Analysis of Alternative Captive Bat Management Strategies in Response to White-nose Syndrome

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PREFACE

This report describes the process and presents the results of a structured decision making effort initiated by the U.S. Fish and Wildlife Service (USFWS) in November 2010 to address the potential efficacy of captive bat management as one possible management response to white-nose syndrome (WNS). This initiative was undertaken as a two-step process for seven bat species of concern. First, for each species, alternative captive management strategies were compared against identified conservation objectives. Preferred captive management strategies were then compared to a "no captive management" alternative. Expert elicitation was used to conduct the analyses, which concluded in 2012. Following the elicitations, a team of USFWS biologists reviewed results, made recommendations, and prepared this report. Given the protracted time frame for finalizing this report, we note that although the biological background has been updated to the extent possible to reflect information current as of 2015, the results and recommendations emanate from the 2010-2012 analyses.

Although the decision framework and analysis results have been presented to USFWS decision makers, this report should be considered a white paper rather than a decision document. Further, the analyses were conducted with a 5-year time frame in mind, and reconsideration of the status of the bats with regard to WNS or future potential management options could result in modification of the decision framework that was developed for the initiative and/or updating of the analysis for one or more of the seven species. Updating is thus an integral aspect of the decision framework, which should remain relevant as long as questions regarding captive management as a possible response to the impacts of WNS on insectivorous bats remain.

INTRODUCTION

WNS, a disease affecting insectivorous, cave-dwelling bats, was first documented in 2006 in caves west of Albany, New York. Since its discovery, WNS has spread rapidly and killed millions of bats. By May 2015, WNS had been confirmed in well over 200 caves and mines in 26 states and 5 Canadian provinces (mapped on: *http://www.whitenosesyndrome.org/about/where-is-it-now*). Given its severity and rapid spread, WNS is one of the greatest threats currently facing North American wildlife.

WNS is caused by the cold-loving fungus *Pseudogymnoascus destructans* (Pd; formerly *Geomyces destructans;* Minnis and Lindner 2013), and is named for the white fungal growth that often occurs on the muzzle of affected bats (Gargas et al. 2009, Lorch et al. 2011) as well as on the exposed skin of the wings, tail membrane, and ears. This fungus has been documented on cave-dwelling bats in Europe, where it may have originated (Martínková et al. 2010, Puechmaille et al. 2010, Wibbelt et al. 2010); more recently the definitive infection of the disease has also been identified in 11 European bat species sampled in the Czech Republic (Pikula et al. 2012, Zukal et al. 2014). However, there have been no reports of mortality associated with these observations in Europe. In North America, Pd invades the tissues of bats during hibernation, possibly causing dehydration, irritation, and frequent arousal, most likely interrupting normal thermoregulatory processes (Lorch *et al.* 2011, Reeder *et al.* 2012, Warnecke *et al.* 2012). Bats affected by the fungus exhibit aberrant behavior such as arousing from torpor more frequently and flying out of caves and mines during the daytime and during winter conditions. While the mechanism(s) leading to mortality have not yet been confirmed, current hypotheses suggest that infected bats die mainly from starvation and/or the effects of dehydration (Cryan et al. 2010, Warnecke et al. 2012), but exposure and predation are also well-documented proximate causes of mortality. Mortality rates have been observed to vary by species and site, but have been as high as 100 percent at some hibernacula.

WNS has been recorded in seven North American bat species known to hibernate in caves and mines: the little brown bat (*Myotis lucifugus*), eastern small-footed bat (*M. leibii*), northern long-eared bat (*M. septentrionalis*), Indiana bat (*M. sodalis*), gray bat (*M. grisescens*), tricolored bat (*Perimyotis subflavus*), and big brown bat (*Eptesicus fuscus*). Presence of Pd, with no other signs of WNS, has been detected on five additional species: the Virginia big-eared bat (*Corynorhinus townsendii virginianus*), southeastern bat (*M. austroriparius*), silver-haired bat (*Lasionycteris noctivagans*), and, most recently, the Rafinesque's big-eared bat (*C. rafinesquii*) and eastern red bat (*Lasiurus borealis*) (Bernard et al. 2015). More information on Pd and WNS can be accessed at: *http://whitenosesyndrome.org*.

Captive Management and WNS

In general, captive population management can range from temporary holding of animals to long-term captive propagation efforts and has, in certain circumstances, been useful in the conservation and management of imperiled wildlife (Snyder et al. 1996, Griffiths and Pavajeau 2008, Hedrick and Fredrickson 2008). Guidelines have been established for the appropriate use of *ex situ* conservation strategies (IUCN 2002), and USFWS actions that involve captive propagation must follow the joint /USFWS-National Marine Fisheries Service (NMFS) policy on controlled propagation (USFWS and NMFS 2000).

The possible use of captive management strategies for insectivorous bats in response to WNS has generated much discussion since the effects of this devastating disease have become known. To investigate the potential role of *ex situ* captive bat management (CBM) as a conservation tool to address the substantial threats posed by WNS, the USFWS formed an internal *ad hoc* team, consisting of staff from four regions in 2010. Formation of this CBM team followed attempts in 2009-2010 to hold endangered Virginia big-eared bats in captivity (USFWS 2009) to explore the feasibility of captive population establishment. The primary goal of the CBM team was to ensure that all conservation options available to address the emerging WNS threat were adequately examined. This charge also responds to Action 3.3 in the *National Plan for Assisting States, Federal Agencies, and Tribes in Managing White-Nose Syndrome in Bats* (FWS 2011a), which identifies the need to determine the "feasibility and role for captive management for (bats) of conservation concern." The CBM team adopted a structured decision making (SDM) approach to evaluate the available options and develop species-specific recommendations.

In 2010, the USFWS, through a cooperative agreement with Bat Conservation International, conducted surveys of bat rehabilitators, zoo staff, and researchers, and found that numerous individuals and organizations, both domestic and international, have held insectivorous bats in captivity, with varying degrees of success (Bayless 2010). With regard to propagation, however, questionnaire responses suggested there are few examples of successful reproduction in captivity (Bayless 2010).

The USFWS also convened an expert workshop in St. Louis, Missouri, in July 2010, in order to obtain additional information about *ex situ* bat populations, to identify available/potential captive management strategies, and to determine which of these strategies would be most feasible in the near- to mid-term. During the July workshop, 11 captive management alternatives, including a "no action" alternative, were identified as potentially feasible. Using this as a foundation, the CBM team then enlisted the assistance of additional bat, genetics, and captive management experts (Appendix I) to help with a detailed decision analysis to determine which, if any, of these strategies warranted further management consideration.

The results of the expert questionnaire and workshop have been reported previously (Bayless 2010, Traylor-Holzer et al. 2010). This report therefore focuses on the results of the SDM process that was undertaken to evaluate the potential efficacy of the eleven captive management alternatives for seven bat species, as discussed below.

Species Considered

The CBM team focused on seven insectivorous bats that were either known to be affected by WNS or had the potential to be affected by WNS in the near future. These species include the federally endangered gray, Indiana, Ozark big-eared (*C. t. ingens),* and Virginia big-eared bats, as well as the eastern small-footed, northern long-eared (not federally-listed at the time), and little brown bats. The endangered bats were selected as focus species because they fall directly under the USFWS's Endangered Species Act (ESA) responsibilities. The eastern small-footed and northern long-eared bats were chosen because they were being evaluated for threatened or endangered species status as a result of a January 2010 listing petition (Center for Biological Diversity 2010). Both species received "substantial" 90-day petition findings (USFWS 2011b), and the northern long-eared bat has since been listed as threatened (80 FR 17973, 4/2/14). The little brown bat was chosen because it is the subject of a USFWS status review prompted in response to threats and documented mortality from WNS. Each species was assigned to a CBM team member who was charged with leading the species-specific SDM analysis. Current information on each of the seven species is provided below.

<u>Gray bat</u> – This federally endangered species is recorded from 12 states in the midwestern and southern U.S. and inhabits caves year-round. Prior to the arrival of WNS, the species was well on the way to recovery, with all but one of the top-priority hibernacula protected and an increase in numbers from an estimated 1.6 million at the time of listing to about 3.4 million in 2004 (*http://ecos.fws.gov/docs/five_year_review/doc2625.pdf*). Pd was first detected in this species in Missouri in May 2010, and WNS was subsequently confirmed through histopathology in gray bats collected from two Tennessee caves. To date, however, no mortality from WNS has been documented, and the overall impact of WNS on the species is yet to be determined. Nonetheless, because an estimated 95 percent of the rangewide population occurs in only nine caves, and because the species hibernates in large colonies with as many as 1 million bats in close proximity to one another (USFWS 2012), there is a likelihood that WNS could spread rapidly through these populations and have a devastating effect on the species.

Indiana bat – This species is federally endangered and has state protection in 18 of the 20 states where it occurs. The 2013 population estimate for the species was 534,000, about half the number documented at the time of listing in 1967. Almost half of all Indiana bats hibernate in caves in Indiana, with other large populations in Missouri, Kentucky, and Illinois. WNS effects on Indiana bats are best known from New York populations, where mortality since the onset of WNS is estimated at 72 percent of the State's Indiana bat population (Turner et al. 2011), a loss of almost 40,000 Indiana bats. WNS was first detected in Indiana and Kentucky during the winter of 2010-2011, at a site in Missouri the following year, and multiple sites were confirmed in Illinois in 2013. Thus, WNS is now confirmed in all states with the largest hibernating populations of Indiana bats. Significant mortality has been detected in these states and is expected to continue. Modeling by Thogmartin et al. (2013) suggests that WNS is capable of bringing about severe numerical reduction in population size and local and regional extirpation of the Indiana bat.

Ozark big-eared bat – This subspecies is federally endangered due to its small population size, reduced and limited distribution, and vulnerability to human disturbance. The entire extant population is estimated at about 1,800 individuals, with a current range that includes northeastern Oklahoma and northwestern and north-central Arkansas. The confirmation of WNS in two northern long-eared bats from a cave in Marion County, Arkansas, sampled in January 2014, was the first confirmed record of the disease in a cave known to also be used by Ozark big-eared bats. In addition, evidence of WNS and Pd was detected in multiple sites within the range of the Ozark big-eared bat in Arkansas between 2012 and 2015. Evidence of Pd also detected in northeastern Oklahoma in 2015.

Virginia big-eared bat – This federally endangered subspecies is known from a small number of caves in eastern Kentucky, West Virginia, western North Carolina, and Virginia. The population is estimated at about 15,000 bats, with only 13 caves documented to have more than 100 animals. The Virginia big-eared bat was the subject of captive holding trials in 2009 and 2010 (USFWS 2009). Although Pd and WNS have been documented from other bat species in the same caves, and Pd has been detected on Virginia big-eared bats, WNS has not been documented in this subspecies. In fact, recent counts of Virginia big-eared bats indicate that the population may be increasing (C. Stihler, West Virginia Department of Natural Resources, pers. comm.).

Eastern small-footed bat – This species, which is uncommon throughout its range, is one of the smallest bats in North America (Harvey et al. 1999). The USFWS was petitioned to list this species under the ESA in 2010; results of a 12-month assessment, published in October 2013 (78 FR 61045; October 2, 2013) indicated that there was insufficient evidence to support federal listing of eastern small-footed bats at that time. Only low numbers of small-footed bats are observed during winter hibernacula counts, but based on available information, the species has declined by 12 percent in the Northeast since the onset of WNS (Turner et al. 2011).

Northern long-eared bat – This species is a small bat that occurs throughout much of eastern and northeastern North America. At the time the team conducted this review the northern long-eared bat was not a federally-listed species. Since that time, the northern long-eared bat has been listed as a threatened species (80 FR 17974). Low numbers of northern long-eared bats are typically observed during winter hibernacula counts. The best available information at the time showed that species has declined by 98 percent in the Northeast since the onset of WNS (Turner et al. 2011). It appears to be one of the species most severely affected by WNS.

Little brown bat – This small bat is broadly distributed through most of North America. The little brown bat is not federally protected, but it is the subject of a USFWS status review. Once considered to be one of the most common and abundant of North American bats, it appears to be one of the species most severely affected by WNS. Although baseline information prior to the onset of WNS is limited, recent evidence indicates that little brown bat populations in the Northeast have been decimated. Frick et al. (2010) developed a population model for the little brown bat that incorporated the impact of WNS and concluded that there is a high probability of regional extinction by 2016. Kunz et al. (2011) prepared a status review of the little brown bat for USFWS consideration in future listing assessments; this review summarized the life history, distribution, and population status prior to and post-WNS. The authors reiterated the grim outlook for the species' long-term survival if effective measures are not implemented to slow or halt the mortality associated with WNS. Kunz et al. (2011) estimated that over one million little brown bats have succumbed to WNS, and recent data indicate that the population continues to decline in affected areas. In the winter of 2010–2011, an examination of little brown bat populations in 42 hibernacula across the Northeast indicated an average decrease of 91 percent from pre-WNS surveys (Turner et al. 2011).

METHODS

Decision Process

Formal structured decision making techniques should lead to rational decisions and are geared to the type of decision that needs to be made. In this case, captive bat management requires decisions about whether to implement captive management for a particular species, and, if so, what type of captive management activities to support. These decisions involve multiple objectives, iterative analyses, a high degree of complexity, and pervasive uncertainty. The SDM techniques applied to captive bat management issues included: (1) describing the needed decisions and the issues surrounding those decision; (2) determining the fundamental objectives for captive bat management; (3) developing captive management alternatives (4) applying multi-attribute decision analysis techniques, including expert elicitation methods and tradeoff analyses to help select best management alternatives; (5) conducting sensitivity analyses; and (6) making recommendations based on results of the analyses.

These elements comprise a *decision framework* for the seven selected species. The USFWS regards the initial decision framework as a prototype, allowing for future refinement based on new information or insights. Captive bat management decisions will likely need to be revisited for bat species known to be particularly susceptible to WNS, and the CBM decision framework should help make such decisions. The specifics of the decision framework follow.

Decision Framework

The CBM decision framework is based on a clear definition of the decision problem. The CBM team initially defined the needed decision as, "Identify whether captive management is preferable to no captive management for bats facing the threat of WNS, and, if so, determine which captive management strategies might be most beneficial for these bats." This was seen as a general decision that could be applied to various insectivorous bat species. Upon further consideration of the problem, we determined that life history, population status, and the response of individual bats to WNS vary significantly among species and that, therefore, CBM decisions need to be made on a species-specific basis. What appeared at the outset to be a single decision problem was divided into independent decisions for each of seven selected species. The problem definition was thus modified to become species-specific, and we worked with a different group of bat experts for each species, with some individuals serving as experts for more than one species.

The formal decision makers were identified as USFWS project leaders and/or Ecological Services Assistant Regional Directors in the Northeast, Southeast, Midwest, and Southwest Regions. In certain steps of the decision making process, CBM team members functioned as proxies for these decision makers.

When the needed decision was adequately defined, an analysis was structured around species-specific matrices that allowed the CBM team to evaluate a range of management alternatives against various management objectives. The matrices were arranged as shown in Table 1.

Each element of the decision analysis is briefly discussed below.

Fundamental objectives and measurable attributes: SDM recognizes that all decisions are based on values as well as information, and these values are expressed as objectives. The CBM team determined that there are many possible objectives for CBM and that these objectives were common to all seven species despite the fact that the decision analysis would be species-specific.

A full slate of objectives suggested by bat and genetic experts both within and outside the USFWS was refined into a set of objectives felt by agency decision makers to be fundamental to determining the efficacy of captive management for a given species. These objectives are:

A. Maximize the persistence of wild populations affected by WNS.

B. Provide sources for continued maintenance and re-establishment, if necessary, of wild populations affected by WNS.

Table 1. Organization of Objectives, Attributes, and Alternatives.

FUNDAMENTAL OBJECTIVES	**MEASURABLE ATTRIBUTES**	**OBJECTIVE WEIGHTS**	**MANAGEMENT ALTERNATIVE 1**	**MANAGEMENT ALTERNATIVE 2 …etc.**
Objective A	metric for Obj A			
Objective B	metric 1 for Obj B	*predicted consequences were scored for each alternative, using the metric developed for each measurable attribute*		
	metric 2 for Obj B			
Objective C …etc.	metric for Obj C			

C. Minimize deleterious effects on wild bat populations due to removal (capture) of bats.

D. Minimize deleterious effects on the viability of wild bat populations due to release of captive bats.

E. Minimize deleterious effects on captive populations, such as loss of genetic diversity, artificial selection, pathogen transfer, and hybridization.

F. Minimize risk of loss of individual bats or captive populations due to anthropogenic causes or disease events (i.e., maximize survival rates).

G. Maximize research benefits of captive management relevant to bat conservation.

H. Maximize public and political awareness and understanding of the need for bat conservation.

I. Maximize agency (USFWS) credibility.

J. Minimize cost of captive management program.

In order to evaluate the management alternatives according to how well they meet the various management objectives, attributes that can be measured (using various scales) are needed. Each fundamental objective may have one or more of these measurable attributes. An example of the attributes and scales used for the eastern small-footed bat analysis is presented in Appendix II.

Management alternatives: The CBM team analyzed the nine alternatives developed at the 2010 St. Louis workshop for the SDM process and added two more alternatives: a no action alternative and a cryopreservation/cell line alternative. Each alternative was described as a general management *strategy* rather than as a particular management *action*; this influenced the analysis phase of the decision process in that broad metrics were applied to sort the relative performance of each strategy. The 11 strategic alternatives[1] were described as follows:

1. No action – Under this alternative, there would be no holding or propagation of bats in captivity. All other WNS management and research activities would continue.

2. Cryopreservation/cell line establishment – Cryopreservation refers to the cold storage of tissues, gametes, or embryos for future uses such as *in vitro* fertilization, genetic cataloguing, cloning, or embryo transfer (possibly even to other species of bats). Cell line establishment refers to culturing living cells under controlled conditions. These cells could be useful for research, including the study of WNS, and are a useful tool for cataloguing genetic diversity. Research would be prerequisite to implementing either of these management options.

3. Holding bats in hibernation over one winter season – Bats would be collected during or after swarming and maintained in a hibernating state in an artificial hibernaculum for one winter season before releasing (at the collection site or an alternative natural site) or providing them for diagnostics/research. Bats could be released via natural egress from the artificial hibernaculum or be released coincident with normal spring emergence. This alternative originally included holding bats for treatment of WNS; however, the USFWS team removed this component of the strategy due to uncertainties about possible treatments, particularly in a captive setting.

4. Holding bats over one winter season with no provision for hibernation – Bats would be maintained in a facility in a non-hibernating state for one winter season, then released back to a natural setting (e.g., near a hibernaculum coincident with natural spring emergence) or provided for diagnostics/research.

5. Holding bats over one summer/active season – Active bats would be maintained in a facility for one summer season, then released back to a natural roosting site or provided for diagnostics/research. This approach could involve opportunistic as well as targeted collection of bats.

6. Holding bats for multiple seasons/years and allowing annual hibernation – Bats would be maintained through multiple seasons and possibly multiple years, allowing for the natural hibernation cycle to occur but preventing breeding. They would then be released (at the collection site or an alternative natural site) or provided for diagnostics/research. After a

[1] There are several projects potentially involving the seasonal relocation of bats and artificial hibernacula that have been discussed or initiated by members of the bat conservation community. These include the possible use of abandoned quarry tunnels (Slider and Kurta 2011) and abandoned military bunkers (in the northeastern U.S.) as hibernacula for several species of bats, and the construction of an artificial cave in Tennessee for the protection of gray bats and other species. While the CBM team did not consider these specific projects, they could fall under one or more of the 11 alternative strategies. Likewise, the CBM team did not consider holding of bats solely for research purposes, but this is currently being implemented at multiple locations (e.g., Bucknell University, National Wildlife Health Laboratory, and the University of Missouri). The decision framework developed by the CBM team can be used flexibly and allows for changing, adding, or removing alternatives, just as it allows for modification of fundamental objectives.

certain amount of time (or other trigger), this strategy could possibly shift to a captive breeding strategy.

7. Holding bats for multiple seasons/years with no provision for hibernation – Bats would be maintained in a facility across multiple seasons, although the natural hibernation cycle and breeding would be prevented. They would then be released (at the collection site or an alternative natural site) or provided for diagnostics/research. After a certain amount of time (or other trigger), this strategy could possibly shift to a captive breeding strategy.

8. Low-intensity propagation without supplementation – Bats would select their own breeding partners, and the founder population would be propagated without being supplemented with additional bats. This approach could be either centralized (with 1-5 main facilities) or decentralized (with several dispersed facilities/institutions participating). As with the remaining alternatives that involve breeding, some of the bats could be returned to the wild or used for diagnostics/research.

9. Low-intensity propagation with supplementation – Similar to Alternative 8, except that adaption would be incorporated by bringing individuals in from the wild on occasion to enhance genetic diversity. This approach could be either centralized or decentralized.

10. High-intensity propagation without supplementation – Captive propagation would be conducted with efforts made to ensure that genes of all individuals are represented in the population. To accomplish this, bats would be housed together, and individual adults and pups would be sampled for genetic analysis, removing individuals that are highly represented in the population from the breeding group. This management strategy excludes supplementation of new genetic material from wild populations. The approach could be either centralized or decentralized.

11. High-intensity propagation with supplementation – Similar to Alternative 10, except that the captive population would be supplemented with wild bats to enhance genetic diversity within the population. Approach could be centralized or decentralized.

Predicted consequences: The first step of the alternatives analysis was to elicit projections from experts about the consequences of each alternative in terms of meeting fundamental objectives. The CBM team identified the types of experts needed to make specific predictions, which divided into two main categories: species experts and general bat and/or captive management experts (Appendix I). We determined that consequences related to some of the objectives could be generalized across species, and these scores were entered into all seven matrices. For the remaining objectives, which needed to be scored with a particular species in mind, seven different groups of species experts were convened, and the expert elicitations were conducted independently for each species. The combined cross-species and species-specific elicitations resulted in a full complement of independent scores provided by various experts for each species. To continue the analysis, the individual expert scores had to be consolidated into a single score for each consequence (i.e., for each cell in the matrix). This was done by teleconference with the various groups of species experts to discuss differences in scoring and allow for some adjustment based upon insights gleaned from the discussion. After needed adjustments were made, the individual scores for each alternative/attribute were averaged.

Simplifying the analysis: The scores from the expert elicitation were reviewed to determine if any alternatives or objectives could be dropped from the analysis. Alternatives could be dropped from further analysis due to poor relative performance or ambiguous scoring, whereas objectives could be eliminated if scores were highly similar across alternatives. Only the cryopreservation/ cell line alternative was eliminated during this step of the process.

Unweighted results: Standard calculations were made to determine which alternative[s] performed best based upon predicted consequences. It is common to find that no single alternative will perform best against all objectives. In such cases, alternatives tend to perform well against some objectives and poorly against others, which is to be expected if objectives are competing against each other. Thus, even the alternative that has the best overall "unweighted" score may not be preferred if the score reflects high performance against less valued objectives. In this case, a tradeoffs analysis is required, as was the situation for all seven bat species.

Tradeoffs analysis: This stage of the CBM project involved (1) weighting objectives, (2) re-calculating overall scores for the management alternatives based on the weighting, and (3) comparing the scores for the top-performing management alternatives against the no action alternative.

> *Weighting technique*: Swing weighting was used to assign a value to each objective. This technique takes into account both the intrinsic value placed on the objective and, just as importantly, the net difference in scores among the alternatives for that particular objective. Although objective weights were assigned independently for each species, team discussions helped to ensure some cohesion of values within the USFWS. The resulting raw weights were then normalized on a scale of 0-1.0.
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> *Weighted results*: An overall weighted score was derived for the no action alternative and each of the 9 remaining management alternatives for each species, using the same standard calculations applied to the unweighted analysis. The weighted results reflected the performance of the alternatives relative to the assigned values of decision makers. Results are presented later in this report for each of the seven species.
>
> *No action versus action alternatives*. To determine whether captive management of any sort was preferred over no action (i.e., no captive management) for a given species, the "action alternatives" (i.e., those that included some form of captive management) were ranked according to their weighted scores, as shown in Table 2 in the Results section below. The three top-performing management alternatives were then analyzed against the no action alternative to see whether any of them performed better or worse than no action. The four alternatives – no action and the top three management alternatives – were re-weighted within this new context and ranked accordingly, as shown in Table 3 in the Results section.

Sensitivity analysis: We performed a sensitivity analysis for some of the seven species when results were unanticipated or when the species lead found it appropriate to test different weighting schemes. This allowed for an examination of the sensitivity of results to different weighting and/or response variables.

Recommendations: Recommendations resulting from the decision analysis are provided in this report. It should be noted, however, that SDM recommendations are neither prescriptive nor exempt from further decision maker consideration; rather, they are intended to provide a robust aid for making final decisions. If final decisions diverge from the SDM recommendations, the rationale for that divergence should be documented so that stakeholders can understand the decision process.

Recommendations consist of (a) the identification of preferred alternatives, including no captive management for certain species; (b) triggers for when to consider implementing preferred captive management strategies for any given species; and (c) identification of research priorities relative to captive management questions. The analysis results and recommendations apply only to the seven species, and they should be viewed in the proper context of emerging information and changes in the status of each of these species. It should be noted, however, that the framework for decision making – including the process, objectives, and alternatives, used in this SDM effort could be extended to additional species.

RESULTS

This section contains general results gleaned from the CBM decision analysis as well as species-specific results. The CBM team also identified research needs through consideration of the uncertainties identified during the consequences analysis.

General Results

Eliminated and preferred alternatives

Following the consequences analysis, the CBM team removed Alternative 2 (cryopreservation/ cell line establishment) from the alternatives under consideration. This was based on significant uncertainty regarding the methods and role cryopreservation could play in the response to WNS, in both the short and long terms. In addition, experts recognized that cryopreservation is an invasive process, often involving the sacrifice of the donor animal to obtain gametes for preservation. Therefore, this alternative differed from the other CBM alternatives (other than no action) in that it did not involve maintaining live bats in captivity. We recommend further investigation into the potential utility of cryopreservation.

With regard to the remaining alternatives, the highest ranking alternatives for the majority of the bats were either Alternative 1 (no action) or Alternative 3 (holding bats in hibernation for one winter); details are discussed in Species-specific Results below. A major determinant for which alternative was preferable appeared to be whether or not the species in question was known to be susceptible to WNS. For species with no documented impacts from the disease, such as the Virginia and Ozark big-eared bats, the preferred alternative was no action. For the little brown and Indiana bats, the preferred alternative was Alternative 3. In addition, there was a general concern about reintroducing captive individuals back into a WNS-infected environment. A management strategy that holds bats for a single season may help bats survive one winter upon return to their hibernaculum; however, bats will still receive spores from other bats and the surrounding environment within a cave or mine.

Overall, there was little support for, or confidence in, the alternatives that involved long-term captivity, holding of bats over the summer, or holding of bats without allowing hibernation (Alternatives 4-11). The final scores for the seven species are shown in Table 2.

Cross-species Research Needs

Priority research needs were identified through the expert scoring process and through discussions with the experts on the insights and uncertainties underlying the scores. In particular, areas of uncertainty related to highly weighted objectives revealed data gaps and important research needs. Four general research needs were identified:

1. Determine the susceptibility of gray bats (recently resolved – see *Species Considered* above), Ozark big-eared bats, and Virginia big-eared bats to WNS in order to foresee if and when captive management may need to be reconsidered.

2. Engage in experimental short-term winter holding of bats in hibernation for the little brown bat and/or Indiana bat to determine appropriate procedures and protocols and to determine the efficacy of this strategy in meeting broader conservation objectives. Selection criteria for determining appropriate subjects for experimentation should include (1) known susceptibility to WNS, (2) the potential for results to be applicable for other species, and (3) the ability to minimize adverse effects of removing bats from the wild population.

3. Determine, for the bats known to be susceptible to WNS, if some individuals or groups display resilience or resistance to the disease, and to what extent. Whether or not a species (or some individuals within a species) have some natural immunity or resistance to WNS is a key factor in decisions on whether or not to remove bats from the wild population for captive management, and which bats will be selected.

4. Determine whether it is possible to control (or at least slow) WNS infection and disease progression in artificial hibernacula, either environmentally (e.g., through controlling the microclimate) or with control agents (e.g., antifungal agents). Holding bats in hibernation over one winter was the preferred alternative for several species, but that alternative is only advantageous if it is possible to control Pd in the captive environment during hibernation.

Species-specific Results

As discussed above, each alternative that described some form of captive management for each bat species (alternatives 3-11) was scored in terms of how well it performed against the stated objectives, then weighted using swing-weighting techniques (in which objectives are weighted according to both their inherent value and the difference in scores among the alternatives). The results allowed for a comparative ranking of the various management alternatives for each species, as presented in Table 2.

Table 2. Ranked Captive Management Alternatives for Seven Bat Species of Concern. The top three rankings for each species are in bold. Alternative 1, the no action alternative, and alternative 2, cryopreservation/cell line establishment, were excluded from this analysis.

	Eastern Small-footed Bat	**Gray Bat**	**Indiana Bat**	**Little Brown Bat**	**Northern Long-eared Bat**	**Ozark Big-eared Bat**	**Virginia Big-eared Bat**
3. Holding bats in hibernation over one winter	**1**	**1**	**1**	**1**	**1**	**1**	**2**
4. Holding bats over one winter with no hibernation	**2**	**3**	**2**	5	**2**	4	**1**
5. Holding bats during one summer/active season	6	4	8	7	5	**2**	5
6. Holding bats for multiple seasons/years, allowing annual hibernation	**3**	**2**	6	**3**	**3**	**3**	6
7. Holding bats for multiple seasons/years with no hibernation	9	5	9	9	9	8	9
8. Low-intensity propagation without supplementation	5	8	7	8	8	9	4
9. Low-intensity propagation with supplementation	4	6	**3**	**2**	7	6	7
10. High-intensity propagation without supplementation	7	7	4	6	4	5	**3**
11. High-intensity propagation with supplementation	8	9	5	4	6	7	8

When the top three alternatives for each species were identified, a second analysis was conducted to compare them against taking no action, that is, not conducting captive management in any form. This involved looking at the range of raw scores in terms of how well both the action and no action alternatives performed against the stated objectives, then once again going through a tradeoffs analysis using weighted scores. The weighted scores, resulting in a ranking from 1-4 for the various alternatives as applied to each species, are shown in Table 3. It is interesting to note that the distribution of scores is much broader for some species than other. Low variation is seen for the eastern small-footed and Indiana bats, while much higher variation is seen for other species, particularly the Ozark big-eared bat. It is also important to note the difference in scores between the no action alternative and the group of management alternatives for each species, with a clear distinction being drawn for the Ozark big-eared bat and, conversely, little distinction being drawn for the little brown and eastern small-footed bats. These results are indicative of the status of the bats in terms of their exposure and vulnerability to WNS at the time of the analysis and may not reflect the current situation for some of these species.

Table 3. Final Species-specific Scores for the Top Three Captive Management Alternatives and the No Action Alternative for Each Species. Dominated management alternatives were excluded from this analysis and are indicated by blank cells.

	Eastern Small-footed Bat	Gray Bat	Indiana Bat	Little Brown Bat	Northern Long-eared Bat	Ozark Big-eared Bat	Virginia Big-eared Bat
1. No action (no captive management)	**0.212**	**0.690**	**0.230**	**0.578**	**0.605**	**0.900**	**0.625**
3. Holding bats in hibernation over one winter	**0.255**	**0.541**	**0.269**	**0.585**	**0.487**	**0.374**	**0.486**
4. Holding bats over one winter with no hibernation	**0.249**	**0.300**	**0.148**		**0.442**		**0.498**
5. Holding bats during one summer/active season						**0.227**	
6. Holding bats for multiple seasons/years, allowing annual hibernation	**0.215**	**0.316**		**0.403**	**0.403**	**0.161**	
9. Low-intensity propagation with supplementation			**0.147**	**0.438**			
10. High-intensity propagation without supplementation							**0.390**

Alternatives for each species are shown in bold as normalized weighted scores. No action was among the top four for all seven species, as well as the top three performing captive management alternatives, which were then used to analyze the benefits of taking any action versus taking no action for each species. Remaining alternatives are shown as relative rankings from fifth to tenth places.

A brief discussion of results for each species follows.

Eastern small-footed bat

Preferred alternatives

The highest ranking alternatives for the eastern small-footed bat, in descending order, were:

1) Holding bats in hibernation over one winter
2) Holding bats over one winter with no hibernation
3) Holding bats for multiple seasons/years, allowing annual hibernation
4) No action

None of the four highest ranking alternatives scored significantly higher than another. The weighted scores ranged from 0.212 to 0.255 and reflected the uncertainty in identifying which captive management strategy, if any, is most appropriate for the eastern small-footed bat. The lack of rangewide status and distribution information made it very challenging for experts to estimate loss of individuals due to WNS and determine the best captive management strategy to alleviate those losses. Eastern small-footed bats roost in cracks, crevices, and talus rock piles, making detection difficult, and the scores reflected these uncertainties. As a result, eastern small-footed bat experts stated that additional data on current population status is needed before beneficial captive management strategies could be determined. In addition, some experts expressed the opinion that none of the captive management strategies would make a substantial difference in the conservation of eastern small-footed bat by 2015 (see Objective A in Appendix II). Uncertainty over the severity of the impact of WNS on the species was cited as a further confounding factor, given that this species does not roost colonially in the winter like heavily affected species such as Indiana and little brown bats do.

Experts also expressed doubts about the number of eastern small-footed bats that could be collected for captive management without impacting population viability in the wild, since relatively small numbers of individuals are found across the landscape. There was also concern about removing potentially resistant individuals from the wild, loss of genetic diversity, and loss of natural behavior (e.g., for migration, foraging, breeding), especially with a strategy involving long-term (i.e., multiple seasons) holding bats. Therefore, a short-term, one-season holding was thought to be preferable over long-term holding. In addition, there are concerns with reintroducing captive individuals back into a WNS-infected environment. A management strategy that holds bats for a single season may help bats survive one winter upon return to their hibernaculum; however, bats will still receive spores from other bats and the surrounding environment within a cave or mine. Research would be necessary to address all concerns stated above before captive holding or rearing could be considered.

Research needs

Research needs relating to captive management of eastern small-footed bats included:

- Conduct additional summer and winter surveys to better understand status and distribution across the entire eastern small-footed bat range.
- Conduct analyses to better understand genetic differences within and between populations. The experts assumed that there is a high degree of population structuring due to the fact that eastern small-footed bats migrate short distances from a hibernaculum to their summer roosts, but no research has been done to date.
- Investigate population viability. Research is needed to estimate numbers of individuals that can be removed from a population to implement any of the captive management strategies in order to avoid a population collapse in the wild. Population viability data are

also needed to determine if there is an Allee affect (correlation between population density and fitness of an individual) in wild eastern small-footed bat populations.

- Investigate survivability and potential resistance. Experts acknowledged that by removing individuals from the wild to begin captive efforts, we may potentially be removing bats that are resistant to WNS. Additional research is needed to determine if the eastern small-footed bats that are surviving WNS are reproducing and if there is successful recruitment to naturally increase the population over time.
- Conduct research to better understand captive impacts related to loss of genetic diversity, loss of natural behavior (especially for pups), stress levels, and survivorship. The experts felt that pilot projects were needed to address many concerns about holding bats over a given length of time.

<u>Gray bat</u>

Preferred alternatives

The highest ranking alternatives for the gray bat, in descending order, were:

1) No action
2) Holding bats in hibernation over one winter
3) Holding bats during one summer/active season
4) Holding bats for multiple seasons/years, allowing hibernation

Responses by gray bat experts were varied. Questions raised whether or not to pursue captive management of gray bats in response to WNS included the inability to obtain a large enough captive sample size to make a difference; the number of uncertainties associated with captive holding; the possibility of stress from captive holding; the general inability of insectivorous bats to adapt to confined conditions; negative impacts on the species' behavior once released; the possibility of introducing diseases in captive settings or in wild populations into which captive bats have been released; potential adverse impacts to the species' genetic diversity due to mortality of bats in captivity; time and financial burdens imposed by captive management efforts; the social nature of gray bats, which often occur in very large congregations that would be difficult to duplicate in a captive situation; and credibility issues based on failed attempts with other species.

On the other hand, the second highest-ranking alternative was holding the species in captivity over one winter. Expert input supporting this alternative was predicated on the supposition that this may be the only way to prevent the species from going extinct or being reduced to a non-viable level. In regard to a preferred captive management alternative, experts posed the following questions: whether the gray bat's social behavior would be adversely affected; the possibility of lack of adverse effects due to the large population numbers of the species, minimal impacts to the genetic stability of the species, benefits obtained in learning more about the species by observing it in captivity, and the potential to increase public awareness of the species and the potential impact of WNS.

Research needs

Suggested research centered on information needed to determine the benefits of no action versus possibly efficacious captive management of gray bats in response to WNS. Research priorities thus included determining the susceptibility of gray bats to WNS (see *Species Considered* above), the degree to which WNS will cause mortality in gray bats (still in question), further investigations into the potential control of and/or treatment for WNS, the impact caused by loss of bat guano on other cave species,, and potential impacts on agriculture and forestry due to increased insect infestations due to loss or significant declines in the number of insectivorous bats.

<u>Indiana bat</u>

Preferred alternatives

Generally, Indiana bat experts expressed uncertainty about whether captive management of Indiana bats is a reasonable response to WNS; for instance, they questioned whether we could successfully breed insectivorous bats and produce pups in captivity, and whether we could produce a sufficient number of bats to make a difference in WNS-caused mortality. These concerns were specifically heightened for the Indiana bat because of the highly social nature of this species, which made experts question the possibility of holding enough bats in captivity to account for this colonial behavior. Despite these concerns, most Indiana bat experts were willing to evaluate potential captive management alternatives as potentially the only alternative to species extinction. However, these experts felt that small-scale feasibility trials were preferable to any large-scale captive management programs, at least until some of the uncertainties regarding captive management can be resolved.

The highest ranking alternatives for the Indiana bat, in descending order, were thus:

1) Holding bats in hibernation over one winter
2) No action
3) Holding bats over one winter with no hibernation
4) Low-intensity propagation with supplementation

An overriding concern among Indiana bat experts was the potential loss of natural behaviors – viewed as a virtually inevitable effect – of Indiana bats brought into captivity. This led to a general preference for short-term holding strategies. Experts also identified hibernation as a behavior of this species, leading to a preference for strategies that would allow bats to hibernate in captivity. These concerns led to a preferred strategy of holding bats in hibernation over one winter for Indiana bats. The no action alternative was the second-ranking alternative (scored only slightly lower than the highest-ranking strategy), reflecting doubts about using CBM to deal with WNS. The third- and fourth-ranking alternatives scored considerably lower than either of the top two strategies.

Research needs

A major source of uncertainty on whether captive bat management strategies should be pursued is whether or not some individual bats have resistance or immunity to WNS. Research into whether or not there are individual bats that have resistance or immunity to WNS is needed to inform whether or not we should pursue captive management, and if so, how to select individuals for a captive management program.

Further, holding bats in hibernation over one winter, the preferred alternative, is only advantageous if it is possible to control Pd in the captive environment during hibernation (see discussion of general research needs across species above).

<u>Little brown bat</u>

Preferred alternatives

The highest ranking alternatives in descending order for the little brown bat were:

1) Holding bats in hibernation over one winter
2) No action
3) Low-intensity propagation with supplementation
4) Holding bats for multiple seasons/years, allowing annual hibernation

The close ranking between two top alternatives highlights the tension, elucidated by the experts, between the immense loss of little brown bats in a short period of time with no viable method in sight for slowing or stopping the spread of WNS (i.e., no hope, therefore no action) and the belief that the survival of small numbers of these bats held for short-term captive maintenance is possible with little adverse impacts to the animals being held and the species in general. For the most part, however, the species experts agreed that holding little brown bats over one winter could increase the survivability of those bats and provide some level of benefit to local populations upon release.

For the remaining alternatives, two strategies for longer-term captive maintenance ranked higher than the remaining alternatives, although the difference in ranks was not as great as the top tier alternatives. The species experts were skeptical of maintaining little brown bats in captivity for long periods of time due to the difficulty in maintaining natural behaviors, a possible decrease in genetic diversity, and the belief that the low numbers of animals that could be maintained in captivity would not buffer the population-level impacts of WNS.

Research needs

The species experts agreed that long-term captive maintenance and/or propagation of little brown bats could provide additional life history information but would not necessarily benefit populations impacted by WNS because of the small numbers of bats that could be held. Little brown bats have been maintained in captivity for research but not for propagation, since a primary difficulty in keeping a captive population is providing the conditions needed for successful reproduction. Research on the laboratory conditions required to maintain natural behavior and physiology, including typical torpor and arousal states during hibernation, reproduction, and foraging, would be important in treating small, captive populations for WNS over one winter then releasing the treated bats to augment local populations.

Northern long-eared bat

Preferred alternatives

The highest ranking alternatives in descending order for the northern long-eared bat were:

1) No action
2) Holding bats in hibernation over one winter
3) Holding bats over one winter with no hibernation
4) Holding bats for multiple seasons/years, allowing annual hibernation

The no action alternative ranked considerably higher than any of the captive management strategies. The next highest ranking strategies included the conservative short-term winter holding strategies. Scores provided by species-specific experts reflected an overall lack of confidence in captive management as a viable option for the northern long-eared bat. Overall, there was a low level of confidence in being able to (1) successfully captive-rear northern long-eared bats, and (2) rear enough individuals to maximize persistence in the wild or reestablish populations given the severe impacts we have observed in the wild from WNS.

Research needs

As with the Indiana bat, there is a need for basic WNS-related research that is not tied specifically to any captive management strategy (for example, how can we reduce mortality or predict survivors?). With regard to the highest ranking management alternative, holding bats in hibernation for one winter, any captive bat management research related to this species should focus on assessing whether there is a way to increase over-winter survival with use of artificial environments.

Another key research need mentioned by experts is whether or not WNS could be controlled (or at least slowed) in an artificial hibernaculum, either environmentally (e.g., through controlling the microclimate) or with control agents (e.g., antifungal agents).

Ozark big-eared bat

Preferred alternatives

The highest ranking alternatives in descending order for the Ozark big-eared bat were:

1) No action
2) Holding bats in hibernation over one winter
3) Holding bats during one summer/active season
4) Holding bats for multiple seasons/years, allowing annual hibernation

The no action alternative ranked considerably higher than any of the captive management strategies, with the next highest ranking strategies being the conservative short-term holding strategies. Scores provided by species experts indicated an overall lack of confidence in captive management as a viable option for the Ozark big-eared bat. Experts predicted high levels of stress and moderate to high mortality rates in captive populations due in part to the bat's known vulnerability to human disturbance. Further, the difficulties experienced during the attempt to establish a security population and develop husbandry practices for the Virginia big-eared bat, a closely related subspecies, generated concerns regarding similar attempts for the Ozark big-eared bat. Experts also anticipated that removal of individuals for captive management would result in an overall deleterious impact on the wild population due to the small population size of the Ozark big-eared bat and high levels of uncertainty regarding whether controlled holding or captive propagation efforts could successfully provide a source of bats to buffer impacts or reestablish wild populations.

Research needs

The susceptibility of big-eared bats (*Corynorhinus spp.)* to WNS: Investigating susceptibility and possible reasons for apparent resistance in big-eared bats will help focus management efforts, possibly including captive management, where they are most needed, and may provide important information on potential control and mitigation methods.

<u>Virginia big-eared bat</u>

Preferred alternatives

The highest ranking alternatives in descending order for the Virginia big-eared bat were:

1) No action
2) Holding bats in hibernation over one winter
3) Holding bats over one winter with no hibernation
4) High intensity propagation without supplementation

The no action alternative ranked considerably higher than any of the captive management strategies. This was primarily due to uncertainty regarding whether the species was susceptible to WNS. The next highest ranking strategies included the conservative short-term holding strategies. Scores provided by species experts indicate an overall lack of confidence in captive management as a viable option for the Virginia big-eared bat. This was primarily based on the difficulties experienced during the initial captive holding trials and the known susceptibility of the species to stress from handling. Experts predicted high levels of stress and moderate to high mortality rates in captive populations. A strong preference towards maintaining natural hibernation patterns was also expressed, as this was felt to be critical to maintaining natural behavioral and physiological conditions of the species.

Research needs

A key research question involves the susceptibility of big-eared bats to WNS. WNS occurs within the range of the Virginia big-eared bat and is known to cause mortality in several bat species hibernating in the same caves used by the Virginia big-eared bat during the winter. However, the Virginia big-eared bat has not shown any evidence of WNS to date. In fact, counts for this species continue to increase annually, suggesting that WNS may pose little to no threat to Virginia big-eared bats. Investigating the susceptibility of *Corynorhinus* to infection and/or potential reasons for apparent resilience will help focus management efforts, possibly including captive management, where they are most needed to minimize the impacts of WNS.

DISCUSSION AND TEAM RECOMMENDATIONS

The use of structured decision making allowed us to consider the numerous alternatives (as well as opposing points of view) identified at the 2010 St. Louis workshop in a systematic way. We also had to be practical. Thus, while we used some quantitative methods to analyze the input of experts and to identify values of decision makers, we did not conduct an extensive statistical exploration of the input. In general, the recommendations in this section represent not only the outcome of the decision analysis, but the guidelines and policies (USFWS and IUCN) that constrain agency decision making for imperiled species. The recommendations also reflect information gleaned from analysis of the captive bat colony questionnaire conducted by Bat Conservation International (Bayless 2010), the 2010 St. Louis Workshop, and numerous CBM team discussions.

Not surprisingly, results for the seven analyses reflected a cautious approach to undertaking any captive management of insectivorous bats for conservation purposes related to WNS, with no action favored for four species and short-term holding strategies favored for three. This precautionary attitude stems from a high level of uncertainty regarding the progression of WNS through wild bat populations, lack of sufficient data for some species, and questions regarding current abilities to successfully maintain large numbers of insectivorous bats in captivity. It may also reflect the lower priority that experts assigned captive management relative to other conservation needs, such as monitoring, research, and treatment, and concerns that the funding and resources needed to mount *ex situ* management efforts may, in some cases, outweigh the benefits.

It is important to note that, in general, there was little variation of final scores across the range of alternatives. Performance of one alternative over another, therefore, was often subtle. Lack of variation can have a number of causes and can be tested through sensitivity analysis. In this case, it appears to be due primarily to the large number of objectives, the gradation of objective weights, and the averaging of experts' scores. If there had been, for instance, few objectives being weighted at different extremes, or if we had employed only the low or high ends of the range of expert scores, we would have seen more variation among the final scores.

In addition to conservative strategies being favored, there was also a great deal of uncertainty about the details of each of the alternatives. Thus, in line with the outcomes of the St. Louis workshop, we considered general captive management strategies rather than specific project proposals. Analyzing the predicted effects of general strategies in light of fundamental management objectives, and accepting the results of the analysis, provides a context for then considering more specific project proposals based on a broader management framework, i.e., there are multiple ways in which each strategy can be implemented. This should provide an atmosphere conducive to reasonable experimentation and monitoring, precluding projects based on cavalier assumptions while encouraging rational action rather than yielding to paralysis based on uncertainty. This also allows us to take into account – and to assess, if necessary – projects that have already been proposed or are underway that relate to or could complement recommendations arising from the CBM analysis.

Finally, it is important to remember that these results reflect information and expert judgment available at the time of the analysis. The decision framework allows for updating of expert input as well as further thought about fundamental objectives; thus, results are likely to change to some extent over time. It would be advisable to review the results for each species before making final decisions about preferred captive management strategies, especially if there has been a significant lag between the time of analysis and decision making.

CBM Team Recommendations

- Remove long-term strategies (Alternatives 6 through 11) from consideration at this time for all seven species considered in this report. Through our investigations we found little evidence that long-term captive management of large numbers of any of our seven target bat species would be an effective response to WNS at this time. Further, although not insurmountable, the feasibility of maintaining bats in captivity over the long term was also viewed as a limiting factor for these alternatives.

- Conduct pilot captive management projects, featuring holding of bats in hibernation over one winter (Alternative 3), based on SDM results. A pilot project would allow us to learn more about the risks and benefits of this type of management. The pilot project could be conducted for Indiana or little brown bats, both of which had Alternative 3 as a preferred strategy. However, the little brown bat, which has been decimated in the northeastern U.S. but is locally abundant elsewhere, may be the best species for an initial pilot project, as it has a wide range, is severely impacted by WNS, and is not currently listed (lessening regulatory requirements and increasing the speed in which the project could be started).

- Take full advantage of the research opportunities provided by a pilot project if one is undertaken. A pilot project would help answer many key questions regarding the feasibility of and techniques for successfully holding a large, socially cohesive group of insectivorous bats in captivity. Such projects could likewise answer pertinent biological questions (e.g., if bats are captured during or after fall swarming and mating, can females successfully store sperm and become impregnated while in captivity?) and could be used to experimentally explore optimal artificial hibernacula design, preferred environmental conditions, physical and biological security measures, and handling protocol. We recommend adhering strictly to the principles and practices of adaptive management in implementing any pilot project.

- Refrain from conducting captive management for the species that had Alternative 1 (no action) as the most preferred alternative. These species should not be considered for operational captive management unless and until defined triggers (i.e., conditions under which captive management is viewed to be less risky than taking no action) are met. Although such triggers need to be defined on a species-by-species basis, at a minimum they should include known exposure to WNS, response in terms of rate of population decline, behavioral traits that increase the likelihood of bat-to-bat/cave transmission, and demonstration, possibly through pilot captive management projects undertaken for other bat species, that Pd can be controlled in a captive environment and that the likelihood of project success is high. If a bat species shows susceptibility to WNS at the individual and population levels and a noticeable decline in the natural population, short-term captive management may be an option. Results from pilot studies would help us determine the efficacy of captive management for particular situations.

- Revisit recommendations when appropriate based on monitoring of the species and WNS exposure/response, further insights into the causes and remedies for WNS, and results of pilot projects. The WNS situation is rapidly changing and we should continually reassess our options based on the best available information.

- Determine the susceptibility of Ozark big-eared bats and Virginia big-eared bats to WNS, and the effects that WNS will have on gray bats. Determining the effect Pd has on these species, including studies on possible reasons for apparent resistance/resilience, would likely influence future decisions regarding whether to engage in captive management. Note that this does not, at this time, include inoculation trials on Virginia big-eared bats.

- Further investigate the potential role of cryopreservation and cell line establishment in response to WNS through discussions with experts and the development of a white paper. These alternatives do not represent captive strategies per se but may hold promise in protecting unique genetic diversity and possible bat repatriation in the future.

Caveats and Considerations for the Decision Maker

If the recommendation to proceed with a pilot project is adopted, the decision to fund the project should be made while keeping in mind other competing conservation projects related to WNS (monitoring, treatments, etc.). We further recommend carefully considering the merits of any proposed captive management program given the limited resources available for responding to WNS.

Proposals for pilot projects should address appropriate animal care and handling standards during transport and captivity (e.g., Institutional Animal Care and Use Committee guidelines when research is being considered), the final disposition of captive animals (e.g., timing and location of release, euthanasia), and outreach activities, as anything involving captive maintenance could be of interest to stakeholders and/or the general public.

While the decision framework developed for our analysis can be extended to other bat species facing the prospect of population declines directly attributable to WNS, the underlying principle we urge experts and decision makers alike to keep in mind is that any captive bat management decision should be made objectively and transparently.

For additional information regarding the content of this report, please contact Mary Parkin or Robert Tawes (see front page for contact information).

DISCLAIMER

The findings and conclusions in this paper are those of the author(s) and do not necessarily represent the official views of the U.S. Fish and Wildlife Service.

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APPENDIX I

List of Experts Involved in Structured Decision Making
Analysis of Captive Bat Management Alternatives

Name	**Affiliation**
Sybill Amelon	U.S. Forest Service
Mike Armstrong	U.S. Fish and Wildlife Service
Ed Arnett	Theodore Roosevelt Conservation Partnership
Michael Baker	Bat Conservation and Research
Diana Barber	Mesker Park Zoo
Robert Barclay	University of Calgary
Susan Barnard	Basically Bats
Meredith Bartron	U.S. Fish and Wildlife Service
Mylea Bayless	Bat Conservation International
Hugh Broders	Saint Mary’s University
Tim Carter	Ball State University
Ellen Covey	University of Washington
April Davis	New York Dept. of Health
Bill Elliott	MO Dept. of Conservation (ret)
Mark Ford	Virginia Tech University
Steve Hensley	U.S. Fish and Wildlife Service
Joshua B. Johnson	University of Maryland
Scott Johnson	Indiana Department of Natural Resources
Andrew King	U.S. Fish and Wildlife Service
Allen Kurta	Eastern Michigan University
Michael Lacki	University of Kentucky
Susan Loeb	Clemson University
Amanda Lollar	Bat World Sanctuary
Keith Martin	Rogers State University
Paul McKenzie	U.S. Fish and Wildlife Service
Robyn Niver	U.S. Fish and Wildlife Service
Sara Oyler-McCance	U.S. Geological Survey
Luis Padilla	Smithsonian Institute
Toni Piaggio	USDA Animal & Plant Health Inspection Service
Lori Pruitt	U.S. Fish and Wildlife Service
Bill Puckette	Poteau County Schools (ret)
Paul Racey	University of Aberdeen
Noelle Rayman	U.S. Fish and Wildlife Service
Ron Redman	Arkansas Natural Resource Commission
DeeAnn Reeder	Bucknell University
Scott Reynolds	North East Ecological Services
Rick Reynolds	VA Department of Game and Inland Fisheries
Amy Russell	Grand Valley State University
Blake Sasse	Arkansas Game & Fish Commission
Brooke Slack	Kentucky Department of Fish and Wildlife
Nucharin Songsasen	Smithsonian Institute
Dale Sparks	Environmental Solutions & Innovations

Richard Stark	U.S. Fish and Wildlife Service
Craig Stihler	West Virginia Division of Natural Resources
Monica Stoops	Cincinnati Zoo
Leslie Sturges	Bat World NOVA
Greg Turner	Pennsylvania Game Commission
Ron Van Den Bussche	Oklahoma State University
Jacques Pierre Veilleux	Franklin Pierce University
Susi von Oettingen	U.S. Fish and Wildlife Service
John Whitaker	Indiana State University
Steven Wing	Louisville Zoo

APPENDIX II

Objectives, Attributes, and Scales used Decision Analysis: *Myotis leibii* Example

<table>
<tr><th>FUNDAMENTAL OBJECTIVE</th><th>MEASURABLE ATTRIBUTE</th><th>SCALE</th></tr>
<tr><td>A. Maximize persistence of wild populations affected by WNS.</td><td>Proportion of the rangewide population that will be lost by 2015, using 2009 numbers as the baseline</td><td>1 = < 25%
2 = 25-50%
3 = 51-75%
4 = > 75%</td></tr>
<tr><td rowspan="2">B. Provide sources for continued maintenance and (in the case of extirpation) re-establishment of wild populations affected by WNS.</td><td>1. Probability of maintaining sustainable populations of the species through 2015. Sustainable populations are defined as not being at risk of extinction due to demographic stochasticity triggered by the additive effects of WNS to other threats facing the population.</td><td>0 = no probability
1 = low (< 33%) probability
2 = moderate probability
3 = high (> 66%) probability</td></tr>
<tr><td>2. Likelihood of maintaining viable captive colonies</td><td>1 = low (< 33%) probability
2 = moderate probability
3 = high (> 66%) probability</td></tr>
<tr><td>C. Minimize deleterious effects on wild bat populations due to removal (capture) of bats.</td><td>Level of impact on wild populations due to removal</td><td>1 = no impact
2 = low impact
3 = moderate impact
4 = high impact</td></tr>
<tr><td rowspan="3">D. Minimize deleterious effects on the viability of wild bat populations due to release of bats.</td><td>1. Likely presence of disease/ pathogens in released bats</td><td>0 = no probability of impacts
1 = low (< 5%) probability
2 = > 5% probability</td></tr>
<tr><td>2. Likelihood of significant genetic divergence of released bats from the wild source populations over time</td><td>0 = no probability of divergence
1= low (< 5%) probability
2 = > 5% probability</td></tr>
<tr><td>3. Likelihood that release of unexposed (to WNS) captive bats will cause a decrease in the survival of offspring of released x wild (exposed but resistant) bats.</td><td>0 = no probability of decreased offspring survival
1 = low (< 5%) probability
2 = > 5% probability</td></tr>
</table>

APPENDIX II

Objectives, Attributes, and Scales used Decision Analysis: *Myotis leibii* Example

E. Minimize deleterious effects on the captive population, such as loss of genetic diversity, artificial selection, pathogen transfer, and hybridization.	1. Likely loss of genetic diversity within the captive populations	0 = no probability of loss of genetic diversity 1 = probability of low-level loss of genetic diversity 2 = probability of high loss of genetic diversity over time
	2. Loss of natural behavior	0 = no detectable change 1 = minimal change 2 = moderate change 3 = substantial change
	3. Presence of pathogens in captive bats	0 = no detectable presence 1 = detectable presence, treatable 2 = detectable presence, untreatable
F. Minimize risk of loss of individual bats or captive populations due to anthropogenic causes or disease events (i.e., maximize survival rates)	1. Stress to individual bats from handling	0 = no stress 1 = low stress 2 = high stress
	2. Mortality rates in captive populations	0 = no mortality 1 = low (<10%) mortality rate 2 = moderate rate 3 = high (> 30%) rate
G. Maximize research benefits of captive management relevant to bat conservation.	Information gained from captive management program	0 = no information 1 = small amount of information 2 = moderate amount 3 = high amount
H. Maximize public and political awareness and understanding of the need for bat conservation.	Interpretive opportunities associated with captive management program	0 = No opportunities1 = 1-5 opportunities2 = > 5 opportunities

APPENDIX II

Objectives, Attributes, and Scales used Decision Analysis: *Myotis leibii* Example

I. Maximize agency (USFWS) credibility.	Support expressed by non-agency experts	0 = Total opposition 1 = Mostly against 2 = 50/50 3 = Mostly for 4 = Total support
J. Minimize cost of captive management program.	1. Capital + annual costs	1 = exorbitant costs 2 = expensive 3 = inexpensive
	2. Percent of cost shared by non-USFWS partners	Percent of total cost of strategy (rough estimate)

Table depicts scores objectives and attributes scored by both general experts and *M. leibii*-specific experts