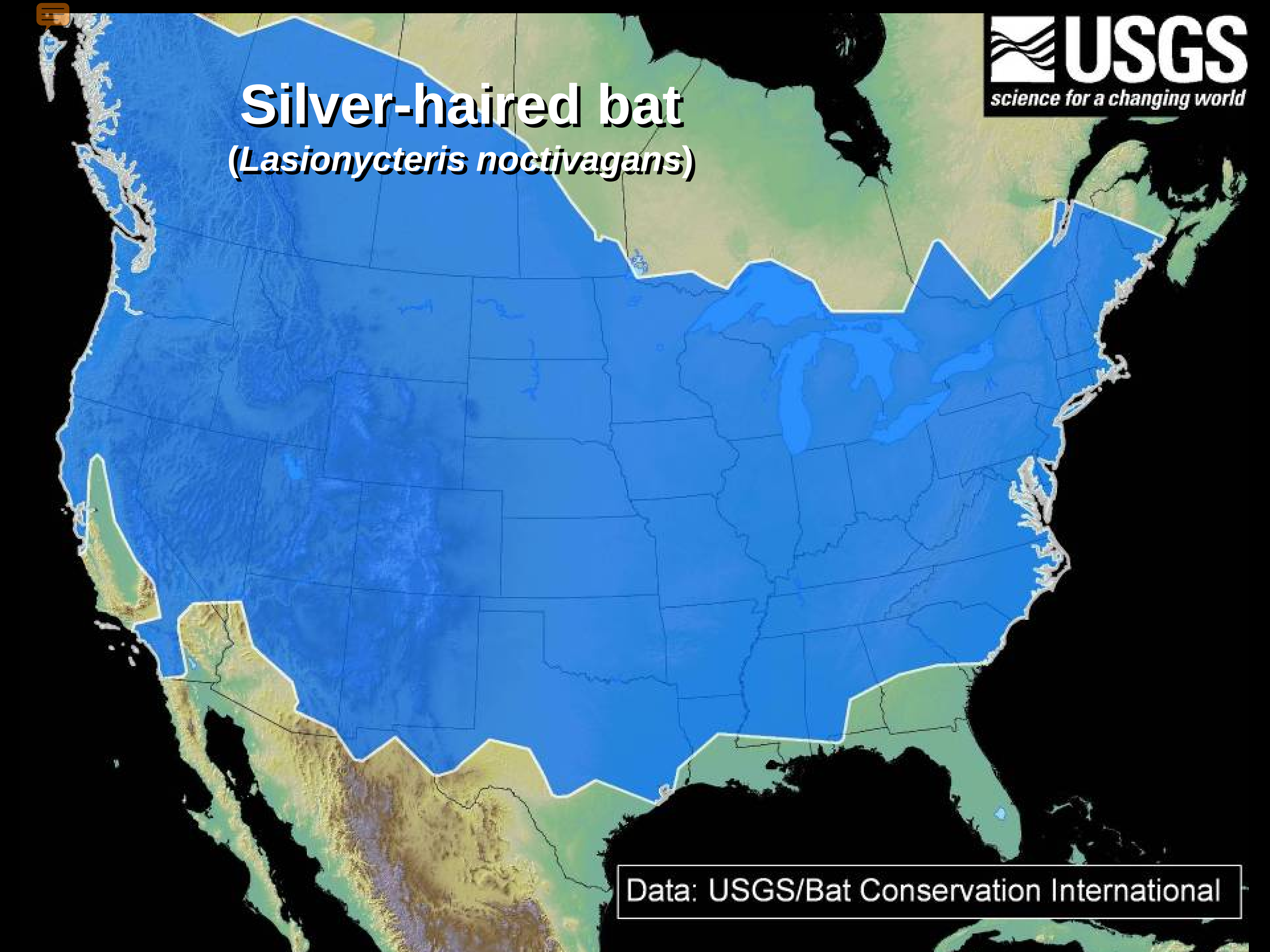
Animated maps available for viewing at:

http://www.mesc.usgs.gov/BatsWindmills/_animations/HoaryBat_Migration.wmv


Red bats
(Lasiurus blossevillii & L. borealis)
USGS
science for a changing world
Data: USGS/Bat Conservation International

Animated maps available for viewing at:

www.mesc.usgs.gov/BatsWindmills/_animations/RedBat_Migration.wmv


Silver-haired bat
(Lasionycteris noctivagans)
USGS
science for a changing world
Data: USGS/Bat Conservation International

Animated maps available for viewing at:

www.mesc.usgs.gov/BatsWindmills/_animations/SilverHairedBat_Migration.wmv

Currently Affected Bat Species

- Not widespread, but wide ranging
- Large seasonal movements
- All probably concentrate in certain areas during migration periods
- Seasonal habitats different
- Important wintering and summering areas for each species occur mostly within the U.S. and Canada

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Protected Species
Unknown Impacts
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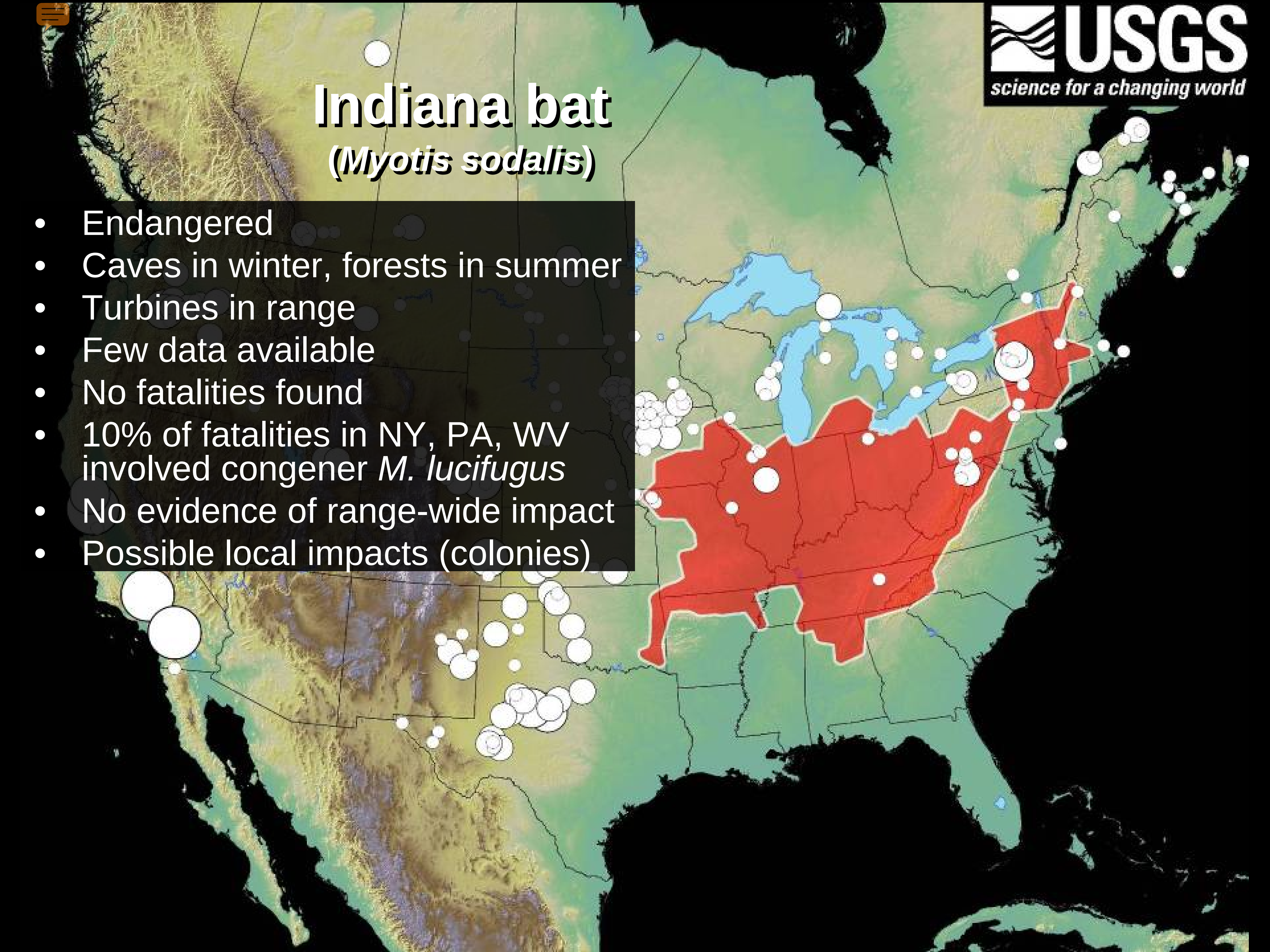

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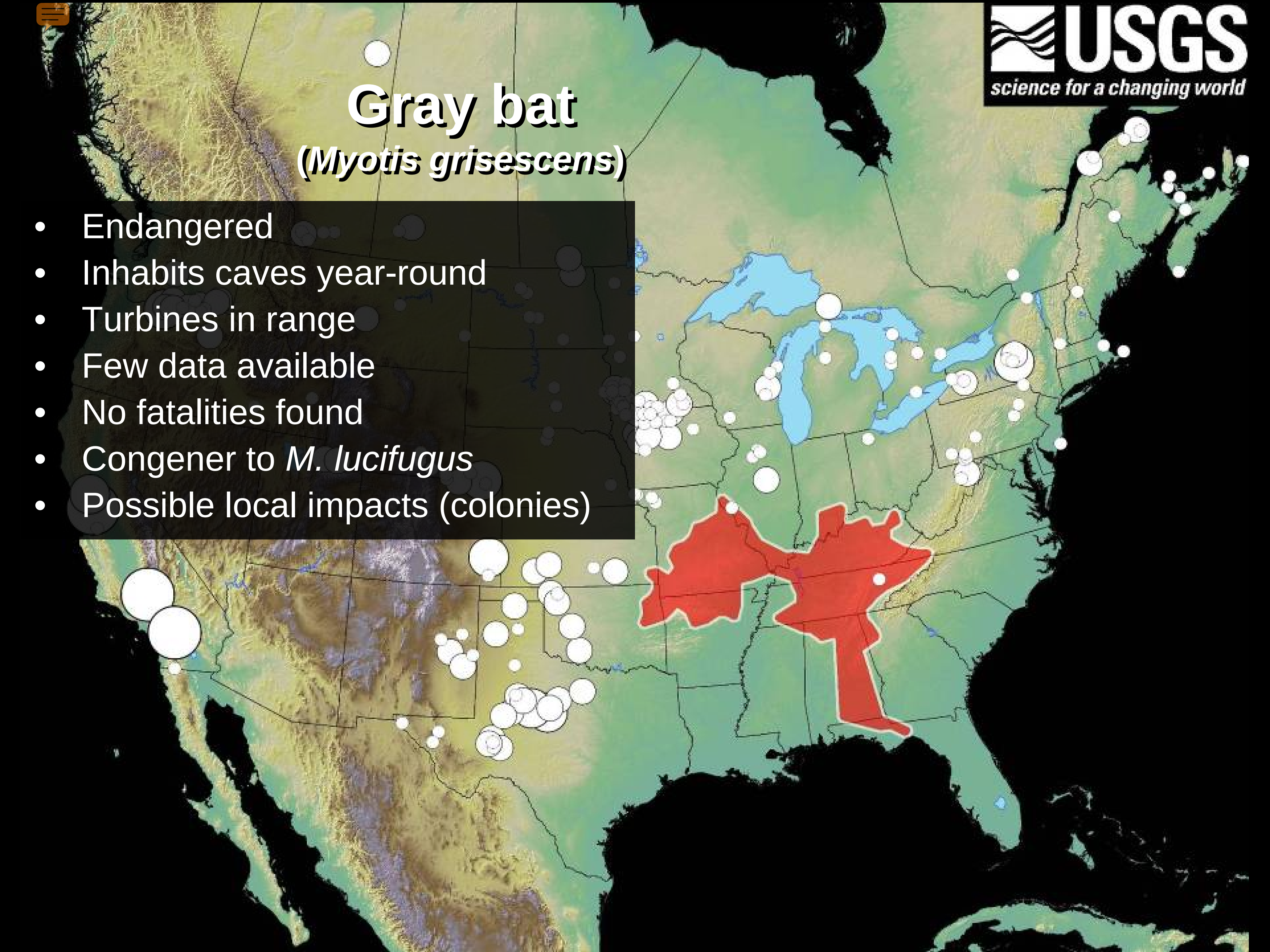
Indiana bat
(Myotis sodalis)
• Endangered
• Caves in winter, forests in summer
• Turbines in range
• Few data available
• No fatalities found
• 10% of fatalities in NY, PA, WV involved congener M. lucifugus
• No evidence of range-wide impact
• Possible local impacts (colonies)

Gray bat
(*Myotis grisescens*)

- Endangered
- Inhabits caves year-round
- Turbines in range
- Few data available
- No fatalities found
- Congener to *M. lucifugus*
- Possible local impacts (colonies)



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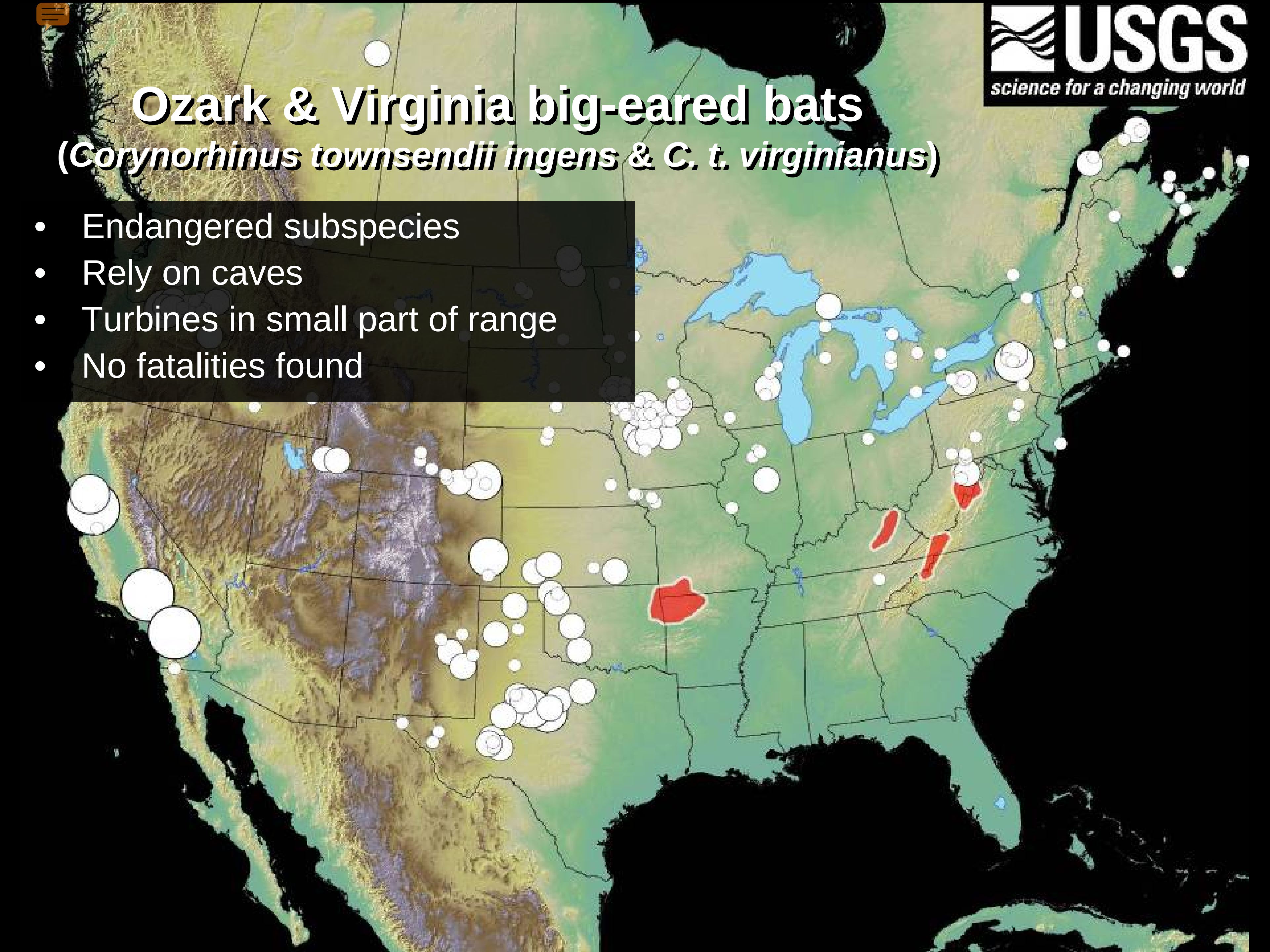
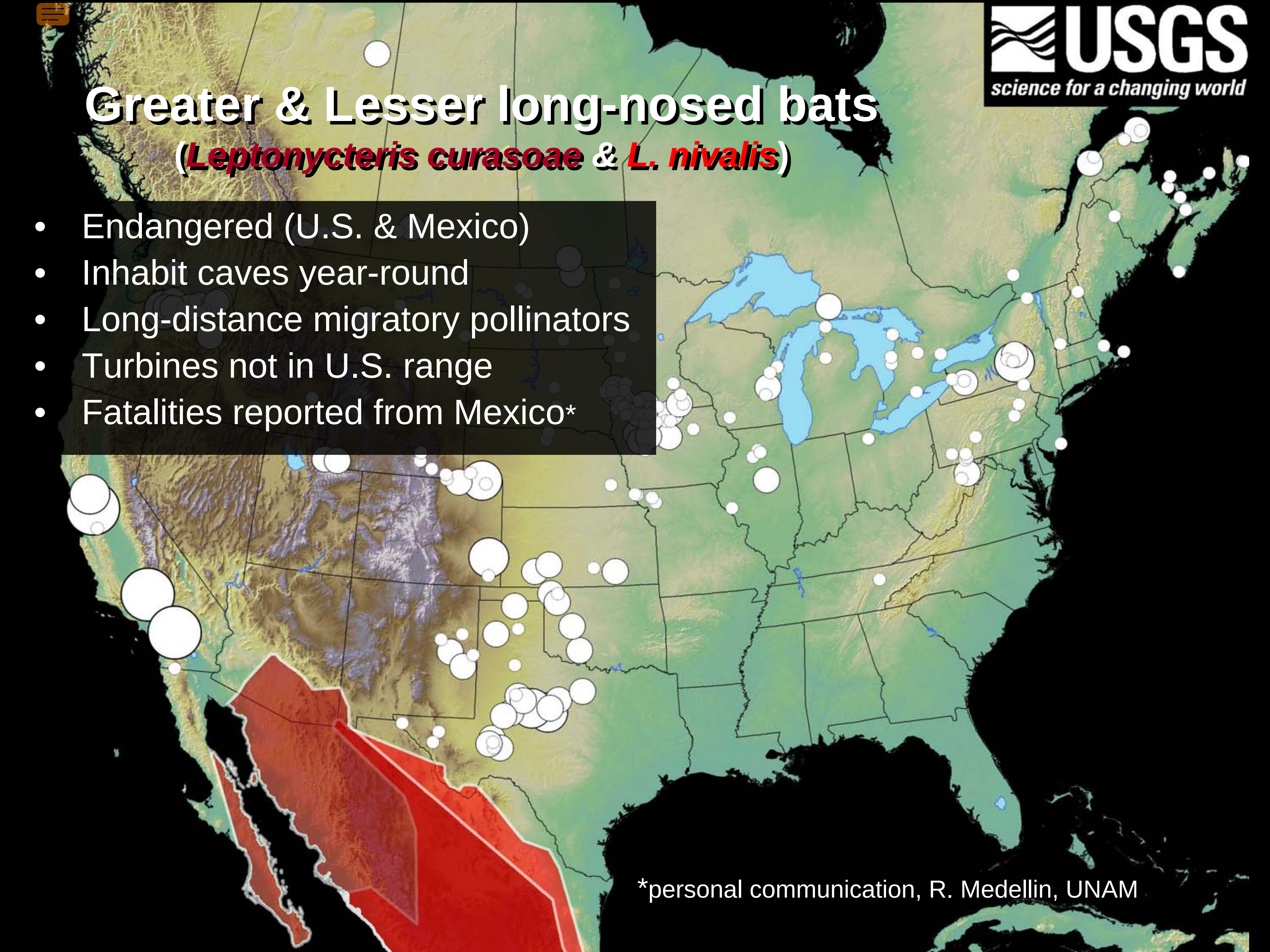
Ozark & Virginia big-eared bats

(*Corynorhinus townsendii ingens* & *C. t. virginianus*)

- Endangered subspecies
- Rely on caves
- Turbines in small part of range
- No fatalities found




Greater & Lesser long-nosed bats
(Leptonycteris curasoae & L. nivalis)
• Endangered (U.S. & Mexico)
• Inhabit caves year-round
• Long-distance migratory pollinators
• Turbines not in U.S. range
• Fatalities reported from Mexico*
*personal communication, R. Medellin, UNAM

Hawaiian hoary bat

(*Lasiurus cinereus semotus*)

- Endangered subspecies
- Inhabits trees year-round
- Seasonal movement on islands
- Turbines on Hawaii and Maui
- No data available
- Mongoose and rat scavengers

Degree of Impact

- Direct mortality
  - Patterns of fatalities
    - Spatial
    - Temporal
    - Other
- Indirect mortality
  - Habitat impacts

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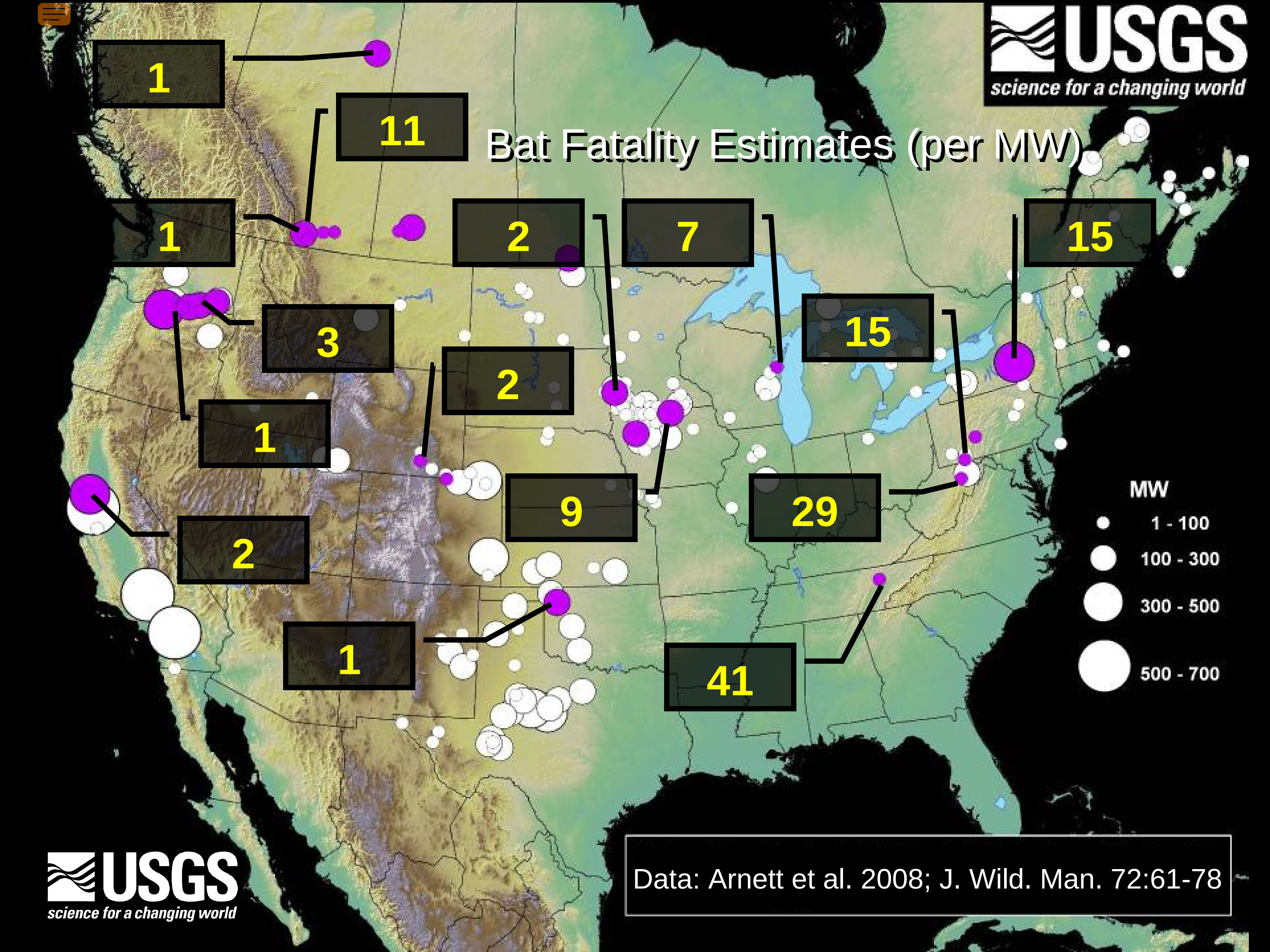
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Bat Fatality Estimates (per MW)
1
11
1
2
7
15
3
15
2
1
9
29
2
1
41
MW
1 - 100
100 - 300
300 - 500
500 - 700
Data: Arnett et al. 2008; J. Wild. Man. 72:61-78
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Sites with High Fatality Rates

Photo: E. Arnett

Photo: R. Barclay

Photo: J. Kerns

Photo: NREL

Timing of Fatalities

- Most in late summer and autumn
- Most sampling from June-Sept
- Few found in spring & winter
- Species differences in timing
    - Tree bats predominate late season
    - Free-tailed bats at site in summer

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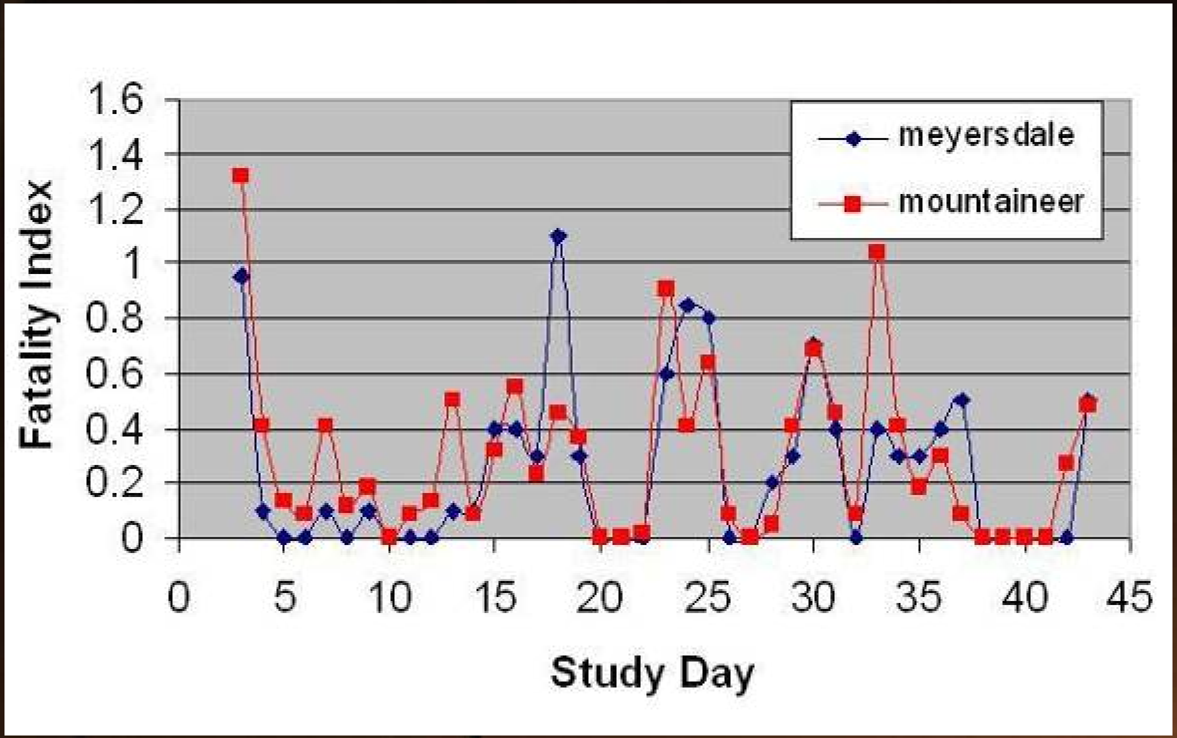
Data: Johnson 2005, Bat Res. News 46:45-49
Cryan and Brown 2007, Biol. Cons. 139:1-11

Timing of Fatalities

- Highly variable
- Periodic
- Spatially correlated



Data: Arnett et al. 2008; J. Wild. Man 72:61-78
Kerns et al. 2005; BWEC

Other patterns

- Most fatalities occur on low-wind nights
- Bigger turbines killing more bats
- No effect of aviation lighting on fatalities
- No evidence of collisions with meteorological towers or stationary blades
- Bat fatalities more clustered around base of towers than bird fatalities
- Evidence of non-collision decompression

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Kunz et al. 2007. Front. Eco. Env. 5:315-324
Arnett et al. 2008; J. Wild. Man 72:61-78
Barclay et al. 2007; Can. J. Zool. 85:381-387

Indirect Mortality

- Loss of foraging habitat?
- Loss of roosting habitat?
- Loss of migration corridors?
- To date, there have been no focused, quantitative studies on the impacts of wind energy development on bat foraging, roosting, or migration habitats
- Busy trying to understand direct impacts

Cumulative Impacts

- Estimates of cumulative impacts
- Other human-induced impacts
  - Habitat loss
  - Contaminants
  - Disease
  - Collisions with other human-made objects

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Estimates of Cumulative Impacts

- National Research Council. 2007. Ecological impacts of wind-energy projects. National Academies Press, Washington, D.C.
- Kunz et al. 2007. Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. Frontiers of Ecology and the Environment 5:315-324.

- Assumptions
  - Variation in current fatality rates representative of region
  - Future changes in turbine design or placement will not change fatality rates
  - Abundance of affected bat species will not decrease due to turbine-related fatalities or other factors
  - Projections of cumulative fatalities for other geographic regions differ

Cumulative Impacts

- 2,158 MW by year 2020*
- **33,000 – 62,000 bats/yr**

- 3,856 MW by year 2020**
- **59,000 – 111,000 bats/yr**

- The crucial issue is whether these impacts affect whole populations of certain species

  - **9,500 – 32,000 hoary bats/yr**
  - **11,500 – 38,000 eastern red bats/yr**
  - **1,500 – 6,000 silver-haired bats/yr**

*NREL WindDS model, **PJM grid model

Kunz et al. 2007. Front. Eco. Env. 5:315-324

Other human-induced impacts

- Known declines of cave bats
- Anecdotal evidence of fewer tree bats
- No recent observations of flocks of tree bats
- Why?
  - Habitat loss?
  - Contaminants?
  - Disease?
- We do not know
- No evidence that other human-induced impacts have caused rapid changes in populations

Contaminants

- Sporadic die-offs attributable to organochlorine pesticides prior to ban
- Effects of modern pesticides unknown
- Poisoning at mine cyanide leaching pools
- Mortality at open sludge pits associated with oil and gas drilling
- Unknown effects of toxic metals in environment

Disease

- No evidence of epizootic diseases
- Bats show unique resistance to disease
- Submissions of downed bats indicate low mortality

Species	Avg. No. Per Year ('93-'00)
Hoary bat	32
Eastern red bat	65
Silver-haired bat	71
Eastern pipistrelle bat	15
Little brown bat	715
Mexican free-tailed bat	84
Big brown bat	2,614

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Source: Mondul et al. 2003.; J. Am. Vet. Assoc. 222:633-639

Collisions with human-made objects

- Buildings and tall structures

Washington Monument, D.C.

- Autumn 1935
  - 246 birds, 33 species
  - 2 eastern red bats
  - 1 little brown bat

Photo: wikipedia.org

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Overing 1936: Wilson Bul. 48:222-224

Collisions with Buildings

Photo: Carl R. Josker

Long Point Lighthouse, Lake Erie

- 9 September 1929
  - 600 birds, many species
  - 3 eastern red bats
- 24-25 September 1929
  - a “destruction of birds”
  - 1 hoary bat
  - 1 silver-haired bat

Empire State Building

- 6 October 1954
  - 123 birds, 23 species
  - 4 eastern red bats
- 19 October 1955
  - 156 birds, 18 species
  - 2 eastern red bats

Photo: Henri Silberman

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Saunders 1930: J. Mammalogy 12:225
Terres 1956: J. Mammalogy 37:442

Convention Center, Chicago, IL

- ~ 1,500 – 2,000 birds per year
- Monitored 8 years (1979-1987)
- Daily search: Feb-Jun & Aug-Nov
- 79 bats recovered
  - 50 eastern red bats
  - 27 silver-haired bats
  - 1 hoary bat and 1 little brown bat
- Almost all collided during autumn

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Timm 1989: Bull. Chicago Acad. Sci. 14:1-7

Collisions with Towers

- WCTV, Leon Co., FL
  - 25 years of monitoring (1955-1980)
  - 54 bats of 7 species
  - 87% species of tree bats
  - Most in autumn

Photo: Paul Schmidt

Crawford and Baker 1981:J. Mammalogy 62:651-652

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Tower kills – birds versus bats

- About 6 other incidents in the literature
- All eastern red bats
- All during autumn

Site	Birds	Bats
Topeka, KS	> 1000	5
Nashville, TN	336	2
Colombia, MO	658	1
North Dakota	561	5

Collision Patterns

- Large numbers of birds of many species
- Small numbers of migratory tree bats
- Collisions of tree bats with wind turbines and non-turbine structures coincide in seasonal timing, but differ in magnitude
- Tree bats interact differently with turbines compared to other tall structures

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Other Collisions

- Military aircraft
  - About 20-30 strikes per year*
- Automobile collisions
  - Very sporadic**
- Barbed-wire fences
  - Very sporadic

Photo courtesy of: S. Peurach

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* Personal communication, Suzy Peurach, USGS/ Gene LeBoeuf, USAF
**Personal communication, Dale Sparks, Indiana State Univ.

There is no evidence of human-induced impacts to the affected bat species that are of similar magnitude to mortality at turbines

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Methods, Metrics, and Effectiveness

- Visual Methods
- RADAR
- Acoustic monitoring
- Radio telemetry
- Capture surveys
- Assessing population size/structure
- Assessing geographic origins
- Pre-construction surveys
- Post-construction surveys
- Mitigation measures

Kunz et al. 2007; J. Wild. Man. 71:2449-2486
Arnett et al. 2007; Wild. Soc. Tech. Rev. 07-2

Visual Methods

- Light tagging
- Night-vision imaging (reflected infrared)
- Thermal infrared imaging


Image: Tom Kunz


Image: Jason Horn

- Effectiveness proportional to cost

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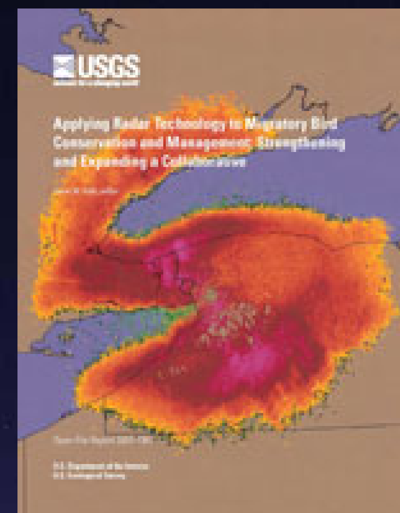
Kunz et al. 2007; J. Wild. Man. 71:2449-2486
Horn et al. 2008; J. Wild. Man. 72:123-132
http://www.bu.edu/cecb/wind/video/

RADAR

- Weather surveillance radar (NEXRAD)
- Portable radar
  - Marine radar
  - Tracking radar
  - Specialized radar
- Birds + bats = "targets"
- Need ground truth
- Best combined with other observation methods



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Kunz et al. 2007; J. Wild. Man. 71:2449-2486
Larkin 2005; Radar Tech. for Wild. Biol.

Acoustic monitoring

- All U.S. bats echolocate
- Bat detectors widely used
- Bat species differ in their echolocation call structure and intensity
- Many species identifiable by their calls, many species are not
- Bat detectors allow the passive monitoring of species presence without having to see or capture the animals

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Kunz et al. 2007; J. Wild. Man. 71:2449-2486
Arnett et al. 2007; Wild. Soc. Tech. Rev. 07-2

Acoustic monitoring (cont.)

- Detectors measure activity (commuting & feeding)
- Detectors do not measure abundance
- Detection probability differs among species
- Cannot provide demographic information
  - (e.g., sex, age, reproductive condition)
- Effectiveness depends on question being asked, but very good at assessing species presence and activity if deployed properly and <u>if bats are using echolocation</u>

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Kunz et al. 2007; J. Wild. Man. 71:2449-2486
Arnett et al. 2007; Wild. Soc. Tech. Rev. 07-2

Radio telemetry

- < 2 g transmitter
- 1-15 km range
- Ground stations
- Pursuit vehicles
- Aircraft
- Best way to follow individuals
- Easy to lose signal

Photos: Mike Bogan

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Kunz et al. 2007; J. Wild. Man. 71:2449-2486
Cryan and Diehl *in press*; Analyzing bat migration

Capture surveys

- Mist nets, harp traps
- Species identification
- Demographic info
- Relative abundance
- Small sampling area
- Susceptible to many biases
  - Availability of surface water
  - Flight abilities of each species
  - Weather conditions at time of sampling

Photo: P. Cryan

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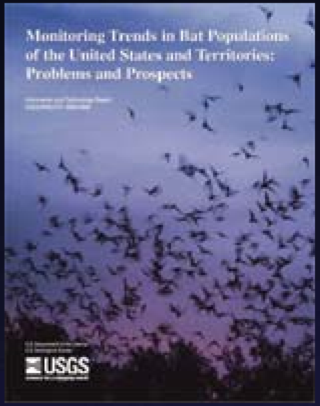
Kunz et al. 2007; J. Wild. Man. 71:2449-2486
Arnett et al. 2007; Wild. Soc. Tech. Rev. 07-2

Population Estimation



- Estimating population sizes
  - No current estimates published
  - Mark-recapture studies not effective
  - Genetic methods most likely (DNA)
    - Effective population size (N_e)
    - Required molecular markers being developed
- Estimating genetic variation
  - Are populations highly structured?
    - Eastern red bats appear panmictic*
    - Required molecular markers being developed

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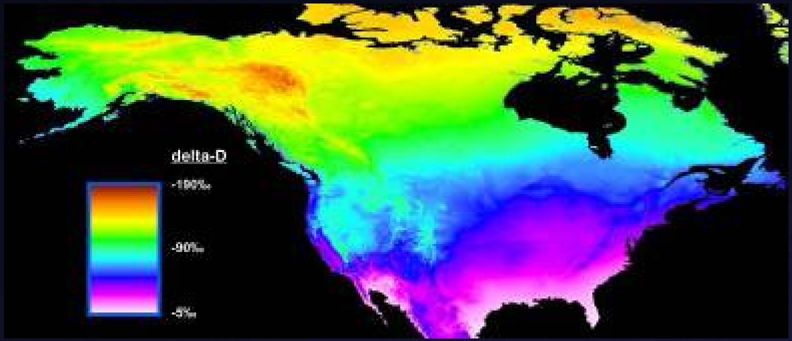
*Maarten Vonhof, personal communication
Nancy Simmons, personal communication
Russell et al. 2005; Mol. Ecol. 14:2207–2222.
Russell and McCracken 2006; Funct. & Evol. Ecol. Bats

Geographic origins of fatalities

- Genetic methods
  - If populations structured
- Geochemical markers
  - Stable isotopes
  - Trace metals
- Results will be coarse in geographic resolution, but may help assess impacts



Meehan et al. (2004); Isotopes in Env. & Health Stud. 40:291-300

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Cryan et al. 2004; J. Mamm. 85:995-1001
Kunz et al. 2007; J. Wild. Man. 71:2449-2486
Arnett et al. 2007; Wild. Soc. Tech. Rev. 07-2

Pre-construction monitoring

- Goal: to predict the probability and magnitude of bat fatalities
- Determine presence and activities of bats
  - Capture surveys
  - Acoustic monitoring
  - Visual surveys
  - RADAR
- Account for spatial and temporal variation
- Correlate pre-construction bat presence and activity to post-construction impacts

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Kunz et al. 2007; J. Wild. Man. 71:2449-2486
Arnett et al. 2007; Wild. Soc. Tech. Rev. 07-2

Post-construction monitoring

- Goal: to determine the number of fatalities
- Detecting fatalities
  - Often difficult to find
  - Can disappear quickly
  - Every site is different
- Estimating fatality rates
  - Mathematical estimation models
  - Searcher efficiency
  - Rate of scavenging
  - Search intervals
  - Other biases: sporadic fatalities, animals leaving search plot
- Consistency is crucial
  - reveal patterns, assess hypotheses of cause, or measure effectiveness of risk assessment and mitigation measures

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Kunz et al. 2007; J. Wild. Man. 71:2449-2486
Arnett et al. 2007; Wild. Soc. Tech. Rev. 07-2

Mitigation Measures

- Goal: to reduce the number of bats killed
- Operational changes
  - Increasing blade “cut-in” speed (e.g., wind speeds > 6m/s)
  - Shut down under high-risk conditions or time periods
  - Fatalities lower in German and Canadian experiments*
- Deterrents
  - Ultrasound blasters to scare bats away
    - Under development and testing
- Off-site mitigation?
  - Not likely for tree bats

*R. Brinkmann, personal communication
*R. Barclay and E. Baerwald, personal comm.
Kunz et al. 2007; J. Wild. Man. 71:2449-2486
Arnett et al. 2007; Wild. Soc. Tech. Rev. 07-2

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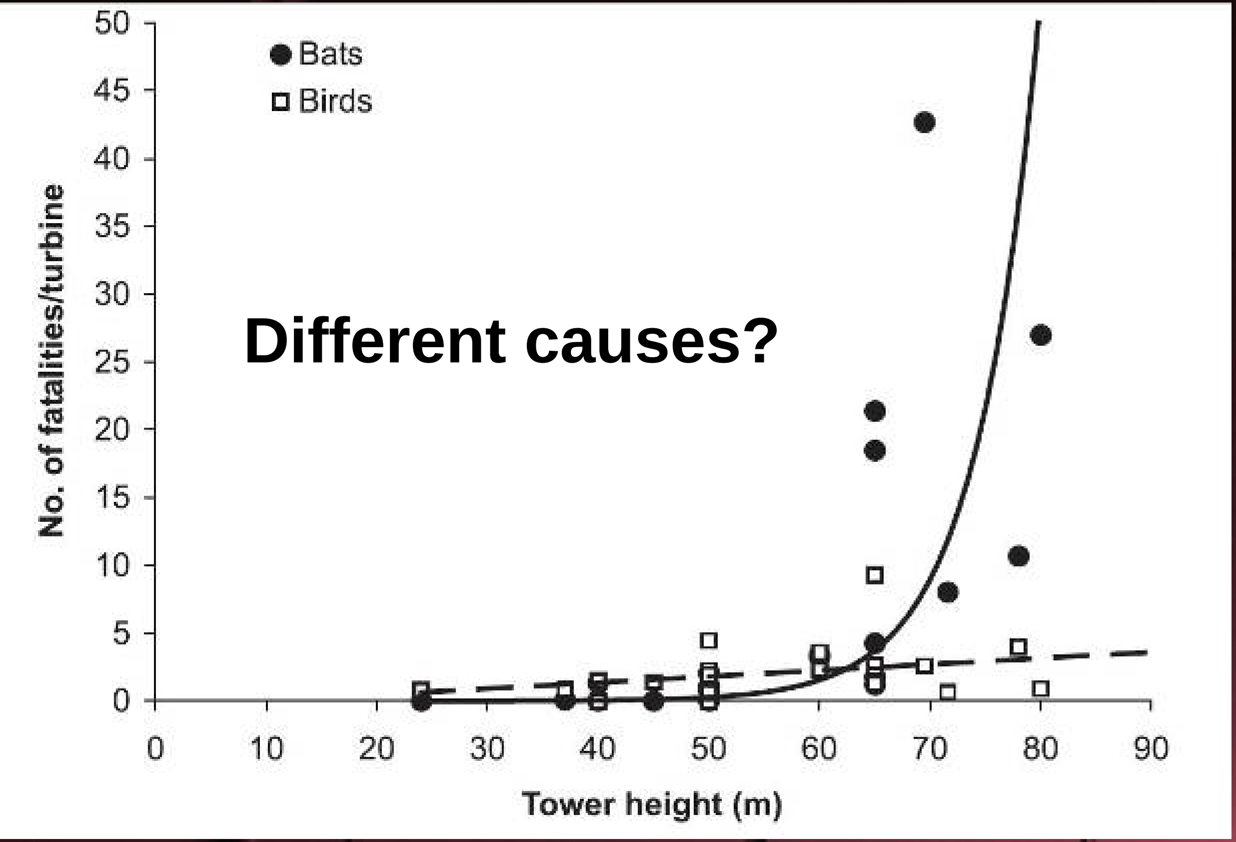
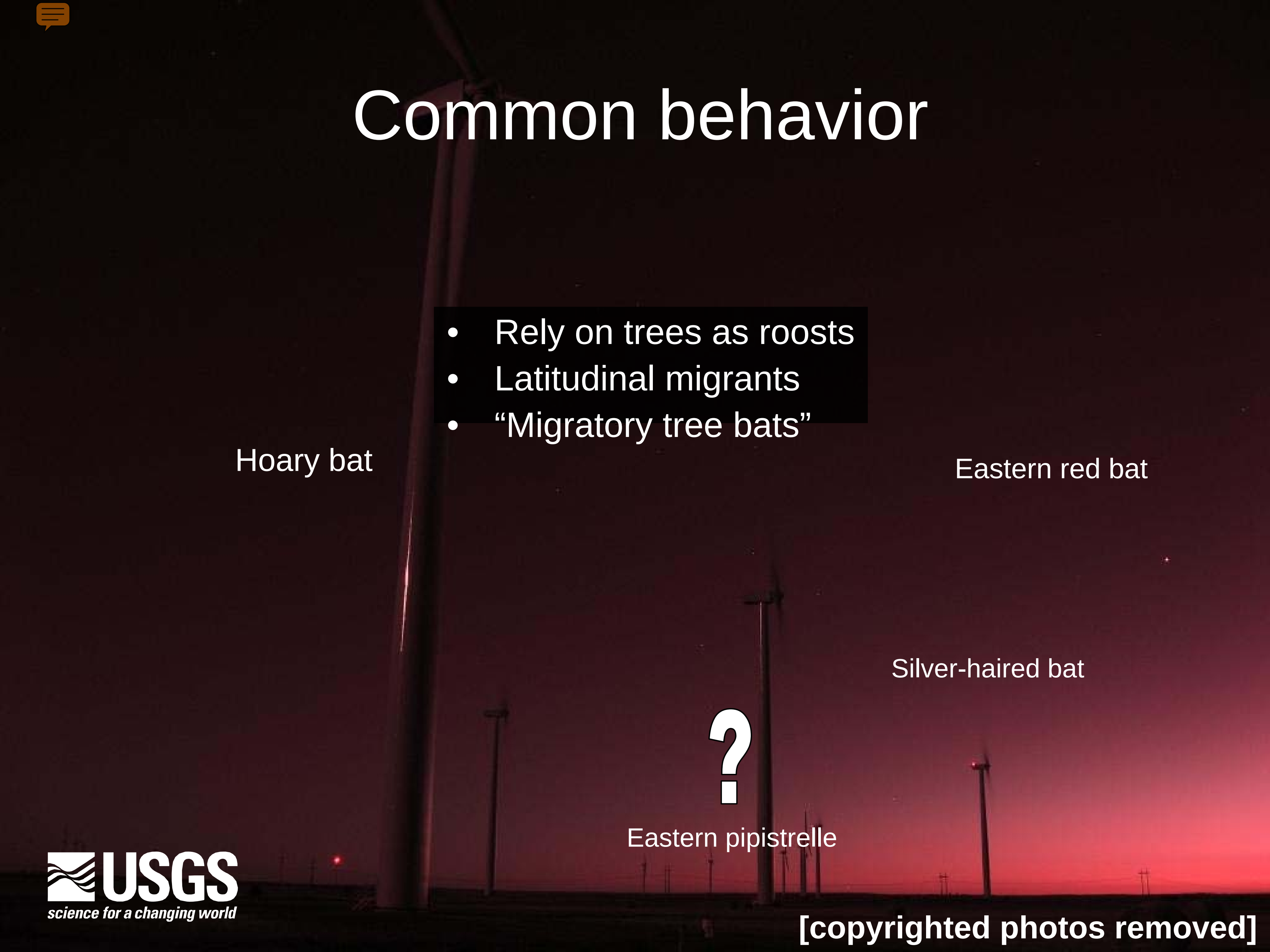
Behavioral Aspects

- Why are so many bats of certain species colliding with wind turbines, but not as frequently with other tall structures?
- Why are the patterns we see in collision fatalities between bats and birds so different?
- What is unique about bats that might help answer some of these questions?

Bats and Birds



From: Barclay et al. 2007; Can. J. Zool. 85:381-387


Common behavior
• Rely on trees as roosts
• Latitudinal migrants
• "Migratory tree bats"
Hoary bat
Eastern red bat
Silver-haired bat
?
Eastern pipistrelle
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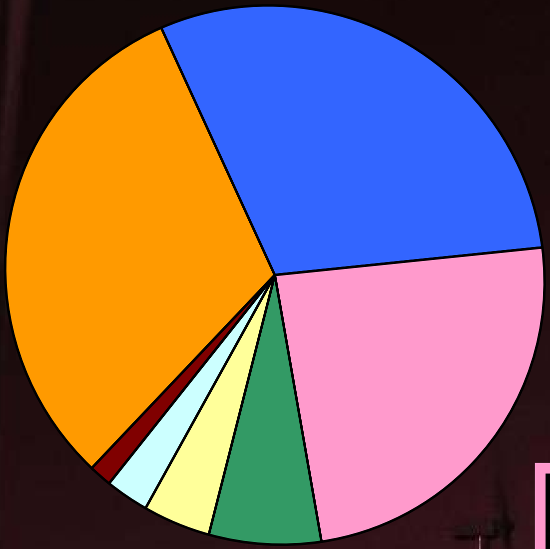
[copyrighted photos removed]

Species Involved in Europe

Sample from Germany; *n* = ~500



photos: www.fledermausschutz.ch

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Data: Brinkmann et al. 2006; www.rp.baden-wuerttemberg.de

Common behavior

- Rely on trees as roosts
- Latitudinal migrants in some part of range
- "tree bats"
- Males defend mating roosts in late summer/autumn

photos: www.fledermausschutz.ch

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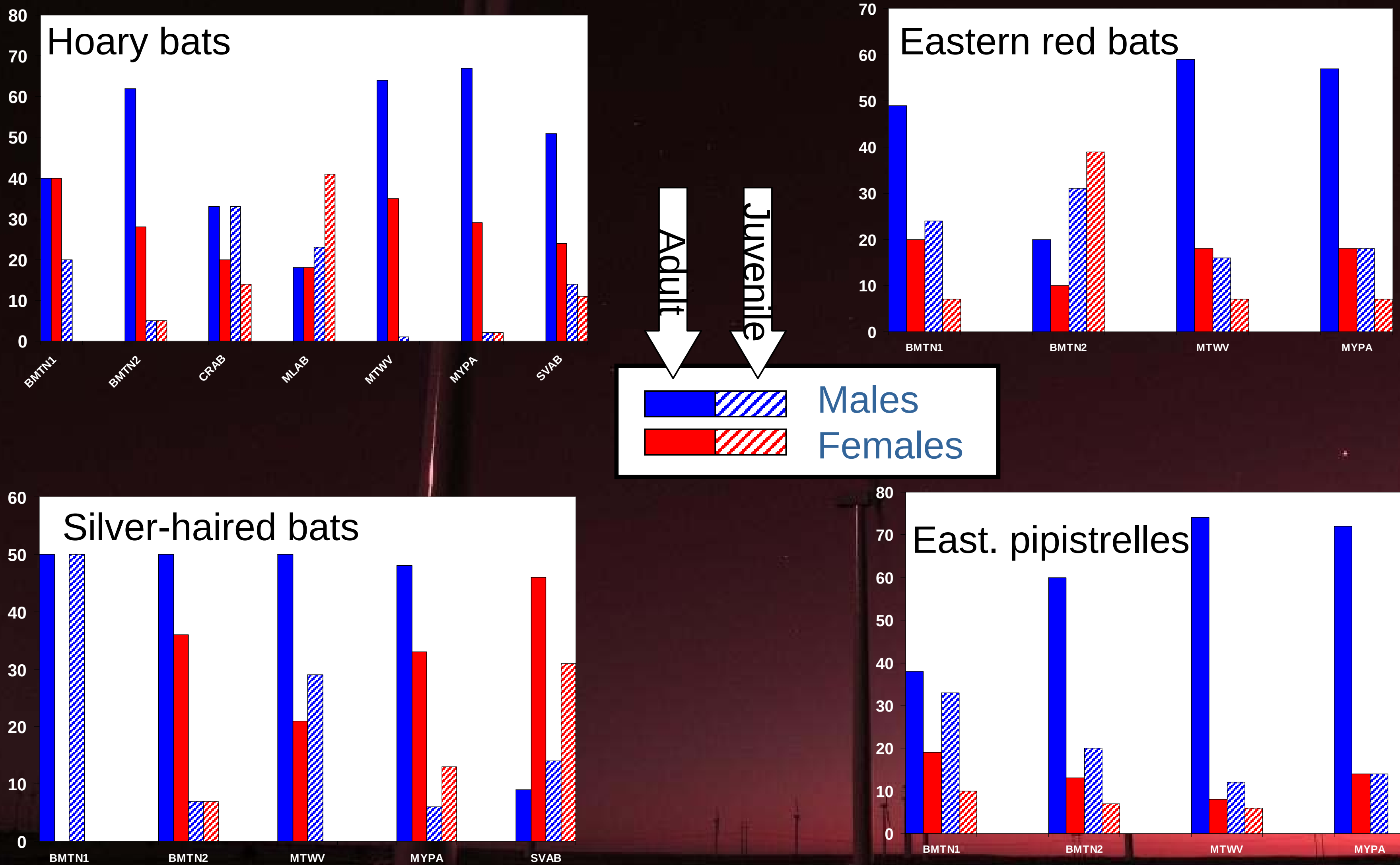
Cryan 2008, J. Wild. Man. [in press]

Demographics of Fatalities



Data: Arnett et al. 2008; J. Wild. Man. 72:61-78

Hypotheses of Attraction

- Attracted to high wind “corridors”
- Attracted to new clearings/linear features
- Attracted to insects at turbines or clearings
- Attracted to noises or motion of turbine blades
- Attracted to turbines as roost sites
- Attracted to turbines as gathering points
- Attracted to turbines as mating sites

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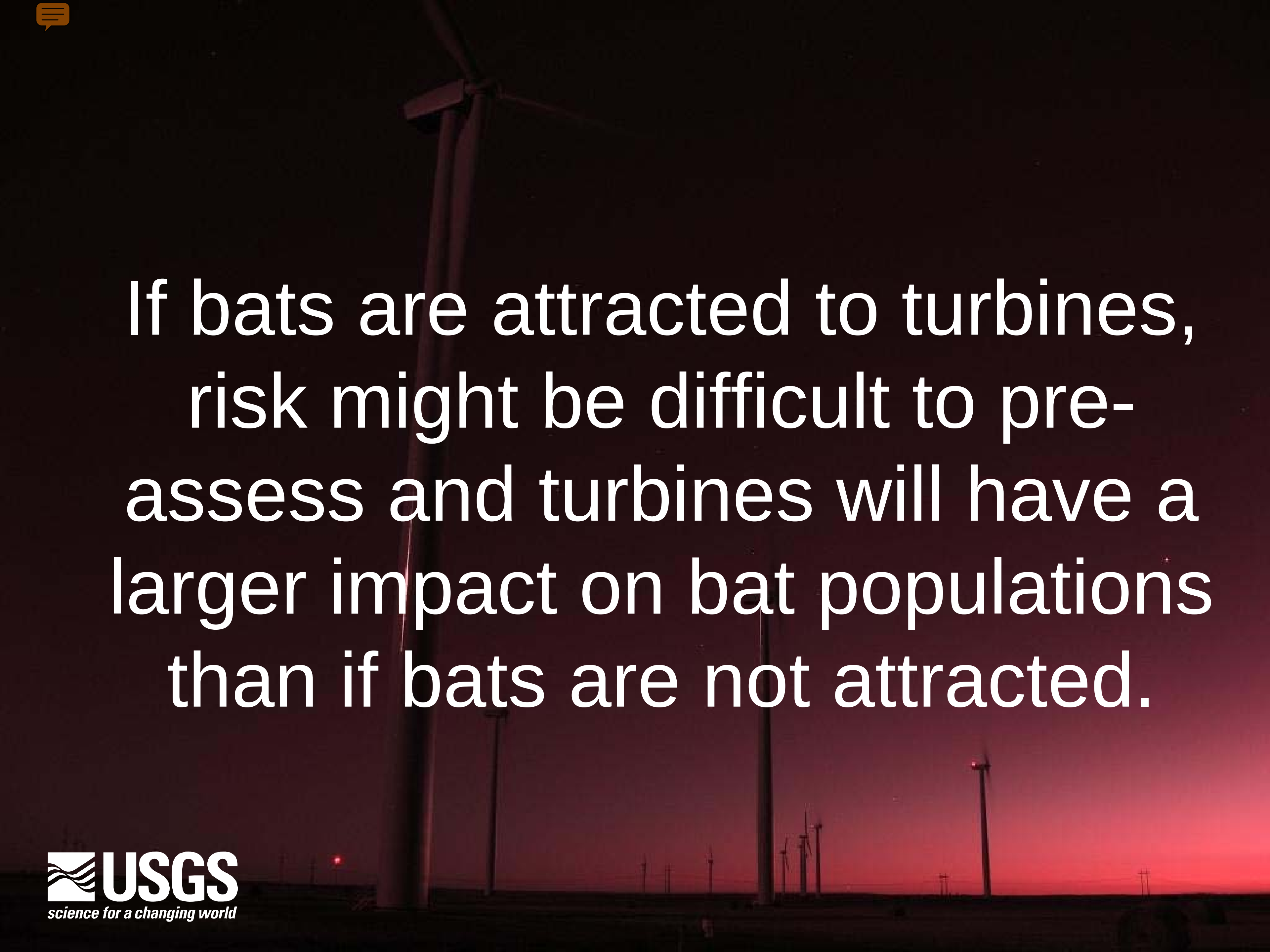
Kunz et al. 2007, Front. Ecol. Env. 5:315-324
Arnett et al. 2008, J. Wild. Man. 72:61-78
Cryan and Brown 2007, Biol. Cons. 139:1-11
Cryan 2008, J. Wild. Man. 72:845-849


If bats are attracted to turbines, risk might be difficult to pre-assess and turbines will have a larger impact on bat populations than if bats are not attracted.
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Major Areas of Uncertainty

- How do we stop or minimize fatalities?
  - Mitigation methods need rigorous testing/development
- How can we better assess fatality and causes?
  - Hindered by lack of standardized, validated methods and the short-term nature of most studies
- Can we predict high-risk sites before construction?
  - Correlation between pre- and post- monitoring
  - Better understanding habits of affected species

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Arnett et al. 2007; Wild. Soc. Tech. Rev. 07-2
Kunz et al. 2007, Front. Ecol. Env. 5:315-324
Arnett et al. 2008, J. Wild. Man. 72:61-78

Major Areas of Uncertainty

- Are bats attracted to turbines?
- Will the affected species persist?

Arnett et al. 2007; Wild. Soc. Tech. Rev. 07-2
Arnett et al. 2008, J. Wild. Man. 72:61-78
Kunz et al. 2007, Front. Ecol. Env. 5:315-324
Cryan and Brown 2007, Biol. Cons. 139:1-11
Cryan 2008, J. Wild. Man. [in press]
Horn et al. 2008, J. Wild. Man. 72:123-132

Photo: P. Cryan