Insectivorous Bat Captive Population Feasibility Workshop

Saint Louis, MO, US
14 – 16 July 2010

Final Report

U.S. Fish & Wildlife Service · Department of the Interior

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Conservation Breeding Specialist Group

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Workshop organized by: US Fish and Wildlife Service (FWS); Bat Conservation International (BCI); The Nature Conservancy (TNC); IUCN Species Survival Commission (SSC) Conservation Breeding Specialist Group (CBSG).

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31 December 2010

CONSERVATION BREEDING SPECIALIST GROUP

Insectivorous Bat Captive Population Feasibility Workshop

Saint Louis Zoo, Saint Louis, Missouri, US
14 - 16 July 2010

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SECTION 1

Executive Summary

Executive Summary

Background

Many species of North American insectivorous bats are at risk due to an emerging disease—White Nose Syndrome (WNS). Caused by the fungus *Geomyces destructans* (Gd), WNS was first detected in 2006 in New York and has since spread rapidly in the northeast and mid-Atlantic regions of the US and two Canadian provinces. WNS infects hibernating bats and has resulted in mortality as high as 95% in many wild bat colonies. At least six species of hibernating bats (both common and threatened) are currently affected, including the federally Endangered Indiana bat (*Myotis sodalis*), while many others are potentially at risk as WNS continues to spread north, south and west. All four federally Endangered cave-hibernating bats (Indiana bat [*M. sodalis*], gray bat [*M. grisescens*], Virginia big-eared bat [*Corynorhinus townsendii virginianus*], and Ozark big-eared bat [*C.t. ingens*]) are potentially at risk and are of particular conservation concern with respect to the spread of WNS.

In the face of this rapidly advancing and potentially devastating threat, the US Fish and Wildlife Service (FWS) is considering the merit of developing captive management options for insectivorous bat species as one component of an overall management strategy for these species. In March 2010 the IUCN Species Survival Commission (SSC) Conservation Breeding Specialist Group (CBSG) was contacted by FWS with a request to co-design and facilitate a workshop aimed at assessing the feasibility of various captive management options for North American bat species. CBSG facilitated a similar workshop in 2007 for the FWS to examine the feasibility of captive management for beach mouse (*Peromyscus polionotus*) subspecies. Unlike mice, however, captive management and successful propagation of insectivorous bats is fraught with many challenges, including feeding and hibernation requirements. There is limited existing expertise for successfully managing, breeding and releasing populations of insectivorous bats, underscoring the importance of a thorough assessment of expertise and feasibility.

Prior to the workshop, FWS developed and distributed a questionnaire to solicit existing expertise and successes/failures in managing insectivorous bats in captivity. The resulting data were compiled by Bat Conservation International (BCI) and represented responses from 42 rehabilitation, zoological and research collections on a global level (10 countries). This information was not only useful during the workshop, but will continue to provide a valuable resource in the future (see Appendix II for summary).

Workshop Process

On 14–16 July 2010, an Insectivorous Bat Captive Population Feasibility Workshop was held at the Saint Louis Zoo in Saint Louis, Missouri, which was organized by FWS, BCI, and The Nature Conservancy (TNC) and facilitated by CBSG. The purpose of the workshop was to explore the potential value and feasibility of various captive management options for bat species under threat of WNS. The 34 workshop participants represented FWS, non-governmental organizations (NGOs), state and federal agencies, universities, rehabilitation facilities, zoos, and the IUCN/SSC Bat Specialist Group, providing the best available expertise on North American bats both *in situ* and *ex situ*.

The workshop began with a series of background presentations in the morning, including relevant bat life history and population viability information, the impact of WNS on bat populations, general principles of captive management for conservation, establishment of emergency rescue captive populations, and the Virginia big-eared bat population case study. The afternoon session began with an overview of the questionnaire results regarding available expertise on captive facilities, diet, reproduction, hibernation, and other challenges. This was followed by an interactive plenary discussion to elicit expert opinions in identifying important life history and behavioral attributes relevant to capture/captive management/release techniques and then to characterize susceptible bat species with respect to these attributes. These data, in combination with the compiled data on existing husbandry expertise, allowed participants to assess the level of existing captive expertise, challenges, and likelihood of success across bat species and to identify potential surrogate species with similar characteristics that may serve as models for the captive management of species of high concern that have not been held in captivity. Participants were then asked to identify the potential value of captive management options to contribute to the conservation of these bat species—i.e., the potential roles or functions that captive management could play. This led to a discussion of the types of captive programs that would meet these functions (e.g., breeding vs. non-breeding population, temporary holding vs. long-term maintenance).

Most of the second day was spent in smaller working groups, which were established based on the length of program and intensity of management, resulting in three working groups: short-term (non-breeding) programs; long-term programs with relaxed (low intensity) management; and long-term programs under intensive genetic and demographic management. Each working group further defined all potential management options under their charge and then completed a value assessment and feasibility assessment for each option. Value assessment included the identification of the role/purpose that each option serves, the benefits of this approach, and the risks or potential negative impacts of the option. The feasibility assessment identified the available expertise, any challenges and knowledge gaps for implementation, the relative scope of the project and resources needed, and any potential collaborators and/or funding sources as appropriate. Since the factors and information affecting feasibility vary by species, the working groups were asked to make note of any species-specific considerations in their assessments. Each working group session (value assessment and feasibility assessment) were followed by plenary reports by the working groups to invite comments and input by all participants on all potential options being discussed.

The final morning was spent primarily in plenary discussion addressing a series of topics. Considerable time was spent outlining the potential benefits as well as risks of *not* establishing a captive population for high risk bat species—i.e., a ‘No Captive Management’ option. A second topic of discussion was a brainstorming session to identify potential triggers for establishing a captive population. Participants were also asked to consider and respond to three questions:

1) Which strategy, including the ‘no captive management’ alternative, is your recommendation?
2) What are the highest priority captive management research questions?
3) What else would you like to convey to the group regarding captive management?

Many of the workshop participants thought there is merit in captive management, acknowledging that it will be important to work with those with captive expertise to promote success. Some participants expressed skepticism regarding the likelihood of success in breeding bats in captivity and/or releasing them. All options were seen to offer some utility and value, and given the variation among species in both risk and ease of management, no single option stands out as the best strategy for all bat species. Rather, it is beneficial to view all captive management options as a toolbox from which managers can choose as appropriate. An adaptive management approach will provide needed flexibility in the face of existing knowledge gaps. The group also identified several priority research topics, ranging from the control of the fungus Gd to treatment options for bats to management alternatives such as cryopreservation. Participants were invited to respond to the third question in writing following the workshop (see Appendix IV).

Next Steps

Because of restrictions of the Federal Advisory Committee Act (FACA), workshop participants were not allowed to reach consensus or make recommendations to the FWS as a group. Rather, the data compiled prior to and during the workshop, along with the results of the working group and plenary discussions, are being considered by the FWS to aid in determining a course of action for bats, especially for species at high risk of being affected by WNS. These data also may be useful to other conservation organizations in considering captive management programs or other conservation actions for insectivorous bat species.

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SECTION 2

Plenary Discussions

Plenary Discussions

Workshop Purpose and Objectives

Prior to the workshop, FWS considered the overall purpose and objectives for this workshop and, in consultation with CBSG, developed the following statements, which were presented to all participants at the onset of the workshop:

Purpose of Feasibility Analysis

Recognizing that the overall issue of concern is that WNS, in concert with other threats, is likely to lead to reduced viability and increased risk of extinction for North American insectivorous bat populations, the workshop will have the following purposes:

- To explore the potential ways in which captive management could help ensure the viability and persistence of wild insectivorous bat populations;
- To assess the relative expertise, resources and constraints associated with various captive management options; and
- To evaluate the relative feasibility and effectiveness of these captive management options for the bat species of concern.

The U.S. Fish and Wildlife Service will then use this information to suggest which, if any, captive management options will be considered for various bat species.

Conservation Objectives

The feasibility analysis will explore captive management as one strategy in a suite of management options that meet fundamental conservation aims, such as:

- Maximizing the likelihood of meeting population viability objectives for species of concern.
- Minimizing the risk of local extinctions for species of concern.
- Maximizing the likelihood of meeting distribution objectives for species of concern.
- Maximizing use of adaptive management principles and practices to increase the effectiveness of conservation actions over time.

It should be noted that, whenever possible, priority will be given to *in situ* efforts to meet these conservation objectives in the wild.

Captive Management Objectives

The following management objectives will come into play when considering if and when to implement captive strategies that show some promise of efficacy:

- Use effective population management and husbandry techniques designed to promote the conservation value of the captive population.
- Minimize any deleterious effects on the viability of wild bat populations, particularly due to removal (capture) and/or release of bats.
- Adhere to the federal Captive Propagation Policy (65 FR 56916-56922) and other applicable laws, regulations, and policies insofar as they apply to conservation of bats in response to WNS, noting that a central tenet of captive management is to promote re-establishment of viable wild populations.
- Maximize effective coordination and integration of *in situ* (in the wild) and *ex situ* (captive, if adopted) conservation efforts, both for individual species and across species.

It was emphasized to the workshop participants that no decision yet had been made with regard to establishing, or not establishing, a captive management program for these bat species, and that the purpose of the workshop was to conduct the data analysis and assessment needed to make that determination. All options with regard to captive management were to be considered, including the option of not developing a captive program at all.

Assessment of captive management options was separated into two components: 1) a value assessment, which considered the overall conservation benefits that a particular captive management program might serve (balanced against any potential negative impacts); and 2) a feasibility assessment, which considered the likelihood of success and resources required. This workshop aimed to compile all available information to make such value and feasibility assessments—this information can then be compared (potential conservation value balanced against feasibility/costs) by FWS and/or others to determine the recommended course of conservation action.

Categorization of Bat Species

To begin the feasibility assessment process, it was essential to compile information regarding the existing experience or estimated ability to successfully capture, maintain, and potentially reproduce various bat species in captivity. Hibernating insectivorous bat species pose significant challenges for *ex situ* management, and expertise is limited. Although these species share some ecological characteristics, it was generally recognized among workshop participants that interspecific differences exist in terms of life history characteristics and difficulty in managing in captivity.

Because only a portion of insectivorous bat species have been maintained in captivity, it was thought useful to attempt to categorize bat species by traits believed to be relevant to captive handling and husbandry techniques and overall captive success. Prior to and during the workshop, participants identified several life history and behavioral traits thought to be potentially relevant. This information was compiled into a species matrix by BCI and was discussed and modified during the workshop. Characteristics identified as potentially relevant were:

- Body size (small, medium, large)
- Foraging behavior (generalist vs. specialist)
- Feeding pattern (aerial vs. gleaner)
- Summer roost sites (crevice vs. open)
- Commensal rooster (during summer) vs. not
- Wintering strategy (hibernate vs. torpor vs. migrate)
- Hibernaculum type (cave vs. other)
- Sociality (highly colonial vs. less social)
- Tolerance to human disturbance (tolerant vs. sensitive)
- Tolerance to human handling (tolerant vs. sensitive)

Also prior to the workshop, FWS developed and distributed a questionnaire to solicit existing expertise and successes/failures in managing insectivorous bats in captivity. Responses were received from 42 rehabilitation, zoological and research collections on a global level (10 countries)(see Appendix II for details). The resulting data were compiled by BCI and added to the matrix (Table 1). Captive expertise data were categorized as short term (ST) or long term (LT); as limited vs. extensive; and as successfully holding, hibernating and/or reproducing bats. Forty species were assessed and are presented in the matrix in the following order: Federally listed threatened species (n = 4); species considered currently at risk of WNS (n = 23); and other North American species potentially at risk in the future (n = 13). The compilation of these data not only provide existing captive expertise for each species of concern, but also allow for the identification of potential surrogate species (that have been managed, or could be used for development of management techniques) for those species for which there is little to no existing expertise.

Table 1. Matrix of relevant life history and behavioral traits and captive expertise for 40 North American insectivorous bat species.

Species	Body size	Foraging (generalist vs specialist)	Feeding pattern (aerial vs gleaner)	Summer roost sites (crevice vs open)	Commensal rooster (summer)	Winter strategy (hibernate vs migrate vs torpor)	Hibernaculum (cave vs other)	Sociality (highly colonial vs less social)	Tolerance to disturbance	Tolerance to handling	Captive Expertise (short-term & long-term)
Myotis sodalis	Medium	Generalist	Aerial	Crevice	No	Hibernate	Cave	Highly colonial	Sensitive	Sensitive	LT, limited
Myotis grisescens	Medium	Generalist	Aerial	Open	Yes	Hibernate	Cave	Highly colonial	Sensitive	Moderate	LT, limited
Corynorhinus townsendii ingens	Medium	Specialist (moths)	Aerial/gleaner	Open	No	Hibernate	Cave	Highly colonial	Sensitive	Sensitive	None reported
Corynorhinus townsendii virginianus	Medium	Specialist (moths)	Aerial/gleaner	Open	No	Hibernate	Cave	Highly colonial	Sensitive	Sensitive	ST, limited
Antrozous pallidus	Large	Generalist	Gleaner	Crevice	Some evidence	Hibernate	Cave	Highly colonial	Tolerant	Tolerant	LT, extensive, breed, hibernate
Eptesicus fuscus	Large	Generalist	Aerial	Crevice	Yes	Hibernate	Cave, other	Highly colonial	Tolerant	Tolerant	LT, extensive, breed, hibernate
Euderma maculatum	Medium	Specialist (moths)	Aerial	Crevice	No	Hibernate	Cave, other	Less social	Unknown	Unknown	None reported
Idionycteris phyllotis	Medium	Generalist	Aerial/gleaner	Crevice	No	Hibernate	Cave, other	Less social	Unknown	Sensitive	None reported
Myotis auriculus	Medium	Generalist	Aerial	Crevice	No	Hibernate	Cave, other	Less social	Unknown	Unknown	None reported
Myotis austroriparius	Medium	Generalist	Aerial	Crevice/open	Yes	Hibernate & Migrate/Torpor	Cave, other	Highly colonial	Unknown	Unknown	LT, limited, hold
Myotis californicus	Small	Generalist	Aerial	Crevice	Yes	Hibernate	Cave, other	Less social	Tolerant	Tolerant	None reported
Myotis ciliolabrum	Small	Generalist	Aerial	Crevice	Yes	Hibernate	Cave, other	Less social	Unknown	Tolerant	ST, limited
Myotis evotis	Medium	Generalist	Aerial	Crevice	Yes	Hibernate	Cave, other	Less social	Unknown	Tolerant	None reported
Myotis keenii	Medium	Generalist	Aerial	Crevice	No	Hibernate	Other	Unknown	Tolerant	Sensitive	None reported
Myotis leibii	Medium	Generalist	Aerial	Crevice	No	Hibernate	Cave, other	Less social	Unknown	Unknown	Limited, hold
Myotis lucifugus	Medium	Generalist	Aerial	Crevice	Yes	Hibernate	Cave	Highly colonial	Tolerant	Moderate	LT, extensive, hibernate
Myotis occultus	Medium	Generalist	Aerial	Crevice	Yes	Hibernate	Cave	Highly colonial	Unknown	Unknown	None reported
Myotis septentrionalis	Medium	Generalist	Aerial	Crevice (tree bark, bat houses)	No	Hibernate	Cave	Less social	Tolerant	Sensitive	ST, extensive, hold
Myotis thysanodes	Medium	Generalist	Aerial	Crevice	No	Hibernate	Cave, other	Less social	Unknown	Tolerant	None reported
Myotis velifer	Medium	Generalist	Aerial	Crevice/open	Yes	Hibernate & Migrate/Torpor	Cave	Highly colonial	Tolerant	Tolerant	LT, extensive, hold

Species	Body size	Foraging (generalist vs specialist)	Feeding pattern (aerial vs gleaner)	Summer roost sites (crevice vs open)	Commensal rooster (summer)	Winter strategy (hibernate vs migrate vs torpor)	Hibernaculum (cave vs other)	Sociality (highly colonial vs less social)	Tolerance to disturbance	Tolerance to handling	Captive Expertise (short-term & long-term)
Myotis volans	Medium	Generalist	Aerial	Crevice	No	Hibernate	Cave	Less social	Unknown	Tolerant	None reported
Myotis yumanensis	Medium	Generalist	Aerial	Crevice	Yes	Hibernate	Cave, other	Less social	Conflicting opinions	Tolerant	None reported
Nycticeius humeralis	Medium	Generalist	Aerial	Crevice	Yes	Hibernate	Other	Highly colonial	Tolerant	Tolerant	LT, extensive, birth
Parastrellus hesperus	Small	Generalist	Aerial	Crevice	No	Hibernate	Cave, other	Less social	Tolerant	Tolerant	ST, limited, hold
Perimyotis subflavus	Small	Generalist	Aerial	Crevice/open	Yes	Hibernate	Cave	Less social	Tolerant	Tolerant	LT, extensive, hold
Corynorhinus rafinesquii	Medium	Specialist (moths)	Aerial/gleaner	Open	Yes	Hibernate & Torpor	Cave, other	Highly colonial	Tolerant	Sensitive	ST, limited, hold
Corynorhinus townsendii (western)	Medium	Specialist (moths)	Aerial/gleaner	Open	Yes	Hibernate	Cave, other	Highly colonial (occasionally found solitary)	Moderate	Moderate	Limited, hold
Lasiurus borealis	Large	Generalist	Aerial	Open	No	Migrate/Torpor	Other	Solitary	Tolerant	Tolerant	LT, extensive, birth
Lasionycteris noctivagans	Large	Generalist	Aerial	Crevice	No	Migrate/Torpor	Other	Solitary	Tolerant	Tolerant	LT, extensive, hold
Lasiurus cinereus	Large	Generalist	Aerial	Open	No	Migrate/Torpor	Other	Solitary	Tolerant	Tolerant	LT, extensive, hold
Lasiurus intermedius	Large	Generalist	Aerial	Crevice (tight veg)	No	Migrate/Torpor	Other	Solitary (mostly)	Tolerant	Tolerant	LT, extensive, birth
Lasiurus seminolus	Large	Generalist	Aerial	Open	No	Migrate/Torpor	Other	Solitary	Tolerant	Tolerant	LT, extensive, birth
Tadarida brasiliensis	Medium	Specialist?	Aerial	Crevice/open	Yes	Migrate/Torpor	Other	Highly colonial	Tolerant	Tolerant	LT, extensive, hold, breed
Eumops perotis	Large	Generalist	Aerial	Crevice	No	Active	Other	Highly colonial	Tolerant	Tolerant	LT, limited, hold
Molossus molossus	Medium	Generalist	Aerial	Crevice	No	Active	n/a	Highly colonial	Unknown		Limited, hold
Nyctinomops macrotis	Large	Generalist	Aerial	Crevice	No	Active	n/a	Highly colonial	Tolerant	Tolerant	LT, limited, hold
Nyctinomops femorasaccus	Large	Generalist	Aerial	Crevice	No	Active	n/a	Highly colonial	Tolerant	Tolerant	LT, limited, hold
Eumops floridanus	Large	Generalist	Aerial	Crevice (tight veg)	No	Active	n/a	Highly colonial	Unknown	Unknown	LT, limited, hold
Macrotus californicus	Medium	Specialist	Aerial	Open	No	Migrate/Torpor	Cave	Highly colonial	Unknown	Unknown	Limited, hold
Mormoops megalophylla	Medium	Specialist?	Aerial	Open	No	Migrate/Torpor	Other	Highly colonial	Sensitive	Sensitive	ST, limited

Summer Roost: This is not exclusively rock and cave crevices but may include under slabs of bark or known bat house use . **Hibernaculum:** "Cave" classification includes both caves and mines.
Captive Expertise: Long-term (LT) = individuals successfully held >1 month; short-term (ST) = held <1 month. Hold = held reproductively active individuals; birth = already pregnant females gave birth to live young; breed = individuals successfully bred in captivity.

The workshop participants discussed which life history traits might be relevant to captive management and why. Generalists that glean were thought to be more likely to adapt easily to captivity than feeding specialists that eat only on the wing. Aerial feeders may have difficulty adapting to a diet of mealworms. Another potential important distinction is colonial species that may not thrive in small groups compared to non-colonial species. Hibernating cave-dependent species may more difficult to get through the winter than non-cave dependent species. Bats that come out of torpor frequently may be more adaptable in captivity since they will just move in the cage and go back into torpor.

Two of the traits discussed were the relative tolerance of each species to human disturbance (both in the wild and in captive environments) and to handling (e.g., during capture, as part of overall captive maintenance). Bats that are commensal with humans (e.g., roost in attics and walls) may be more likely to do better in captivity, although some species that do not routinely encounter humans (e.g., *Lasionycteris* and *Lasiurus*) also do well in captivity. Workshop participants offered their collective expert opinion for species for which they had knowledge or experience; while general classifications were recorded in the species matrix, more detailed species-specific comments are listed below. Participants recognized that although there may be some correlation between these types of traits and ease of captive management, there is also significant variation among individual bats, even within a species.

Tolerance to Disturbance and Handling (Species Characterization)

The following discussion summarizes comments received by participants when discussing specific bat species. These comments are not consensus opinions of the group but were offered by specific individuals.

Indiana bat (*Myotis sodalis*)*:* Highly intolerant to disturbance. Can be tolerant of noise next to their roosts and will actually roost next to a parking lot; however, individuals must be acclimated to disturbances or they will abandon a site. When handled, have been observed to pass out.

Gray bat (*Myotis grisescens*)*:* Highly intolerant to disturbance. Sturdier than Indiana bats during handling.

Virginia big-eared bat (*Corynorhinus townsendii virginianus):* Highly sensitive in both summer and winter; very intolerant of handling and get very stressed out when handled and may even die from being caught or handled. VA big-eared bats are somewhat tolerant in outdoor situations, though, and are only intolerant in their roosting sites. In outdoor monitoring sites they will sometimes come up and "check out" the researcher. However, in roosts they may even abandon a roost site for the season due to disturbance.

Ozark big-eared bat (*Corynorhinus townsendii ingens*): Same as for Virginia big-eared bats.

Pallid bat (*Antrozous pallidus*)*:* Have no problem and are very hardy and sturdy. There was a comment that they dislike being handled, but this may be situational and specific to individuals versus species constraints.

Big brown bat (*Eptesicus fuscus*)*:* Very tolerant in maternity roosts.

Spotted bat (*Euderma maculatum*)*:* No information.

Allen's big-eared bat (*Idionycteris phyllotis*)*:* They tend to be fairly stressed when handled, but burrow in (which is not a bad response) and do not die.

Mexican long-eared bat (*Myotis auriculus*): No information.

Southeastern bat (*Myotis austroriparius*): No information; however, they probably behave like other *Myotis*.

Californian myotis (*Myotis californicus*): Do just fine.

Western small-footed myotis (*Myotis ciliolabrum*): Do just fine.

Western long-eared myotis (*Myotis evotis*): Do just fine.

Keen's myotis (*Myotis keenii*): No information.

Eastern small-footed myotis (*Myotis leibii*): Respond as a typical *Myotis*.

Little brown bat (*Myotis lucifugus*)*:* Tolerant of some handling, but will abandon sites if handled too much. It appears that bats may view handling as a predation attempt and they can recover from it.
Arizona myotis (*Myotis occultus*)*:* Probably like little brown bats. Males seem more intractable than females.
Northern long-eared myotis (*Myotis septentrionalis*): They do not do well in captivity. Very high strung and will tip over in your hand. Others said that they are tough and hardy when caught in a mist net.
Fringed myotis (*Myotis thysanodes*): No information, but may not be problematic like gray bats.
Cave myotis (*Myotis velifer*): They are feisty and have an attitude. Very hardy and will not pass out on you. More likely than other bats to bite if given the chance when handled.
Long-legged myotis (*Myotis volans*): No problem.
Evening bat (*Nycticeius humeralis*): Some individuals do not adapt well but other individuals do just fine. Frequently live with big brown bats and are not so sensitive that they will die in your hands.
Canyon bat (formerly western pipistrelle) (*Parastrellus hesperus*)*:* Very easy to have in captivity and are easy to capture. Do not fight that much but also do not pass out.
Tricolored bat (formerly eastern pipistrelle) (*Perimyotis subflavus*)*:* Highly tolerant of some disturbance such as people walking by, but do not deal well with handling.
Rafinesque bat (*Corynorhinus rafinesquii*): Very tolerant of human disturbance at both summer and winter roosts. Some disagreement within the group on this; we should probably consider them variable and that it depends on the site and disturbance.
Townsend's big-eared bat (*Corynorhinus townsendii (western)*)*:* Do not go into shock. Rehabbers say they are fine in captivity. Many have handled them frequently, taken wing punches, etc., with little problem. Second-hand reports from some biologists suggest that individuals occasionally go into shock.

Note: For most species there appears to be a sexual difference, but the direction of the difference is not always consistent. In general females may become more stressed than males. Even in a mist net females exhibit more of a stress response. However, some agreed that male Virginia big-eared bats seem to stress more and that females tolerate handling better. In Indiana bats, males seem to have more of a shock response than females. When lactating, females may have a different stress response due to the need to care for their offspring.

It was recognized that behavioral / physiological stress and the physical manifestation of stress are two different things. Even if a bat does not seem to have a stress response, physiologically they may be stressed—we just may not be perceiving it as stress. Stress may explain why some bats go into shock, as shock is a stress response.

Participant Comments Related to Captive Management

- Do you need hibernation for sperm viability in the spring?
- Some captive facilities do not allow their bats to hibernate so that they can keep them from breeding.
- There is some evidence that some species come out of torpor one out of three nights and still have viable sperm.
- Big brown bats typically wake up once a week, drink and feed, but they are still successfully storing sperm.
- If you put big brown bats in a flight cage in the winter, they are pregnant in the spring.
- Sometimes males will come out of torpor in the winter and copulate, which successfully leads to offspring. Therefore not all copulation occurs prior to torpor. Males will even mate with females in torpor.
- Need to consider the transportation of bats from the field to the lab. Recommendation is to transport each individual bat in a small cloth bag since transportation is stressful. A specific recommendation was made to transport bats in roosting pouches within small carriers.

- Is it better to transport bats taken out of hibernation warm or cold? Probably cold, but once you start moving them about they will wake up anyway. Once they wake up, they would use less energy in a warm environment.
- Do not disturb while in deep hibernation (can kill them). Do not wake up to feed. Do not micromanage, but just let them alone.
- Bats are complex animals, and their physical and psychological requirements in captivity are more complicated than many small mammals and require dedicated attention.

Potential Roles for Captive Bat Populations

Another essential component in the evaluation of captive management as one part of an overall bat conservation management strategy is an assessment of the potential conservation value and benefits that these options might provide. The overall conservation goal for each bat species is to maintain a stable, viable population across the species' range. A plenary brainstorming session generated the following list of ways in which a captive population might help to achieve this goal (listed in order of priority):

- Provide a way to remove or ***minimize a seasonal threat*** (e.g., from WNS in the winter). Maybe keep individual bats in captivity in the winter only.

- Provide a ***treatment opportunity*** for WNS-infected bats.

- Bring a subset of the population into captivity until we find a way to minimize WNS—not necessarily for a breeding program, but to hold the individuals as an ***assurance population***. Captive holding would assure persistence of the individuals captured, but would not necessarily lead to a sustaining captive population.

- Maintain ***genetic reservoir*** as an insurance policy in case there is a loss in the wild.

- ***Reduce the spread of WNS*** in wild populations by reducing bat density (by bringing some individuals into captivity). This effect seems to be present in amphibian rescue efforts.

- Provide a ***source population for supplementation***.

- Provide ***educational outreach opportunities***.

- Provide ***source animals for research***.

- ***Prevent species extinction***.

A general discussion followed regarding specific issues or questions to be considered if captive management options are pursued, and are summarized below:

- It was recommended that any assumptions should be made clear at the onset of any captive program. For example, one assumption might be that it will eventually be possible to eliminate, or successfully treat, WNS.

- It would be valuable to examine other captive and reintroduction programs to learn from past successes and failures. Why were they successful, or why did they fail? This could begin with a literature review.

- The establishment of captive programs will bring in new partners and strengthen collaboration for conservation in the long term. More partners bring more resources and ideas, and increase the potential for what can be accomplished.

- It will be necessary to have a powerful outreach/education component prior to initiating any captive propagation, or we may not have public support. It may be difficult to hold bats in a public viewing exhibit since insectivores do not handle "viewing" well and frequently die from stress. Alternatives such as Webcams or newsletters may be necessary.

- When is the best time to capture bats? Fall swarm has advantages for cryopreservation, but a disadvantage is a co-mingling of species and possible cross contamination. Capturing bats during hibernation also has an advantage in that bats are hungry and more motivated to eat; however, this is a physiologically challenging time for bats and some believe hibernation to be a bad time for collection. Also, collecting them during hibernation will disturb those left in the wild.

- Waiting until the "last minute" to bring bats into captivity is a poor option, as there may not be sufficient husbandry knowledge to maintain and propagate them successfully; in addition, if the wild population is small, this might result in a genetic bottleneck in a captive colony. In some cases it will be necessary to "practice" bringing bats into captivity and maintaining them successfully in a captive facility, which ideally should be done while the wild population is still large. It is important for people to understand that some individuals will likely die until we develop the knowledge base and techniques to keep that particular species in captivity, especially if it is a challenging or sensitive species.

- There is a risk that bringing individual bats into captivity will reduce the ability of natural selection to act on the wild population. Bats may need to coevolve with WNS; however, this assumes that this is possible and that there would be survivors of WNS. If some bats do survive in the wild in the presence of WNS, they can be used to augment other natural populations.

- Little brown bats are the most common and may serve the most ecosystem functions. Do we try to save a species that has only 15,000 individuals left, or do we focus on species that provides the most ecosystem functions such as the little brown bat?

It is important that the role(s) or potential role(s) of any captive program be identified at the onset, as the role(s) will define particular aspects of the program itself, such as the number of bats to be captured to ensure any demographic or genetic requirements; the length of the program; and whether it needs to be a breeding population held over multiple generations. The workshop participants decided that possible captive management options could be broadly divided into short-term, non-reproducing populations and long-term, breeding populations. This distinction formed the basis for convening smaller working groups to continue the feasibility assessment of these options (see Sections 3–5).

Benefits and Risks of the 'No Captive Management' Option

After the working groups completed their tasks related to the feasibility assessment of various short- and long-term captive management options, a plenary discussion was conducted to identify the potential benefits and risks of *not* establishing any captive management programs for bats in response to the WNS threat—termed the "No Captive Management" option. This option excludes not only long-term captive propagation programs but also temporary captive holding, such as bringing bats into captivity during winter to reduce WNS exposure. The only captures that would occur under the No Captive Management option would be very short-term care of injured individuals for treatment and release (rehabilitation).

It was suggested that any assumptions should be clearly articulated. Three assumptions were offered by some participants: 1) wild bat populations will go extinct or experience severe population decline due to WNS; 2) there is insufficient evidence that WNS affects all bat species; and 3) not all captive breeding efforts will be successful. Not all participants agreed with these assumptions.

Benefits of Having No Captive Management Programs

The following potential benefits were identified in plenary discussion by the workshop participants:

- All genetic material is kept in the wild (no loss of genetic lines to the captive program).
- No impact on natural selection (allows natural selection to favor WNS-resistant bats).
- Free up financial resources for other WNS-related efforts (no competition for funds).
- Avoid disease transmission risks due to human activity (variety of risks, including accidental transmission of WNS between regions or species).
- Avoid bat mortality due to captive maintenance.
- Would maintain normal social structure in the wild. Wild bats are able to experience normal behavior, environment, and natural ecosystem functions.

Risks of Having No Captive Management Programs

- Multi-species extinction (level of acceptable risk is defined by the stakeholder)
- May lose localized populations of a species (e.g., in the Northeast).
- Functional extinction (both genetic bottleneck and also loss of ecological functions)
- Loss of subpopulations within a region, therefore lose some of the genetic diversity within the species.
- Loss of individual bats
- Loss of credibility (zoos have a moral obligation to step up to the conservation challenges)
- Risk of lawsuits (can go either way—action or no action)
- Public outcry (upset you did something/upset you didn't do something)
- There are a lot of data gaps. If we do not bring them in, we will not have the opportunity to learn and fill these gaps.
- Risk greater catastrophic failure if we wait too long.
- Risk opportunity to develop husbandry techniques and lose critical time.
- Ecosystem collapse due to loss of bats (non-bat species/loss of guano)
- Loss of bats as pest consumers (agriculture, forestry impacts)
- Increase in disease vectors
- There may be survivors of WNS in the wild but are too widely dispersed for long-term viability. In such a case, we may need to bring them into captivity to breed and grow the population. We need to have the knowledge and ability to run captive propagation facilities before there are only a few individuals left of a species or population.
- Loss of potential collaborators if we do not establish captive programs. Captive programs would build momentum, public awareness, potential funding, and additional expertise.
- Loss of treatment opportunities (will not be able to do experimental treatments if there are no captive bats).

Additional Considerations

- There are a lot of unknowns; however, 5 to 10 years from now, we may say "why didn't we keep these animals in captivity?" If we do not establish captive populations, we may lose the ability for adaptive management in the future. There is a risk of regret for doing nothing now.
- How aggressive are we going to be in the face of a rapidly spreading disease? Are we going to be more or less aggressive?

- Do we have a responsibility to other countries to develop and provide the tools they will need if WNS spreads there? We need to be able to offer other regions/countries as much as possible.
- When discussing captive management we often talk of costs. We also need to consider the value of the ecosystem benefits that bats bring to our economy (dollar figure on ecosystem services).

Triggers

Workshop participants were asked to consider what situations or criteria might serve as "triggers" for establishing a captive population. The following list was produced during a plenary brainstorming session:

- WNS is confirmed a specific distance from species X.
- Loss of X% of a species from a multitude of stressors (WNS and other stressors)
- If a PVA is available, X% PE over X years.
- X% loss of species and X% loss of range of species
- Proximity of threat of WNS to geographic range of the species (maybe when WNS is X kms away).
- Scope and severity of threat (e.g., X% of species is threatened)
- Small population size (lower genetic diversity and less likely to have any resistance to WNS)
- Number of populations. The critical number would be fewest populations seasonally. For example, if an entire species hibernates in 2 or 3 hibernacula, then 2 or 3 is the critical number, regardless of the number of individuals in that species. A threshold would need to be identified for each species.
- Microclimate constraints (e.g., if certain bats hibernate in caves that are more conducive to WNS).
- Susceptibility of a given species to WNS
- Possibly genetic triggers? Given the rate of WNS spread and mortality, species will need to be monitored intensively before WNS is anticipated. The genetic trigger may really be a demographic trigger. A species that is already at high risk may already be at demographic risk, and there may be no unique genetic triggers.
- In western states in particular, the trigger may be when *Geomyces destructans* is detected in a state and not when WNS manifests itself.

Related considerations (but not actual triggers themselves) might be the likelihood of success, level of uncertainty, establishment of a successful pilot project, and available funding sources and facilities.

Concluding Discussion and Questions

The workshop concluded with a final plenary discussion that posed three questions to all participants:

1) Which strategy, including the no action alternative, is your recommendation?
2) What are the highest priority captive management research questions?
3) What else would you like to convey to the group regarding captive management?

Some participants shared their viewpoints on Questions #1 and #2 during plenary. Participants were offered the opportunity to provide their comments for #3 in written form to FWS after the workshop for consideration (see Appendix IV).

Question #1: Which strategy, including the no action alternative, is your recommendation?

Many of the workshop participants thought there is merit in captive management, acknowledging that it will be important to work with those with captive expertise to promote success. Some participants expressed skepticism regarding the likelihood of success in breeding bats in captivity and/or releasing them. All options were seen to offer some utility and value, and given the variation among species in both risk and ease of management, no single option stands out as the best strategy for all bat species. Rather, it is beneficial to view all captive management options as a toolbox from which managers can choose as appropriate. An adaptive management approach will provide needed flexibility in the face of existing knowledge gaps. Specific individual comments are given below:

“There is no single strategy that is best for all situations; we need to consider all strategies. We also need to consider treating animals as they hibernate. I do not support the No Captive Management option. While there are many caveats, captive management can be done.”

“Captive management may be doable, but what is our capacity to release bats afterward? If successful reintroduction is not possible, then we should not bring bats into captivity. We also need treatment options, but we are not there yet. We need pilot projects so that we can develop the techniques; there is value in the tool. But I have concerns of cost versus benefits. Is it valuable to keep captive populations if they are extinct in the wild?”

“Agree with the previous comment. Keep in mind that scientists have been researching and working on a cure for chestnut blight for 50 years now, and that is a species that we really understand. There is no guarantee that we will find a cure for WNS and we need to keep in mind that there are a lot of bat species.”

“Favor short-term captive colonies. If you cannot effectively re-introduce them, don’t do it.”

“There is considerable merit on working through husbandry techniques. We need to fine tune this. It may be expensive, but at least we’ll have a tool that can be used later.” (Note: there was significant support for this idea among the participants.)

“Need to apply adaptive management strategy and its principles. We need to try something and if it is not working, we need to be willing to abandon it and try something else.”

“All options need to stay on the table—what works in one case may not work in another.”

“Short-term management has a lot more flexibility. We are learning from zoos that we do not have large enough populations to manage an entire species and will need to bring in additional founders. Maybe we should bring in individuals for a couple of years and see what happens in nature.”

“Keep all tools in the toolbox. It is extremely doable if we do this for only one or two species. I do not believe that reintroduction will be that much of a problem. The social/political constraints in the human arena may be the bigger constraint (for example, groups may develop that are opposed to any reintroductions, as happened with the red wolf). NIMBYs (Not In My BackYard opinions) may develop.”

“Options of taking animals from the wild under the short term buy time. Then later we need to consider if we want to do captive breeding. All options then will be maintained.”

“Need a pilot to see if we can do captive propagation (breeding). We can do captive holding.”

“It takes longer than we think to work out the bugs, especially for long-term strategies.”

“If we are thinking of doing it, we need to get going now. Get the techniques down now.”

“Agree to not eliminate long-term options yet. Because there are so many things we need to know about the genetics and numbers, we need to try something now or it may be too late.”

“Captive facilities can act as a flagship for the species. For example, captive cheetahs raise a lot of money by increasing public awareness. The increased funds then go to conservation efforts in the wild. The captive population provides research dollars. This may be a way of getting people excited about it.”

Additional comments heard from invitees who did not attend the workshop:

- Money is an issue. If you fund captive programs you will drain money from other needed efforts. If we make captive colonies a top priority we may out-rank other efforts.
  Response to above: If zoos and other partners get involved they will likely be sharing the financial burden. FWS may still be providing some funding, but the FWS would not be the sole funder.

Ethics:

- Is it appropriate to bring these individual bats into captivity knowing that we currently do not have a great track record at keeping them alive? Is it appropriate to have some individuals suffer?
  Response to above: The group agreed that individual bats may have a reduced quality of life, but the conservation of the species outweighs it. That being said, we need to do it correctly and build on the capabilities for captive holding that already exist. We need to ensure that any facilities actually will meet the goals. If questioned on the appropriateness of holding wild bats, remind people that there may be some benefits to the individual bats too (life in the wild is difficult).

Question #2: What are the highest priority captive management research questions?
The group also identified several priority research topics, listed below:

- Susceptibility of specific species to WNS
- Treatment/cure for WNS
- Role of hibernation in reproduction in captivity
- Potential methods for natural control of *Geomyces destructans* (biocontrol)
- Develop cryopreservation and assisted reproduction techniques as less expensive alternatives to captive propagation.
- Bank cell lines immediately.
- Post-release survivability studies.
- Genetic population structure of captured animals
- Annotated bibliography on other captive management programs.
- Identification of resistant individuals. Is there a genetic basis for resistance?

Next Steps

The workshop concluded with the above discussion. Because of the restrictions due to the Federal Advisory Committee Act (FACA), workshop participants were not allowed to reach consensus or make specific recommendations to the FWS as a group. Rather, the data compiled prior to and during the workshop, along with the results of the working group and plenary discussions, are being considered by the FWS to aid in determining a course of action for bats, especially for species at high risk of being affected by WNS. These data also may be useful to other conservation organizations in considering captive management programs or other conservation actions for insectivorous bat species.

Insectivorous Bat Captive Population Feasibility Workshop

Saint Louis, Missouri, US
14 – 16 July 2010

Final Report

SECTION 3

Short-Term Management Strategies Working Group Report

Short-Term Management Working Group Report

Members: Mylea Bayless, Jeremy Coleman, Barb Douglas, Bill Elliott, Cory Holliday, Randy Junge, Robyn Niver, Luis Padilla, Mary Parkin, Lori Pruitt, Noelle Rayman, Craig Stihler, Leslie Sturges, Steve Wing

Potential Roles and Strategies

This working group focused on the possible short-term captive holding options for insectivorous bats, which represents non-breeding holding strategies. Participants reviewed the list of potential roles generated in the plenary discussion, and identified the following roles that potentially could be met with non-breeding options:

Potential roles of non-breeding strategies:
A = minimize seasonal threats
B = source of research animals
C = WNS treatment options
D = short-term persistence of individuals
E = decrease spread of WNS in wild
F = education/outreach
G = holding and translocation

Several short-term management strategies were discussed that could meet one or more of these roles. These can be simplified into three overarching strategies ranging from extremely short-term to multi-season with variations on how bats are kept, when collection occurs, etc. The group recognized that there were sub-strategies within some of these strategies.

Strategies discussed:
1. Seasonal holding (winter)—bats in hibernation state
2. Seasonal holding (winter)—bats in non-hibernation state
3. Seasonal holding (active period) (dates can vary geographically)
4. Multi-season up to multi-year holding—include hibernation state
5. Multi-season up to multi-year holding—maintain in active state
6. Short-term holding for treatment application

The group prioritized strategies 1, 4, and 5 (seasonal hibernating holding and multi-season holding options) to discuss first; however, sufficient time was available to discuss all of the strategies.

Potential funding sources, expertise, and collaborators were similar for all strategies, with slight variations. Feasibility (costs, capacity, and immediacy) was highest for shortest length of holding and declined for seasonal and multi-year holding. For strategy 6, there are no known treatment options that exist at this time; pilot projects can begin as soon as possible for others.

Challenges/knowledge gaps generally increase as strategies progress from very short-term to multi-year. However, no known treatment options exist for successful implementation of strategy 6.

There were differences of opinion regarding which projects caused the greatest anxiety/concern about being able to effectively implement them. Some group members believed that trying to maintain bats in a natural hibernation state was most risky because it may not be possible to monitor bats as frequently.

Others believed that seasonal winter holding in a natural state would be the most likely to succeed in the short term because the bats will be able to do what they normally do.

There is a need to clearly articulate goals for each approach for any potentially involved species. There is also a need to clearly determine how to measure success for each approach.

Seasonal, Short-Term Strategies (less than one year)

Strategy 1: Winter holding, Hibernating:
Collect bats during or after swarming, keep bats in an artificial hibernaculum for one winter season and then release (at collection site or alternative natural site) or provide for research. Allow natural release if possible or release at normal spring emergence time.

***Roles*—**A, B, C, D
A = minimize seasonal threats
B = source of research animals
C = WNS treatment options
D = short-term persistence of individuals

Benefits

- No need to maintain bats year-round
- Learn more about hibernation requirements
- Increased husbandry techniques
- Could work with a larger number of animals
- No genetic concerns
- More economical (less care for bats = fewer staff providing care, fewer handling and food requirements)
- Fewer concerns with losing natural behaviors
- Reduced stress for bats
- Less disturbance of seasonal reproductive cycle
- Can potentially implement sooner and have success
- Ability to manipulate the environment (provide bat needs and potentially decrease effects of WNS)

Risks

- Unable to control WNS in an artificial hibernaculum at this time
- Disturbance to colony and structure
- Catastrophic failure of artificial hibernacula
- Lack of knowledge on species-specific requirements to maintain appropriate microclimate for hibernation
- Not enough known to guarantee success
- Could increase stress
- Exposure to parasites and pathogens

***Expertise*—**Species dependent. Some expertise exists on captive holding in hibernation, some expertise exists on constructing large artificial hibernacula, knowledge of some species hibernation needs.

Challenges
- Expanding capacity
- Identifying pertinent experts
- Building artificial hibernacula
- WNS treatment of bats and/or hibernacula
- Transportation challenges
- Timing of collection
- Overall planning process/permitting
- Staffing challenges (i.e. rabies vaccinations)
- Catching bats
- Monitoring clusters while minimizing disturbance to bats
- Rescue plan if bats start to die
- Security

Knowledge gaps
- Hibernacula microclimate information for some species
- Social behavior/dependence
- WNS treatment of bats and/or hibernacula
- Optimal timing of collection

Potential collaborators— state agency biologists, zoos, rehabilitators, universities, cavers, non-governmental organizations (NGOs), engineers/consultants, corporations, Department of Defense (DOD), U.S. Fish & Wildlife Service (FWS), U.S. Forest Service (FS), Nuisance Wildlife Control Operators (NWCOs)

Funding sources/other—Morris Animal Foundation, Disney, Wallace Global Foundation, FWS, local or regional family foundations, NGOs, cave conservancies, corporations (e.g., pest control)

Scope

a) Number of bats/colonies—start with a small number; consider cluster size; colonial vs. non-colonial species; suitable cluster size based on species life history; start with unaffected bats; possibly use species where microclimate and hibernation cycle is known (e.g., little brown bats).

b) Facilities—pilot project of one or two facilities, full scale would involve multiple facilities
   1. artificial structure at/near hibernaculum location (e.g., pod) with easy access; temperature and humidity controlled; remote monitoring (infrared cameras); develop rescue plan if bats start to die; provide different microclimates and roost opportunities; provide sufficient room to fly around inside pod.
   2. laboratory setting; temperature and humidity controlled; remote monitoring (infrared cameras)

c) Timeline—pilot project could begin as soon as winter 2010-2011

d) Costs—pilot project
   1. Pod ($50,000 per pod), initial costs $200K up to millions for fully implemented project
   2. Laboratory—unknown

Strategy 2: Winter holding, Non-Hibernating:
Keep bats in a facility in a non-hibernating state for one winter season, then release back to natural hibernacula or for research.

Roles—A, B, C, D, F, G
A = minimize seasonal threats
B = source of research animals
C = WNS treatment options
D = short-term persistence of individuals
F = education/outreach
G = holding and translocation

Benefits
- No need to maintain bats year-round
- Fewer bats will be needed
- Fungus doesn't grow
- Access to bats for a longer period
- More treatment opportunities
- More outreach opportunities
- See Hibernating Strategy 1 benefits

Risks
- More labor intensive and costly
- More disturbance to their natural hibernating cycle
- More long-term treatment is needed
- Not known if all bat species can skip hibernation cycle
- Risk of decreasing natural breeding cycle
- Potential for other physiological effects
- Potential for captive selection
- Potential for out of season parturition
- Possibility for catastrophic failure
- Long-term maintenance of facilities with short-term use

Expertise—Species dependent. Some expertise exists on captive holding in active season, design of facilities, expertise in physiology (e.g., torpor), social behavior, indoor enrichment, feeding.

Challenges
- Expanding capacity
- Identifying pertinent experts
- WNS treatment of bats
- Transportation challenges
- Timing of collection
- Overall planning process/permitting
- Staffing challenges (i.e. rabies vaccinations)
- Catching bats
- Monitoring clusters
- Rescue plan
- Security
- Maintaining appropriate photoperiod

Knowledge gaps

- Social behavior/dependence
- WNS treatment of bats
- Timing of collection

Potential collaborators—state agency biologists, zoos, rehabilitators, universities, cavers, NGOs, engineers/consultants, corporations, DOD, FWS, FS, NWCOs, National Park Service (NPS), U.S. Geological Survey (USGS)

Funding sources/other—Morris Animal Foundation, Disney, Wallace Global Foundation, FWS, local or regional family foundations, NGOs, cave conservancies, corporations (e.g., pest control)

Scope

a) Number of bats/colonies—most likely to be used with affected bats; start with a small number; colonial vs. non-colonial species; consider suitable group size based on species life history,
b) Facilities—pilot project at existing facilities; full scale would involve multiple off-site facilities with flight cages and veterinary care
c) Timeline— pilot project may be reasonable to start as soon as 2010.
d) Costs
   i. Pilot project—limited capital costs but seasonal animal care cost
   ii. New facilities—$1-1.5 million/facility plus seasonal animal care costs

<u>Strategy 3: Summer/Active Period Holding:</u>

Maintain bats in a facility, then release back to natural roosting site or research. This may involve opportunistic collection, as well as targeted collection of bats.

Roles**—**B, C, D, F, G

B = source of research animals
C = WNS treatment options
D = short-term persistence of individuals
F = education/outreach
G = holding and translocation

Benefits

- Increased husbandry techniques
- Lower cost than multiple season
- Multiple-year scenario
- Increased research opportunities
- Increased educational opportunities
- Opportunity for birth (WNS-free young)
- Reduced impact to breeding cycle
- Maintains support from and increased collaboration with rehabilitation community (use of existing resources/smaller facilities and less reliance on a large facility)

Risks

- Challenge with temperature control when transporting during summer
- Increased stress (teaching bats to self-feed, etc.)
- Highly labor intensive and more expensive
- Small-scale population impact/benefit

- Negative public and professional response
- Exposure to pathogens and parasites

Expertise—Species dependent. Some expertise exists on captive holding in active season, design of facilities, expertise in physiology, social behavior, indoor enrichment, feeding, rearing of pregnant females and pups, and veterinary care.

Challenges
- Expanding capacity
- Identifying pertinent experts
- WNS treatment of bats
- Transportation challenges
- Timing of collection
- Overall planning process/permitting
- Staffing challenges (i.e., rabies vaccinations)
- Catching bats
- Monitoring clusters
- Rescue plan
- Security
- Husbandry techniques unknown for all species

Knowledge gaps
- Social behavior/dependence
- WNS treatment of bats
- Optimal timing of targeted collection (spring emergence is most feasible)
- Nutrition necessary to maintain pregnancy and lactation

Potential collaborators—state biologists, zoos, rehabilitators, universities, NGOs, corporations, DoD, FWS, FS, NPS, NWCOs, USDA, USGS

Funding sources/other—Morris Animal Foundation, Disney, Wallace Global Foundation, FWS, local or regional family foundations, NGOs, cave conservancies, corporations (e.g., pest control)

Scope
a) Number of bats/colonies—small numbers
b) Facilities—start with existing facilities; full scale would involve multiple off-site facilities with flight cages and veterinary care
c) Timeline—immediately develop standard rearing protocols to start using to develop husbandry techniques
d) Costs—new facilities- $1-1.5 million/facility plus seasonal animal care costs

Multiple Season / Multiple Year Strategies

Strategy 4: Hibernating:
Maintain bats in a facility across multiple seasons to allow for natural hibernation cycle to occur. Goal is to multi-season holding without captive breeding. After a certain amount of time (or other trigger) the strategy will likely shift to a captive breeding strategy.

Roles—A, B, C, D, F, G
A = minimize seasonal threats
B = source of research animals
C = WNS treatment options
D = short-term persistence of individuals
F = education/outreach
G = holding and translocation

Benefits
- Preserves options
- Improving husbandry techniques (more so than above)
- Less disturbance of the wild populations (depends on scale though, more disturbance initially to hibernaculum, but less over long-term)
- Potential for lower costs (bats will adapt over time)
- Overall less labor intensive than strategy #5

Risks
- Removal of individuals from wild breeding population
- More captive selection
- Requires more expertise and facility(s) capacity
- Increase in risk of changing wild behaviors
- Smaller sample size so less genetic maintenance
- Increased risk of unintentional breeding
- Hybridization
- Negative publicity from failures
- Exposure to pathogens and parasites

Expertise—Species dependent. Some expertise exists on captive holding in hibernation/active season, some expertise exists on constructing large artificial hibernacula, design of facilities, expertise in physiology, social behavior, indoor enrichment, feeding, and genetics.

Challenges
- Social behaviors
- How to select bats for captivity
- Maintain bat health
- Expanding capacity
- Identifying pertinent experts
- Building artificial hibernacula
- Transportation challenges
- Timing of collection
- Overall planning process/permitting
- Staffing challenges (i.e. rabies vaccinations)
- Catching bats
- Monitoring clusters
- Rescue plan
- Challenges to releasing bats
- Loss of natural behavior and memory
- Security
- Hybridization

Knowledge gaps

- Social behaviors
- Long-term active care for certain species
- Hibernation microclimate
- Identifying triggers for alternate strategies (e.g., if WNS still exists)
- How many bats to bring in

Potential collaborators—state agency biologists, zoos, rehabilitators, universities, cavers, NGOs, engineers/consultants, corporations, DoD, FWS, FS, USGS, NPS

Funding sources/other—Morris Animal Foundation, Disney, Wallace Global Foundation, FWS, local or regional family foundations, NGOs, cave conservancies, corporations

Scope

a. Number of bats/colonies —ultimately at least two colonies per species; start with a small number; consider social group size; colonial vs. non-colonial species; suitable cluster size based on species life history; start with unaffected bats for pilot project if possible.
b. Facilities—off-site facility with outdoor flight cages and hibernation chambers (possibly with public viewing access); medical/vet care facilities; must be regional proximity; species represented in at least 2-3 facilities; small-scale use of existing facilities
c. Timeline—begin planning efforts for building facilities and working with rehabilitators immediately
d. Costs—Initial capital costs of $1-2 million (building with appropriate HVAC, power supply); annual animal care costs ($100,000-$1 million)

Strategy 5: Non-Hibernating:

Maintain bats in a facility across multiple seasons to prevent natural hibernation cycle. Goal is multi-season holding without captive breeding. After a certain amount of time (or other trigger) the strategy will likely shift to a captive breeding strategy.

Roles**—**same as Strategy 4

Benefits**—**no need to develop hibernation techniques, otherwise same as Strategy 4

Risks

- Same as Strategy 4
- Most labor intensive option we have
- Most unintentional risk of disease and quarantine
- Increase changes in physiology/behavior
- Risk of out-of-season parturition (birth)
- Exposure to pathogens/parasites

Expertise**—**Species dependent. Some expertise exists on captive holding in hibernation/active season, design of facilities, expertise in physiology, social behavior, indoor enrichment, feeding, and genetics.

Challenges

- Social behaviors
- How to select bats for captivity
- Maintain bat health

- Expanding capacity
- Identifying pertinent experts
- Transportation challenges
- Timing of collection
- Overall planning process/permitting
- Staffing challenges (e.g., rabies vaccinations)
- Catching bats
- Monitoring clusters
- Rescue plan
- Challenges to releasing bats
- Loss of natural behavior and memory
- Security
- Hybridization

Knowledge gaps
- Social behaviors
- Long-term active care for certain species
- Hibernation microclimate
- Identifying triggers for alternate strategies (e.g., if WNS still exists)
- How many bats to bring in
- Role of photoperiod

Potential collaborators—state agency biologists, zoos, rehabilitators, universities, cavers, NGOs, engineers/consultants, corporations, DOD, FWS, FS, NPS, USGS

Funding sources/other—Morris Animal Foundation, Disney, Wallace Global Foundation, FWS, local or regional family foundations, NGOs, cave conservancies, corporations

Scope

a. Number of bats/colonies—ultimately at least two colonies per species of interest; start with a small number; consider social group size; colonial vs. non-colonial species; suitable cluster size based on species life history; start with unaffected bats for pilot project if possible.
b. Facilities—off-site facility with outdoor flight cages (possibly with public viewing access); medical/vet care facilities; must be regional proximity; species represented in at least 2-3 facilities; small-scale use of existing facilities
c. Timeline—begin planning efforts for building facilities and working with rehabilitators immediately
d. Costs—$1-1.5 million (building costs may be slightly less than #4); greater animal care costs than #4 (maybe $200,000-$2 million annually)

Holding for Treatment

Strategy 6: Short-Term Holding for Treatment Applications:
Need number of days, treatments could happen any time (winter, summer). Holding only for as long as needed to apply treatment and release (days-month?).

Short-term roles that fit under this—A, B, C, D, F
A = minimize seasonal threats
B = source of research animals
C = WNS treatment options
D = short-term persistence of individuals
F = education/outreach

Benefits
- Very short term holding
- No need to develop longer-term techniques
- Less husbandry/labor costs
- Increased short-term survival
- Treatment for a larger number of individuals (?)
- Increased public support

Risks
- Interfering with natural selection
- High re-infection risk
- Affecting non-target species
- Treatment may prove toxic (direct or indirect effects)
- Risk of artificially spreading WNS
- Repeated disturbances to sites

Expertise—Species dependent. Some expertise exists on captive holding in active season, expertise in physiology, social behavior, feeding, veterinary care, and pathology.

Challenges
- No known successful/feasible treatments- ID treatments
- Test treatments in lab and in field
- Maintain bat health
- Identifying pertinent experts
- Transportation challenges
- Timing of collection
- Overall planning process/permitting/licensing
- Staffing challenges (e.g., rabies vaccinations)
- Catching bats
- Security

Knowledge gaps—treatments

Potential collaborators—state agency biologists, zoos, rehabilitators, universities, veterinary schools, cavers, NGOs, corporations, FWS, FS, USGS, pharmaceutical companies, DoD, National Institute of Health, USDA

Funding sources/other—Morris Animal Foundation, Disney, Wallace Global Foundation, FWS, local or regional family foundations, NGOs, corporations (medical, pharmaceutical, pest control)

Scope

a. Number of bats/colonies—pilot or R/D phase will be driven by each research project; full scale-as many as possible (dependent on treatment type)
b. Facilities
    i. Mobile facilities to be brought to hibernacula
    ii. Off-site lab facilities—medical/vet care facilities may be needed; regional proximity to minimize transportation.
c. Timeline—continue to conduct research until treatment option is available.
d. Costs—Unknown

Other Considerations

- Short-term holding for diagnostics/research (ties into the above three strategies)
- Collection timing (e.g., during swarming)
- Location of release (e.g., collection site vs. other site)

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SECTION 4

Long-Term Low Intensity Management Strategies Working Group Report

Long-Term Low Intensity Management Working Group Report

Members: Sybill Amelon, Ellen Covey, Rita Dixon, Sarah Long, Paul Racey, DeeAnn Reeder, Rob Tawes, Aaron Valenta, Ron Van Den Bussche, Allyson Walsh

This working group was initially combined with the Long-Term High Intensity Working Group discussed in Section 5. This larger group found that there were two different strategies to be considered and that it would be useful to split the larger group into two smaller groups to divide the tasks and increase productivity. This working group focused on long-term, reproducing, captive bat strategies. While the other working group was focused on "high intensity" long-term breeding programs (those that involve controlled breeding, maintenance of detailed genetic records, etc.) the "low intensity" group concentrated on scenarios that would involve grouping bats together under less controlled circumstances where they would interact and breed more naturally.

Group Vision for a "Less Intensive" Long-Term Captive Colony

We envisioned a program that would be organized in a manner similar to the Amphibian Ark program, which was established to conserve amphibians in response to threats in the wild from the invasive chytrid fungus, *Batrachochytrium dendrobatidis* (Bd). Under this strategy there would be an umbrella organization dedicated to the long-term maintenance of captive bat colonies. This overarching organization would consist of a consortium of captive facilities run by numerous partners that would all have the common goal of conserving bats in the face of white-nose syndrome. This "Bat Ark" could be centralized (fewer but larger facilities) or decentralized (consisting of numerous smaller facilities), depending on scope, opportunities, and target species. The actual facilities would likely consist of zoos, educational institutions, and rehabilitation centers. In contrast to the short-term strategies, long-term strategies involve holding bats for many seasons, and would involve reproduction of these captive bats.

Under this scenario, captive bats would be less intensively managed, possibly through the use of more natural enclosures and flight areas. Under low intensity management bats would be allowed to select their own breeding partners, with some generalized guidelines. This approach could be either "closed," whereby no new bats are brought into the population for genetic diversity or population augmentation purposes, or open, where wild bats are occasionally brought in. Specific strategies would vary on a species-by-species basis. The population would occasionally be sampled to ensure that all genetic lines are represented. Individuals (adults and pups) will be sampled for genetic analysis. Individuals that are highly represented in the population will be removed from the breeding group providing the opportunity for less represented individuals. Facilities would need to be biosecure, likely to the BSL-2 level.

Value Assessment

Roles/Goals

Low intensity long-term scenarios could meet the three unique goals of long-term captive populations: 1) maintaining a genetic reservoir for the target species; 2) provision of animals for reintroduction or range expansion (providing threats have been removed in the wild); and preventing extinction and catastrophic loss.

Risks of Long-Term, Low Intensity Scenarios

- <u>Loss of genetic diversity</u>
  It would be more difficult to maintain genetic diversity when mating is not controlled. A larger breeding population may be required under this approach.

- Animal mortality
  As with any captive bat colony, there is a risk of failure. Captive care of large numbers of insectivorous bats can be challenging, or infrastructure could fail. Along with failure would come bad press and public relations issues.

Benefits of Long-Term, Low Intensity Scenarios

- Greater capacity for maintaining normal behavior (than with high intensity options). Less stress due to reduced handling.
- Greater success of likelihood of releasing individuals.
- Greater likelihood of success in breeding for species for which little is known.
- Less costly and labor intensive (than "high intensity" approaches).
- Greater flexibility—may allow for high intensity management if warranted and for inclusion of new wild stock.

Feasibility/Knowledge Gaps

There is limited expertise out there in long-term captive populations, especially for long-term breeding bat populations. However, there is more experience with low intensity management approaches than with more controlled high intensity approaches. The group believed that it has the knowledge and ability to tackle less intensive captive management. Knowledge gaps for this approach include limited previous success with captive bat reproduction, limited captive holding expertise, lack of baseline genetics data, and a paucity of veterinary expertise with insectivorous bats. In order to be successful with this approach we would need personnel with captive and field experience; reintroduction expertise; infrastructure expertise; pathogen management; quarantine facilities; population and genetics expertise. The biggest challenges would be getting bats to breed, tackling unforeseen technical and biological challenges ("We don't know beforehand what we don't know and what won't work"), and generating offspring that would be capable of successfully returning to the wild and reproducing.

Challenges

- Not harming captive and wild populations, successfully establishing breeding captive populations.
- Avoiding adaptation to captivity (reacquisition of essential life skills and behaviors after multiple generations in captivity)
- Dietary transition from mealworms to feeding "on-the-fly."
- Restoring site fidelity if the original habitat is suitable for reintroduction but also redirecting or encouraging new site fidelity if the old habitat is unsuitable and reintroductions/translocations occur in a new location.
- Securing institutional support and funding over many years.
- Maintaining cultural memory within bats.
- Successful breeding
- Maintaining health (such as bone and muscle density)
- Maintaining inter- and intra- specific differences.
- Meeting needed environmental requirements (humidity, lighting, etc.)
- Biosecurity (prohibiting entry of WNS and spread of other pathogens)
- External affairs and public relations.
- Maintaining flight capacity; forage behavior; hibernation
- Maintaining wild habitat (necessary for eventual reintroduction). This includes having areas that are free of *Geomyces destructans.*
- Dealing with permits and bureaucracy (e.g., interstate transport, USDA guideline exemptions, Endangered Species Act permitting)

- Maintaining open communication, collaboration, and communication among parties internal and external to “the Ark”.
- Opposition from outside groups (such as animal rights groups that would not approve of captive programs for bats and some of the mortality that may be associated with them).
- Physical facility security

An additional challenge includes successful genetic management. With less intensive genetic management there could be an *increased* risk of domestication. This is because individuals that are good at breeding in the captive environment will survive and their progeny could take over while less successful lineages could be lost.

Knowledge Gaps

- “Just about everything.” We have a lot to learn about large scale, long term captive colonies of insectivorous bats
- Abatement of natural threats. We do not know whether we can actually reintroduce offspring at some point in the future. For instance, will there be caves free of *Geomyces destructans*?
- Success rate of reintroduced animals back into the wild.
- Reproductive knowledge/requirements.
- Specific species requirements- some are flexible some have precise needs.
- Climate change and its impact on reintroduction and wild bat populations
- Persistence of *Geomyces destructans* in the environment.
- Effective population size, founder size.
- Population genetics for each species.
- Uncertainty of impacts on western bat species.
- Trigger points for pulling specific species into captivity.
- Species-specific facilities requirements.

Scope of Long-Term, Low Intensity Scenarios

- As a general rule, a founder population should consist of 40-200 bats.
  - The assumption underlying these numbers is that these 40-200 founders are unrelated and will successfully breed. If high mortality or low fecundity is expected, then higher numbers should be brought in to reach the goal of 40-200 founders who successfully reproduce.
  - 200 was recommended for populations that will be managed at a low intensity (e.g., very large colonies, little or no movement or manipulation of animals for genetic mgmt reasons) or that have large source populations from which to draw.
  - 40 was recommended for populations that will be more intensively managed (e.g., species held in smaller groups, or that can have some rotation of bats to boost breeding of more individuals, Ne/N = 0.30) or species that have limited source population sizes.
- Long-term population size targets would range from 250-1000 animals.
- Recommend two facilities/species (redundancy in the event of problems with one facility).
- Facilities should possess multiple flight cages with outdoor components, quarantine facilities, an incubation room, medical treatment facilities, prep rooms, isolation cages, a dedicated hibernation facility, backup generators, office space/facilities, and shower and dressing facilities/ decontamination area.

Costs

Costs are difficult to estimate without knowing the scope of the project and which species would be targeted. Costs would obviously be higher if new large centralized centers are built. Existing facilities could also be employed (or expanded). The group briefly discussed the use of pods (aka climate controlled containers) employed by the Amphibian Ark program.

We discussed some example costs. The raw costs for maintaining a colony of fruit-eating bats is $610,000/year for 220 bats (see Appendix V). However it was generally agreed upon that fruit-eating bats are more expensive to maintain. One bat rehabilitation facility pays $15,000-20,000 for one year's worth of mealworms (colony of 370 bats). It costs $7000/month for 400 bats for the entire facility. Costs could possibly be reduced by having a centralized facility that raises all mealworms. It was noted that these costs are only samples from some existing operations. Costs for a long-term, low-intensity captive program could vary widely depending on the species involved, the number of bats in captivity, the needed facilities, etc.

Timeline

- Could be staged (starting out small with one or two species) but if decision is made to proceed, should be undertaken very soon (because of WNS spread).
- The program would be multi-generational, and could go on for some time if there are no safe reintroduction sites.
- Bats should be captured when they go to maternity colonies.

Other Resources Needed

- "Mega bucks," long-term sponsorship
- Management plan
- Long-term sponsorship and commitment

Potential Collaborators and Funding Sources

- Federal government (U.S. Department of Agriculture, US Fish and Wildlife Service, National Park Service, etc.)
- Zoos
- Association of Zoos and Aquariums (AZA)
- Bat rehabilitation specialists
- Academicians and universities
- State wildlife agencies
- Non-governmental organizations (e.g., BCI, TNC, World Wildlife Fund)
- Philanthropic bodies
- Congressional advocates
- Industry sponsorship

After discussing these various aspects of needs, benefits, and constraints of a low intensity, long-term captive bat program, the group decided to discuss what such a program would look like for various species. Three species were chosen—the little brown bat (*Myotis lucifugus*), Ozark big-eared bat (*Corynorhinus townsendii ingens*) and tricolored bat (formerly known as eastern pipistrelle) (*Perimyotis subflavus*) – because of their different life history characteristics and variations in size in their natural ranges.

Little Brown Bat (*Myotis lucifugus*): One of the most common bats in North America, it roosts in caves, mines, and human-built structures. It has a wide distribution and can be found across much of the United States. This species has suffered high mortality rates when exposed to WNS.

Captive Colony Considerations:

- Set up genetically discrete populations since there are approximately five subspecies.
- Use 200 founder individuals per population (approximately 40 if donor population is already decimated by WNS as in the northeastern U.S.)
- Spread bats among at least two discrete, or multiple small, facilities.

- Set goal of up to 1000 individuals per managed population.
- Species would need complete facilities with all attendant features.
- Facility would need high humidity, roosting pouches to mimic natural roosting preferences.

Ozark Big-Eared Bat (*Corynorhinus townsendii ingens*): A federally listed Endangered bat with a reduced and limited distribution and small population size. The current range of the Ozark big-eared bat is limited to northeastern Oklahoma and northwestern Arkansas (near the state line) and north-central Arkansas. The rangewide population is estimated to currently consist of about 1600 – 1800 individual bats, with about 400 – 600 in Arkansas and 1200 – 1400 in Oklahoma. This is a medium-sized insectivorous bat that preys primarily on moths but will also eat beetles and other flying insects.

Captive Colony Considerations:
- Set up two populations with individuals coming from both states. Two groups of 20 x 2, with one group established from individuals from northeastern OK/northwestern AR, and the other group from individuals from north-central AR.
- Two discrete facilities (intentional redundancy to guard against disease, catastrophes, etc.)
- Set goal of up to 250 individuals per managed population.
- Species would need complete facilities with all attendant features.
- Have ceiling surfaces amenable to roosting
- Hibernate animals for a shorter period of time and provide temperature gradient within facility.
- Provide females with cave-like summer roosts with ample hiding places.

Tricolored Bat (= Eastern pipistrelle) (*Perimyotis subflavus*): Another small bat that is found in caves and mines in the eastern United States. Tricolored bats tend to roost singly in caves.

Captive Colony Considerations:
- Establish four groups of 40 (even sex ratio) founder populations (one from each ecoregion).
- Provide more space than with other species (tricolored bats are single roosters).
- Provide high humidity conditions.
- This species more easily handled & less sensitive to disturbance than others.
- Feed small mealworms and flies.
- Species would need complete facilities with all attendant features.

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SECTION 5

Long-Term High Intensity Management Strategies Working Group Report

Long-Term High Intensity Management Working Group Report

Members: Diana Barber, Meredith Batron, Amanda Lollar, Paul McKenzie, Nucharin Songsasen, Richard Stark, Monica Stoops, Kevin Zippel

This working group was initially combined with the Long-Term Low Intensity Working Group (see Section 4). The original large group was initially formed to discuss all long-term management options for bats. In the course of outlining and describing potential long-term options, it became apparent that these options stretch across three continuums: 1) intensive management vs. low level of management; 2) open vs. closed populations (with respect to supplementation with new individuals from the wild); and 3) centralized vs. decentralized facility organization. Participants decided to split into two working groups based on the level of management. This report follows the discussion and assessment of the long-term, high intensity management options, which examined strategies across the remaining two continuums.

Scope of Management Options

High intensity, long-term management options are options that involves captive propagation of an *ex situ* population, in which effort will be made to ensure that the genes of all individuals are represented in the population. To accomplish this, bats will be housed in harem groups, and individuals (adults and pups) will be sampled for genetic analysis. Individuals that are highly represented in the population will be removed from the breeding group.

The working group further divided high intensity, long-term management options into four population categories: 1) closed-centralized; 2) closed-decentralized; 3) open-centralized; and 4) open-decentralized.

- *Closed, centralized management* involves a few large facilities (3–5) that house large numbers of bats (> 100 per species). This type of management excludes the supplementation of new genetic from wild population.
- *Closed-decentralized management* entails several facilities with small number of bats per facility (~50); there will be no supplementation of wild bats.
- *Open-centralized management* is similar to the first option (3–5 facilities), but will bring in wild bats to enhance genetic diversity within the population.
- *Open-decentralized management* is similar to option 2 (more facilities with fewer bats each), but will bring in wild bats to maintain gene diversity.

In all cases, the group did not discuss the transfer of bats among facilities in detail, although the participants recognized that this is possible. This high intensity management program will serve most roles identified during brainstorming plenary session, except reducing the spread of WNS. Centralized and decentralized options can be combined into a hybrid approach, in which there are a couple of central large facilities with several satellites members holding smaller numbers of bats.

Intensive Management Options

High Intensity/Closed/Centralized Option

Purpose: To prevent extinction; maintain genetic diversity; and serve as a source population for supplementation.

***Risks*:**
- Catastrophic loss
- Transportation
- Potential loss of genetic diversity
- Implementation of umbrella approach (buy in issue from others that are not part of the centralized facilities)
- More bats/keeper (higher mortality; note BatWorld Sanctuary where proper facility and trained staff are available can take 500 bats in one shipment)

***Feasibility*:**
- Permits
- Funding
- Large numbers individuals maintained
- Expertise (diversity of fields)
- Size of facility
- Cost
- Species dependent (knowledge)
- Travel for bats
- Quarantine

***Benefits*:**
- Research and education opportunity
- Teaching facility
- Likely increase potential of success (offspring production for supplementation)
- Recognized expertise and central location
- Ability to maintaining larger colony (appropriate per species)
- Reduced new permit need in case of established rehab facility.

***Expertise*:** There are people that have experience in keeping bats in captivity (species limited), known expertise, personnel and literature (husbandry, reproduction [unintentional]). There is a general lack of geneticists, veterinarians, reproductive physiologists, cryobiologists, and field biologists specializing in bats (although there is some expertise in these areas).

***Challenges*:**
- Length in captivity (may have to maintain them for a long time)
- Making sure to have plan for offspring and reintroduction plan
- Capacity-size for effective population
- Hibernation and acclimation
- Genetic monitoring
- Individual
- Developing assisted reproductive techniques
- Bring people of all expertise to the table

***Knowledge gaps*:**
- Reproduction and reproductive behavior
- Gamete cryopreservation
- Husbandry (missing for some species)
- Genetic markers

***Scope*:**
- Population size—large (but less than low intensity)
- Larger for less known species
- 3-5 facilities

***Collaborators*:** Universities, rehabilitation centers (accredited sanctuary), Association of Zoos and Aquariums (AZA) zoos, federal and state agencies, international partners, and NGOs

High Intensity/Closed/Decentralized Option
(cooperative among independent facilities; SSP for management)

***Purpose*:** To prevent extinction; maintain gene diversity; and serve as a source population for supplementation.

***Risks*:**
- Potential loss of gene diversity
- Potential variation in use of protocols (not consistent)
- Increased risk of biosecurity breach
- Maintaining smaller population and may not be able to maintain species that require large population size (roosting in cluster)
- Production may be lower associated with variation in reproductive ability among institutions

***Benefits*:**
- Innovation (learn from each other, if variation in protocols)
- Decreased cost
- Reduction of risks associated with catastrophic loss
- More opportunities for securing funds (for local interest)
- Ability to maintain local populations in their range
- Less paperwork for funding competition (have increase opportunities for competitive funding, so less paperwork, open bidding)
- Use of resource (staff and infrastructure) at the existing facilities

Feasibility:
- Permits (increased numbers of permits)
- Numbers of participants
- Clear, approved protocols
- Expertise
- Budget (travel for experts)
- Species dependent (knowledge)
- Type of facilities
- Cost
- MOU (workshop, inspection, compliance)
- Quarantine

***Expertise*:** husbandry-training, same as Intensive-centralized

***Knowledge gaps*:** same as high intensity-centralized

***Challenges*:**
- Communication and same as intensive-centralized
- Getting experts to bats and facility
- Funding (increase number of facility)
- Retrofitting
- Federal and state regulations

***Scope*:**
- Larger number of facilities
- Smaller population size (but more numbers of populations)
- In partnership with large facility (may be it should be done/hybrid of two strategies)

***Collaborators*:** similar to intensive-centralized, but make sure that include more people at each location.

<u>High Intensity/Open/Centralized Option</u>

Purpose: To prevent extinction; maintain genetic diversity; and serve as a source population for supplementation.

***Risks*:**
- Catastrophic loss and increase disease-related catastrophic loss
- Transportation
- Gene diversity and fitness trade off (wild bottle neck, but more fit)
- Implementation of umbrella approach
- More bats per care taker
- In-house biosecurity

***Benefits*:**
- Increase fitness of population and potential for recovery
- Same as closed-centralized

***Feasibility*:**
- Health assessment of wild individuals
- Quarantine
- In-house biosecurity
- Sources (where to find bats to supplement captive population)
- Same as closed centralized

***Expertise*:** same as centralized closed

***Challenges*:**
- Quarantine
- Federal and state regulations
- Integration of new individuals to existing groups
- Disruption of existing social order
- Same as above
- Screening resistant vs. sick (new batch)

Knowledge gaps:
- Population genetic structure of remaining population,
- Social behaviors

Scope**:** Same as above

Collaborators**:** Same as above

High Intensity/Open/Decentralized Option

Purpose**:** To prevent extinction; maintain genetic diversity; and serve as a source population for supplementation.

Risks**:**
- Local disease related catastrophic risk
- Gene diversity and fitness trade off
- In-house biosecurity
- Same as high intensity/closed decentralized

Benefits**:**
- Increase fitness
- Potential recovery
- Same as high intensity/closed/decentralized
- Outreach media when getting more

Feasibility**:**
- Same as high intensity-closed-decentralized
- Health assessment of wild individuals
- Quarantine
- In-house biosecurity
- Where to find remaining bats (sources)

Expertise**:** Same as high/closed/decentralized, veterinarian screening

Challenges**:**
- Screening resistant/unexposed vs. sick (new bats)
- Same as high intensity/closed decentralized
- Same as open/centralized

Knowledge gaps**:**
- Reproduction
- Reproductive behaviors
- Cryopreservation
- Husbandry in less known species
- Genetic markers
- Population genetic structure of remaining populations
- Social structure

Scope: Same as above (high intensity/closed/decentralized)

Collaborators: same as high intensity/closed/decentralized

Universal Issues for All Strategies

1. Social structure: colonial versus solitary (how captive management disrupt social structure in colonial species)
2. Appropriate numbers for each species
3. Genetic structure
4. Adaptability of captive born (2nd generation and up) bats to wild
5. Collection guideline
6. WNS testing prior to captivity

Trade off: Large vs. small captive groups in family structured/social bats versus maintain gene diversity.

Species-Specific Assessments

The group discussed the type of captive management for two bat species: *M. grisescens* and *P. subflavus*

Gray bat (*M. grisescens*)	**Tri-colored bat (*P. subflavus*)**
Trigger has to be met	Trigger has to be met
Federal and state permit (and regulation) required	State permit (and regulation) required
Initial colony size is larger (may be better for centralized), minimum 500/facility (typical maternity colony in the wild 15,000 bats), may be seasonally variables (mother and young kept together and bachelor separated), all hibernation, space needs to allow voluntary separation, hibernacula (10,000 to 350,000 bats)	Maternity colony in the wild (50–100), original size 50/facility (but need more data on accurate colony size), hibernation (solitary)
Collection site and time: Large number in single collection in one collection effort, may not need individual bag, Timing swarm vs. hibernacula (impact on genetic diversity, social structure), high stress from collection at hibernacula to both the ones that were caught and ones that are left behind, more challenging to get sufficient numbers at the foraging site, maternity colony can be disruptive	One individual per bag, Timing swarm vs. hibernacula (impact on genetic diversity, social structure). No knowledge of swarming behavior; may not be large cluster to pick up large numbers. Individuals will scatter throughout the cave (challenging in finding sufficient numbers), collection in fall if Harp trap recognized risk in trapping non-target species), winter from hibernacula or late summer. Potentially less stress.
Acclimation: smaller cage, more staff, simulated natural habitat, need to maintain 50 °F (there is discrepancy in information of hibernation temp, need to check) at 90% humidity during hibernation, light cycle, specific temperature and humidity during active phase (often found in the dome area in the cave, where there is warm air).	Labor intensive to feed each bat because they are harder to teach to self feed, simulated natural habitat, less temperature and humidity specific (more flexible).
Centralized, opened strategy may present some social challenges	Can be either centralized or decentralized, significant challenge to find resistant individuals (due to solitary habit)
$20,000 (500 bats) for mealworms	$7,000 for mealworms (50 bats)

Comments during Plenary Presentation

- On-going research on developing *Geomyces destructans* antibody assay to screen bats.
- It is very difficult to duplicate hibernation environment for gray bats.
- Good timing for bringing bats in can be when bats are moving to maternity colonies (when females gain some weight, but hungry), but tricolored bats maternity colony is very difficult to find.
- Gray bats likely can be put in hibernation chambers in large numbers, but tri-colored bats that are solitary may need more space.

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APPENDIX I

Workshop Participants and Agenda

Workshop Participant List and Agenda

Attendees ***Name***	***Affiliation***	***Email***
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Insectivorous Bat Captive Population Feasibility Workshop

July 14 – 16, 2010, River Camp, Saint Louis Zoo, Saint Louis, MO
US Fish and Wildlife Service – Bat Conservation International – The Nature Conservancy

Purpose of the Workshop: To explore and assess the value and feasibility of various captive management options as part of an overall conservation management strategy to promote viable wild bat populations under threat from White Nose Syndrome.

AGENDA

Wednesday, July 14 (8:00am – 5:00pm)

Status, Threats, and Potential Role of Captive Management

7:30am	Shuttle departs Sheraton Clayton Plaza Hotel
8:00am	Welcome and participant introductions Workshop purpose and process (Tawes, Traylor-Holzer) Presentations: WNS and impact on bat populations (Coleman) Overview of bat life history and population viability (Amelon)
	Break
	Emergency rescue captive populations: Amphibian case study (Zippel) Principles of captive management for conservation (Long) VBEB project at CRC: lessons learned (Douglas/Songsasen)
12:00pm	*Lunch*
1:00pm	Plenary discussions: Bat species categorization/captive expertise summary (Bayless)
	Break
	Potential conservation roles of captive bat populations Identification of captive management options Formation of working groups / instructions
4:00pm	Tour of hellbender captive facility
5:00pm	Depart for hotel

Thursday, July 15 (8:00am – 5:30pm)

Analysis of Captive Population Options

7:30am	Shuttle departs Sheraton Clayton Plaza Hotel
8:00am	Working group tasks: Value assessment - Description of option(s) - Benefits of each option (role(s)/potential contributions to bat conservation) - Risks of each option (potential negative impacts) *(Breaks self-regulated by working groups)*

11:00am Plenary session: Working group reports/feedback from all participants

12:00pm *Lunch*

1:00pm Working group tasks: Feasibility assessment (for each species type)

- Available expertise/challenges/knowledge gaps
- Scope (founders/population size/facilities/timeline/resources needed)
- Potential collaborators, funding sources, other resources

  (Breaks self-regulated by working groups)

5:30pm Depart for hotel

Friday, July 16 (8:30am – 12:00pm)

Synthesis of Needs, Options and Feasibility Information

8:00am Shuttle departs Sheraton Clayton Plaza Hotel

8:30am Plenary session:

Working group reports/discussion
Benefits and risks of no captive management
Identification of priority research needs

Break

Discussion of remaining topics
Collection of working group reports/individual recommendations

12:00pm End of workshop

Insectivorous Bat Captive Population Feasibility Workshop

Saint Louis, Missouri, US
14 – 16 July 2010

Final Report

APPENDIX II

Management Questionnaire and Summary Results

Insectivorous Bat Holding/Propagation Experience Questionnaire
April 2010

The U.S Fish and Wildlife Service is currently reviewing the feasibility of captive holding and propagation strategies for ***insectivorous*** *bat species as a result of white-nose syndrome (WNS), which is associated with significant declines in bat populations in the northeastern U.S. The goal of this questionnaire is to obtain information on current and past efforts to maintain captive bat colonies.*

Name:

Affiliation:

Contact information (address, telephone, email)(**optional**)

Briefly describe your background experience working with bat handling/propagation.

What kind of captive effort for bats have you been involved with?
- ☐ Rehabilitation and release
- ☐ Maintenance of captive colony for education
- ☐ Maintenance of captive colony for propagation
- ☐ Other, please explain

What species of bat have you held in captivity?

Approximately how many individuals (by species) have you kept at one time?

What is the longest period you have kept an individual (or colony)(by species)?
- ☐ < 1 month
- ☐ 1-6 months
- ☐ 6-12 months
- ☐ >1 year (how long ________________)

Has any successful reproduction (pups survived) occurred while you maintained bats?

What types of feeding strategies do you use?

What types of hibernation strategies do you use?

What sort of facility do you have?

Did you experience any problems or challenges?

What are the biggest challenges with holding and captive propagation of insectivorous bats?
Have you provided veterinary care for sick or injured bats? For bats affected by WNS?

Are there lessons to be learned from other taxa (e.g., insectivores, hibernators, colonies formed to deal with disease)?

Are you aware of any physical (e.g., facilities) or financial resources (e.g., grants, matching funds) available to support captive holding or controlled propagation?

Are there other key people you recommend we contact on this issue?

May we contact you for further information?

Please respond by May 7, 2010. Questionnaires can be emailed to Richard_stark@fws.gov, faxed to (918) 581-7467, or mailed to U. S. Fish and Wildlife Service, 9014 East 21st Street, Tulsa, OK, 74129, ATTN: Bat Questionnaire

Thank you!

Questionnaire Summary Results

(excerpted from report submitted by Mylea Bayless, Bat Conservation International)

Survey Responses

BCI was contracted to review the captive care questionnaires distributed by FWS prior to the workshop. Forty-two surveys were returned to the USFWS to be included in the workshop summary presentation and discussion, and one additional survey was submitted after the workshop. The summarized results include only those surveys submitted prior to the workshop. Surveys were returned from 10 countries, including the United States (n = 30), two surveys each from England, Japan, and Germany, and one each from South Africa, Mexico, Austria, Canada, New Zealand, and Australia. Surveys were returned from a variety of institutions (Table 1).

Table 1. Institutions submitting survey results to the USFWS.

Bat Rehabilitation Centers	Universities	Zoos	Other research/education institutions
21	10	5	6

Insectivorous Bat Holding Experience

Survey respondents reported holding 29 U.S. species in captivity for any length of time (Table 2). The maximum number of bats held by each institution ranged from a single bat to over 150 individuals. Institutions have the broadest experience (>10 respondents) with *Eptesicus fuscus*, *Myotis lucifugus, Lasiurus borealis, Perimyotis subflavus, Lasionycteris noctivagans, Lasiurus cinereus, Nycticeius humeralis*, and *Tadarida brasiliensis* , and have held *E. fuscus, M. lucifugus, L. borealis, Lasiurus seminolus, T. brasiliensis, N. humeralis, Antrozous pallidus* and *Eumops floridanus* in larger groups of individuals (>10). Only *E. fuscus, M. lucifugus, L. borealis,* and *T. brasiliensis* have been held in groups over 50 individuals. Institutions reported varying levels of experience holding bats in hibernation and observing reproduction during captivity (see Table 1 in Section 2). Respondents reported holding an additional 55 species from beyond the United States (Table 3).

Table 2. Survey respondents reported experience holding 29 bat species endemic to the United States.

Species	**# institutions (holding species)**	**# individual bats (held at one time)**	**Max. length in captivity (at least 1 individual)**
Eptesicus fuscus	27	> 150	17 years
Myotis lucifugus	18	240	5 years
Lasiurus borealis	18	78	7 years
Perimyotis subflavus	17	8	2 years
Lasionycteris noctivagans	15	10	3 years
Lasiurus cinereus	14	10	5 years
Tadarida brasiliensis	13	81	18 years
Nycticeius humeralis	13	26	12 years
Myotis septentrionalis	9	10	1-6 months
Antrozous pallidus	6	40	10 years
Myotis velifer	5	4	8 years
Lasiurus intermedius	5	7	4 years
Lasiurus seminolus	5	>10	4 years
Myotis austroriparius	3	10	7 years
Parastrellus hesperus	3	2	6-12 months
Eumops perotis	2	2	5 years
Nyctinomops macrotis	2	6	6 years
Nyctinomops femorasaccus	2	4	4 years
Molossus molossus	1	1	not reported
Myotis sodalis	1	2	2 years
Myotis leibii	1	1	not reported
Myotis ciliolabrum	1	1	6-12 months
Myotis grisescens	1	1	4 years
Eumops floridanus	1	13	2 years
Macrotus californicus	1	1	not reported
Corynorhinus townsendii	2	1	not reported
Corynorhinus rafinesquii	1	1	6-12 months
Corynorhinus t. virginianus	1	not reported	< 1 month
Mormoops megalophylla	1	2	< 1 month

Table 3. Survey respondents reported experience holding 55 international bat species.

Species	# institutions	# bats		# institutions	# bats
Eptesicus serotinus	3	24	*Nyctalus aviator*	1	nr
Hipposideros arminger	1	nr	*Nyctalus leisleri*	1	1
Hypsugo savii	1	nr	*Nyctalus noctula*	3	24
Rhinolophus clivosus	1	1	*Vespertilio murinus*	1	nr
Rhinolophus ferrumequinum	2	nr	*Vespertilio sinensis*	1	nr
Rhinolophus paradoxolophus	1	nr	*Balantiopteryx plicata*	1	nr
Miniopterus schreibersii	1	1	*Chaerephon pumilus*	1	4
Myotis bechsteinii	1	nr	*Chrotopterus auritus*	1	nr
Myotis bocagei	1	5	*Corynorhinus mexicanus*	1	nr
Myotis daubentonii	2	24	*Macrotus waterhousii*	1	nr
Myotis emerginatus	1	nr	*Mollossus ater ater*	1	nr
Myotis myotis	2	nr	*Mops condylurus*	4	2
Myotis mystacinus	1	nr	*Mustacina tuberculata aupourica*	4	9
Myotis nattereri	2	24	*Neromicia capensis*	4	7
Pipistrellus abramus	1	5	*Nycteris thebaica*	4	1
Pipistrellus javanicus abramus	1	nr	*Otomops martiensenni*	4	9
Pipistrellus kuhlii	2	5	*Pteronotus parnellii*	1	nr
Pipistrellus nanus	1	4	*Scotoecus albofuscus*	4	2
Pipistrellus nathusii	2	1	*Scotophilus dinganii*	4	8
Pipistrellus pipistrellus	3	50	*Scotophilus viridis*	4	2
Pipistrellus pygmaeus	2	5	*Tadarida aegyptiaca*	4	2
Plecotus austriacus	1	nr	*Taphozous mauritianus*	4	1
Plecotus auritus	2	24			

*** nr = not reported**

Insectivorous Bat Diets

Survey respondents reported a variety of diets fed to insectivorous bats in captivity. Most institutions reported using some form of mealworms (blended, viscera, or whole) as the mainstay of their captive diets. Several variations on the mealworm diet were reported including gut-loading mealworms according to established protocols (e.g., Bat World Sanctuary, Barnard) and/or blending them with vitamins and minerals, occasionally essential fatty acids. Some institutions used crickets, locusts, and beetles for variety (particularly for *Eptesicus* & *Antrozous* species). Others reported using wax worms or phoenix worms (which are softer bodied) for *Myotis* species. A few installations even caught and fed wild insects based on availability, and bats housed outdoors were noted feeding on wild moths that accessed the flight cages. Full accounts of diet responses are available in the original surveys provided in digital format to the U.S. Fish and Wildlife Service in Atlanta, Georgia.

Feeding strategies varied among survey respondents. Most reported hand-feeding mealworms (blended, viscera, or whole) and indicated this was necessary for newly acquired bats, injured bats, training, and bats that wouldn't learn to self-feed. Institutions reported success training bats to self-feed from plates or bowls (whole mealworms & other insects) or to self-feed on natural prey in flight cage (supplemental). Many respondents indicated this was necessary to reduce handling and subsequently reduce stress to the captive individuals. Other variations on the self-feeding strategy included presenting the food in different places and varying types of invertebrates to provide behavioral stimulation. Once established, most bats were proficient in drinking water on the wing from water dish or pond. Many respondents noted behavioral differences in bats indicating that some species, and individuals within species, learn to self-feed and others do not. Several respondents also noted that bats were observed learning to self-feed from other bats and that captive born pups learn these behaviors from their mothers.

Reproduction in Captivity

Institutions reported varying approaches to bat reproduction in captivity. Most discouraged reproduction either by housing sexes apart or by neutering males. Twenty facilities worldwide reported successful reproduction of captive bats, but this was driven by relatively few species. When pregnant females were taken into captivity they subsequently gave birth to live young, but bats in all but a few cases bats were not actively breeding captive colonies (see Table 1 in Section 2). Several facilities provided observations about captive breeding that are worth noting. Respondents noted that hibernating bats will not typically breed without exposure to natural temperature fluctuations and photoperiods. They also will not breed with suboptimal diet and some reported that bats tend to have more problems when pregnant mothers do not fly regularly (>1hr each night). Several facilities noted they were not successful breeding certain species (e.g., *Myotis*). Additionally, a few respondents noted that their captive born pups did not learn to fly unless they were housed with flying members of their species and had free access to an appropriately sized outdoor flight cage that is readily accessible to prey species.

Hibernation in Captivity

Hibernation strategies varied among survey respondents as well. Overall, they reported using one of four general strategies to address hibernating bats: 1) do not hibernate captive bats; 2) allow natural hibernation; 3) hibernate bats in laboratory environmental chambers; and 4) hibernate bats in other cool conditions. Many respondents choose not to hibernate captive bats, but rather keep them warm and active throughout the winter months. In these situations, bats were fed and watered regularly so they would maintain normal metabolic levels. Some respondents indicated this was an intentional strategy to prevent reproduction. Natural hibernation strategies typically involved allowing bats to move into colder areas of ambient temperature outdoor flight cages on their own and enter torpor or hibernation. In these situations, they were visually checked either daily to weekly for dehydration or weight loss and were warmed and replenished as necessary to prevent excessive metabolic stress. Several facilities had sophisticated environmental chambers that could be carefully adjusted to temperatures (generally 4-12 °C) and maintained at high humidity (80-95%). Bats were provided with water, but generally left alone for several months. Some protocols allow for intermittent warming to administer food and/or water. Where facilities did not have laboratory environmental chambers, sometimes other cool environments were used to actively hibernate bats. In these situations, bats were placed in boxes or coolers in cellars, refrigerators, cold room, or some other stable cool or cold environment. Respondents were able to develop a range of behaviors from deep hibernation to shallow torpor. In all cases, the humidity was kept high and bats were checked daily to weekly for dehydration or weight loss and were warmed and replenished as necessary. Regardless of the hibernation method employed, respondents who answered this question recommended avoiding training or handling bats more than once a week in winter.

Bat Holding Facilities

Bat holding facilities were also variable and were typically dependent on the goal of captivity, but they usually consisted of some combination of a treatment room, small holding enclosures, long-term holding enclosures and a flight cage. Treatment rooms are typically quarantined, indoor, and climate controlled. This is where medical care is administered and other treatments are applied. Bats are seldom housed in the treatment room. Small holding enclosures are typically used for short-term housing or transportation; these may be reptariums, soft-sided crates, or some other similar enclosure. In some cases, bats are kept for longer periods of time in these smaller enclosures, and sometimes these are placed within larger enclosures to allow bats to self-select different roosting areas. Long-term housing is typically in somewhat larger enclosures, at least 2 x 2m, with adequate space for bats to distribute among different roosting locations, drink, and self-feed. Many facilities also offer a flight cage to allow bats to maintain natural flight and feeding behaviors. Flight cage spaces are quite variable ranging from 4 x 4m to 7 x 14m. Although there were some general patterns in types of enclosures for holding bats, the dimensions and details of each facility seemed to be a based on availability and function rather than uniform guidelines.

Challenges Holding Insectivorous Bats in Captivity

Survey questions inquired about difficulties or challenges encountered while trying to hold insectivorous bats in captivity. The most commonly reported challenges include ensuring adequate nutrition, avoiding dehydration, maintaining environmental temp/humidity, avoiding dental and reproductive problems (difficult pregnancy and deliveries), avoiding shock and stress related illness, maintaining natural behaviors and flight muscles, understanding and addressing differences in species tolerance to captivity, maintaining experienced and consistent keepers (bats do not respond well to rotating keepers), and the costs associated with necessary (daily) time-consuming bat care. Other reported problems include deficient data on insectivorous bat care, difficulty training bats to self-feed, inter-bat aggression, occasional cage injuries, occasional skin problems (*Seratia marcenscens*, dermatitis, wound infections), food supply shortages, and modifying veterinary care that is typically geared toward larger animals.

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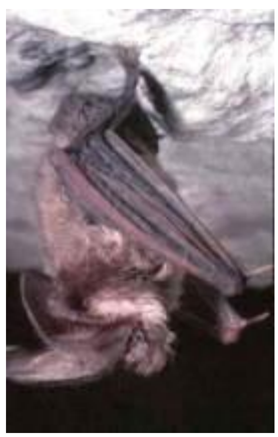

APPENDIX III

Summary Information on Federally Listed Bat Species

Summary Information for Federally Listed Bat Species

GRAY BAT

Scientific name: *Myotis grisescens*
Common name: Gray bat
Compiled by: Paul McKenzie, USFWS
Note: The following information is taken from the FWS-completed 5-year review for the gray bat (USFWS 2009).

Geographic range: Mostly Missouri and N. AR east to S IL, KY, TN, E AL, and extreme NW GA with scattered records from FL, IN, KS, OK, and VA

Status (listed): Endangered

Population(s) estimate and trend (increasing/stable/declining):
Since the completion of the 1982 Gray Bat Recovery Plan and the 1991 5-year review, ongoing surveys have been undertaken throughout the species' range. Counts have been conducted at hibernacula and maternity sites, and there have been surveys conducted for the species associated with various development projects. Depending on the situation and season, different techniques have been used to monitor various gray bat populations including direct counts, emergence counts and measuring the extent of guano piles or ceiling stains at established roosts. More recently, species' numbers have been monitored using technologically advanced equipment such as near-infrared (NIR) or thermal infrared (TIR) videography with computer and statistical software packages. In addition to problems inherent with using various census techniques, other complications associated with differences in observers' counting abilities, movements of gray bats between transient and permanent hibernacula or maternity sites, seasonality (e.g., counts at maternity sites before or after birth of young), inability to census sites the same year, and the potential of disturbing hibernating bats at critical hibernacula, all further hamper the ability to obtain accurate population trends for the species. The difficulty in obtaining meaningful trend data for various species of bats including *Myotis grisescens* has been exhaustively examined (Tuttle 1979; Sabol and Hudson 1995; Ellison *et al*. 2003, Kunz 2003, O'Shea and Bogan 2003, Tuttle 2003, Martin 2007, Sasse *et al.* 2007, Elliott 2008). Despite these limitations, various analyses have recently been conducted to assess changes in the population levels of gray bats since the recovery plan for the species was completed in 1982.

Ellison *et al.* (2003) of the U.S. Geological Survey (USGS) developed an extensive bat population database for 45 species of bats known from the United States including gray bat. From this database, the authors statistically analyzed 1,879 observations of gray bats obtained from 334 roost locations (103 summer colonies and 12 hibernacula) in 14 south-central and southeastern states. These authors reported upward, downward, or no trends for all sites analyzed. The USFWS interpreted an upward trend to be defined as an increasing population, a downward trend to be defined as a decreasing population, and no trend to be defined as a stable population. This follows terminology used in analysis of the status of gray bat populations in the western portion of the species' range by Sasse *et al.* (2007). Ellison *et al*. (2003) determined that 94.4% (85.4% no trend; 9% upward trend) of the populations showed stable or increasing populations while 6% revealed a decreasing population. Stable or increasing populations were reported for 83% (58% no trend; 25% upward trend) of the 12 hibernating colonies examined. For populations where there was a downward population trend, decreases in population numbers were mostly attributed to continued problems with human disturbance.

Sasse *et al.* (2007) analyzed data from 48 gray bat maternity sites involving three subpopulations in Missouri, Arkansas, and Oklahoma between 1978 and 2002, and calculated that 79% of the colonies were stable or increasing. Elliott (2008) examined population trends of gray bats at nine, Priority 1 caves and concluded that although the species had increased by approximately 21% between 1980 and 2005, it had only reached roughly 37% of its maximum historic populations at these sites. Martin (2007) compiled a rangewide exhaustive review of gray bat hibernacula and maternity sites and summarized conservation actions that had been undertaken and suggested steps that were necessary to achieve full recovery. Based on general population trends across the range of the species, Dr. Michael Harvey of Tennessee Technological University has attempted to estimate changes in the species status. He reported that the species increased from approximately 1,575,000 to roughly 2,678,000 in 2002, and to ca. 3,400,000 in 2004 (see Ellison *et al.* 2003 and Martin 2007). Martin (2007) noted that gray bat population levels have increased approximately 104% since 1982.

Wide population fluctuations of gray bat numbers have been documented at many maternity sites across the species' range, but there have been significant population increases in some of the major hibernacula. Martin (2007) noted that gray bat populations exhibited increases at Coach Cave, Kentucky from 0 in 1995, to 337,750 in 2007; at Blanchard Springs Caverns, Arkansas from 33 in 1985, to 128,005 in 2006; at Cave Mountain Cave, Arkansas from 205 in 1988, to 139,740 in 2006; and at Bellamy Cave, Tennessee from 347 in 1965, to 139,364 in 2006. Similarly, Martin (2007) and Elliott (2008) reported that populations of gray bat at Coffin Cave, Missouri increased from an estimate of 250,000 in 1977-79 to 561,000 bats in 2005. Although increases at some hibernacula may be due to movements from other caves [e.g., possible shift of bats from Jesse James Cave to Coach Cave after air flow was restored in the latter cave (Richard Clawson, Missouri Department of Conservation, pers. comm. 31 July 2009)], overall, gray bat populations have increased and recovered in many areas throughout the species' range (Tuttle 1987; Harvey and Britzke 2002; Ellison *et al.* 2003; Tuttle and Kennedy 2005; Martin 2007; Sasse *et al.* 2007).

Brief life history description:
The gray bat is one of the largest species in the genus *Myotis* in eastern North America (Decher and Choate 1995) with forearm lengths 40–47 mm long, a wingspan of 275 to 300 mm and weights ranging between approximately 7.0-16 g (Tuttle 1976a; USFWS 1980; Harvey *et al.* 1981; Decher and Choate 1995). The gray bat can be distinguished from other species in the genus *Myotis* by the uniform color of its dorsal fur in which hair shafts are gray from base to tip, by the wing membrane, which attaches at the ankle of the foot instead of at the base of the toes; and by a notch in the claws of the hindfeet (Barbour and Davis 1969; Harvey *et al.* 1981; Decher and Choate 1995; Tuttle and Kennedy 2005). The calcar on gray bats is not keeled and the skull has a distinct sagittal crest (Harvey *et al.* 1981; Mitchell 1998).

The primary range of gray bats is concentrated in the cave regions of Alabama, Arkansas, Kentucky, Missouri and Tennessee, with smaller populations found in adjacent states, including a growing population in a quarry in Clark County, Indiana (Harvey *et al.* 1981; Brack *et al.* 1984; Harvey 1992; Harvey 1994; Mitchell 1998). With a few exceptions (Hays and Bingham 1964; Gunier and Elder 1971; Timmerman and McDaniel 1992; Martin 2007), gray bats are one of the few species of bats in North America that inhabit caves year-round. The species occupies cold hibernating caves or mines in winter and warmer caves during summer (Tuttle 1976a; Harvey *et al.* 1981; Harvey 1994; Martin 2007). In winter, gray bats hibernate in deep vertical caves that trap large volumes of cold air and the species typically forms large clusters with some aggregations numbering in the hundreds of thousands of individuals (Harvey 1994; Tuttle and Kennedy 2005). The species chooses hibernation sites where there are often multiple entrances and where there is good air flow (Martin 2007) and where temperatures are approximately 5-9° C, though 1–4° C appears to be preferred (Tuttle and Kennedy 2005). Tuttle (1979) noted that an estimated 95% of the species rangewide population was confined to only 9 caves.

Male gray bats arrive at hibernacula first and aggressively compete for females (Tuttle and Kennedy 2005). Courtship and mating of gray bats occurs in the fall when the species arrive at hibernacula. Females enter hibernation first (usually during September and October) immediately following copulation but do not become pregnant until emergence from hibernation in late March or early April (Harvey 1994; Tuttle and Kennedy 2005). Males may remain active until November 10 before entering hibernation (Tuttle 1976a). Average gestation is approximately 64 days and a single pup is born in late May or early June. Females typically do not give birth until the second year. Newborn young weigh approximately one-third of their mother's weight and are volant within 21-33 days (Tuttle 1976b; Harvey 1994; Tuttle and Kennedy 2005).

In summer, female gray bats form maternity colonies of a few hundred to many thousands of individuals. Nursery colonies typically form on domed ceilings that are capable of trapping the combined body heat from clustered individuals and where the temperature ranges between 14 and 25° C (Harvey 1992; Harvey 1994; Tuttle and Kennedy 2005; Martin 2007).

Foraging of gray bats in summers is strongly correlated with open water of rivers, streams, lakes or reservoirs. Although the species may travel up to 35 kilometers between prime feeding areas over lakes or rivers and occupied caves (LaVal *et al.* 1977; Tuttle and Kennedy 2005), most maternity colonies are usually located between 1-4 kilometers from foraging locations (Tuttle 1976b). Tuttle (1976b) noted that the home range of one colony of gray bats included five caves and covered an area approximately 50 kilometers long by 5 kilometers wide. Newly volant gray bats travel 0.0–6.6 kilometers between roost caves and foraging areas (Tuttle 1976a; Tuttle 1976b). At foraging sites, Tuttle (1976b) estimated that gray bats forage within roughly three meters of the water's surface. Gray bats are highly dependent on aquatic insects, especially mayflies, caddisflies, and stoneflies. The species is an opportunistic forager, however, and also consumes beetles and moths (Harvey 1994; Tuttle and Kennedy 2005).

Gray bats show strong philopatry to both summering and wintering sites (Tuttle 1976a; Tuttle 1979; Kennedy and Tuttle 2005; Martin 2007). Because of their highly specific roost and habitat requirements, only about 5% of available caves are suitable for occupancy by gray bats (Tuttle 1979; Harvey 1994). At all seasons, males and yearling females seem less restricted to specific cave and roost types (Tuttle 1976b). Bachelor males segregate in separate aggregations within a colony home range that usually includes several caves that may extend up to 70 km along a particular river valley (Tuttle and Kennedy 2005).

Gray bat hibernacula are often made up of individuals from large areas of their summer range. Based on band recovery data, Hall and Wilson (1966) calculated that a *Myotis grisescens* hibernaculum in Edmonson County, Kentucky, attracted individuals from an area encompassing 27,195 square kilometers in Kentucky, southern Illinois, and northern Tennessee (Hall and Wilson 1966). Gray bats have been documented to regularly migrate from 17 to 437 kilometers between summer maternity sites and winter hibernacula (Tuttle 1976b; Hall and Wilson 1966), with some individuals moving as much as 689–775 kilometers (Tuttle 1976b; Tuttle and Kennedy 2005).

Recorded longevity for gray bat is approximately 14-17 years, but may be longer (Harvey 1992; Tuttle and Kennedy 2005). *Myotis grisescens* reach sexual maturity at 2 years of age (Miller 1939).

WNS Status/Risk: 5 bats from Round Spring Cave in Shannon Co., Missouri tested positive for *Geomyces destructans* (Gd) in May 2010- this was the first record of Gd documented for Gray bat; the official designation of the cave where Gd was documented is "presumptive positive"- histological exams for full blown expression of WNS in the gray bat samples collected were negative. Because an estimated 95% of the species rangewide population occurs in only nine caves, and the fact that Gd has already been documented in one cave in Missouri, the risk to gray bats is extremely high and the species could be threatened with extinction.

Recovery plan date: 1982

Recovery goals: Because the Recovery Plan is very old for this species, the overall recovery goal was to delist the species following certain criteria:

Gray bat may be reclassified from endangered to threatened when there is:

1. Documentation of permanent protection of 90% of Priority 1 hibernacula.
With the exception of Marvel Cave in Missouri, all Priority 1 hibernacula and Priority 1 maternity sites have been protected through acquisition, gates, fences, or signage (Table 1 of the FWS' 5-year review). Other than Marvel Cave, this reclassification criterion has been met. Conservation measures undertaken at Priority 1 hibernacula and maternity sites are excellent examples of partnerships developed between the FWS and other Federal, State, and private entities to contribute to the recovery of gray bat. Four National Wildlife Refuges (NWR) have been established in Alabama that, in part, provide protection for some of the largest populations of gray bat in the country: Fern Cave NWR, Sauta Cave NWR, Key Cave NWR, and the Wheeler NWR which includes Cave Springs Cave. Other gray bat sites protected on federal land include Bonanza Cave and Blanchard Springs Caverns in Arkansas managed by the U.S. Forest Service, and Cave Mountain Cave in Arkansas managed by the National Park Service. An excellent partnership developed between a private land owner and several entities at two of the largest gray bat sites in Kentucky (i.e., Coach and Jesse James Cave) has contributed to the conservation of the gray bat in Kentucky (Traci Hemberger, Kentucky Department of Fish and Wildlife Resources, pers. comm., 21 Sept. 2009). With financial support of the U.S. Department of the Army's Legacy funds, over 40 volunteers, including cavers, and representatives of the Coach and James Mapping Group, the American Cave Conservation Association, the Kentucky Department of Fish and Wildlife Resources, and the FWS participated in an effort to repair damaged and decayed wooden structures in Jesse James Cave (Martin 2007). In Tennessee, a collaborative effort involving the Tennessee Wildlife Resources Agency, the Nature Conservancy, Bat Conservational International, the American Cave Conservation Association and the FWS were successful in acquiring Pearson's Cave, a Priority 1 gray bat hibernaculum (Martin 2007).

2. Documentation of stable or increasing populations at 75% of Priority 1 maternity caves for 5 years.
This criterion has not been met. The spread of white-nose syndrome (WNS) continues to threaten the species' long term recovery (see section 2.3.2.3 of the FWS' 5-year review). Of the 29 Priority 1 maternity sites listed in the 1982 approved Gray Bat Recovery Plan, an analysis of data received from state personnel throughout the range of the species and reports by Martin (2007), Sasse *et al.* (2007) and Elliott (2008) reveal that populations at 13 sites (45%) have been stable or increasing (Table 2 of the FWS' 5-year review).

Gray bat may be removed from the List of Endangered and Threatened Wildlife (50 CFR 17.11) when the reclassification criteria and the following delisting criteria have been met:

1. Documentation of permanent protection of 25% of Priority 2 caves in each state.
This criterion has not been met. Analyses provided by Martin (2007), Sasse *et al.* (2007), Elliott (2008) and data provided by various state personnel within the range of gray bat were used to assess the protection and population status of gray bat Priority 2 caves listed in Table 6 of the 1982 Gray Recovery Plan (Table 3 of the FWS' 5-year review). Based on available information, approximately 98 of the 135 (73%) Priority 2 caves are protected with gates, fences, or signage (Table 4 of the FWS' 5-year review). There are numerous examples of partnerships that have developed that provide conservation benefits to Priority 2 gray bat sites. In Missouri, collaborative efforts involving the installation of proper gates at the

Missouri Department of Conservation's Mary Lawson Cave and the Missouri Department of Natural Resources' River Cave in HaHa Tonka State Park have contributed to a rebounding of gray bat numbers at these sites.

2. Documentation of stable or increasing populations of 25% of Priority 2 caves in each state for 5 years. Opinions differ among gray bat researchers whether this criterion has been met. The spread of WNS continues to threaten the species' long term recovery (see section 2.3.2.3 of the FWS' 5-year review). Some gray bat experts (e.g. Sasse *et al.* 2007) believe that 5 years is an inadequate time period to assess stable or increasing trends for this species. Nonetheless, populations of many gray bat Priority 2 caves have been monitored for more than 5 years and roughly 33% of Priority 2 caves across the species' range have stable or increasing populations (Table 4 of the FWS' 5-year review).

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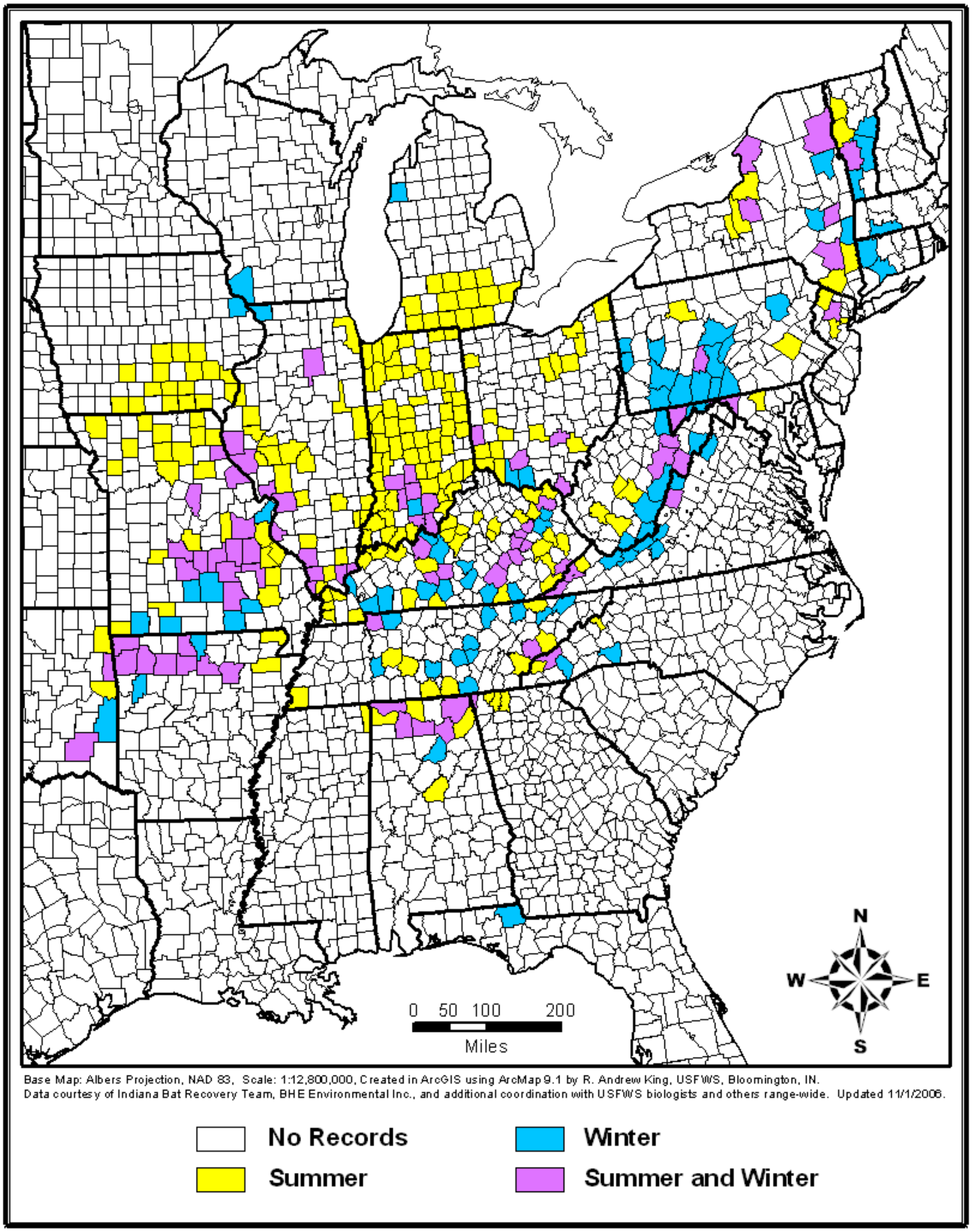
INDIANA BAT

Scientific name: *Myotis sodalis*
Common name: Indiana bat
Compiled by: Lori Pruitt, USFWS

Geographic range:
Distribution of counties with known summer and winter records of the Indiana bat.



Status (listed):
The species was originally listed as in danger of extinction under the Endangered Species Preservation Act of 1966, and is currently listed as endangered under the Endangered Species Act of 1973, as amended. Indiana bat is state listed in 18 of 20 states where it currently occurs including Alabama, Arkansas, Connecticut, Illinois, Indiana, Iowa, Kentucky, Ohio, Oklahoma, Maryland, Michigan, Missouri, New Jersey, New York, Pennsylvania, Tennessee, Vermont, and Virginia. The species is also listed in four states where there are no current records (Florida, Georgia, Massachusetts, and South Carolina).

Population(s) estimate and trend (increasing/stable/declining):
As of October 2006, the Service had records of extant winter populations at approximately 281 hibernacula in 19 states and 269 maternity colonies in 16 states. The 2009 winter census estimate of the population was 387,835; the population is declining (see attached 2009 Rangewide Population Estimate for the Indiana Bat by Recovery Unit).

Brief life history description:
The Indiana bat is a temperate, insectivorous, migratory bat that hibernates colonially in caves and mines in the winter. In spring, reproductive females migrate and form maternity colonies where they bear and raise their young in wooded areas. Males and non-reproductive females typically do not roost in colonies and may stay close to their hibernaculum or migrate to summer habitat. Summer roosts are typically behind exfoliating bark of large, often dead, trees. Both males and females return to hibernacula in late summer or early fall to mate and enter hibernation.

The Indiana bat is a nocturnal insectivore. It emerges shortly after sunset and begins feeding on a variety of insects that are captured and consumed while flying. Indiana bats typically forage in closed to semi-open forested habitats and forest edges.

WNS Status/Risk: The Indiana bat is currently affected by white-nose syndrome (WNS). Accurate estimates of the number of Indiana bats that have died due to WNS are not available, but New York Indiana bat populations alone have declined by more than 20,000 due to WNS. The largest populations of Indiana bats (in Indiana, Kentucky, and Illinois; see attached 2009 Range-wide Population Estimate) will likely be affected by WNS within the next year or two.

Recovery plan date: Current plan is the Draft First Revision (USFWS 2007); work on finalizing this plan is ongoing.

Recovery plan: Recovery goals and objectives as stated in the Draft First Revision of the Recovery Plan are listed below. Note that the Service anticipates that the Recovery Objectives will be revised based on public and peer review comments received on the 2007 draft of the first revision of the recovery plan.

Recovery goal: The ultimate goal of this Recovery Plan is to remove the species from the Federal list of Endangered and Threatened Wildlife. The intermediate goal is reclassification of Indiana bat to threatened status.

Recovery objectives: To reclassify the Indiana bat to threatened, the following objectives must be achieved: 1) permanent protection of 80 percent of Priority 1 hibernacula, 2) a minimum overall population number equal to the 2005 estimate (457,000), and 3) documentation of a positive population growth rate over five sequential survey periods. The Indiana bat will be considered for delisting when the Reclassification Criteria have been met and the following additional criteria have been achieved: 1) permanent protection of 50 percent of Priority 2 hibernacula, 2) a minimum overall population number equal to the 2005 estimate, and 3) continued documentation of a positive population growth rate over an additional five sequential survey periods.

2009 Rangewide Population Estimate for the Indiana Bat (*Myotis sodalis*) by Recovery Unit

Estimates are primarily based on winter surveys conducted in January and February 2009 at known Priority 1 & 2 hibernacula throughout the species' range. Additional data from Priority 3 and 4 hibernacula were included when available.

IBat Recovery Unit	State	2001	2003	2005	2007	2009	% Change from 2007	% of 2009 Total
Ozark-Central	Illinois	21,677	43,646	55,166	54,095	53,276	-1.5%	13.7%
	Missouri	18,999	17,752	16,102	15,895	13,674	-14.0%	3.5%
	Arkansas	2,475	2,228	2,067	1,829	1,480	-19.1%	0.4%
	Oklahoma	0	5	2	0	0	0.0%	0.0%
	Total	43,151	63,631	73,337	71,819	68,430	-4.7%	17.6%
Midwest	Indiana	173,111	183,337	206,610	238,026	189,994	-20.2%	49.0%
	Kentucky	51,053	49,544	65,611	71,250	57,325	-19.5%	14.8%
	Ohio	9,817	9,831	9,769	7,629	9,261	21.4%	2.4%
	Tennessee	4,192	3,246	3,221	2,929	1,663	-43.2%	0.4%
	Alabama	173	265	296	258	253	-1.9%	0.1%
	SW Virginia	373	430	202	188	217	15.4%	0.1%
	Michigan	20	20	20	20	20	0.0%	0.0%
	Total	238,739	246,673	285,729	320,300	258,733	-19.2%	66.7%
Appalachian Mountains	West Virginia	9,714	11,444	13,417	14,745	14,855	0.7%	3.8%
	E. Tennessee	5,372	6,556	8,853	5,977	11,058	85.0%	2.9%
	Pennsylvania	702	931	835	1,038	1,031	-0.7%	0.3%
	Virginia	596	728	567	535	513	-4.1%	0.1%
	North Carolina	0	0	0	0	1	0.0%	0.0%
	Total	16,384	19,659	23,672	22,295	27,458	23.2%	7.1%
Northeast	New York	29,671	32,981	41,702	52,783	32,734	-38.0%	8.4%
	New Jersey	335	644	652	659	416	-36.9%	0.1%
	Vermont	246	472	313	325	64	-80.3%	0.0%
	Total	30,252	34,097	42,667	53,767	33,214	-38.2%	8.6%
Rangewide Total:		328,526	364,060	425,405	468,181	387,835	-17.2%	100.0%
	2-yr. Net Change:		35,534	61,345	42,776	-80,346		
	2-yr. % Change:		10.8%	16.9%	10.1%	-17.2%		

VIRGINIA BIG-EARED BAT

Scientific name: *Corynorhinus townsendii virginianus*
Common name: Virginia big-eared bat (VBEB)
Compiled by: Barbara Douglas, USFWS

Geographic range: West Virginia, Virginia, North Carolina, Kentucky.

Status (listed): Endangered

Population(s) estimate and trend (increasing/stable/declining): Currently stable. The rangewide population of VBEB is estimated to be approximately 15,000 bats. Approximately 12,000 of these bats hibernate in West Virginia. The 2009 maternity counts in West Virginia were the highest on record (7245) and the 2010 count documented 7179 bats, the second highest count on record (WVDNR 2009; Stihler, pers. comm.). Four genetically-distinct sub-populations of VBEB occur in northeastern West Virginia/northwestern Virginia, southern West Virginia, eastern Kentucky, and western Virginia/North Carolina (Piaggio 2009). Throughout this range, there are only 13 caves that have been documented to support groups of more than 20 hibernating VBEB, and only eight that have supported groups of more than 100 individuals. There are only 17 caves known to be used as maternity sites and six other caves that are known to support summer bachelor-colonies composed of more than 20 individuals.

The northeastern West Virginia/northwestern Virginia region, which encompasses Tucker, Pendleton, and Grant counties, West Virginia, and Highland County, Virginia, supports the largest population segment. Caves in this region support approximately 77% of the rangewide maternity population (Service 2008a, Service 2008b). Over 60% of the rangewide population hibernates in these counties. Almost all of these bats (10,025 as of 2010) hibernate in a single cave, Hellhole. There are five caves (Hellhole, Hoffman School, Cave Mountain, Cave Hollow/Arbogast, Sinnitt/Thorn Mountain) designated as critical habitat under the Endangered Species Act. All are located in this region of West Virginia. The area encompassed by all the hibernation and maternity caves in this region is approximately 30 miles long and 36 miles wide. There are only three caves located outside of West Virginia that support more than 100 hibernating VBEB (Service 2008a). These caves are located in Tazewell County, Virginia; Avery County, North Carolina; and Lee County, Kentucky.

Brief life history description: The VBEB is a medium-sized bat that has brownish fur, long ears, weighs less than 0.5 ounces, and is approximately four inches in length from head to toe. They inhabit caves and mines in both summer and winter. During the winter they hibernate in clusters that may contain many hundreds of individuals. During the summer they use caves for maternity sites and roosting. Sexes tend to segregate into separate caves to form maternity or "bachelor" male colonies. During the summer, the bats emerge each night to forage for moths and other insects among woodlands, forest edges, old fields, and hay fields. Mating begins in autumn. Sperm are stored in the female reproductive tract through the winter, and fertilization occurs shortly after arousal from hibernation. When the females arrive at their maternity sites they are pregnant and have one young per pregnancy. Young are born around mid-June, and by mid-July the young begin to leave the cave at night to forage. Most bats leave the maternity cave by late September. Although they may use different caves during the summer and winter periods, no long-distance migrations are known, and movements of up to 20 miles have been documented between summer roosts and hibernacula (Stihler 1994; Stihler 1995; C. Stihler, personal communication). The bats return year after year to the same hibernation and maternity sites (C. Stihler, personal communication). Bats that use different maternity caves may mix together in the same hibernation site and vice versa. Banding data collected by the West Virginia Division of Natural Resources (WVDNR) documented that bats roosting in four separate summer roosts hibernate primarily in a single roost in Pendleton County, West Virginia.

Some individuals from two of the four summer roosts were also found in another hibernaculum approximately one mile away (C. Stihler, personal communication).

WNS Status/Risk: To date, no VBEB have shown visible signs of WNS. However, a number of caves known to support VBEB have had other confirmed positive bat species. Hellhole, which contains the largest hibernating population of VBEB in the world, was confirmed positive for WNS in January, 2010. In addition to VBEB, the cave contains significant numbers of Indiana bats and little brown bats. In 2010 the cave contained 18,557 Indiana bats, up approximately 5,700 from the previous survey in 2007. Approximately 1.6% of the Indiana bats showed signs of WNS. There were 38,155 little brown bats in the surveyed areas of the cave in 2010. This is an approximately 50% decline from the 2007 survey (WVDNR, 2010). The area of the cave where VBEB roost is known to be drier than other areas of the cave. It has been suggested that bats roosting in drier caves/areas may be less susceptible to the effects of WNS. However, some LBB in rooms containing VBEB did exhibit signs of WNS in 2010. In 2009, a little brown bat was observed in Cliff Cave, a site that supports 125 hibernating VBEB. Due to hazardous access conditions, this site was not resurveyed in 2010. WNS has also been observed in little brown bats from Cave Mountain and Sinnitt/Thorn Cave which are designated critical habitat for VBEB as maternity sites.

In summer 2010, the Service outlined a number of factors that potentially make VBEB extremely susceptible to the risk of extinction and/or local extirpation from WNS. These include:

- the extremely limited number of caves known to support the subspecies (only eight hibernacula rangewide that support groups of more than 100 individuals);
- the concentration of the largest sub-population (containing 60-77% of the rangewide population) within a restricted geographic range (a 30 x 36 mile area);
- the documented emergence of WNS within this area including within the fourth largest VBEB hibernaculum for that sub-population and also in another cave that is one of the five caves designated as critical habitat;
- the proximity of the remaining sub-populations to other known WNS-affected caves (30-60 miles to western Virginia/North Carolina, 60 miles to southern West Virginia, and 150 miles to the Kentucky populations);
- the limited number of caves that support VBEB in the three smaller sub-populations (The States of Virginia, Kentucky, and North Carolina each have only one cave that supports groups of more than 100 hibernating individuals);
- the geographic isolation and genetic distinction of the four sub-populations, making it unlikely that bats could naturally re-colonize areas historically occupied by another sub-population once the effects of WNS are ameliorated.

It was/is anticipated that WNS could occur throughout the entire range of the VBEB within the next 1-2 years.

Recovery plan date: 1984
The VBEB was listed as endangered under the Endangered Species Act (87 Stat. 884, as amended; l6 U.S.C. l53l et seq.) in 1979 due to their small population size, limited distribution, and vulnerability to human disturbance. Since the time of listing, recovery efforts have been focused on purchasing important VBEB habitats, and working with private landowners to implement protective measures such as gating cave entrances and restricting access to caves during times that VBEB are present. These measures have been extremely successful, and numbers of hibernating VBEB have increased approximately 450% since 1984, when the recovery plan was finalized (Service 2008a, Service 1984).

Recovery goals: The Recovery Plan (Service, 1984) lists four criteria for consideration when deciding whether to propose downlisting of VBEB to threatened status:

1. Documentation of long-term protection of 95% of all known active colony sites.
2. Documentation of stable or increasing populations at 95% of the known active maternity sites and hibernacula for a period of five years.
3. Foraging habitat for both subspecies must be identified, and restored as much as possible. However, a given amount of foraging habitat cannot be required in the objective at this time due to lack of information on colony needs.
4. Finally, a periodic monitoring program must be established to ensure a continued awareness of the status of these animals.

The Recovery Plan also concluded that "It seems unlikely that the Virginia big-eared bat will recover to a point where it can be removed from the threatened list. However, this matter should be reconsidered at the time its status is reduced from endangered to threatened."

Currently, downlisting criteria 1–3 have not been met. Although significant progress has been made to protect major hibernacula and maternity caves from disturbance through gates, fences, or signed closures, only four of the seven major hibernacula throughout the species' range have documented long-term protection. Hellhole, the largest hibernaculum is on private-lands. As a result, approximately 36% of the hibernating population has long-term protection. Only seven of the 13 major maternity colonies have documented long-term protection. The protected caves comprise 59% of the total population of VBEB. Although there have been fluctuations and decreases in populations within individual caves, the rangewide population within both hibernacula and maternity colonies has increased since the time of listing. While the documented range of the species has expanded, the major population concentrations remain within the range of the species that was known at the time of listing. A number of additional caves have been discovered, including significant hibernacula within North Carolina. An effective periodic monitoring program has been implemented rangewide that provides information on population trends and continued awareness of the status of the VBEB.

Continuing threats include lack of long-term protection, loss of cave habitat from quarries and mining activities, the presence of oil and brine separation pits, and loss of foraging habitat through development and road construction. In addition, the construction of wind farm projects within close proximity of VBEB caves, coupled with the lack of consistent and effective regulatory oversight of these projects, represents a significant and newly emerging threat. Although predation and vandalism at caves seems uncommon, one predator or vandalism event could have significant adverse impacts on a colony. This threat is a potential problem at all VBEB caves. Natural changes in caves, such as breakdown, sinkholes, landslides, and flooding, can also alter cave conditions so that they are no longer suitable to support the species or create safety hazards that affect the ability of biologists to monitor the species.

Information on foraging behavior has been gathered; however significant data gaps remain, particularly in regard to seasonal movements and species ecological requirements. With the exception of lands within the National Forest System, very little protection or management of VBEB foraging habitat has been achieved. Finally, genetic research has indicated that there are at least four geographic regions within the range of the species that are significantly differentiated and genetically unique populations. These populations should be recognized as distinct evolutionary significant units and managed as such. The Recovery Plan for the species is outdated and needs to be updated to address current species information, including genetics, distribution, and threats.

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OZARK BIG-EARED BAT

Scientific name: *Corynorhinus townsendii ingens*
Common name: Ozark big-eared bat (OBEB)
Compiled by: Richard Stark, USFWS

Geographic range: The Ozark big-eared bat is endemic to the Ozark Highlands and Boston Mountains ecoregions (Omernik, 1987) where it occurs in oak-hickory hardwood forests (Clark, 1991; Leslie and Clark, 2002; and U.S. Fish and Wildlife Service, 1995). The current range of the Ozark big-eared bat includes northeastern Oklahoma and northwestern Arkansas. In Oklahoma, Ozark big-eared bats currently are known to occur in Adair, Cherokee, and Sequoyah counties. They were historically known from two caves in Delaware County, but have not been observed there recently. Twelve caves considered essential for the continued existence of the Ozark big-eared bat (*i.e.,* used by colonies of Ozark big-eared bats for maternity sites and/or hibernacula) occur in Oklahoma. In Arkansas, the Ozark big-eared bat is known to occur in Marion, Washington, Searcy, Crawford, and Franklin counties. Seven essential caves occur in Arkansas.

Status (listed): The Ozark big-eared bat was federally-listed as endangered on November 30, 1979, due to its small population size, reduced and limited distribution, and vulnerability to human disturbance. The Ozark big-eared bat also is listed as endangered by the States of Oklahoma, Arkansas, and Missouri. The species is considered extirpated from Missouri.

Population(s) estimate and trend (increasing/stable/declining): At the time of listing, the Ozark big-eared bat was known from only a few caves and the entire population was estimated to consist of about 100-200 individuals. Since listing, additional caves used by maternity colonies in the summer and as hibernacula have been discovered in Oklahoma and Arkansas. Ozark big-eared bat populations at essential hibernacula and maternity sites have been monitored using minimal census techniques since each essential site was discovered to obtain estimates on colony size and population trends. The population is estimated to currently consist of about 1,800 individual bats with about 1,300 – 1,400 in Oklahoma and 400 - 500 in Arkansas. Census counts through 2009 indicate that the overall population has experienced a slightly increasing trend since 1997, when the last discovered essential maternity site from which we have several years of population data (a maternity cave in Arkansas) was added to the annual counts. However, population trends of all individual colonies at essential caves are not well explained by available monitoring data due to bat movement among caves, likely including sites not known to us, and due to the difficulty in monitoring bats at certain caves. Recent monitoring at maternity caves during the 2010 summer indicates that colony sizes are down at several sites.

Brief life history description: The Ozark big-eared bat is an insectivorous bat that uses caves year-round. Ozark big-eared bats typically emerge from their caves to forage shortly after sunset (Clark *et al.*, 1993 and 2002). They primarily feed on moths, but also are known to eat beetles and other flying insects (USFWS, 1995; Leslie and Clark, 2002; Dodd, 2006; Dodd and Lacki, 2007). The Ozark big-eared bat typically forages in edge and forested habitats (Clark *et al.*, 1993; Wethington *et al.*, 1996). Females forage relatively close to the maternity cave (about 1.0 – 2.0 km; 0.6 – 1.2 miles) during the early and middle portions of the maternity season. Female bats likely forage only short distances from the cave in order to return several times

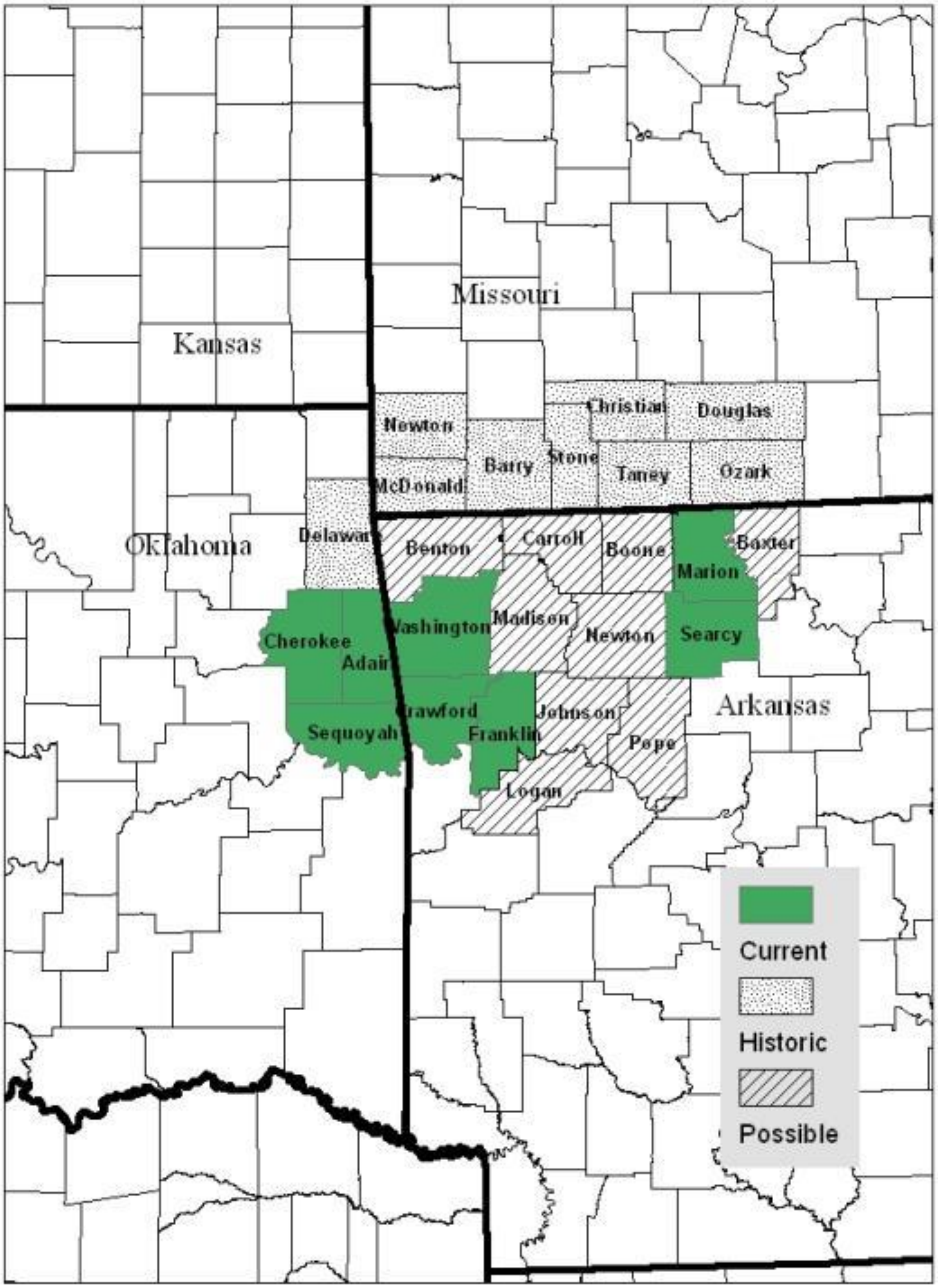

Figure 1. Current, historic, and possible range of the Ozark big-eared bat.

during the night to take care of flightless young. As the season progresses, average distance to foraging sites (up to 7.3 km; 4.5 miles) increases (Clark *et al.*, 1993; Harvey, 1992). Foraging farther distances from the cave later in the summer may reduce competition with newly volant young that have begun to forage.

Ozark big-eared bats mate during fall and winter. Females become reproductively active during their first fall (Kunz and Martin, 1982; U. S. Fish and Wildlife Service, 1995), while young males do not reach sexual maturity until their second autumn (Kunz and Martin, 1982). Females store sperm in their reproductive tract during the winter hibernation period.

Colonies typically begin to form at hibernacula in October and November (Clark *et al.*, 1996 and 2002). Both sexes hibernate together in clusters that typically range from 2 -135 individuals (Clark *et al.*, 1993, 1997 and 2002). Ozark big-eared bats also will hibernate singly (Clark *et al.*, 1996, 1997, and 2002) and in larger groups that have consisted of up to about 400 individuals. Sex ratios from Arkansas hibernacula indicate about an equal number of males and females at hibernacula. The Ozark big-eared bat is known to hibernate in both twilight areas near the entrance of caves and in areas of total darkness deep within the coldest regions of caves (Harvey *et al.*, 1978; Clark *et al.*, 1996 and 2002). Bats select sites with the appropriate microclimate to ensure that their metabolic rate will not deplete fat reserves required to sustain them through the winter (Clark *et al.*, 2002). When temperatures near the entrance become too extreme, Ozark big-eared bats relocate to a more optimal and stable roost site. The temperature and humidity of areas selected for hibernation ranges from 4° to 11°C (40° to 52°F) and 60 – 95%, respectively (Harvey *et al.*, 1978; Clark *et al.*, 1996 and 2002).

The Ozark big-eared bat is known to exhibit winter activity (Kunz and Martin, 1982; Clark *et al.*, 2002). Winter activity may be for foraging. However, insect activity typically is very low during cold nights. Activity likely also occurs in order to relocate within the same hibernaculum or among hibernacula to find a more thermally stable location when temperatures at the initial location become too extreme.

Hibernating colonies gradually begin to break up in spring from April through May (Clark *et al.*, 2002). Females also become pregnant during this time (Kunz and Martin, 1982) and slowly begin to congregate at warm maternity caves to give birth and rear their young over the summer (Clark *et al.*, 1993, 1996, and 2002). Distances between hibernacula and summer caves are known to range from 6.5 to 65 km (4 to 40 miles). The exact timing of the formation of maternity colonies varies between years, but usually occurs between late April and early June (Clark *et al.*, 2002; U. S. Fish and Wildlife Service, 1995). Maternity caves range in ambient temperature from 10° to 15°C (50° and 59°F). Relative humidity near roost sites is known to range from 86-95%. Fetal and neonatal growth can be adversely affected when bats roost in less than optimal locations. Females select warm areas within caves for optimum growth and development of young (Kunz and Martin, 1982). The warmest areas are those near the cave entrance. However, these locations also are most susceptible to disturbance. Ozark big-eared bats are known to select areas near the entrance but just beyond the light zone for maternity roosts. Roosting at such locations may be a compromise between areas of optimal microclimate and minimizing disturbance (Clark *et al.*, 1996).

Ozark big-eared bats give birth to a single offspring in May or June after a two-three month gestation period (Kunz and Martin, 1982; Clark *et al.*, 2002). Young bats grow quite rapidly and are capable of flight at three weeks and are weaned by six weeks (Kunz and Martin, 1982). Maternity colonies begin to break up in August (Kunz and Martin, 1982; Clark *et al.*, 1996; Wethington *et al.*, 1996).

The Ozark big-eared bat is known to move among caves during the maternity season (Clark *et al.*, 2002), but generally return to the same maternity caves each year (Clark *et al.*, 1996). A recent genetics study provides further insight into the need to protect each maternity colony. Weyandt *et al.* (2005) examined population genetic variability and found that maternally inherited markers differed among sites, indicating very strong site fidelity and limited dispersal by females and high natal philopatry. Due to the natural tendency for limited dispersal by females and the apparent corresponding lack of connectivity among colonies, caves that experience a local extinction are unlikely to be naturally re-colonized. These results suggest that failure to protect a maternity site may result in the loss of genetic variation.

Males are solitary during the summer maternity period (Kunz and Martin 1982; Harvey and Barkley, 1990; Clark *et al.*, 1993). Little else is known about their summer habitats (U. S. Fish and Wildlife Service, 1995).

Maximum life span is estimated to be about 16 years based on recovery of banded bats.

WNS Status/Risk: Although mortality attributable to WNS has not occurred within the range of the Ozark big-eared bat, the fungus associated with WNS recently was documented on a single cave myotis *Myotis velifer* collected alive from a cave on May 3, 2010, in northwestern Oklahoma. The fungus also was found on gray bats in Missouri during the spring of 2010, a species that co-occurs in caves with the Ozark big-eared bat. Should WNS move into the range of the Ozark big-eared bat (and should Ozark big-eared bats prove to be susceptible to the disease), the potential impact would be severe due to the high mortality rate of affected bats in the northeastern and eastern United States, and the small population size (1,800) and limited distribution (eight counties in Oklahoma and Arkansas) of the Ozark big-eared bat.

Recovery plan: Ozark Big-Eared Bat (*Plecotus townsendii ingens*) Revised Recovery Plan, March 28, 1995. The original recovery plan was approved on May 8, 1984 (Bagley 1984). The recovery plan included both federally-listed subspecies of *Corynorhinus townsendii*, the Ozark big-eared bat (*C. townsendii ingens*) and the Virginia big-eared bat (*C. townsendii virginianus*). The original recovery plan was revised to specifically address and update biological information, management techniques, and identify new recovery tasks for the OBEB

Recovery goals:

- Stable or increasing populations at all essential caves (*i.e.,* caves used as a maternity site and/or hibernacula that are considered essential to the continuing existence of the Ozark big-eared bat).
- The Ozark Plateau National Wildlife Refuge is operational with authority, funds, and manpower to a) enhance management of Refuge caves and properties, b) construct cave gates and fences where needed, c) monitor populations, d) deter human disturbance through law enforcement, e) implement cave management agreements with private landowners, and f) coordinate recovery efforts on an ecosystem basis across State and Fish and Wildlife Service regional boundaries.
- Protect all limited-use sites (*i.e.,* sites used by single individuals and small groups).
- Reestablish stable or increasing populations at all available historic caves in Oklahoma, Arkansas, and Missouri.

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Insectivorous Bat Captive Population Feasibility Workshop

Saint Louis, Missouri, US
14 – 16 July 2010

Final Report

APPENDIX IV

Pre- and Post-Workshop Questionnaires / Comments

Post-Workshop Questionnaires / Pre-Workshop Comments

Anonymous Responses to Questions Posed in Post-Workshop Questionnaire

1) Which strategy, including the "no captive management" alternative, is your recommendation and why?

"I think captive management is a reasonable response to the WNS due to the husbandry expertise available (based on several successful insectivorous bat colonies currently in captivity), sufficient numbers to found a genetically healthy captive population, and the threat of extinction facing some of the affected species. A short-term captive management strategy with a relatively quick reintroduction (< 1 generation in captivity) may be ideal to avoid selection to captivity, retain natural behaviors and genetic diversity, and reduce costs. However, I think a long-term breeding strategy is more realistic in order to provide sufficient time to 1) understand *G. destructans* in the animals and their environment and 2) plan successful reintroduction strategies. Therefore, any captive management action should have preparations for long-term breeding from the beginning (i.e., sufficient numbers of founders for genetic diversity, sufficient target population sizes, dedicated facilities, husbandry development, breeding and hibernation attempts, etc) - with short-term management/reintroduction as a desirable alternative as conditions allow. In other words, hope for the best but prepare for the worst. As a potential side benefit, a long-term management response now for this syndrome may also increase husbandry expertise that can be used for combating other threats to Microchiropteran species (taxa for which captive management has historically not been widely utilized)."

"I say explore all options. If captive management can be used to stave off imminent extinctions, or just to attempt to stave off imminent extinctions, then it must be considered as an alternative to extinction. In addition, captive populations can likely yield valuable information on disease dynamics and cure, as well as basic micro-bat biology."

"My opinion is that no option should be pursued at a full-scale at this point.

My highest priority for a pilot project is the short-term strategy of hibernating bats in an artificial hibernaculum on site at a natural hibernaculum. Bats would be captured on site after completing the fall swarm (so mating would have already occurred) and would be released at the same time that bats naturally emerge from the hibernaculum in the spring. Before this strategy can succeed (as a WNS management strategy) we must be able to control WNS in the artificial hibernaculum, and we do not currently have the tools to accomplish this."

"Short-term: Holding of hibernating bats in winter—most conservative starting point, most closely reflects natural life history, some chance of combating mortality from WNS.

Long-term: Based on outcomes of research and experimental management."

"Short/Long-term Captive Management, especially in 'high risk' species because (1) this can serve as insurance population, and (2) serve as research population (in case of lower risk species) that allow better understanding of bat biology that are important for long-term captive propagation program."

"Captive management. Certain species will likely become extinct if sufficient numbers of these bats are not taken into captivity in the near future."

"In St. Louis we were directed to discuss the feasibility of captive breeding in isolation from the "no captive management "alternative. We were not offered any information on what other options constituted the "no captive management option", nor were we given population data / information about what triggers would guide a response to put a captive management strategy into operation, nor was reintroduction feasibility a key element of our discussions. All of which have direct bearing on an answer. My recommendation is therefore based on my 20 years experience working to conserve bats, and not solely on the discussions held in St. Louis.

Reviewing IUCN SSC *Reintroduction Specialist Group* guidelines, the aim of these guidelines is to ensure that "reintroductions are both justifiable and likely to succeed, and that the conservation world can learn from each initiative, whether successful or not" (IUCN 1995). For insectivorous hibernating bats, the data we reviewed at St. Louis zoo made it clear that the probability of achieving successful breeding and reintroductions is unfortunately *very low* for this particular group of animals.

In our discussions in St. Louis, we used frogs as a comparison animal group. Many frogs are exceedingly problematic in their management, but on balance they are a lot less demanding than bats. The captive management of bats is possibly a decade behind that of amphibians. Other than captive breeding for short-term laboratory research (*Eptesicus fuscus*), or offspring produced in captivity accidentally, there are no examples of successful captive breeding or reintroductions of hibernating insectivorous bats. For many species this is because it has not been attempted, for others, the attempts documented have failed due to inability to maintain the animals in a captive environment that meets their complex thermoregulatory, nutritional and behavioral needs.

While we do need the techniques of intensive management to maintain hibernating bats for research to combat WNS, it is not likely to be an intelligent investment strategy for multiple endangered species for now. Using other strategies to cope with WNS while the skills of captive management are being developed is a more logical approach.

A fundamental problem the captive breeding community has always faced is working with difficult and exacting species, and unfortunately we can only learn empirically, so some failure in the early stages is unavoidable. Given the discussions in St Louis, it became evident that despite failures, some of the behavioural, ecological, nutritional and genetic challenges posed by hibernating insectivorous bats may be possible to overcome, with time and investment in experimentation keeping common species in captivity first. There were some limited but hopeful examples of animals feeding on the wing after a period of captivity, animals being maintained in a hibernated state in captivity, and animals surviving greater than one year after having been released to the wild. However, truly fundamental questions remain. Bringing together all the information and knowledge we have on keeping micro-bats and learning from those who have already had limited success may help us establish how to breed hibernating species, and how to release them and get them to survive and flourish in the wild. These intensive management techniques will enable us to maintain bats for immediate research needs to explore WNS and ways to combat this conservation crisis. Captive research animals may also eventually lead to methods to temporarily maintain and translocate animals and enhance survival rates in populations when the need arises in the future. Disease is an emerging threat considered an issue of global concern for endangered species, and thus every conservation tool we develop may be valuable for the future, not just in the US but worldwide."

"Because of the many variables and unknowns involved, it would be counterproductive to recommend a single one-size-fits-all strategy. Instead, I would recommend an adaptive management strategy that incorporates "no captive management" as well as short-term holding of hibernating populations, longer-term holding of threatened bat populations, and captive breeding colonies."

“I think we should investigate some of the short-term strategies, for one or two non-listed species, on a limited basis (keeping costs as low as possible), and then move into longer term (breeding) strategies if we are able to document success. I also believe we should look into cryopreservation of gametes and cell line establishment with two aims: 1) archive the genetic material that is out there (and rapidly being lost) and 2) have a source for future repatriation if whole species are wiped out in the wild. While cloning and embryo transfer are difficult, expensive techniques right now, they may be much more easily done in the future.

I **do not** think the Service should invest heavily in some sort of large scale, long-term, captive breeding facility. Based on what I have seen, read, and heard, there is a good chance it would not be successful, and it would require substantial funding (that would most likely be at the expense of other important WNS research). It does not seem like a good investment of limited conservation monies at this point.”

“I recommend a full, long-term program for 1–3 species if possible. I understand that this will be very difficult but I believe that white-nose will not be our last challenge.”

“I recommend taking several captive approaches at least in pilot or early phases. Also each species response needs to be tailored to the species in question. The program longevity, etc for each can be reevaluated as time goes on. I don’t recommend counting any of the half dozen options discussed out of hand, but in particular, I’d like to see the idea of using artificial hibernation as a seasonal stop gap on WNS explored more fully and I’d like to see several pilot programs in longer term captive propagation started (perhaps with substitute species). I see little point in beginning a long-term captive management program without attempting to breed (even if it’s not successful in the initial period). The risk of seasonal holding is, of course, that they die in a man-made hibernation chamber from WNS as easily as in the wild, so there would need to be some kind of monitoring, etc. The huge benefits are that you can still have natural mating, selective pressure (during the active season), and can perhaps maintain cultural transmission of roosting sites, etc (probably a little cheaper to do than full blown captive work, too.)”

“For three reasons, I still favor no captive management as my favored approach. ***First***, if WNS originated in Europe and was subsequently brought to the U.S., I think it is best to let natural selection take its course. Support for this is that some species of European bats have been documented with WNS yet there does not appear to be significant die-offs of European bats. This would suggest that WNS has run its course in Europe and the bats remaining are resistant to WNS. ***Second,*** we lack the necessary knowledge for captive rearing and breeding of many species of North American insectivorous bats. Even if we are able to overcome this hurdle, how many bats and from where, as well as how many species are we going to be able to bring into captivity? This will be a significant financial investment. Moreover, can we bring in a sufficient number of bats to retain enough genetic variation so that if we are able to release them into the wild at some point in the future that the bats have sufficient genetic variability so that they (1) can avoid potential problems with inbreeding depressions and (2) to evolve with changing environmental conditions? ***Finally***, how long will the spores of *G. destructans* survive in the environment? This is a critical question because it helps to determine minimally how long we are planning for the captive breeding program to be ongoing. This is important in the initial design of the program to address potential problems of inbreeding, artificial selection, and adaptation to captivity.

Given these concerns, I am supportive of captive breeding if it is a way to address many of the important questions regarding bat biology that we still do not have answers for. I am just against captive breeding as the mechanism to address WNS because I don’t think it will work for that (too large of a problem—too many species, too many individuals).”

"I'm preferential to the short term/seasonal w/hibernation strategy. This is the least invasive and disruptive strategy. It seems very feasible as well. Even if a treatment is never found, we could bring bats into a "clean" environment every year."

"I recommend the establishment of captive colonies with the intention of only holding bats for a single generation. The goal would be to hold them until we are able to figure out how to ensure resistance to WNS and then release them back into their native habitats. That being said, we need to collect enough bats so that if the decision is made at a later date to convert to a long-term captive propagation facility that we have appropriate genetic diversity and numbers to successfully manage the species in captivity. Captive facilities would need to be established using the best available information on how to successfully maintain insectivores in captivity."

"I think all the strategies have value and can all be applied and changed based on circumstances. But I think the definition of a 'pilot project' needs to be fleshed out. Bringing in large numbers of bats is probably ill-advised, but I kept hearing numbers creep up as strategies were discussed. Obviously, to protect genetic diversity and probably to elicit appropriate mating behaviors and maintain appropriate hibernating behavior, large numbers of bats will be needed. But pilots should be kept small and have the goal of developing, or confirming, species-specific husbandry practices, which can be done with very small numbers."

"I base this opinion on my expertise in establishing the first captive breeding colony of vespertilionid bats, at the Wellcome Institute of Comparative Physiology, Zoological Society of London, 1966–1971. In my care, the noctule bat, *Nyctalus noctula*, a large (20–25g) robust, tree-dwelling hibernator, bred repeatedly to fertile F1 generations, and the majority of individuals survived for the duration of the project. In contrast, none of the other five species (*Eptesicus serotinus, Plecotus auritus, Pipistrellus pipistrellus, Myotis daubentonii* and *M.nattereri*) that I maintained in captivity bred there, and with the exception of *Eptesicus serotinus*, survived for shorter periods. In the intervening decades, I have maintained several bat species in captivity for research purposes, but for short periods.

In North America, a large robust bat, *Eptesicus fuscus*, has bred successfully in captivity, but despite huge research efforts over the past fifty years, and the more recent growth in knowledge and expertise of rehabilitators, breeding has not been reported in any other species of hibernating vespertilionid bat.

There is therefore no precedent to indicate that the establishment of captive colonies of the small hibernating vespertilionids threatened with extinction by White Nose Syndrome (WNS) will result in captive breeding and lead to a successful reintroduction program. It was clear from our discussions in St. Louis zoo that a captive breeding and reintroduction program would, if established, be the most expensive of any yet established for mammal species. Although such expense could be justified by the threat of bat species extinctions resulting from WNS, it cannot be justified on the basis of the probability of success, which is unfortunately very low."

"Short term management. It is more quickly achievable, allows flexibility, is less expensive, has less impact on the wild population, and minimizes effects on animals taken from the wild."

2) What are the highest priority captive management research questions?

- Understanding *G. destructans* in bats (species affected, potential resistance by individuals, species, environmental conditions, behavior)
- Understanding *G. destructans* in the environment (persistence, variability)
- Reintroduction strategies – e.g., what is the survival rate of species similar to bats (e.g., group living, philopatric) that are released from captivity? What captive management or reintroduction strategies could increase the overall fitness of bats returning to the wild?

"Establishment of husbandry practices for insectivorous bats, achievement of reproduction in captivity."

"So far as pressing research needs are concerned, my view is that captive propagation should be possible, if the appropriate way of hibernating males and females is discovered, so that the sperm remain alive in the reproductive tract of females and the epididymes of males. The appropriate conditions are likely to be species-specific and reflect what happens in the wild where some species hibernate more deeply and continuously than others.

I just hit lucky with the European noctule which arouses often and flies during winter—so I fed them twice a week during winter rather than daily as in summer.

It's primarily a husbandry issue. My approach would be to feed them enough to get them into peak body condition in fall, hibernate them as deeply as possible with minimal disturbance, check their weight occasionally, preferably when they arouse spontaneously to drink, (even remotely by having a weighing platform in front of the water dispenser—I used aviarist's tube dispensers). Bird researchers use these platforms all the time to weigh what is being brought in for the chicks etc. If the downward weight trajectory for hibernating bats suggests that they will run out of fat before winter ends then food will have to be provided.

In spring, provide mating opportunities as in fall, because that's why males also store sperm, as an insurance policy, and pile in the food so they ovulate and get pregnant.

It is however important that anyone trying this knows the literature, and the relevant literature is 'kitchen sink' stuff which academics tend not to bother with—I left a couple of copies of each of my three papers on the table and one of the review."

"Using captive bats to determine if a technique can be developed (e.g., drug treatment, immunity, selection) to save bats in the wild, obviating the need for captive pops."

- "Will captive management detract from maintaining resistant populations in wild?
- What are the treatment options if bats are brought in from the wild?
- Species by species, is captive propagation biologically/technically feasible?"

"Hibernation, how captivity might impact bat behavior and their ability to survive in the wild."

"Develop effective treatment in clinical trials without sacrificing bats in the process."

- "What are the population triggers we would use to prompt a captive propagation option for a particular species? Should we manage captive colonies of more common species both for and as experimental research at this stage?
- Can we successfully keep hibernating insectivorous bat species alive and meet their basic nutritional and thermal environmental requirements in a captive setting? Which species do we know these two basic needs for? Should we be doing ecological research in the wild to fill this knowledge gap?
- What are the physiologic stress responses and clinical signs and symptoms of bats taken from a wild setting to a captive setting? How can we reduce the effects of stress? Do we know the natural stress state of different species in the wild? Should we be doing ecological research in the wild to fill this knowledge gap?
- Can we successfully provide a captive environment that permits natural social and mating behaviors, and successfully hibernate bats artificially or naturally, obtaining successful long-term breeding? Can we enable sperm storage and viability of sperm over winter? What do we know about each species needs in the wild? Should we be doing ecological research in the wild to fill this knowledge gap?
- How will we maintain biosecurity of the captive colonies?
- Can we reintegrate bats into the wild including successful release, roosting, hibernating and breeding?
- How will funding be secured for the long-term nature of captive propagation?

There are many more, and I know you have Tom Kunz's and Sue Barnard's comments/questions, so I have just listed ones that pop out."

"How can we move from a successful rehab program to a multi-institutional program?"

"***How does artificial hibernation (presence/absence, specific parameters, etc.) impact breeding success?*** This is critical to seasonally captive projects such as artificially hibernating of bats as a WNS management strategy. It does no good to artificially hibernate thousands of bats if you kill all their offspring as a result. It is likewise very important piece of information to have for captive propagation.

Can we/How to detect WNS in hibernating bats with a minimum of disturbance? This may have slightly different answers in the field and in captivity.

Are there species specific differences in susceptibility to WNS? This could be due to differences in the species behavior, genetics, or environmental factors. Critical to determine which species would need a response."

"Clearly, the highest priority is to find a way to prevent death of bats due to WNS and eliminate the need for captive management or other heroic measures. It will be important to determine whether the fungus responsible for WNS is the direct cause of death or whether it represents a secondary infection that invades opportunistically when populations are already weakened by another disease or environmental factor. Unfortunately, research on the cause and prevention of WNS takes time and many populations may be threatened before this goal can be accomplished.

If captive colonies of bats are to be maintained, an important area of research will be strategies to keep captive-held bats fit for re-release, and studies on the success rates of captive-held/captive-born bats when released to a natural environment.

I have no doubt that most or all species of temperate zone insectivorous bats can be held and bred successfully in captivity, but more research is needed into the most cost-effective ways to meet the needs of the highest priority threatened species and minimize loss of individuals when they are brought into captivity."

"What is the long-term effect (if any) on the nutrition of bats held in captivity for long periods of time (who knows how long WNS will remain in the environment)?

Prior to collecting individuals to bring into captivity, it is critical to have at least a baseline understanding of the partitioning of genetic variation within and among populations and normal levels of relatedness within colonies.

Is competition among males for females important in different species of bats?

Is mate choice important for females?

Is sperm competition and/or multiple copulations important for breeding?"

"It seems that there are a lot of questions concerning long term holding of insectivorous bats in larger numbers. The first question seems to be, can a holding facility provide the requirements needed for insectivorous bats to live healthy lives. Do some species require foods other than mealworms? Can a captive facility provide enough flight time to maintain natural muscle mass? Are there physiological requirements met by migration and fall swarming? Etc."

----

1. "Methodology for maintaining insectivores in captivity.
2. Developing resistance to WNS in bats.
3. Can bats be re-introduced into the wild after multiple generations?"

- "Targeted research to determine the proper methods to cryopreserve genetic material for bats and establish cell lines, and to determine gamete viability after cryopreservation.
- Facilitation of natural hibernation/torpor in captivity
- Investigate methods to incorporate more natural food items into the diet of captive bats
- Development of more natural captive facilities to reduce animal stress and encourage normal behavior
- WNS treatment and studies on the susceptibility of different species to WNS
- Reintegration of captive bats into the wild

- "Are there individuals (of all affected species) that survive WNS (resistant individuals)?
- Are there species (not yet currently affected) that are resistant to WNS?
- WNS treatments"

3) Is there anything else the U.S. Fish and Wildlife Service should know before making decisions regarding captive propagation?

- Potential stakeholders (rehab facilities, zoos, research facilities) should be surveyed as to willingness and ability (in terms of facilities, husbandry, staffing, finances) because these may limit the number of species or individuals that can be successfully managed in captivity.
- Clarification and communication of bat husbandry & housing requirements and investigation of existing facilities (structures created for other species or non-animals purposes – e.g., echidna exhibits, shipping containers, underground storage bunkers, etc.) could greatly expedite implementation of captive management plans by reducing costs and preparation time.
- I think a major factor in the success (or lack thereof) of many zoo animal programs is a dedicated program leader with strong organizational, communication, and coordination skills. The number of institutions involved may not matter as much as the level of cooperation and dedication of those that are involved and the strength of the program leader coordinating them.

"Species-specific risks"

"The VBEB project should **not** be given consideration in making future decisions on captive assurance colonies, as this project is considered an outlier. The methods used to care for the VBEBs were not traditional and would have resulted in the same fatalities for any other species of insectivorous bats receiving the same treatment.

As Steve Wing, head of the Bat TAG, stated during the meeting, the AZA has not been successful to date in keeping insectivorous bats in captivity. It is my feeling that assurance colonies should not be housed at facilities that house other animals. However, if zoos must be utilized, a dedicated staff should be hired to care for the bats, and the bats should be housed in a building completely separate from other animals. Assurance colonies should never be placed on display for the public, but outreach programs utilizing bats with little propensity for stress could be considered."

"Should USFWS opt for some form of captive propagation strategy, I do wish to indicate that I would be happy to advise/assist, and/or for Lubee to act as a breeding center with a WNS research–oriented goal. We have a long standing history of success with fruit bat species, dedicated staff used to caring for bats, access to specialist microbat veterinary care (Dr Deborah Cottrell, plus UF vet school.), and have worked closely here at our bat facility with key researchers now involved in WNS research (Prof. Tom Kunz, Dr. DeeAnn Reeder).

I have emailed a cost analysis of how much it costs to maintain fruit bats in captivity, I suspect microbats would be comparable given the increased cost of meal worms, increased costs of hibernating animals in cool rooms balanced against decreased cost of having more bats in fewer enclosures. Given the numbers of bats we were talking about to ensure maintenance of genetic diversity, this would be a high financial cost that would require long-term commitment.

If a zoo network was considered, zoos would seek these funds from USFWS and would not likely have enough funds to continue in the likely event of stoppage of USFWS funds after a specified length of time. Given the environment is not yet (? will ever?) be safe from the initial threat of WNS, and we would not be able to return bats to the wild for some time, this would again mean a high financial cost that would require long-term commitment. In the past year I have received calls from at least 3 zoos closing down their night exhibits and trying to get rid of their bats. I noted that only one frog reintroduction was mentioned, all other frogs are in captivity and the fungus is still in the environment, currently excluding reintroductions with no end point or "exit strategy" in sight."

“You folks have a difficult job ahead of you. We can help, even if we don’t pursue a captive management strategy!!”

“Few institutions could afford to do such projects without significant funding.”

“Politically, I think you are damned if you do and damned if you don’t. Legally, I think you are covered by continuing efforts in the field (though there may be an argument there—I am no lawyer). While there may be absolutely nothing anyone can do to save our native bat species in the face of a fungus that almost seems designed to be a bat killer, I believe it is a moral and ethical imperative to do everything and anything we can. Insectivorous bats do not have a long history in captive breeding programs, but I believe it can be done and it can be done well.”

“At the meeting, I made the following notes:

- Captive holding and breeding should be seriously considered, but *only* if/when there is a clear threat to the bat population in question and the possibility that inaction could result in disaster.

- Captive populations, especially those that are rare and/or endangered, should only be taken in by persons who have proven experience maintaining the same or similar species. A threatened species should under no circumstances be used as a test population for husbandry methods by inexperienced caretakers.

- Facilities need to be adequate to meet bats’ needs, and they need to be secure. However, they probably do not need to be extremely high-tech. Facilities should take advantage of natural environmental conditions to the extent possible rather than trying to micro-manage environment through the use of expensive cold rooms, artificial lighting, etc. It would be useful to talk to rehabilitators and researchers who currently maintain bat colonies to get an idea of what is adequate. I doubt that any of these people have extremely expensive setups.

- The FWS should take full advantage of facilities that are already successfully housing bats (e.g., rehabilitators, universities). Many of these facilities could probably take in threatened colonies if provided with some sort of guaranteed financial support for the extended time that the bats might need to be held.

- If the captive management strategy were adopted for some species, the best model would probably be distributed housing at small local facilities with some services and infrastructure provided by a centralized organization. Possible centralized functions could include mealworm growing and distribution, arranging for rabies immunizations of personnel through government agencies, arranging for training classes to instruct caretakers, etc.”

“I would just hope that if the FWS decided to go forward with captive breeding, in the process of choosing species, specialists that work with those species as well as geneticists, reproductive biologists, etc. are sought for their input in the design of such a program.”

“I didn’t feel we were able to go deep enough when considering the feasibility of the captive holding strategies.”

"The following directly affect the short term strategies discussed:
- Developing effective treatment in clinical trials
- Determining if bats from affected populations can remain WNS-free in 'clean' hibernacula
- Determining if summer bats harbor infective elements of WNS

And, again, determining post-release survivability. There is no point bringing animals into captivity of doing so extinguishes their ability to survive in the wild. There is a sample available right now to start those studies, albeit in non-listed species. However, if we can show that red bats, big brown bats, Mexican freetails, tri-colored bats, and even *Myotis* species survive post-rehab, it is not such a great leap to suggest that listed species can as well."

"While the concept of hibernating bats in artificial hibernacula sounds very attractive, it is not as simple as shutting bats in an appropriately climate-controlled box and walking away. Many, many bats are lost during hibernation studies and during artificial hibernation for other reasons. The technology to effectively remotely monitor bats in hibernation needs a great deal of attention before any such projects are undertaken."

"We need to estimate, as best we can, the risks associated with different decisions facing us. All choices we have before us, from "no action" to full scale, long-term breeding programs for all species, have pros and cons associated with them."

4) How do you think the workshop went? Do you have any suggestions on how we can improve future workshops?

- I think the workshop was very effective for bringing together people from several important areas of expertise related to this issue. The positive communication and networking that occurred as a result of formal and informal discussions at the workshop should prove valuable for improving the status of bats and building future relationships.
- I think some time was lost by the sometimes too structured, sometimes too open-ended working group topics. Perhaps other methods of group decision making could expedite the process? – for example:
    - Start with the state of current knowledge already written down (by USFWS or meeting participants submitting individual responses in writing ahead of time) and then have working groups discuss and focus these thoughts
    - Structured decision making?

"The workshop was very interesting and productive; good opportunity for information-sharing and clearing the air. Regarding future workshops, it might help to have a morning recap of the main ideas (for instance, a brief summary of the mgmt options) and concerns generated the day before—this could be done in a half-hour or so by the workshop facilitator."

"Went well. Appreciate the opportunity to attend this workshop."

"The workshop was great! I enjoyed meeting all of the participants. No suggestions for improvement. Thank you for what you do."

"Good overall. I have attended workshops that didn't go as well!!

But the big question you are clearly trying to answer is the question you asked as # 1) Which strategy, including the "no captive management" alternative, is your recommendation and why? Yet you did not set up the workshop to give us insight into being able to answer that question any better than we can already answer it through our own opinions. We were charged only with the task of assessing different options for captive propagation strategies. I do think it would have been appropriate to indicate, just thru a few slides and for our information, exactly what is being considered under the "no captive management option ". Perhaps if it's actions we think will not help the situation much, we would be more swayed to suggest captive propagation, or perhaps if it's a suite of actions that we feel may do a better job of helping, we would be more swayed to avoid a costly captive propagation option."

"I felt the workshop went very well…a nice line-up of speakers and having Kathy really helped."

"I have no serious complaints; beyond that I completely exhausted my "idea creator" muscle and my regular job keeps expecting me to have ideas. Sigh. A follow up email reminding non-USFWS folks how to request reimbursement for travel would be nice. Some kind of mid-morning caloric option might have also been good—maybe put out the pretzels or snack mix early, or some nuts. Not a big deal, but there were lots of stomachs growling by 11-ish."

"I thought the workshop went as well as could be expected given that it was a large and diverse group talking about issues that cannot easily be resolved. Future workshops could benefit from more small-group discussions such as those that occurred toward the end.

I would like to add a couple of comments regarding resources and expertise that I could contribute to the efforts to fight WNS:

- I will be sending you the paper on husbandry methods for a captive breeding colony of *Eptesicus* that my technician and I are currently writing up. I'll get that to you as soon as possible, hopefully by the end of August.

- I could potentially provide *Eptesicus fuscus* to those who are setting up captive colonies and need a surrogate species to test the adequacy of their facilities. Although more adaptable than some species, *E. fuscus* is a typical temperate-zone insectivorous bat with typical needs, so just about any husbandry program would be based on the *Eptesicus* model with species-specific variations.

- I could potentially provide *Eptesicus* to researchers who need animals for research on causes, treatment, and prevention of WNS. We know that *Eptesicus* is susceptible, so it would be the ideal model species for this purpose. Captive-born bats would be free of other significant diseases found in wild populations (e.g., rabies) that might impact results.

- My lab and I could provide hands-on training to individuals who will be setting up captive bat colonies or working as caretakers in these facilities.

I enjoyed the meeting, and hope that it will result in some useful outcomes."

"Overall, this was excellent. I liked the diversity of individuals that you brought together. Having the "rehabbers" present provided me with important insight. Additionally, there was good diversity of other bat biologists that included ecology, reproduction, and genetics. (Of course having the FWS personnel was also important.) I really have no suggestions for improving the workshop."

"I thought the workshop went very well. I was impressed by Cathy's facilitation skills and the workshop was well organized."

"Most excellent!!!!!!! Rob did a great job."

"I think the workshop went very well and was effectively run. I was very happy with the wide range of expertise represented. I'm sorry the phone-in participants couldn't contribute more. I've been on the phone-in end and find it extremely difficult to follow the conversation, so web-based participation may be something to look into. Defense uses the technology a lot for meetings.

I would like to see some more breaks to give people a chance to rest their brains and get some exercise! And if the meeting is going to be held at a zoo or similar, the meeting hours should allow time for exploration. We might as well have met in the hotel, with the exception of the hellbenders and burying beetles, which were fantastic, but could have been done as an after-hours field trip.

That said, thank you for the opportunity to participate. I think voices were heard that needed to be heard. There is more expertise available than has previously been recognized, and learning about that was very valuable.

Finally, if the so-called 'tri-colored bat' ever gets listed, can you do something about changing the name back to the wonderful, melodic 'pipistrelle'?"

"Very well! Great mix of expertise, good discussions, logical progression of the thought process."

"I thought it went well. I thought it was going to involve consolidating all known husbandry info and discussing organization of the *ex situ* conservation response/partners (e.g., Bat Ark), but perhaps this will come next?"

"Very well. I think if we could do it again we would extend it by a day to allow more discussion. Workshop planning/logistics could also have been simplified by having the meeting space in our hotel."

"I thought the workshop was productive. Having the (captive management) questionnaire results summarized and available to participants prior to the workshop would have been valuable."

Pre-Workshop Comments (submitted by two invitees unable to attend and participate in the workshop discussions and process)

To: Robert Tawes,
From: Sue Barnard, batcons@mindspring.com

July 14, 2010 F&WS meeting on WNS.

In addition to the recent (2009), failed attempt to captive breed the Virginia big-eared bat by the National Zoo's Conservation and Research Center, other failures should be noted:

1971. Six of 26 female Mexican free-tailed bats conceived in captivity. Only two gave birth; two died of dystocia, and two aborted. Neither surviving pup was released to the wild. Rate of success: 0

2005-2006. Pregnant New Zealand short-tailed bats gave birth to 25 young. Twelve young survived and were released. Of those, all developed life-threatening ear dermatitis in the wild and had to be recaptured. Rate of success: 0.

Other than captive breeding for short-term laboratory research, or offspring produced in captivity accidentally, no long-term captive breeding of insectivorous bats has been successful, and for good reasons.

- The fact that captivity cannot duplicate the wild, changes in a bat's genetic make-up occurs rapidly.
- Bats loose immunity to pathogens in the wild.
- Over time, bats loose predator-avoidance behavior.
- If not allowed to fly and capture natural insects, they lose the ability to hunt in the wild, knowledge of appropriate food items, and have loss of skeletal and muscle mass.
- Because no two bat species are alike (i.e., food habits, flight patterns, echolocation, roosting habits, thermal and humidity requirements, tolerance for stress and so forth), gaining information about the captive breeding of one species does not translate to successful captive breeding and maintenance of another species, and practicing on the endangered target species is unethical.

Questions:

- With bats that produce on the average of one pup annually, and that do not live in large groups, how will enough numbers be produced to maintain genetic diversity?
- How will housing be designed to ensure the species in question maintains its ability to hunt its natural food, and what is the species natural food?
- How will housing be designed to ensure the species natural social structure, not only of the species, but of the particular individuals being taken captive?

- How will roosts be designed to mimic the natural roosting behavior of the species?
- How will the bats be able to enter and maintain natural hibernation?
- How will captive stress, injury, and disease be prevented?
- How will the species natural thermal environment be managed?
- Why will money be wasted on a project that has failed so many times in the past, instead of using those funds to prevent further contamination of the species' natural habitats?

If there is a lack of knowledge to even one issue presented here, then the concept of captive breeding to save a species is irresponsible and should be disregarded.

BOSTON UNIVERSITY
Center for Ecology and Conservation Biology

Dr. Thomas H. Kunz, Director

TO: Participants of the St. Louis WNS Meeting on Captive Breeding

FROM: Thomas H. Kunz

RE: Captive Breeding of Insectivorous Bats

DATE: 7 July 2010

With regrets, I am unable to attend the USFWS Meeting in St. Louis on captive breeding. Below, I have expressed my concerns, raised some questions, and made comments that I hope you will consider in your discussions regarding captive maintenance and breeding of insectivorous bat species as they relate to those affected or may be affected by WNS.
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Captive maintenance for short-term experiments has been successful and has benefited the scientific community, but this approach is quite different than maintaining, managing, and breeding bats in captivity for subsequent release. I have many reservations and concerns about the practical and philosophical rational for breeding insectivorous bats in captivity.

First, I would like to know the rationale and ultimate goal for breeding of captive insectivorous bats. Even if insectivorous bats could be bred in captivity, how can those who would do so insure the scientific community and public (government funding agencies such as USFWS and assorted private donors) that the bats could ever be successfully released? If the latter goal is in response to the first question, I must ask if there is enough known about the physiology, endocrinology, and genetic diversity of any bat species to establish a successfully breeding program? Based on studying bats for over 40 years, and reviewing the published literature, I am not convinced we do! If bats are not being bred to be released, then why should they be bred in captivity?

It is important to understand that each insectivorous species has its own unique diet, roosting habits, thermal neutral zone, flight abilities, ability to tolerate captive situations (tolerance for being handled), etc. What species would one choose to house and breed in captivity, and why? Many insectivorous bat species show geographic variation in many traits--some to the point of having differentiated both genetically and morphologically, and some only genetically. Given that this variation exists, what populations or subpopulations would be selected for captive breeding? How many individuals should be maintained for such a study? What knowledge is needed to make these determinations? Is this knowledge available for any insectivorous bats species in North America?

How much would it cost to: 1) establish and maintain genetically diverse populations of captive bats, 2) design and construct appropriate facilities, 3) maintain healthy bats, 4) provision them with appropriate diets (quality and quantity), 5) train and retain qualified keepers, 6) pay for veterinary services, etc. What would be the benefits of this kind of investment versus investment in research and management of natural populations to better understand the causes and consequences of WNS, or other diseases that may
affect insectivorous bats?

Captive management requires more than feeding bats to ensure that they maintain stable body mass. As I stated at the Pittsburgh meeting, body mass is not a reliable index of a healthy bats (for any species) held in captivity. Moreover, hibernating bats should not be brought into captivity, held at room temperature (75 to 75 F) and expected to survive and breed, because their hormone levels, gut morphology, vascular system, bone density undergo major changes in preparation for or as a consequence of hibernation. Insectivorous bats held in captive situations are usually, if not always, precluded from engaging in their normal, free-ranging activities (e.g. opportunities to form dense clusters, fly for 4-8 hours per night, with access to highly varied diet) during warm periods of the year. Under these conditions, they would most certainly loose muscle mass and the ability to forage on the wing on from the ground (depending upon the species). Is shifting bats to a day: light cycle in captivity, to accommodate the normal work schedule of their designated caretakers, a successful protocol for breeding bats?

Understanding the role of day length for successful reproduction is essential, just as understanding that the endocrine system, digestive system, cardiovascular systems, skeletal and neuromuscular systems of insectivorous bats held in captivity during the active season and in preparation for and during hibernation go through complex, genetically adapted (modified by the environment) physiological (enzymatic and thermoregulatory changes), and morphological changes (e.g. deposition and mobilization of body fat, including brown bat in hibernating species) that when modified under captive conditions are not likely survive to survive or reproduce. Captive insectivorous bats may learn to feed on insects from dishes (typically mealworms, but sometimes crickets and other assorted mix of insects) fortified with vitamins and mineral nutrients, but few if any are able to capture bats on the wing for a sufficient amount of time to maintain their health. At the very minimum, the consequence for their flight muscles will lead to atrophy. Moreover, temperate zone insectivorous bat species held in captivity at temperatures below thermoneutrality will either enter daily torpor or expend much of their ingested energy on maintaining a euthermic body temperature, with less energy available for reproduction. Humidity is also a \critical issue, with different species having varied levels of tolerance or requirements for high, low, and moderate levels. Dehydration is one of the major causes of mortality in bats held under captive conditions.

Hibernating bats should not be brought into captivity and maintained for prolonged periods at room temperature (or higher) during the winter. Physiological, morphological and behavioral changes occur during pre-hibernation fattening and during hibernation, which can compromise their ability to digest and assimilate food, maintain normal bone density, retain sperm in the uterus of females, and to maintain normal body condition, etc.

How will diseases and parasites be managed? What procedures will be used to insure that North American insectivorous bats brought into captivity are free of rabies or some other viral disease that could be transmitted to other members in the colony? All bats could be vaccinated against rabies, but there is no foolproof method to determine whether they are rabies free.

These are just a few questions and comments that I wish to share with those who are able to attend this meeting. Feel free to share my thoughts with others, and contact me if you have any questions.

Sincerely yours,

T z
Professor and Director

Insectivorous Bat Captive Population Feasibility Workshop

Saint Louis, Missouri, US
14 – 16 July 2010

Final Report

Lubee Bat Conservancy
Saving bats. Conserving ecosystems

APPENDIX V

Budget Information from the Lubee Bat Conservancy

Budget Information, Lubee Bat Conservancy

Per Diem Cost Evaluation for Fruit Bat Propagation
Lubee Bat Conservancy.
Based on Operating Budget for 2009 (Sept 08-Aug 09)

Facility Operating (electric, insurance, buildings maintenance, equipment) $122,796.54
Admin/Program Support (taxes, office expenses, accounting services) $25,575.00
Animal Care Direct expenses (food, supplies, vet expenses) $96,756.83
Personnel (Animal Care/Maintenance x 8.5, Admin x 1) $365,255.20

Sub Total: $610,383.57

Excluded expenses (Staff Training/Meetings $10,518.18, Membership & Fundraising $8,628.01, Capital Costs/Depreciation $56,692.0, Conservation, Research, Education Program Activities $60,044.75, Contract Labor/Book Keeping/Accounting $61,048.81).

Cynopterus brachyotis 50g
Rousettus aegyptiacus 150g
Pteropus rodricensis 300g
Pteropus hypomelanus 650g
Pteropus vampyrus 1000g
Artibeus jamaicensis 50g.
Pteropus conspicillatus 800g
Epomophorus wahlbergi 120g
Eidolon helvum 200g
Pteropus pumilus 250g
Pteropus giganteus 750g
Carollia perspicillata 20g
Pteropus poliocephalus 750g

Total Annual Animal & Facility Operations Expenditure $610,384
Total No. Animals = 220 Av. $2,775/bat/year
Av. $7.60/bat/day
[205 animals in 13 Lg pens – 132,500g , 10 in 1 Med pens – 1500g, 5 in 2 Sml pens – 250g]
Total Gross Weight = 134,250 g $4.55 per gm

Species	Weight	# Animals	Total Weight	Total Cost/year ($)	Individual Cost/ year ($)	Individual cost/day ($)
Vampyrus	1000g	57	57,000g	270180	4740	12.99
Conspicillatus	800g	1	800g	3640	3640	9.97
Poliocephalus	750g	21	15750g	71662.5	3412.5	9.34
Giganteus	750g	5	3750g	17062.5	3412.5	9.35
Hypomelanus	650g	63	40950g	186322.5	2957.5	8.10
Rodricensis	300g	11	3300g	15015	1365	3.74
Eidolon	200g	16	3200g	14560	910	2.49
Pumilus	250g	31	7750g	35262.5	1137.5	3.11
Rousettus	150g	10	1500g	6825	682.5	1.87
Cynopterus	50g	3	150g	682.5	227.5	0.62
Artibeus	50g	2	100g	455	227.5	0.62
Large Bat (>500g)	1000g	147	147000g	668850	4550	12.46
Med bat (100-500g)	400g	68	27200g	123760	1820	4.99
Small bat (<100g)	100g	5	500g	2275	455	1.25

Insectivorous Bat Captive Population Feasibility Workshop

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APPENDIX VI

Cryopreservation Information and Sample Collection Protocol

Center for Conservation and Research of Endangered Wildlife
Saving Species with Science®

Cryopreservation to Preserve Genetic Diversity of Insectivorous Bats

1) Establish/Cryopreserve Cell Lines from Insectivorous Bats:

Cell lines can serve as a repository of genetic material from endangered/extinct species. In addition, cell culture would be useful for studying the mechanics of white nose syndrome (WNS), how it is transmitted between individuals and how it may be treated without harming living animals. Therefore, it is important to preserve cellular material from those bat species facing extinction from WNS. Currently, tissue sampling for DNA analysis is achieved through a small wing punch using a biopsy punch. Cell lines could be established from such tissue. Therefore, incorporating cell line production into current sampling protocols would be relatively easy.

Recommendation: Get experts on board to establish and cryopreserve cell lines from highly endangered insectivorous bat species.
Contact: Marlys Houk at San Diego Zoo; mhouk@sandiegozoo.org

2) Research into Cryopreservation of Insectivorous Bat Gametes & Establishing a Genome Resource Bank for Bats:

Genome resource banks (GRB) are organized repositories of cryopreserved spermatozoa, oocytes (eggs) or embryos. Establishing a GRB specifically for insectivorous bats would insure that existing genetic diversity is preserved and provide a means to infuse new genes into future captive/wild populations. It could serve as a valuable tool for bat populations that undergo a bottleneck due to WNS.

Spermatozoa:
Sperm cells can be obtained from living individuals (electroejaculation (eej)/manual massage) and post-mortem (gamete rescue).

Preliminary research on semen collection and cryopreservation in fruit bats indicate *Pteropus* sperm are sensitive to cooling and cryopreservation (de Jong et al 2005, Melville et al 2008). However, similar studies have not yet been conducted in insectivorous bat species. Unfortunately, taxonomically related species can experience a full spectrum of sperm sensitivities to cryopreservation. A model insectivorous bat species (little brown bat) could be used to develop sperm cryopreservation protocols.

Potential Impact of Gd on Spermatozoa Collected via EEJ or Manual Massage:

Evidence shows *Geomyces destructans* (*Gd*) invades the skin and mucosal surfaces. However, we do not know if it has an affinity for reproductive tissue and if it is present in seminal fluid. Some microorganisms can survive cryostorage. Research would need to address whether 1) *Gd* positive male bats have *Gd* present in seminal fluid and if *Gd* is presen,t 2) can *Gd* withstand cryopreservation. *Gd* is a "cold loving" fungus, but cryostorage is generally -396°F.

<u>*Gamete Rescue:*</u>
Due to the blood-testis barrier, spermatozoa rescued directly from the epididymis of the testicle post-mortem would provide "clean" sperm cells (ie, no seminal fluid involved). Research in *Emallonurid* bats (insectivorous species native to tropics) indicates that despite fluctuations in testosterone, spermatozoa remain stored in epididymides throughout the year (Singh & Krishna 2000). Therefore, the potential for rescuing spermatozoa from insectivorous bats at any time of year appears feasible.

<u>*Oocytes (eggs):*</u>
Female bats have been shown to develop large antral follicles that are maintained for up to 6 months prior to ovulation (Srivastava & Krishna 2008, Voight & Schwarzenberger 2008). This phenomenon points to the high probability of rescuing oocytes post mortem. Protocols would need to be developed for oocyte maturation, fertilization and embryo culture.

Recommendation: Get experts on board with expertise for cryopreserving gametes from highly endangered species.

References:
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Insectivorous Bat Sperm Rescue Protocol

In an effort to preserve the genetic diversity currently represented in the bat population, sperm rescue should be attempted on male bats that die unexpectedly or require euthanasia. There are scientists available who are willing to attempt to rescue, revive and cryopreserve sperm from bats post-mortem. These samples will be banked for future study and use, and could be used to augment wild populations in the future. However, there are no established protocols for sperm cryopreservation in these species, so initially the process will be considered a research effort. Below is a brief protocol on what should be done to improve the chances of a successful sperm rescue attempt. If any advance notice is possible, it would be most appreciated and would more likely yield a positive result.

Processing and shipping of testicles

1) As soon as possible after death the testicles should be removed from the bat leaving intact and attached as much of the vas deferens as possible.
2) The end of the vas deferens should be tied off to avoid sperm leakage during transport.
3) Place testicles in zip-lock baggies with gauze soaked in saline or PBS to keep tissue moist.
4) Baggies with testicles should be wrapped in a towel or in multiple layers of paper towels so they are protected from direct contact with the ice pack.
5) Wrapped testicles should be placed in a polystyrene container with ice packs (one or two will be sufficient) making sure the tissue is not directly in contact with an ice pack.
6) In separate small zip-lock bag please include a small, recent fecal sample (for testosterone analysis).
7) Depending on location, package should be shipped as follows for next day delivery:

For bats in U.S.A:
Name of Scientist
Institution
Address
City, State Zip Code
Ph: XXX/ XXX-XXXX
Please call and email with package tracking number. (Call ahead if you want a shipping account number to charge.)
1) ___________ at XXX/ XXX-XXXX or XXX/ XXX-XXXX (cell) and email address of person 1
Or if you can't reach Scientist 1)
2) _____________ at XXX/ XXX-XXXX and email address of person 2
Or if you can't reach Scientist 1) or 2)
3) _____________ at XXX/XXX-XXXX and email address of person 3

Please call if you have any questions regarding the protocol.