Region 3

Indiana Bat

Resource Equivalency Analysis Model

for

Wind Energy Projects

Version 4: July 7, 2014

Authors: Jennifer Szymanski, Forest Clark, and Drew Laughland

Table of Contents

Introduction

BACKGROUND

Resource equivalency analysis (REA) was developed in the natural resource damage assessment and restoration (NRDA) arena to enable a fair comparison between resources lost in an oil spill and resources gained through compensatory restoration (based on Unsworth and Bishop 1994; Jones and Pease 1997). It provides a unit of measure and a framework for comparing losses and gains. REA is referenced in the U.S. Department of the Interior's Natural Resources Damage Assessment (NRDA) regulations (2008) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); National Oceanic and Atmospheric Administration's Oil Pollution Act (OPA) guidance documents; and is commonly used in NRDA cases (see Sperduto et al. 1999, 2003; Skrabis 2005).

Given its extensive use in natural resources mitigation, REA was recently applied to the Endangered Species Act of 1973 (ESA) arena. It was used to estimate (quantify) the losses of eagles that would be avoided by electric pole retrofitting as mitigation for mortalities from collisions with wind energy facilities in the western U.S. (Skrabis 2011) as well as Norway (Cole 2009). We believe REA provides a suitable framework for evaluating the sufficiency of proposed mitigation measures to off-set the take of the endangered Indiana bat (*Myotis sodalis*) from wind energy projects.

REAs are typically denominated in units of resource services (e.g., bird years, bat years), which account for more than simply bodies (e.g., ecosystem services provided). Within our decision context, permitting take of Indiana bats (Ibat) pursuant to the ESA, the services of primary interest are reproductive services; specifically, female Indiana bat reproductive potential. When an adult female bat is prematurely killed at a wind energy facility, her and her offspring's reproductive potential is lost. In REA terminology, the lost females plus their future lost reproductive potential are called debits. Similarly, when mitigation is applied, female bats and their future reproductive potential are gained. These gained resources are referred to as credits. The REA model calculates the both the debit and credit associated with specific projects to determine whether the mitigation is sufficient. That is, whether the credit gained exceeds the debit accrued.

To assist our Field Offices with advising project proponents and evaluating their mitigation proposals, we developed an Indiana bat specific REA model. The purpose of the Model is to determine the debit and credit of losing and gaining individuals. It is not constructed to assess the debit or credit at a population level (i.e., a maternity or hibernaculum colony). It is assumed that the level of take will not incur colony level impacts; it is simply determining the debit and credit associated with a lost or gained individual Indiana bats.

GENERAL INFORMATION ON THE IBAT REA MODEL

Structure

As explained above, the Model entails credits accrued, debits accrued and credit due. The credits are accrued via gained females and gained reproductive potential from mitigation projects that protect or restore habitat; debits are accrued via lost females and reproductive potential from project proponent actions. Figure 1 shows the structure of the Model.

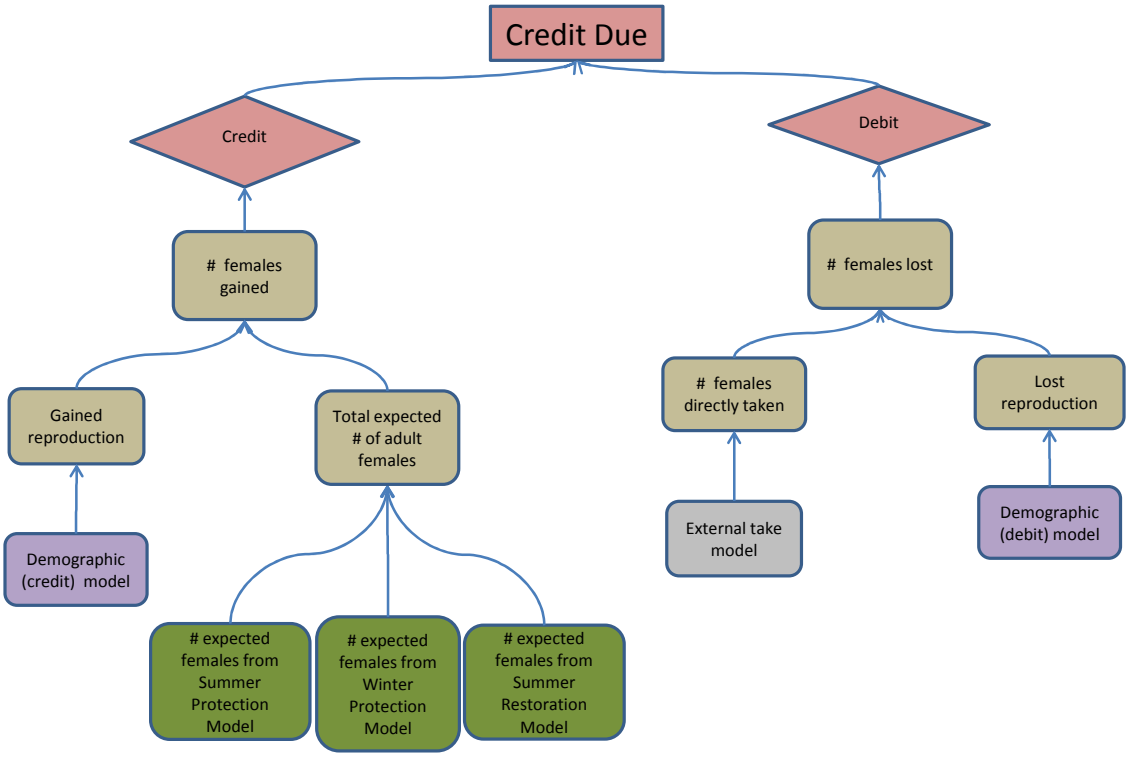
The platform of the Model is an Excel Spreadsheet with multiple, linked tabs corresponding to three mitigation models (Winter Habitat Protection, Summer Habitat Protection, and Summer Habitat Restoration) and a demographic model. For clarity purposes, we refer to these constituent models as modules. In addition, there are four other linked modules within the Model (see Text Box). For all projects the user will enter data into one or more of the mitigation modules and the Impacts module. The Model tabs are labeled (from left to right): Instructions, Conceptual Model, Mit-WinHabPrt (Winter Habitat Protection), Mit-SumHabPrt (Summer Habitat Protection), Mit-SumHabRst (Summer Habitat Restoration), Impacts, Services, and
Parameter Sets.

The spreadsheet modules are easy to use but require the user to understand the input cells. Detailed descriptions of all input and non-input cells are given in the module-specific sections of the User Guide. The mitigation modules are where the user will enter most of the data based on the type of mitigation proposed; the Impacts Module is where the user enters the number of females that will be taken annually and the length of the permit (how long the take will occur). The Impacts module also displays the credit accrued from the mitigation modules and the resulting debit from the take data entered.

Uses

The Model is designed to evaluate the level and types of mitigation appropriate to compensate for the direct take of Indiana bats from wind energy projects. As stated above, it is not constructed to analyze population level impacts nor is it appropriate to use if impacts are to habitat rather than animals. The determination of the amount of direct take must be completed prior to using the Model. Lastly, as the Model is based upon Indiana bat biology, it is not readily suited for use on other species.

Figure 1. A schematic of the Indiana bat REA Model.



Credit due is the difference between the debit accrued via a proposed project and the credit gained via a mitigation project. The gained reproduction and the lost reproduction are derived from the same demographic model. The number of adult females gained is calculated via mitigation-specific modules. The number of females directly taken is calculated via take models independent of the Indiana bat REA model.

The Model necessarily specifies thresholds, but we fully anticipate FO biologists to interject their professional judgment. For example, it may be the case that a hibernaculum does not meet the model's definition of "easily accessible," yet you have experience and knowledge that human disturbance is a threat at this cave. We would expect biologists to override the model by selecting "yes" for this input cell. To be most effective, biologists should use their professional judgment and site-specific knowledge in applying the model. We recommend the reasons underlying such overrides be documented for the administrative record.

Keys to Fonts, Colors, and Symbols

For clarity, we use specific fonts to distinguish between input and non-input cells, and different styles or symbols to highlight input options.

- References to data entry cells are typed in Courier New brown. For example, "`Project Start Year` **[**C4]" indicates that in cell C4 of the Summer Habitat Protection Module an entry is required, in this case the project start year.

- The input into those cells is identified by Courier New brown, bold italics to indicate the possible entries. For example, "`Clumped or clustered` [C13] – This is a ***Yes*** or ***No*** toggle." Yes and no are possible entries at cell C13 of the Winter Habitat Protection Module.

- Double quotation marks are used to identify Model components that do not require inputs or are automatic inputs (e.g., "Expected female gain").

- Throughout the User Guide, terms that are defined in the glossary are highlighted the first time in each module in Times New Roman bold font.

- Text Boxes are used to offer additional explanation or call key elements to the reader's attention.

Users must zero-out the inactive mitigation modules prior to entering data into the module being used – make "Expected female gain" read zero by entering zero in the relevant acreage cell for any module you are not using. Cells for summer restoration and winter protection should be zeroed- out for a summer protection project. This is not required when using multiple modules to calculate different restoration components of a single project. For example, if a project has both summer habitat protection and restoration components, zero-out the winter protection module only.

Fundamental Assumptions

In addition to the standard biological assumptions we typically apply (e.g., average home range of a maternity colony is a 2.5 mile radius around a roost tree; average maternity colony size is 80 females, 1:1 sex ratio) the following assumptions underlie the Model:

1. 46 acres of suitable summer habitat can support 1 female bat

The amount of habitat required to support a colony s is dependent upon the quality and juxtaposition of essential resources and is therefore inherently difficult to determine. Looking at habitat use for multiple colonies across a diverse landscape, however, can lend some insights to answering the question of how much habitat is needed to support a colony. Drawing from a GIS habitat analysis of 138 maternity colonies, we are assuming that 46 ac of suitable habitat will support 1 female. The metric was derived by plotting the locations of approximately 269 bat locations from the states of MO, IL, KY, IN, MI, OH, and IA. Using the standard 2.5 mile home range radius, we delineated the location of 138 maternity colonies. Using U.S. Geological Service 2006 NLCD data, we quantified the amount of summer habitat (broadly defined to include the four major classes of trees. The acres of habitat were summed across all home ranges and divided by the

estimated total females in the 138 maternity colonies yielding 46 acres per female Indiana bat. Additional refinement of this number is currently under investigation.

2. Mis-estimations of credit gained due to local conditions will be offset in the aggregate.

For any one project, it is uncertain whether a female gain will incur. We have constructed the Model and applied minimum requirements to combat this uncertainty from aggregate perspective. The number of credits accrued may not meet the anticipated amount for any single project (and for winter protection projects, we will never know whether the gain was realized), while for other projects, the mitigation may accrue more females than predicted (e.g., bats continue to successfully use restored habitat beyond our predicted timeframe). Because we have built in conditions to mediate this uncertainty, we believe, in aggregate, the projects will offset the composite take that occurs.

3. Indiana bats are lethally injured and are 2 years old.

The basis for this supposition is simply the majority of bats on the landscape are adults and that most of the mortality (at least from wind energy facilities) seems to occur in the fall (i.e., post breeding). Thus, it is reasonable to assume females killed after their second breeding year.

Model Requirements

In addition to these assumptions, there are several over-arching conditions that must be met in order to use the Model. They include:

A summer habitat component must be included in all mitigation projects. The reason for this condition is to sufficiently address uncertainty. We have evidence that bats will use restored/enhanced habitat (Lori Pruitt, U.S. FWS, personal communication), and thus, have reasonable confidence that the take anticipated will be offset by restoration mitigation. For winter protection, however, we are less certain that gating will gain females as the gain relies on an unknowable future action. Requiring a summer component to accompany a winter mitigation project reduces this uncertainty by increasing our confidence that a gain will be delivered.

A minimum of 46 acres of suitable Indiana bat habitat must be protected or restored at each maternity colony. The reason for this condition is twofold. First, given fundamental assumption #1, to ensure that at least one female is produced, 46 acres of habitat must be restored or protected. Second, from a logistic perspective, managing and tracking mitigation projects across Region 3 may quickly become onerous. To minimize the number of small mitigation projects, we are imposing the minimum mitigation package size.

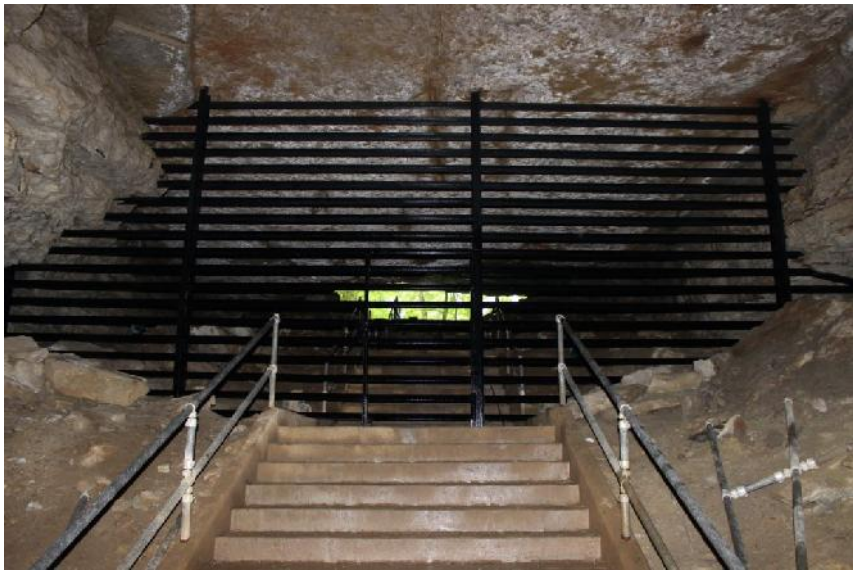
All restored habitat must be permanently protected (i.e., fee simple, easement, or other method agreed upon by the applicant and the Service). This is a standard mitigation requirement, which simplifies the tracking of mitigation and helps ensure that maternity colonies that realize an increase in size because of the mitigation are not stressed by the removal of that additional habitat as it matures and begins to provide additional benefits.

Mitigation Options

Currently, the Model evaluates 3 types of mitigation options, which are hibernacula protection, summer habitat protection, and summer habitat restoration. The three options constructed were chosen because we have data upon which we could develop region wide metrics and decision rules. For example, maternity colony radio-telemetry studies are numerous across the range. As further explained in the Fundamental Assumptions section, we believe an acre/female metric can be derived and scientifically supported from the maternity colony studies conducted. Similarly, we have robust data on Indiana bat use of hibernacula and sufficient information on the harmful effects of human visitation to establish and attempt to quantify the value of hibernacula protection. Other mitigation options may exist, but as of yet, we are unable to develop scientifically based metrics.

An obvious example of a potential mitigation option is swarming habitat. The importance of swarming habitat is well documented, but the question is can we derive a scientifically robust relationship between winter colony size and the amount of swarming habitat needed? It seems logical to assume that the amount of swarming habitat required is correlated with the size of the winter colony. However, based on the analyses completed to date, we are unable discern any such relationship; the number of studies are just too few and too variable to soundly quantify this relationship. A more detailed analysis of existing data might provide better clarity of the relationship between the size of a winter colony and the requisite swarming habitat. If so, a swarming habitat mitigation option can be incorporated into the Model at that time.

Therefore, although there may be other viable mitigations options, they are currently outside the purview of the Model. Field Offices that wish to consider other such options should evaluate the proposal with particular attention to the mitigation's contribution of additional Indiana bats to the population, and document that in their decision rationale.



R3 Indiana Bat REA Model Winter Habitat Protection Module

BACKGROUND

Winter habitat protection is one of the three available types of mitigation modules comprising the REA Model. The Winter Habitat Protection Module (Winter Module) has the following mitigation option(s) available:

- Gating a known hibernaculum

The above option reflects the only currently supported mitigation action involving winter habitat. Project proponents could meet part of their mitigation requirements for the take of individual Indiana bats by protecting **hibernacula**. A winter habitat protection proposal (mitigation proposal) may include the protection of one or more hibernacula, with one or more **gating** actions (protection project).

The logic underpinning this module is that by essentially eliminating the likelihood of a catastrophic impact from **unauthorized human visitation**, the number of female bats that survive hibernation to reproduce is increased. This leads to an "**Expected female gain"** over a specified number of years identified in the model. In order for the "Expected female gain" to be realized, there must be some chance that a catastrophic disturbance event would have occurred but for the gating. The module is constructed so that only projects with a reasonable likelihood of a catastrophic event occurring are considered. A conceptual model and the underlying formulas of the Mit-WinHabPrt module are provided in the Supporting Models chapter.

Winter Mitigation Protection is defined narrowly in REA Model v 3 to gating known hibernaculum with existing populations of vulnerable, wintering Indiana bats. Management authority must be sufficient to provide for Indiana bat population monitoring and monitoring and maintenance of the gate. Opportunities for this mitigation option are likely limited.

INSTRUCTIONS FOR WINTER MODULE DATA INPUT

Below we provide instructions for inputting data into the Winter Module. It is composed of two parts: Project details, and Hibernaculum Conditions.

Input Cells

Project Details

`Project Start Year` [C4] – Input the year that the mitigation project is in place on-the-ground (note this may be different from the first year of a project proponent's permit).

`Project end year (include 10 years beyond last monitoring year)` [C5] – Input the last year for which the project proponent is responsible for monitoring the mitigation plus an additional 10 years to account for a reasonable period the project could be expected to continue to accrue benefits (note this additional period could be reduced or increased with justification by the Field Office).

Hibernaculum Conditions

`N (population size of hibernaculum)` [C7] – Input the total number of Indiana bats using the hibernaculum as of the last biennial census (unless there has been a known change and a more recent and reliable population estimate exists).

`Evidence of disturbance/vandalism?` [C8] – This is a ***Yes*** or ***No*** toggle. Select ***Yes*** if there is documented physical evidence or past accounts of human disturbance or acts of vandalism at the hibernaculum. If ***No*** is selected, winter habitat protection is not a valid mitigation project at this hibernaculum.

`Cave easily accessible` [C10] – This is a ***Yes*** *or* ***No*** *toggle. Select* ***Yes*** if there is easy access to the cave. Select `No` if access to the cave is difficult,(i.e., requires technical or vertical gear or no roads within one mile of the entrance). If ***No*** is selected, winter habitat protection is not a valid mitigation project at this hibernaculum.

`Bats in accessible cave locations` [C11] – This is a ***Yes*** or ***No*** toggle. Select *`Yes`* if bats hibernate near entrances or areas of the cave easily accessible by visitors (e.g., a long "belly crawl" is <u>not</u> required to reach hibernating bats). Select *No* if all Indiana bats hibernate deep within the cave or other areas not accessible by visitors. If *No* is selected (no Indiana bats are in accessible locations) winter habitat protection is not a valid mitigation project at this hibernaculum.

`Low ceiling` [C12] – This is a ***Yes*** or ***No*** toggle. Select ***Yes*** if the ceiling (s) where accessible Indiana bats are hibernating [C11] (above) is 10 feet or lower, allowing hibernating bats to be easily reached or harmed. If *No* is selected for both this input and the ***Clumped or clustered*** input below, winter habitat protection is not a valid mitigation project at this hibernaculum.

`Clumped or clustered` [C13] – This is a ***Yes*** or ***No*** toggle. Select ***Yes*** if most of the accessible bats [C11] (above) are hibernating in clusters allowing the majority of bats to be harmed with minimal effort. If ***No*** is selected for both this input and the `Clumped or clustered` input below, winter habitat protection is not a valid mitigation project at this hibernaculum.

`Proportion of N in accessible locations` [C15] – There are four options for this input: *< 25%*, ***25–49%***, ***50-74%***, and ***75% or greater***. If the answer to [C11] (above) is ***Yes***, an estimate of how many bats are accessible is required. This is the number of bats out of the total hibernaculum population that are in harm's way, and is the number upon which "Expected female gain" will be based.

The determination of bat accessibility will be based upon the best available data. These parameters are meant to provide the Field Office with help to establish, for purposes of the Model, the general location and position of most of the vulnerable bats in a hibernaculum in most years under "normal" conditions.

Non-input Cells

Vulnerability of bats to disturbance [D9] – is a function of `Cave easily accessible` [C10], `Bats in accessible cave locations` [C11], `Low ceiling` [C12], and `Clumped or clustered` [C13]. If [C10] or [C11] or both [C12] and [C13] are ***No***, [D9] is 0.

Expected female gain [C16] - is the output of the Winter module This would be calculated independently for each cave gated, and potentially for each gate where multiple gates protect one hibernaculum if each gate protected a different part of the population. In that case, the sum of "Expected female gain" for each calculation would be used as the total for the protection project the winter habitat mitigation proposal. The "Expected female gain" will be 2% of the vulnerable population if the "Hibernaculum Conditions" are met. Under certain conditions, unauthorized

visits to a hibernaculum could have a greater impact on bats than is accounted for in the model. For example, if there is evidence that repeated disturbance is causing reduced fitness of a larger percentage of the vulnerable population than might be killed. We do not expect this to be common, but where it can be demonstrated, a higher percentage (> 2%) can be assigned to "Expected female gain". Where this circumstance is suspected, the applicant or Field Office should coordinate with the REA Model managers.

Winter Module Example

The project proponent estimates take of 3 female Indiana bats every year over a 25 year ITP beginning in 2013. The `Lambda Condition` is ***`Stationary`*** (Figure 1). The debit accrued is 217.5 Indiana bats (Figure 2).

Figure 1 – Winter Example Input Parameters Impacts Module

Permit start year:	**2013**		2038
Injured Adult Females Annually:	**3**		
Permitted take years	**25**	years to 2038	
Lambda condition	**Stationary**		
Adult Female Breeding Rate	0.601	pups/female/year = AP*AB	
Adult F-F Breeding Rate	0.301	female pups/female/year	
Juvenile Female Breeding Rate	0.143	pups/female/year	
Juvenile F-F Breeding Rate	0.071	female pups/female/year	

Pup Survival to juvenile	0.636	rate
Juvenile Annual Survival	0.697	rate
Adult Annual Survival	0.873	rate

The project proponent proposes to gate a hibernaculum with a total population of 5,000 bats based on the 2011 biennial census. Both known cave entrances are near county roads and both are visible to casual visitors to the area. Both are also un-gated. The project proponent wants to construct their mitigation in 2013 and the project end year (i.e., the last year of monitoring per their ITP) is 2033. Census counts over the last 10 years indicate that Indiana bats are located in two areas of the cave isolated from each other and each associated with one of the known entrances. The project proponent proposes gating projects for both cave entrances.

Figure 2 – Debit Accrued Winter Protection Project

Debit Accrued		
Undiscounted		
Direct take	75.0	female adults
Total lost reproduction	142.5	female pups
Total Lost	**217.5**	

Figure 3 reflects inputs for hypothetical Winter Protection project involving constructing a gate at Entrance A. This entrance opens into a chamber where approximately 40 percent of the 5,000 bats hibernated based on the 2011 biennial census. In this chamber the ceiling averages 20 feet high, but most of the 2,000 bats are hibernating in a few large clusters.

Required inputs include the project start and end years. `Project start year` is the year mitigation would be constructed (2013) and does not necessarily coincide with the first year of the ITP. The project end year is defined as the last year the project proponent is required under the ITP to monitor mitigation (2033) plus an additional 10 years. `N (population size of the hibernaculum)` is the estimated total Indiana bat population of the hibernaculum, in this case 5,000. In this case the project proponent has been able to demonstrate to the Field Office that there is evidence of disturbance at this cave and has entered ***Yes***. It is clear that the cave is easily accessible and in the case of Entrance A, that the bats are in an accessible location near the entrance (***Yes*** is entered for both). For a viable project, bats have to be either hibernating in a few discreet groups, hibernating within easy reach, or both. In this case, the ceiling is high, but the bats are hibernating in a few large clusters. Therefore **No** has been entered for `Low ceiling` and ***Yes*** for `Clumped or clustered`. We assume that biologists conducting the biennial census were able to estimate the percentage of bats hibernating in this chamber at about 40 percent, and ***25-49%*** is selected. The inputs for this project yield an "Expected female gain**"** of 25.

Figure 3 – Project 1 Winter Protection Proposal

Hibernaculum protection		
Project Details:		
Project start year	2013	
Project end year (include 10 years beyond last monitoring year)	2043	
Hibernaculum Conditions:		
N (population size of hibernaculum)	5,000	
Evidence of disturbance/vandalism?	Yes	0.02
Vulnerability of bats to disturbance:		1
Cave easily accessible	Yes	1
Bats in accessible cave locations	Yes	1
Low Ceiling	No	0.00
Clumped or clustered	Yes	1
Likelihood of disturbance		0.02
Proportion of N in accessible locations	25-49%	0.50
Expected female gain	25.00	

Project 2 involves constructing a gate at Entrance B, which opens into a small chamber leading to a near vertical descent that requires technical climbing gear. A belly crawl is required at the bottom of the vertical shaft, which opens into several small chambers. Although difficult to census, it is estimated that about 60 percent of the population of Indiana bats hibernate in this area of the cave.

The first five required inputs in Figure 4 are the same as in Figure 3. `Bats in accessible cave locations` is subjective and ultimately determined by the Field Office.

Figure 4 – Project 2 Winter Protection Proposal

Hibernaculum protection		
Project Details:		
Project start year	2013	
Project end year (include 10 years beyond last monitoring year)	2043	
Hibernaculum Conditions:		
N (population size of hibernaculum)	5,000	
Evidence of disturbance/vandalism?	Yes	0.02
Vulnerability of bats to disturbance:		0
Cave easily accessible	Yes	1
Bats in accessible cave locations	No	0
Low Ceiling	Yes	1.00
Clumped or clustered	No	0
Likelihood of disturbance		0.00
Proportion of N in accessible locations	50-74%	0.00
Expected female gain	0.00	

In this case, because climbing gear and a long crawl are required to reach the Indiana bats, ***No*** is the appropriate answer here. The bats are dispersed in several low chambers at the end of the crawl, and represent about 60% of the cave's population. ***Yes, No***, and ***50-74%*** are entered. Since the bats are determined not to be in accessible, however, the "Expected female gain**"** for this project is 0.

Figure 5 is from the Impact Module indicating the results of the calculation of mitigation credit. The Impacts Module is explained in more detail in that chapter. For this example, the direct females added by the project ("Expected female gain**"**) as calculated in the Winter Habitat Module is 25. The total reproduction gained is 84 female Indiana bats. The "**Total Gain**" from gating Entrance B (in this case 0) is added manually to the 84 females for a summed "Total Gain" of 84 female Indiana bats (note the Impact Module will add the value of two different types of projects, a summer protection and winter protection, for example, but it will not automatically sum the "Total Gain" for multiple projects of the same type). Figure 6 indicates that the project proponent remains 133.5 female Indiana bats short of the required mitigation.

Figure 5 – Mitigation Credit Accrued Winter Protection 1 and 2

Mitigation Credit Accrued		
Undiscounted		
Direct females added by project	25.0	female adults
Summer habitat protection	-	female adults
Hibernaculum protection	25.0	female adults
Maternity habitat restoration	-	female adults
Total reproduction gained	59.1	female pups
Total Gain	**84.0**	**females**

Figure 6– Mitigation Credit Due Winter Protection 1 and 2

Mitigation Credit Due		
Net gained	**-133.5**	
Total qualifying mitigation acres	**0.0**	must be >46 acres

R3 Indiana Bat REA Model Summer Habitat Protection Module

BACKGROUND

Summer Habitat Protection (Summer Protection) module is the second of the three available mitigation modules comprising the Model. It is located at the tab labeled Mit-SumHabPrt. The Summer Protection Module has the following options available:

- Protection of roosting and foraging habitat
- Protection of foraging-only habitat
- Protection of functional travel corridor
- Protection of roosting and foraging plus corridor habitat

A summer habitat protection proposal must include the protection of occupied maternity colony habitat that is currently threatened. It may include roosting, foraging, or travel corridor habitat. The Level of threat is a function of a physical or other manageable stressor. The "**Expected female gain"** is a function of the carrying capacity of the "to be protected forest blocks" and the level of threat to such forest blocks. The carrying capacity is a function of size of the forest block "to be protected" or size of the termini forest blocks connected by the "to be protected" corridor. Based on analysis of 138 Indiana bat home ranges across the MRU, the estimated acres required to support one female bat at a maternity colony is 46 acres. This constitutes the baseline in both the Summer Habitat Protection and Summer Habitat Restoration modules.

The logic underpinning this module is that protection of the habitat will prevent the loss of occupied habitat thereby preventing the loss of reproductive capacity by the colony using the habitat. This leads to an "Expected female gain**"** over a specified number of years identified in the model. The module is constructed so that only mitigation projects with a reasonably high **threat level** (***Imminent demonstrable threat*** or are threatened because of scarcity of habitat (***Limited habitat threat***) are considered. A conceptual model and the underlying formulas of the Summer Protection module are provided in the Supporting Models chapter.

INSTRUCTIONS FOR DATA INPUT

Below we provide instructions for inputting data into the Summer Protection module. The module is divided into two parts: "Project Details" and "Required Conditions".

Project Details

`Project Start Year` **[**C4] **-** Input the year that the mitigation project is in place on-the-ground (note this may be different from the first year of a project proponent's permit).

`Project end year (include 10 years beyond last monitoring year)` [C5] **-** Input the last year for which the project proponent is responsible for monitoring the mitigation plus an additional 10 years to account for a reasonable period the project could be expected to continue to accrue benefits (note this additional period could be reduced or increased with justification by the Field Office).

`Habitat function Served by the "to be protected" habitat` [C6] **-** Select among the following four options: `Roosting & Foraging`**,** `Foraging only`**,** `Functional Travel Corridor`**,** ***or*** `Roosting & Foraging + Corridor`.

- Select `Roosting & Foraging` if the "to be protected" habitat has at least one active primary or secondary roost tree within it and is sufficiently large and suitable that other roost trees are likely to be available in the future. Use your biological judgment to determine whether or not the habitat is of sufficient size and quality to offer future roosting and foraging habitat. Your supporting rationale should be recorded in the applicable section 7 or 10 document.

- Select `Foraging only` if the "to be protected" habitat is forested and suitable as foraging habitat, but does not have known existing primary or secondary roost trees within it.

- Select `Functional travel corridor` if the "to be protected" habitat serves only as a corridor. A functional travel corridor is one that: (1) connects two isolated (i.e., at least 500 feet apart) forest blocks (termini) of at least five acres and (2) serves as the only--or an otherwise essential--conduit between the forest blocks. The first requirement is straight-forward. The second requires the Field Office to determine whether or not the forest blocks would become functionally isolated should the corridor be lost. If yes, it meets the second requirement of a `Functional travel corridor`. There are two possible corridor project scenarios. The user must be cognizant of the particular scenario that is applicable to their situation to correctly use the model. If either scenario applies, select `Functional travel corridor`. In the first scenario, a `Functional`

travel corridor connects two occupied forest blocks, and at least five acres of both are blocks are adequately protected by a third party (state or local government, an NGO, etc). A second possible scenario occurs when a forest block is restored along a corridor (at least 500 feet from an occupied forest block). The existing corridor could be protected as a part of the restoration project (note, the credit for the restoration portion is calculated separately using the "Summer Habitat Restoration" module).

- Select Roosting & Foraging + Corridor if there are both corridor and roosting & foraging protection components as described above. Roosting & Foraging + Corridor protects the corridor along with protection of a minimum of five acres at one or both termini. The key in this scenario is the applicant not only protects the corridor but must provide protection for at least five acres of one or both of the termini (in the one- terminus protection scenario, the other terminus is protected by a third party or as in the Functional travel corridor example, could be restored). Normally under Roosting and Foraging + Corridor at least one terminus has to be roosting habitat - connecting two patches of foraging habitat would not be acceptable (the Field Office, however, could accept with justification).

Acreage of the "to be protected" occupied forest block [C7] - Input the amount (in acres) of Roosting & Foraging or Foraging only habitat protected by the applicant (note this is grayed-out except when the Roosting & Foraging or Foraging only options are selected. Habitat protected by a third party should not be entered here.

Acreage of the "to be protected" corridor [C8] - Input the amount (in acres) of corridor habitat protected by the applicant. This is grayed-out except when one of the two corridor options (Functional travel corridor or Roosting & Foraging + Corridor) are selected (note this will typically be a small number and could be less than an acre when the corridor is near the minimum 500 feet long and approximately 30 feet wide).

Acreage of the "to be protected" roosting and foraging habitat [C9] – Input the amount (in acres) of roosting and foraging habitat protected by the applicant when there is also corridor protection (note that "**Qualifying acreage**" is only counted when both [C8] and [C9] are non-zero). This line is active only when Roosting & Foraging + Corridor is selected.

More complex mitigation efforts could involve both protection and restoration elements and will require the project proponent to use two different modules (i.e., Summer Habitat Protection and Summer Habitat Restoration) to complete the mitigation calculation.

Required Conditions

`Is the "to be protected" roosting and foraging habitat >=5 acres?` [C11] – This is a ***Yes*** or ***No*** toggle. Indicate whether or not at least five acres of roosting or foraging habitat is being protected.

`Are the "to be connected" termini blocks >500' apart?` [C12] - This is a ***Yes*** or ***No*** toggle. Indicate whether the termini are more than 500 feet apart at their nearest point (i.e., the habitat patches connected by the corridor are isolated). This line is active when one of the two corridor habitat functions is selected in cell C6. If you enter ***No***, the "Expected female gain**"** and "Qualifying acreage" go to 0.

`Are the occupied "to be connected" termini blocks >= 5acres?` [C13] – This is a ***Yes*** or ***No*** toggle. Indicate whether or not both of the termini forest blocks are at least five acres. Select ***Yes*** if this is the case. If you enter ***No***, the "Expected female gain**"** and "Qualifying acreage" will go to 0.

`Are the unoccupied "to be connected" terminus block >=20 acres?` `[C14]-` There are ***Yes***, ***No,*** or ***NA*** options. It is possible that a valid corridor project could connect an occupied terminus to an unoccupied terminus. In this case, the unoccupied terminus must be at least 20 acres to provide a greater chance that the unoccupied habitat is suitable and will be used – if it is less than 20 acres select ***No*** ("Expected female gain**"** and "Qualifying acreage" will go to 0). If unoccupied habitat is 20 acres or larger, select ***Yes***. If both termini are occupied the requirement is that they only have to be 5 acres, in this case select ***NA***.

`Will or are both termini forest blocks protected?` `[C15]` - This is a ***Yes*** or ***No*** toggle. For a valid corridor project both termini must be protected. This can occur as part of the mitigation project or the habitat can be protected by a third party. If at least 5 acres of both termini are protected, select ***Yes,*** if not select ***No*** in which case "Expected female gain**"** and "Qualifying acreage" will go to 0.

`Level of threat` [C17] - Select the `Level of threat` currently facing the "to be protected" habitat from among the following three choices: ***Imminent demonstrable threat***, ***Limited habitat threat***, and ***No demonstrable threat***. Select

Imminent demonstrable threat if there is credible information indicating that the quality of the "to be protected" forest block or corridor would be reduced within 10 years unless protected. Select ***Limited habitat threat*** if % forest cover of the estimated maternity colony home range is less than 20 percent. Calculate % forest cover by defining the boundaries of the maternity colony home range and use GIS or other appropriate evaluation methods to determine the percent of the site that is suitable Indiana bat habitat. Select ***No demonstrable threat*** if the "to be protected" forest block or corridor is unprotected, but forest cover in the estimated maternity colony is >= 20% and there is no ***Imminent demonstrable threat*** as defined above. Both ***Imminent demonstrable threat*** and ***Limited habitat threat*** yield the same value for "Expected female gain**"**, all else being equal. A determination of ***No demonstrable threat*** causes "Expected female gain**"** and "Qualifying acreage" to go to 0.

EXAMPLE OF SUMMER PROTECTION PROJECT

The project proponent plans to compensate for part of their mitigation debt by protecting summer habitat within 2.5 miles of a known Indiana bat maternity colony. The project proponent surveyed the site the previous summer and determined the location of two roost trees, which established the center of the 2.5 mile radius circle. The project proponent used recent landcover data supplemented with aerial photographs to determine that the percentage forest cover within the 2.5 mile radius circle is approximately 20 percent. The mitigation proposal consists of two separate projects at the same maternity colony. In this example the project proponent has estimated take of 2 female Indiana bats per year for 20 years under a ***Stationary*** `Lambda Condition` for an accrued debit ("Total Lost") of 116 female bats (Figure 1).

Figure 1 - Debit Accrued Summer Protection Project

Debit Accrued		
Undiscounted		
Direct take	40.0	female adults
Total lost reproduction	76.0	female pups
Total Lost	**116.0**	

Project 1 involves the protection of 25 acres (containing one of the known roost trees) of a 70 acre forested block. It is proposed to start in Year 1 of the ITP.

The `Project start year` is 2013 and `Project end year (include 10 years beyond last monitoring year)` is 2033 with 10 years added beyond the last monitoring period (assumed to be the last year of the project). Because it has been established that the proposed `Acreage of the "to be protected" occupied forest`

block (25 acres) encompasses one of known roost trees, the Field Office agrees that this is a Roosting & Foraging protection project. The project proponent has established that the forest cover within the estimated home range is less than 20 percent and therefore the Level of Threat is ***Limited habitat threat***. The "Expected female gain**"** is calculated as 0.54 (Figure 2).

Figure 2 – Project 1 Summer Protection Proposal

Summer habitat protection			
Project Details:			
Project start year	**2013**		
Project end year (include 10 years beyond last monitoring year)	**2043**		
Habitat function served by the "to be protected" habitat	**Roosting & Foraging**		
Acreage of the "to be protected" occupied forest block	**25**	1.00	
Acreage of the "to be protected" corridor	3.0	Qualifying acreage	25
Acreage of the "to be protected" roosting & foraging habitat	20		
Required Conditions:		1.00	implies 46 acres/bat
Is the "to be protected" roosting and foraging habitat >=5 acres	**Yes**	1.00	
Are the "to be connected" termini blocks >500' apart	Yes	1.00	
Are the occupied "to be connected" termini blocks >= 5acres	Yes	1.00	
Is the unoccupied "to be connected" terminus block >=20 acres	NA	1.00	
Will or are both termini forest blocks protected	Yes	1.00	
Expected K		0.54	
Level of threat	**Limited habitat threat**	1.00	
Expected female gain	**0.54**		

Figure 3 indicates the credit for the 25 acres of permanent protection equates to 16 female bats. Note that Figure 4 alerts the project proponent that they have met neither their required "**Total Gain**" (-100.0 female bats) nor their required 46 acres at this maternity colony (they still need 21 acres).

Figure 3 – Project 1 Mitigation Credit Accrued

Mitigation Credit Accrued		
Undiscounted		
Direct females added by project	4.9	female adults
Summer habitat protection	4.9	female adults
Hibernaculum protection	-	female adults
Maternity habitat restoration	-	female adults
Total reproduction gained	11.6	female pups
Total Gain	**16.0**	**females**

Figure 4 – Project 1 Mitigation Credit Due

Mitigation Credit Due		
Net gained	-100.0	
Total qualifying mitigation acres	25.0	must be >46 acres

Project 2 is a corridor project at the same maternity colony. It involves the protection of 2.5 acres of a narrow riparian corridor connecting a 19 acre block of forest approximately 1500 feet from a 75 acre patch of mature forest protected in perpetuity by a local land trust (Figure 5). The land trust site contains the other known roost tree for this colony. Both sites are presumed to be occupied because an existing corridor connects the land trust site (with the roost tree) to the 19 acre forest block. The area containing the 19 acre block of forest has been identified in a county planning document as a potential site for an industrial park. The 19 acres will be permanently protected by the project proponent. This project will not be implemented until 2023.

Figure 5 – Project 2 Mitigation Diagram

Figure 6 shows that `Roosting & Foraging + Corridor` has been selected because this project is protecting both and existing corridor and protecting a block of existing habitat (note that since the 19 acre block is connected by an extant corridor to the known occupied habitat, it is presumed occupied).

The "Qualifying acreage" is the sum of the riparian corridor acreage to be protected and the forest block to be protected. ***NA*** is selected for `Are the unoccupied "to be connected" terminus block >=20 acres?` because in this case unoccupied habitat is not part of the proposal. The "Expected female gain "is slightly lower than the previous example at 0.41.

Figure 6 – Project 2 Summer Protection Proposal

Summer habitat protection			
Project Details:			
Project start year	2023		
Project end year (include 10 years beyond last monitoring year)	2043		
Habitat function served by the "to be protected" habitat	Roosting & Foraging + Corridor	1.00	
Acreage of the "to be protected" occupied forest block	25		Qualifying acreage 21.5
Acreage of the "to be protected" corridor	2.5		
Acreage of the "to be protected" roosting & foraging habitat	19		
Required Conditions:		1.00	implies 46 acres/bat
Is the "to be protected" roosting and foraging habitat >=5 acres	Yes	1.00	
Are the "to be connected" termini blocks >500' apart	Yes	1.00	
Are the occupied "to be connected" termini blocks >= 5acres	Yes	1.00	
Is the unoccupied "to be connected" terminus block >=20 acres	NA	1.00	
Will or are both termini forest blocks protected	Yes	1.00	
Expected K		0.41	
Level of threat	Imminent demonstrable threat	1.00	
Expected female gain	0.41		

The credit for this project is 8 females gained (Figure 7). This would be added to the 16 females gained from Project 1 for a total of 24. The remaining mitigation debt is 92 bats. With the addition of Project 2's "Qualifying acreage" of 21.5 acres (forest block and corridor), the project proponent has met the **46 acre** minimum requirement at this maternity colony.

Figure 7 – Project 2 Mitigation Credit Accrued

Mitigation Credit Accrued		
Undiscounted		
Direct females added by project	2.5	female adults
Summer habitat protection	2.5	female adults
Hibernaculum protection	-	female adults
Maternity habitat restoration	-	female adults
Total reproduction gained	5.9	female pups
Total Gain	**8.0**	**females**

R3 Indiana Bat REA Model Summer Habitat Restoration Module

BACKGROUND

Summer habitat restoration is the third of three available types of mitigation modules comprising the Model. It is located at the tab labeled Mit-SumHabRst. The Summer Habitat Restoration (Summer Restoration) Module has the following options available:

- Restoration of Roosting and Foraging Habitat
- Restoration of Corridor Habitat
- Restoration of Roosting and Foraging plus Corridor Habitat

The logic underpinning this module is that by increasing the acres of maternity colony habitat, the connectivity of existing maternity colony habitat, or both, the K (carrying capacity) of the colony increase and thereby increasing the number of bats in the colony and subsequent reproductive potential.

Summer habitat restoration is only valid at sites that are habitat limited and like the Summer Habitat Protection module can only occur at extant maternity colonies. These are defined generally as a 2.5 mile radius circle around a known roost tree (s) (see USFWS Section 7 Guidance for Wind Energy Projects to help more precisely delineate Indiana bat home range).

For maternity colonies that are **severely habitat limited** (=< 20% forest cover) the model allows for a 4.5 multiplier to encourage restoration on those sites where the principal threat is limited forestarea and the colony may be in decline from lack of suitable habitat.

A conceptual model and the underlying formulas of the Summer Restoration module are provided in the Supporting Models chapter.

INSTRUCTIONS FOR SUMMER RESTORATION DATA INPUT

Below we provide instructions for inputting data into the Summer Restoration module. This module has three subsections: “Project details”, “Habitat Conditions”, and “Required Conditions”.

Project Details

`Project Start Year` [C4] – Input the year that the mitigation project is in place on-the-ground (note this may be different from the first year of a project proponent's permit).

`Project end year (include 10 years beyond last monitoring year)` [C5] – Input the last year for which the project proponent is responsible for monitoring the mitigation plus an additional 10 years to account for a reasonable period the project could be expected to continue to accrue benefits (note this additional period could be reduced or increased with justification by the Field Office).

`Habitat Function` [C6] – Select the type of restoration being proposed from the three options: ***Roosting and Foraging***, ***Corridor***, or ***Roosting and Foraging + Corridor***. If the project proponent is restoring only roosting and foraging habitat (e.g., 30 acres of cropland 300 feet from existing occupied habitat is being reforested) then ***Roosting and Foraging*** should be selected. For example, if the project proponent is reforesting five acres of cropland (800 linear feet) along a fence row that connects an occupied block of forest to one that is assumed unoccupied, then ***Corridor*** should be selected. If a project proponent is proposing the restoration of a corridor (as above) connecting occupied habitat to a 21 acre area of cropland that will be reforested, the ***Roosting and Foraging + Corridor*** should be selected.

`Acres of "to be restored" forest adjacent to (within 500' of) occupied habitat` [C7] – Input the number of acres restored within 500 feet of one or both termini (the accepted distance Indiana bats will fly across open landscape). This line is active only when `Roosting and Foraging` or `Roosting and Foraging + Corridor` are selected for `Habitat Function` [C6]. `Roosting and Foraging` will be selected in cases of habitat restoration adjacent to existing occupied habitat where no corridor restoration occurs. `Roosting and Foraging + Corridor` is used where corridor restoration occurs along with restoration of habitat adjacent to existing occupied habitat and/or terminus habitat restoration. If no adjacent habitat is restored ***NA*** must be selected at cell [C14] and if the minimum 5 acres is met, ***Yes*** should be selected at cell [C14] (note if terminus habitat is restored, both [C9] and [C16] must also be populated.

`Acres of "to be restored" corridor habitat` [C8] – Input the number of acres restored as corridor. This line is active only when `Corridor` or `Roosting and Foraging + Corridor` is selected for `Habitat Function` [C6]. It applies to restoration of the corridor habitat itself (e.g., three rows of trees planted along a fence row). There is no minimum acreage for this input, but the linear distance of the corridor must be > 500 feet (the number of acres could be less than one for this input if a corridor is near the minimum size of 500 feet long by approximately 30 feet wide).

`Acres of "to be restored" forest at unoccupied terminus` [C9] – Input the number of acres the project proponent will restore at the unoccupied end of a corridor (the occupied end being the extant occupied maternity colony habitat). This is active only when `Roosting and Foraging + Corridor` is selected for `Habitat Function` [C6]. The nearest point of the restoration must be at least 500 feet from the occupied maternity habitat. The minimum acreage for this input is 20 acres.

Habitat Conditions

`Is the project within the known range of a habitat-limited maternity colony?` [C11] – This is a ***Yes*** or ***No*** toggle. This input cell requires the project proponent to document and the FO to verify two conditions of mitigation project, first that the proposed restoration is within the home range (2.5 mile radius) of the center of a known maternity colony, and second that the maternity is habitat limited. Habitat limited is left to the Field Offices to determine and could entail more than simply low forest cover. Both must be true to input ***Yes***. If ***No*** is selected, "**Expected female gain**" and "**Qualifying acreage**" goes to 0.

`Existing % forest cover` [C12] – There are two options ***< 30%*** and ***30% or more***. Select the appropriate percentage of forest based on analysis of forest within a 2.5 mile circle surrounding the approximate center of the known maternity colony where the proposed habitat restoration will occur. Restoration is assumed appropriate at maternity colonies where existing habitat (i.e., forest cover) is limited. If ***30% or more*** is selected, the value of the restoration toward "Expected female gain**"** declines by 25%.

`Is the existing % forest cover =< 20%` [C21] - This is a ***Yes*** or ***No*** toggle. Where forest cover is severely limited for a maternity colony, input ***Yes,*** the "**Expected female gain**" will increase by a factor of 4.5 in the Impact module.

Required Conditions

`"To be restored" forest area >5 acres` [C14] – There are ***Yes***, ***No***, and ***NA*** options. This line is active only when `Roosting and Foraging` or `Roosting and Foraging + Corridor` are selected for `Habitat Function` [C6]. Select ***Yes*** if `Roosting and Foraging` habitat is restored within 500 feet of extant maternity colony habitat. Select ***NA*** if `Roosting and Foraging` habitat is restored at the terminus of a restored corridor. If ***No*** is selected, "Expected female gain" and "Qualifying Acreage" go to 0.

`Unoccupied terminus forested block >500' from occupied forest block` [C15] - This is a ***Yes*** or ***No*** toggle. This input cell is active only when `Corridor` or `Roosting and Foraging + Corridor` are selected for `Habitat Function` [C6]. It applies to the distance between the extant occupied maternity habitat and the presumed unoccupied habitat a corridor will connect. If ***No*** is selected, "Expected female gain" and "Qualifying Acreage" goes to 0.

`Unoccupied terminus forested block >20 ac` [C16] - This is a ***Yes*** or ***No*** toggle. This input cell is active only when `Corridor` or `Roosting and Foraging + Corridor` are selected for `Habitat Function` [C6]. It applies to the area restored at the unoccupied end of a corridor. The minimum acreage ensures that a corridor is not restored to a restored terminus that is too small to be viable. If ***No*** is selected, "Expected female gain" and "Qualifying acreage" goes to 0.

`Will or are both termini forest blocks protected` [C17]- This is a ***Yes*** or ***No*** toggle. This line is active only when `Corridor` or `Roosting and Foraging + Corridor` are selected for `Habitat Function`. Whenever a corridor is restored, both ends termini must either be protected by the applicant as part of the mitigation project or suitably protected by a third party.

A required component in the Summer Restoration module is the identification of the plant material to be used in the restoration. Field Offices will provide specifications, but these should generally fall into three categories (i.e., cottonwoods, softwoods, and hardwoods). The combination is designed to provide for foraging habitat, as soon as, possible and both near term and long term roosting habitat. Species chosen should reflect known roost trees documented in the Draft Indiana Bat Recovery Plan (p 59). The percent of each category, and tree species for softwoods and hardwoods, will be selected based on local and site specific conditions. The proportion of any one category should typically not be lower than approximately 20% and cannot be 0.

EXAMPLE OF SUMMER RESTORATION PROJECT

The project proponent estimates the take of 1 female Indiana bat every year over a 20 year project life. The `Project start year` is ***2018*** and the Service has determined that the `Lambda Condition` for Indiana bats in the recovery unit is ***declining*** (Figure 1).

Figure 1 – Inputs for Summer Restoration Project

Permit start year:	**2018**		2038
Injured Adult Females Annually:	**1**		
Permitted take years	**20**	years to 2038	
Lambda condition	**Declining**		
Adult Female Breeding Rate	**0.562**	pups/female/year = AP*AB	
Adult F-F Breeding Rate	0.281	female pups/female/year	
Juvenile Female Breeding Rate	**0.130**	pups/female/year	
Juvenile F-F Breeding Rate	0.065	female pups/female/year	
Pup Survival to juvenile	**0.585**	rate	
Juvenile Annual Survival	**0.674**	rate	
Adult Annual Survival	**0.857**	rate	

Figure 2 indicates that the "Total Lost" female Indiana bats equals 50.8 from a direct loss of 20 female Indiana bats and lost reproduction of 30.8 bats.

Figure 2 – Debit Accrued Summer Restoration Project

Debit Accrued		
Undiscounted		
Direct take	20.0	female adults
Total lost reproduction	30.8	female pups
Total Lost	**50.8**	

The project proponent proposes to mitigate for the taking in part by restoring habitat at two separate maternity colonies. Primary roost trees have been identified at both sites. GIS analysis using the most recent available **landcover data** indicates the area within the 2.5 mile radius around Site 1 is 25 % forested and the area at Site 2 is 32% forested. The project proponent proposes three separate restoration projects at the two maternity colonies: a `Foraging` project, a `Corridor` project, and a `Foraging + corridor` project. The Field Office has provided guidance on the tree species to be planted, which consist of approximately equal proportions of cottonwoods, softwoods (e.g., soft maples), and hardwoods.

Project 1 involves constructing a corridor along a ditch at Site 1 between the woodlot containing the roost tree and a 25 acre block of existing forest approximately 750 feet away (note that the 25 acre forest block is presumed to be unoccupied in this case because the patch is isolated - no functioning corridor connecting it to the roost tree site).

This project will be implemented in the first year of the **ITP**. The estimated area of the restored corridor, which entails planting 3 rows of trees on 10 foot centers, is approximately 0.5 acre. The project proponent proposes to protect the 25 acre woodlot and 10 acres of the forest that harbors the roost tree (Figure 3). The project proponent must use the Summer Protection module to calculate the existing habitat protected.

Figure 3 – Diagram of Summer Restoration Project 1

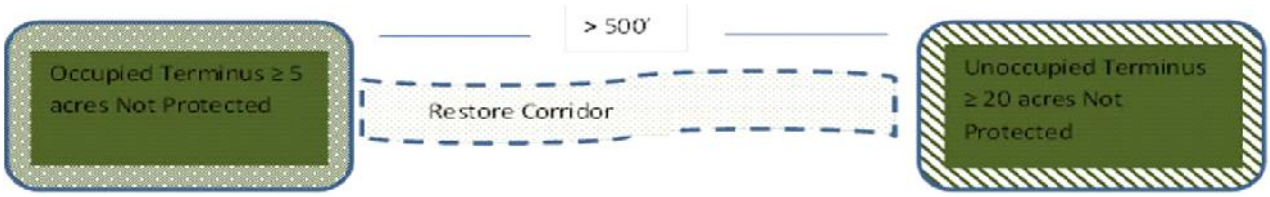


Figure 4 displays inputs into the Summer Restoration module for Project 1 (Restoration). `Project start year` is 2018 and the `Habitat function` is ***`Corridor`***. The project proponent estimates that approximately 0.5 acre of corridor will be restored. This project occurs within the range of a habitat limited maternity colony and ***`Yes`*** is selected – restoration projects are not valid at colonies where habitat is not limiting. Note the "Qualifying Acreage" is 0.5 acres.

Figure 4 – Summer Restoration Project 1

Summer habitat restoration			
Project Details:			
Project start year	2018		
Project end year (include 10 years beyond last monitoring year)	2048		
Habitat function	Corridor		
Acres of "to be restored" forest adjacent to (within 500' of) occupied habitat	46	Qualifying acreage:	6.50
Acres of "to be restored" corridor habitat	0.5		
Acres of "to be restored" forest at unoccupied terminus	6		
Habitat Conditions:			
Is the project within the known range of a habitat-limited maternity colony?	Yes	1	
Existing % forest cover	<30%	1.00	
Required Conditions:		1.00	implies 46 acres/bat
"To be restored" forest area ≥5 acres	Yes	1	
Unoccupied terminus forested block >500' from occupied forest block	Yes	1	
Unoccupied terminus forest block ≥20 ac	Yes	1	
Will or are both termini forest blocks protected	Yes	1	
Expected K		0.22	
Expected female gain	0.22		
Is the existing % forest cover =<20%?	No		

The credit accrued for just the corridor restoration component of this project as displayed in the

Impact module is one female bat (Figure 5).

Figure 5 – Mitigation Credit Accrued Restoration Project 1 (Corridor)

Mitigation Credit Accrued		
Undiscounted		
Direct females added by project	0.4	female adults
Summer habitat protection	-	female adults
Hibernaculum protection	-	female adults
Maternity habitat restoration	0.4	female adults
Total reproduction gained	0.9	female pups
Total Gain	**1.0**	**females**

The simplest way to include the protected acreage is to add the 10 acres that will be protected at the roost tree site and the 25 acres at the site the restored corridor will connect and input this total as `Acreage of the "to be protected" occupied forest block` under `Roosting & Foraging` in the Summer Protection Module (Figure 6). While the 25 acre block is not technically occupied, the proposed corridor will connect the site and we assume that both sites will be occupied within a few years.

Figure 6 – Summer Restoration Project 1 (Protection)

Summer habitat protection			
Project Details:			
Project start year	2018		
Project end year (include 10 years beyond last monitoring year)	2048		
Habitat function served by the "to be protected" habitat	Roosting & Foraging	1.00	
Acreage of the "to be protected" occupied forest block	35		Qualifying acreage 35
Acreage of the "to be protected" corridor	10.0		
Acreage of the "to be protected" roosting & foraging habitat	46		
Required Conditions:		1.00	implies 46 acres/bat
Is the "to be protected" roosting and foraging habitat >=5 acres	Yes	1.00	
Are the "to be connected" termini blocks >500' apart	Yes	1.00	
Are the occupied "to be connected" termini blocks >= 5acres	Yes	1.00	
Is the unoccupied "to be connected" terminus block >=20 acres	NA	1.00	
Will or are both termini forest blocks protected	Yes	1.00	
Expected K		0.76	
Level of threat	Limited habitat threat	1.00	
Expected female gain	0.76		

The "**Total Gain**" from the protection component of Summer Restoration Project is 19 female Indiana bats (Figure 6). Adding the "Total Gain" from the corridor restoration and protection components of Summer Restoration Project results in 20 female Indiana bats gained.

Figure 6 – Mitigation Credit Accrued Project 1 (Protection)

Mitigation Credit Accrued		
Undiscounted		
Direct females added by project	6.4	female adults
Summer habitat protection	6.4	female adults
Hibernaculum protection	-	female adults
Maternity habitat restoration	-	female adults
Total reproduction gained	12.6	female pups
Total Gain	**19.0**	**females**

Users must zero-out the inactive mitigation modules prior to entering data into the module being used – make "Expected female gain" read zero by entering zero in the relevant acreage cell for any module you are not using. If a project, for example, has only a summer protection component, cells for summer restoration and winter protection should be zeroed- out. This is not required when using multiple modules to calculate different restoration components of a single project. For example, if a project has both summer habitat protection and restoration components, zero-out the winter protection module only

Summer Restoration Project 2 involves the restoration of foraging habitat also at Site 1 in a 30 acre row crop field contiguous with the woodlot containing the roost tree. The project will not be implemented until 5 years into the ITP. Restoration adjacent to occupied habitat must be less than 500 feet from the edge of the occupied patch (Figure 7).

Figure 7 – Diagram of Summer Restoration Project 2

Figure 8 displays the inputs into Project 2 (Restoration). Although the project proponent's ITP begins in 2018, `Project start year` is ***2023*** because this project will be implemented five years into the permit term. Note that the Project ends, however, in 2048 (20 years plus 10 years after 2018). The proposed project is a habitat restoration project with no corridor restoration. A ***Roosting & Foraging*** restoration project must be at least 5 acres. Guidelines from the Field Office for this planting are the same as for the corridor in the previous example.

Restoration value in the model is based on planted trees as foraging habitat only because this is understood to be limiting with respect to increasing maternity colony size. In the long term, however, provided a maternity colony remains in the same area, roosting habitat will accrue to all restorations because of the requirement to permanently protect all restoration project sites.

Figure 8 – Summer Restoration Project 2

Summer habitat restoration			
Project Details:			
Project start year	2023		
Project end year (include 10 years beyond last monitoring year)	2048		
Habitat function	Roosting & Foraging		
Acres of "to be restored" forest adjacent to (within 500' of) occupied habitat	30	Qualifying acreage:	30.00
Acres of "to be restored" corridor habitat	0.5		
Acres of "to be restored" forest at unoccupied terminus	6		
Habitat Conditions:			
Is the project within the known range of a habitat-limited maternity colony?	Yes	1	
Existing % forest cover	<30%	1.00	
Required Conditions:		1.00	implies 46 acres/bat
"To be restored" forest area ≥5 acres	Yes	1	
Unoccupied terminus forested block >500' from occupied forest block	Yes	1	
Unoccupied terminus forest block ≥20 ac	Yes	1	
Will or are both termini forest blocks protected	Yes	1	
Expected K		0.65	
Expected female gain	0.65		
Is the existing % forest cover =<20%?	No		

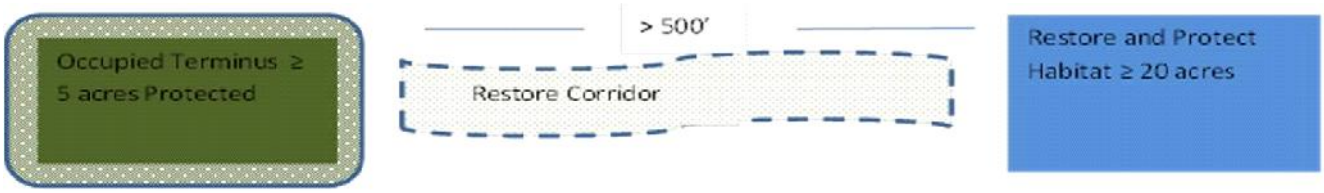
The "Total Gain" for this project is 3 female Indiana bats (Figure 9). This comparatively small "Total Gain" reflects the time it takes for trees planted as habitat to gain some utility for foraging (in the model zero utility until eight years) and the stepwise increase in that utility as the trees mature over approximately 50 years. It also reflects the start of this restoration project five years into the ITP.

Project 3 involves the restoration of a corridor along 900 feet of fence row (approximately one acre) connecting the known occupied habitat (with the Site 2 roost tree) to a 40 acre agricultural field that will be reforested. Field Office guidance on tree species to be planted is the same as in previous examples. The occupied habitat has a permanent conservation easement that precludes tree harvest. The 40 acre restoration will be protected by the applicant in perpetuity. This project is expected to be implemented in Year 10 of the permit. The diagram reflects both a corridor and terminus restoration project. Because this is a corridor project, the unoccupied terminus must be greater than 500 feet from the occupied habitat (Figure 10).

Figure 9 – Mitigation Credit Accrued Summer Restoration Project 2

Mitigation Credit Accrued		
Undiscounted		
Direct females added by project	0.9	female adults
Summer habitat protection	-	female adults
Hibernaculum protection	-	female adults
Maternity habitat restoration	0.9	female adults
Total reproduction gained	1.7	female pups
Total Gain	**3.0**	**females**

Figure 10 – Diagram of Summer Restoration Project 3



`Project start year` (***2028***) reflects the estimated start date for this restoration 10 years after the beginning of the ITP. Again note that the end date is the duration of the ITP (20 Years) plus 10 years after the start of the ITP, in this case 2048. Because both a corridor and terminus habitat (roosting and foraging habitat) will be restored, `Habitat Function` is ***`Roosting & Foraging + Corridor`***. GIS analysis estimates the forest cover within the maternity colony at Site 2 at 32%. Because forest cover is greater than 30%, the value of the restoration declines by a quarter (note the 0.75 to the right of the input cell). The project proponent is not restoring habitat within 500 feet of occupied habitat as in Project 2 above, so `"To be restored" forest area ≥5 acres` is ***`NA`***. The unoccupied terminus (proposed 40 acre restoration) is farther than 500 feet from the occupied habitat and is greater than 20 acres. Last, both termini (the existing occupied habitat and the 40 acres that will be restored) either are or will be permanently protected (Figure 11).

Figure 11– Summer Restoration Project 3

Summer habitat restoration			
Project Details:			
Project start year	2028		
Project end year (include 10 years beyond last monitoring year)	2048		
Habitat function	Roosting & Foraging + Corridor		
Acres of "to be restored" forest adjacent to (within 500' of) occupied habitat	0	Qualifying acreage:	41.00
Acres of "to be restored" corridor habitat	1.0		
Acres of "to be restored" forest at unoccupied terminus	40		
Habitat Conditions:			
Is the project within the known range of a habitat-limited maternity colony?	Yes	1	
Existing % forest cover	30% or more	0.75	
Required Conditions:		1.00	Implies 51 acres/bat
"To be restored" forest area ≥5 acres	NA	1	
Unoccupied terminus forested block >500' from occupied forest block	Yes	1	
Unoccupied terminus forest block >20 ac	Yes	1	
Will or are both termini forest blocks protected	Yes	1	
Expected K		0.73	
Expected female gain	0.73		
Is the existing % forest cover –<20%?	No		

Restoration projects can be particularly important where habitat for Indiana bat maternity colonies is limited. Additional value is attributed where habitat is severely limited. Because there is a lag time before restored habitat is suitable even for foraging, however, restoration projects should be implemented early in the permit period to get maximum return in Total Gain.

The "Total gain" from Restoration Project 3 is rounded down to 2 female bats (Figure 12). The comparatively small gain is again attributable to the delayed start of the project until Year 10 of the ITP, the lag time before the restored habitat becomes suitable for Indiana bat foraging, and the greater than 30% forest cover.

Figure 12 – Mitigation Credit Accrued Summer Restoration Project 3

Mitigation Credit Accrued		
Undiscounted		
Direct females added by project	0.7	female adults
Summer habitat protection	-	female adults
Hibernaculum protection	-	female adults
Maternity habitat restoration	0.7	female adults
Total reproduction gained	1.3	female pups
Total Gain	**2.0**	**females**

In this case the project proponent would do the Mitigation Credit Due calculation outside the model. The "Total Gain" from the three mitigation projects in this **mitigation proposal** is: Project 1 = 12.0 (19.0 + 3.0); Project 2 = 3.0; and Project 3 = 2.0 for a total of 25 female Indiana bats. The Debit Accrued for the take of one female Indiana bat annually for 20 years under a declining Lambda is 50.8. The Mitigation Credit Due is -25.8. The project proponent would also have to sum the **"**Qualifying acreage**"** at each mitigation site because there must be a minimum of 46 qualifying acres at each maternity colony. The "Qualifying Acreage**"** for the two projects at Site 1 (the first maternity colony) is: Site 1 (Project 1 = 35.0 + 0.5) and (Project 2 = 30) for a total of 65.5 acres. The **"**Qualifying acreage**"** for the project at Site 2 (Project 3 = 41 acres) is a total of 41 acres.

The project proponent cannot meet its restoration requirements with this summer habitat mitigation proposal on two counts. First the Net Gained is (– 25.8). Second, the minimum "Qualifying Acreage" of 46 is not met at Site 2. In this case, the project proponent has multiple options including: find additional mitigation opportunities to increase the "Total Gain" and **"**Qualifying acreage**"** at Site 2; abandon Site 2 and look for another summer project or a Winter Protection project that would make up the shortfall of 46.8 bats; or find additional opportunities to meet the 46 acre minimum at Site 2 and identify a third summer project if Net Gained is still negative.

R3 Indiana Bat REA Model Impact Module

BACKGROUND

The primary purpose of the Impact module comprising is to calculate the amount of mitigation owed (debit) resulting from the take of female bats and the mitigation credit when any of the mitigation modules are employed. It is located at the tab labeled Impacts. The Impact module does not estimate the amount of take. An estimate of the number of female bats annually killed is an input variable. Instead, the module estimates the lost reproduction associated with the anticipated number of females taken by the wind facility.

The Impact module calculates debit as the sum of the female take (**Direct Take*)*** and the consequent loss in reproduction (**Total Lost Reproduction*)*** over the life of the proposed project. Note that the Impact module only uses female bats (females taken and their offspring) to calculate the mitigation debt. If there is evidence that significant impacts are occurring to male Indiana bats, the mitigation for those animals should be evaluated independently of the REA model. Note that the impact module does not include 10 years past the permit life since take is only occurring during the permit.

The Impact Module also sums the mitigation credit. Typically, the mitigation credit is going to reflect inputs into more than one mitigation module (e.g., inputs into the Winter Habitat Protection module and Summer Habitat Protection module). The total credit from all mitigation modules and the comparison of the mitigation credit and debit are reflected in the Mitigation Credit Accrued box.

INSTRUCTIONS FOR IMPACT MODULE DATA INPUT

Below we provide instructions for inputting data into the Impact module. Terms that are in Courier New font refer to input cells in the model. The corresponding cell reference for an input term is provided in brackets. The model is composed of four parts: Project details, Required Conditions, Forest Composition, and Non-Input Cells.

Input Parameters

Input Cells

`Permit Start Year` [C6] – Input the year that take will begin to occur.

`Injured Adult Females Annually` [C7] – Input the estimated annual number of females taken by the proposed project (note, this estimate must be calculated prior to employing

this model).

> Most take estimates will include all bats (male and female) estimated to be killed by a wind energy project. Enter into the Model only the estimated number of females killed. Additional evaluation of fatalities may be needed.

`Permit lifetime` [C8] – Input the number of years that annual take will occur (for Section 10 ITPs, this will typically be the life of the permit.)

`Lambda condition` [C10] – Select the trend in **lambda** from the following three options: ***`Stationary`***, ***`Declining`***, or ***`Increasing`***. In choosing the appropriate lambda option, select the choice that reflects the trend observed at the time of project initiation in the specific Recovery Unit.

> Although there is an option to override the demographic rates, for most projects, the default estimates of Indiana bat demographic parameters should be used. In certain instances, the default parameter estimates may not be the best available data. In those cases, the FO can contact the REA Model manager to discuss revising the estimates at [C10] [C12] [C15] [C16] and [C17] below.

Output

The Output side of this module consists of three components: Debit Accrued, Mitigation Credit Accrued, and Mitigation Credit Due. Data are imported automatically into these components based on what is input into the Input Parameters section of this module and what is input into the mitigation modules. More explanation of this side of the Module follows in the example.

Impact Module Example

The project proponent calculated an annual take of three female Indiana bats and requested this level of take for 21 years. The proposed project is in the Midwest Recovery Unit and the Service has determined that the `Lambda Condition` as of 2013, the `Permit start year`, is ***`Stationary`***. Figure 1 shows the Input Parameters component of the Module indicating that `Permit start year, Injured Adult Females Annually` (annual take from a project), `Permit lifetime,` and `Lambda condition` are all required inputs. The user inputs ***`2013`***`, `***`3`***`, `***`21`**, and ***`Stationary`*** respectively.

Figure 1 – Input Parameters from Take Estimate

Permit start year:	**2013**		2034
Injured Adult Females Annually:	**3**		
Permit lifetime	**21**	years to 2034	
Lambda condition	**Stationary**		
Adult Female Breeding Rate	**0.601**	pups/female/year = AP*AB	
Adult F-F Breeding Rate	0.301	female pups/female/year	
Juvenile Female Breeding Rate	**0.143**	pups/female/year	
Juvenile F-F Breeding Rate	0.071	female pups/female/year	

Pup Survival to juvenile	**0.636**	rate
Juvenile Annual Survival	**0.697**	rate
Adult Annual Survival	**0.873**	rate

In this representative example, none of the optional parameter estimates (`Adult Female Breeding Rate, Juvenile Female Breeding Rate, Pup Survival to juvenile, Juvenile Annual Survival`, or `Adult Annual Survival`) have been changed.

Figure 2 shows the output from the Debit Accrued component of the Impacts Module for an annual take of three female Indiana bats for 21 years under stationarity. It calculates direct take of 63 females and total lost reproduction of 125.7 females for a total debit of 188.7 Indiana bats.

Figure 2 – Debit Accrued

Debit Accrued		
Undiscounted		
Direct take	63.0	female adults
Total lost reproduction	119.7	female pups
Total Lost	**182.7**	

Figure 3 shows the Mitigation Credit Accrued output from the Impacts Module. In this case the output ("**Total Gain**" 0.0 females) reflects the fact that no projects have been entered into the mitigation modules. This component of the Impacts Module is explained in detail in the mitigation modules.

Figure 3 – Mitigation Credit Accrued

Mitigation Credit Accrued		
Undiscounted		
Direct females added by project	-	female adults
Summer habitat protection	-	female adults
Hibernaculum protection	-	female adults
Maternity habitat restoration	-	female adults
Total reproduction gained	-	female pups
Total Gain	**0.0**	**females**

The Total gain is the sum of the values for each type of mitigation (i.e., Hibernaculum Protection, Summer Habitat Protection, and Summer Habitat Restoration). For projects with more than one of the same type of mitigation the Total Gain (as well as the Mitigation Credit Accrued and Qualifying Acreage) is calculated by manually summing to the project outputs.

The final component of the Impacts Module is Mitigation Credit Due. As Figure 4 shows, it provides two separate pieces of information to the user. The first is how much excess credit the project proponent has or alternately, how much is owed. In the example below, both the red shading and the minus sign indicate that the project proponent still owes 182.7 bats. Second, it indicates the number of qualifying acres. In this simplified example, the applicant has not contributed any qualifying acres because there is no summer mitigation (Winter Protection projects do not contribute to "**Qualifying acreage**").

Figure 4 – Mitigation Credit Due

Mitigation Credit Due		
Net gained	**-182.7**	
Total qualifying mitigation acres	**0.0**	must be >46 acres

The Input Parameters side of this Module should be employed early in the development of the project in to gain an understanding of the reproductive consequences of the take and information on possible mitigation options.

R3 Indiana Bat Mitigation Model Glossary

Corridor – a linear expanse of forest (extant or restored) that has a minimum length of 500 feet and a minimum width of approximately 30 feet that connects presumably occupied Indiana bat habitat to existing or restored terminus habitat of a minimum size. The maximum size of a corridor and distinguishing the beginning and end points of a corridor from the adjacent terminus habitat is determined by the Field Office. At one extreme, the corridor will be too narrow to function as a corridor and at the other there will not be two habitat blocks connected by a corridor, but rather one large forest block.

Direct Take – this is the sum of the actual female bats taken each year for every year of the project.

Expected Female Gain - is the output of the mitigation modules and is the amount of credit automatically inserted into the Mitigation Credit Accrued sub-module at the Impacts tab. The Expected female gain will typically be around 1.00 if the total restoration area for a project is near 46 acres and will go to 0 if a project is deficient in a critical factor (e.g., percentage of forest in the maternity colony home range).

Foraging Habitat – is forested patches, wooded riparian corridors, and natural vegetation adjacent to suitable summer roosting habitat (which is characterized by trees--dead, dying, or alive--or snags with exfoliating or defoliating bark, or containing cracks or crevices that can be used as a roost.

Gating – the installation of a structure at one or more entrances to an Indiana bat hibernaculum that is sufficiently designed and constructed to permit unimpeded ingress and egress of bats and exclude, with a high degree of reliability, unauthorized human visitation to the hibernaculum (populations of vulnerable Indiana bats).

Hardwoods – deciduous trees native to the Eastern United States as defined in the USDA's Silvics of North America and typically including (oaks, hickories, some species of maples) that are on the list of suitable Indiana bat roost trees in the Draft Indiana Bat Recovery Plan.

Hibernaculum/Hibernacula – a cave, mine, or similar structure that provides winter habitat for Indiana bats.

Imminent Demonstrable Threat - if there is credible information indicating that the quality of the "to be protected" site would be reduced within 10 years unless protected.

Incidental Take Permit (ITP) – a permit from the U.S. Fish and Wildlife Service pursuant to the ESA that authorizes incidental take of a federally listed species by a non-federal entity in conjunction with the development of a habitat conservation plan (HCP).

Known Primary Roost Tree – a roost tree located by telemetry or other means and having a documented exit count within the last five years of at least 30 Indiana bats.

Known Secondary Roost Tree – a roost tree located by telemetry or other means and having a documented exit count within the last 5 years of less than 30 Indiana bats.

Lambda – the population trend of Indiana bats within a recovery unit and described in the model as being in one of three states (increasing, stationary, or declining). .

Landcover Data – satellite or other remotely sensed data that provides categorized information at a known scale on the surface cover of the landscape (e.g., forest, grassland, urban, water, etc.).

Limited Habitat Threat – if the percent forest cover of the "to be protected" is less than 20 percent.

Mitigation Proposal –the total mitigation package proposed for either summer habitat restoration and protection or hibernacula protection. For example summer habitat restoration could comprise multiple projects to reach the required mitigation and could be combined with summer habitat protection projects.

Permanently Protected – means protected in such a way that adverse impacts are legally precluded in perpetuity. This might include: in fee by the Service or an authorized entity, or protected by a permanent easement accepted by the Service and held by an authorized entity, or other means of protection accepted by the Service.

"Qualifying Acreage" – it is the acreage of summer habitat that is being protected or restored by the applicant at any one and each maternity colony.

Restoration Project – a restoration project that can be entered into under the SHRM. Multiple restoration projects or a combination of one or more restoration and one or more Summer Habitat Protection projects could comprise a Mitigation Proposal.

Roosting and Foraging Habitat - a forest block of at least five acres with minimum structure (trees are approximately 10-15 feet tall) necessary for bats to forage. The guidance on tree species and the requirement for protection in perpetuity will ensure the ultimate presence of suitable for roosting. In addition, the forest block must be either occupied habitat (or if restored) must be within 500 feet of occupied habitat.

Severely Habitat Limited – for purposes of the Model, this refers to maternity colonies that are 20 percent forested or less. In these cases, a 6x multiplier is incorporated into the restoration module, which reflects the Service priority for planting trees within that colony to help ensure its persistence.

Softwoods – deciduous trees native to the Eastern United States as defined in the USDA's Silvics of North America and typically including trees (e.g., some maples) that are on the list of suitable Indiana bat roost trees in the Draft Indiana Bat Recovery Plan.

Terminus, Termini – for purposes of the Model, this refers to the Indiana bat habitat at the end or ends of a corridor. This has to be a minimum size (5 acres of extant and 20 acres if restored) and the habitat at both ends of the corridor (both termini) must always be permanently protected for a valid corridor project to exist.

Total Gain – this is the model calculation for the amount of females (adults and pups) that are anticipated to be gained from a mitigation project. A detailed explanation of the mathematical model underlying this calculation is provided in the introduction and in the Appendices.

Total Lost Reproduction- this is the model calculation of the impact of the taking of the number of female bats entered as Injured Adult Females Annually**.** A detailed explanation of the mathematical model underlying this calculation is provided in the introduction and in the Appendices.

Total Qualifying Mitigation Acres – the sum of the summer habitat acres protected; the sum must be at least 46 acres.

Unauthorized Human Visitation – entrance to a hibernaculum that is not sanctioned by the managing agency (e.g., a state department of natural resources) and that causes or has the potential to cause negative impacts to Indiana bats or their habitat.

Unoccupied Terminus Forested Block – a forest block (or a forest restoration site) of at least 20 acres ≥ 500 feet from occupied habitat. It is by definition isolated and therefore presumed unoccupied until connected by a corridor to occupied habitat.

Vulnerable (population) – a population of Indiana bats within a hibernaculum that is by virtue of its location within the hibernaculum or lack of existing protection (i.e., acceptable gate) is susceptible to unauthorized human visitation.

R3 Indiana Bat Mitigation Model Underlying Formulas

Background

As explained in the Introduction Section of this User Guide, REA is used to enable a fair comparison between resources lost and resources gained through compensatory restoration. We applied REA to develop an Ibat specific REA model.

REA responds to the question, "What, but for the event, would have happened to the injured individuals?" With REA, the reproductive consequences of the animals that are anticipated to be killed (i.e., the number of bats for which incidental take is granted) are calculated; collectively, the number of bats directly taken and the foregone reproductive potential represent bat debits. The model allows the user to evaluate various mitigation scenarios to assess whether the "credits" (the number of females and future reproduction contributions gained) offset the calculated debits of the project. Mathematically, a typical REA debit is calculated as:

$$I = \sum_{t=o} \frac{(NB_t - NI_t)}{(1+r)^t} \qquad (1)$$

where I is the injury in lost animal-years, NB_t and NI_t represent the number of individuals in the population (at time t) under "baseline" and "injured" scenarios, respectively, t indexes time (usually years), and r is the discount rate (Zafonte and Hampton 2005). The goal of the credit calculation process is to find the increase in population above baseline (NP_t in equation (2)) that will make the mitigation, C, sufficient for the injury, I.

$$C = \sum_{t=o} \frac{(NP_t - NI_t)}{(1+r)^t} \qquad (2)$$

Mitigation projects often preserve or improve habitat, or prevent other risks to the population. Projects are evaluated in the same discounted animal-year units as the debit using the same model of population growth. In order to find NP_t, we calculate the number of discounted animal-years per unit of mitigation project and then divide by the total debit to find the number of units the project must encompass.

For Ibat REA model, we have customized the model in several distinct ways. First, we are

not accounting for lost or gained services other than reproduction. Although it is standard in REAs to consider ecosystem services in addition to demographic losses and gains, within our ESA decision context, the project proponent is not required to offset lost resources other than the animals themselves. Thus, we modified the REA model to assess debits and credits based on the demographic losses and gains alone, i.e., not on the ecological services such individuals may provide.

Second, debit and credit are based on the median breeding lifespan of an individual rather than the full lifespan. This modification was made to balance protocol and perception needs. An earlier version of the Ibat REA model used a population growth model standard in REAs. The results of the REA, both the debits and credits, caused some consternation, however. Both credits and debits seemed to be highly exaggerated relative to what we observe in reality. This is not unexpected because the population model provides the biological capacity of the species. It does not account for colony dynamics or carrying capacity, both of which constrain losses and gains. As stressed at the outset of the User Guide, the REA model does not account for colony level impacts; it simply gives the costs and benefits associated with losing and gaining a certain number of individuals. Despite being straightforward and logical, the explanation is not readily intuitive, however. The outputs, on the other hand, are so there was concern about objections to the Ibat REA model on the basis of the grossly unrealistic results. To address this concern, we used median reproductive life span instead of the full life span of an individual. The difference between the two approaches is noticeable for "credit gained" and "debit accrued," but because we apply it in calculating both credits and debits, there is no overall impact (e.g., increasing the life span will increase the debit incurred, but will as also, increase the credit accrued, so the net credit due is the same.)

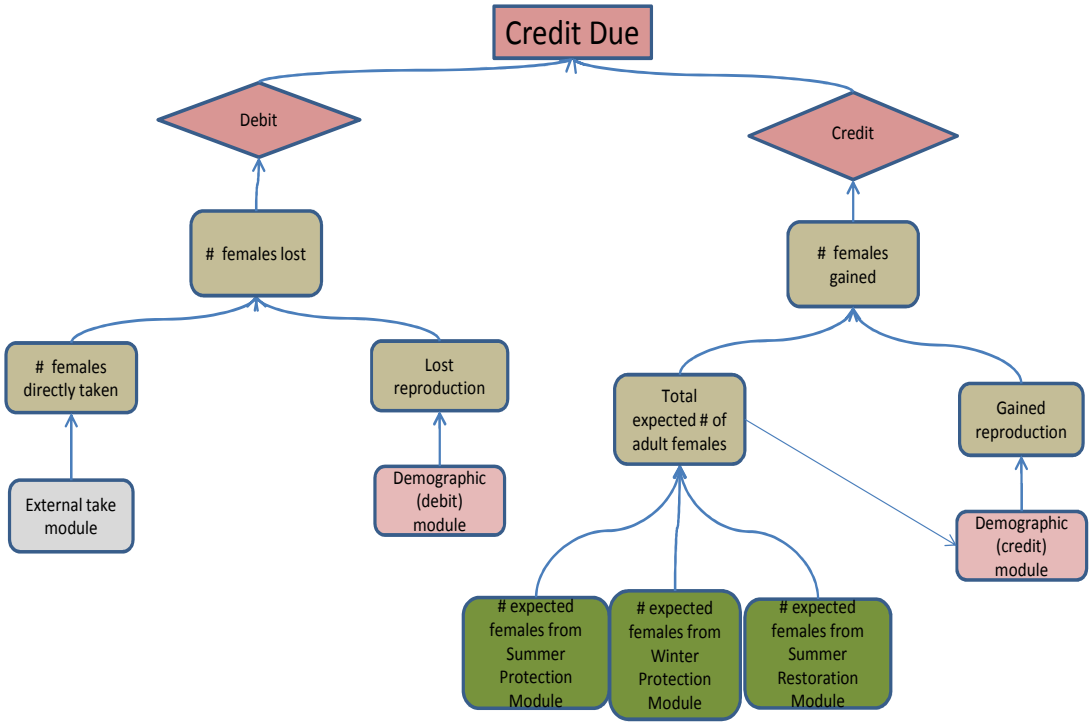
Third, owing to point two, the underlying population model differs slightly for the credit and debit scenarios. The population models are detailed below, but in brief, the credit model accumulates credit over a 7 year reproductive lifespan for both adults and pups/juveniles, while the debit model accrues over a 5 year adult lifespan and 7 year pup/juvenile lifespan. The difference in adult reproductive lifespan is due to an underlying assumption that females are taken after their second reproductive season; this reduces the number of reproductive years lost by 2, and hence a 5-year debit accrual time. The credit equation, however, assumes that a new recruit is added to the population, and thus, she has her entire [median] reproductive lifespan to produce pups.

Lastly, we are not applying discounting to either the debit or credit calculations. Typically, REA models apply a discount rate both to the debit and credit aspects of the model. The purpose is to capture society's preference for current consumption. However, discounting take (debit) is not appropriate for endangered species REAs because society's preferences are codified in the ESA. The ESA prohibits consideration of economic effects in listing decisions indicating that species survival cannot be traded for other benefits. Simply stated, the take of a listed animal today is valued as much as the take of the same animal next year (the legal consequences are the same). Although the value given to credits gained in the

future is not clearly defined by the ESA, typically, the uncertainty associated with future gains, makes the gain tomorrow not as certain as a gained today, and thus, less valuable. However, to maintain equity between the credit and debit calculations, the Ibat REA model does incorporate discounting.

In all other aspects, the Ibat REA model resembles a prototypical REA. Figure 1 displays a visual depiction of the relationships among underlying sub-models (referred to as modules) comprising the Ibat REA model. The core Ibat REA model consists of three mitigation modules and a demographic module. Although following the mitigation modules in the REA model and the User Guide, for clarity purposes we first discuss the demographic model found in the Parameter Sets Module.

Figure 1. A schematic of the Indiana bat REA model.



Credit due is the difference between the debit accrued via a proposed action and the credit gained via a mitigation project. The gained reproduction and the lost reproduction are derived from the same population model. The number of adult females gained is calculated via mitigation-specific modules. The number of females directly taken is calculated via take models independent of the Indiana bat REA.

In simplest notational terms, the underlying formula for "Credit Due" is Credit – Debit. Following this through, the formula for Debit is the sum of the adult females killed over the life of the project (Take) plus the sum of the annual lost reproduction. Credit is the sum of the expected females gained (EFG) over the project life plus the sum of the annual gained reproduction.

Take is calculated outside the REA framework (i.e., an input value that tracked through the model and is used to calculate lost reproduction) and EFG is derived from the three mitigation modules. Both gained reproduction and lost reproduction are derived from the Parameter Sets module, which is described below. Figures 2a and b display visual depictions of the debit and credit formulas, respectively.

Figure 2a. A schematic showing the structure of the Debit formula for the Ibat REA model. Debit is a function of adults killed by the proposed action and their foregone reproduction.

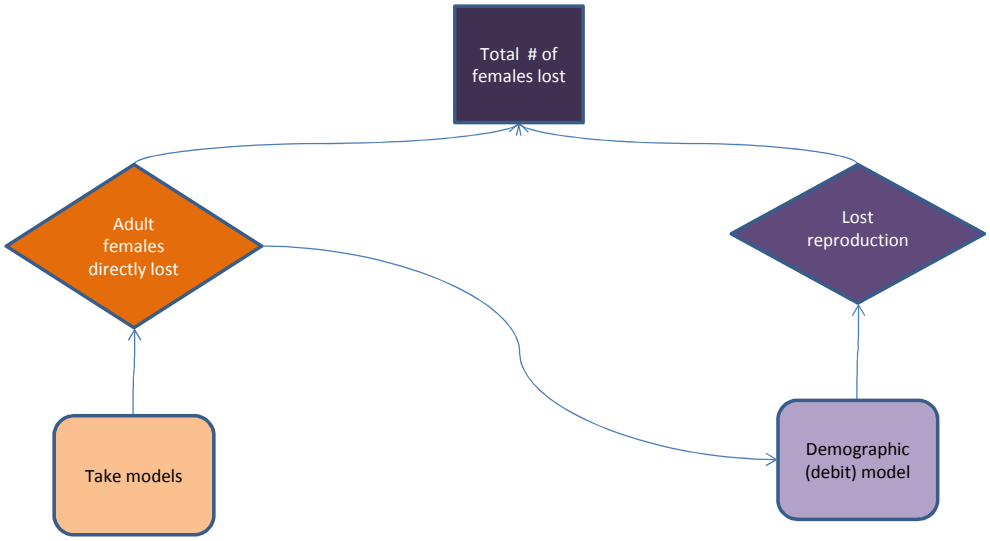
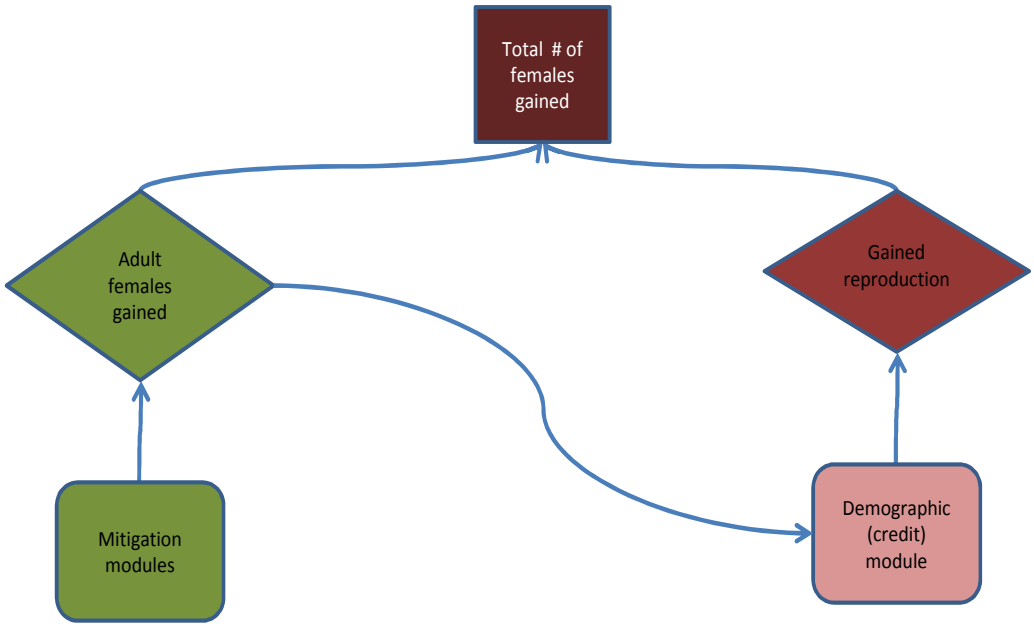


Figure 2b. A schematic showing the structure of the Credit formula for the Ibat REA model. Credit is a function of females gained from a mitigation project and their future reproduction.



Parameter Sets Module

The Parameter Sets module houses the population model used to calculate gained and lost reproduction. Several underlying assumptions apply to this module:

1. The median values calculated from a subset of parameters values derived from Thogmartin et al. represent reasonable estimates of annual survival and reproductive rates for female Indiana bats.

2. The calculated median reproductive lifetime represents a reasonable estimate of the breeding lifespan of an average female Indiana bat.

3. Adult females are killed after their second year of breeding. Females gained from mitigation projects are afforded their entire [median] reproductive life span.

4. The benefits afforded to female Indiana bats will sufficiently account for male Indiana bat losses.

5. Females gained tomorrow are valued the same as females gained today, and females lost tomorrow are valued the same as females lost today (i.e., no discounting applied)

As explained previously, REAs are denominated in units of resource services. For our decision context, the services of primary interest are reproductive services; specifically, female Indiana bat reproductive potential. When an adult female bat is prematurely killed, she and her future reproductive potential are lost. In REA terminology, lost females plus their lost future reproductive potential are called debits. Lost future reproductive potential is calculated as:

$$FG = \frac{1}{2} b_A \frac{1-s_A^{T+1}}{1-s_A} \qquad (3)$$

where FG is the number of daughters a female would have produced over her adult reproductive life span (T=0…,4), S_A is adult survival probability and b_A adult breeding rate. We multiply the expression by 0.5 to account for a 50:50 sex ratio. The median reproductive life span of a female is 6.78 years, but as we are assuming that a female is killed after her second year of breeding. Thus, the lost reproduction time is 5 years, i.e., for each female killed, the debit includes 5 (4.78 years) year of reproduction.

Furthermore, the potential offspring of her pups (i.e., second generation pups, SG) are also lost. Equation (4) follows the same reasoning as equation (3) with the addition of potential early death as a pup (S_p) or juvenile (S_j) and lower birth rates in the first breeding year (b_J). The expression in brackets represents the reproductive potential of the injured female's

offspring while the outside term reflects the probability that the offspring would have survived. The reproductive life of the offspring is the full breeding life span. Thus, *T* is 7 (6.78 years). Again, the expression is multiplied by 0.5 to account for a 50:50 sex ratio.

$$SG = \frac{1}{2} s_P \left| b_J + s_J b_A \left(\frac{1 - s_A^{T+1}}{1 - s_A} \right) \right| \qquad (4)$$

As explained elsewhere in this guide, each mitigation project generates a pattern of gains (in REA terms, credits) in female bat reproductive potential by providing habitat or reducing risks. These patterns are inputs to a similar population model that is used for calculating the debit, with one notable exception. The gained female is assumed to have her entire reproductive life span, so *T* is 7 years in the FG formula. Figures 3a and b display a simplified visual of the underlying structures of the lost and gained reproduction formulas, respectively. Within the Services module, equations 3 and 4 are found in cells I6 & 8 for Debit and K6 & 8 for Credit. For clarity purposes, the equations are expanded out in cells C29-AR44.

Thogmartin et al. (2012) developed a stepwise matrix model for Indiana bat that distinguishes fall, winter, and summer survival rates for pups (defined as birth up to first hibernation), juveniles (defined as the stage from first hibernation to second hibernation) and adults (defined period beginning with second hibernation and beyond). The model also distinguishes breeding success of juveniles from more experienced adults. The Thogmartin model samples from sets of life table parameters within a range of expected growth rates (lambdas). For the Ibat REA model, we used the sets of parameters associated with three choices– declining, stationary, and increasing (i.e., the sets of parameters that yield λ=0.97-0.98; 0.99-1.01; 1.02-1.03, respectively) population growth. Using these 3 sets, the median annual survival and birth rates were calculated.

As the model parameters (other than *T*) of the debit and credit models are identical, the choice of parameter values has little effect on the outcome of the REA model (i.e., the REA model is fairly robust to the uncertainty surrounding the parameter values).

The allocation of debit and credit are displayed in the Services module. The full debit for females killed is accrued cotemporaneous with the timing of the take. The EFG accrual, however, is allocated over time. EFG from winter habitat protection is allocated evenly over the life of the project. EFG from the summer mitigation options must be multiplied by the adult birth rate to show the reproduction gained from the increase in females. From a model perspective, the summer mitigation options are creating an annual opportunity to reproduce. This opportunity is the probability that the EFG will be reproduce that year, and if successful, then reproductive gain (and hence credit) calculated as her offspring and their progeny for their breeding life span (7 years). The pattern of gain through time, for the summer habitat restoration option, reflects the improvement in habitat as it matures. As explained previously this guide, credit is accrued for 10 years post the last monitoring year.

Figure 3a. A schematic showing the structure of the "Lost Reproduction" term of the Debit formula for the Ibat REA model.

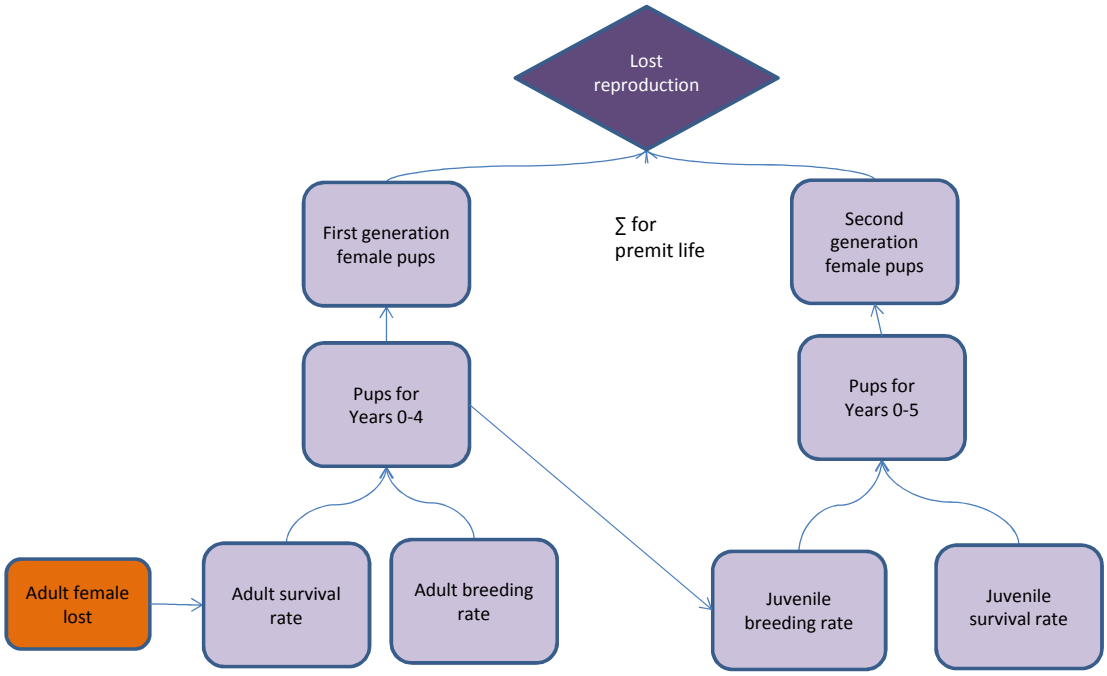
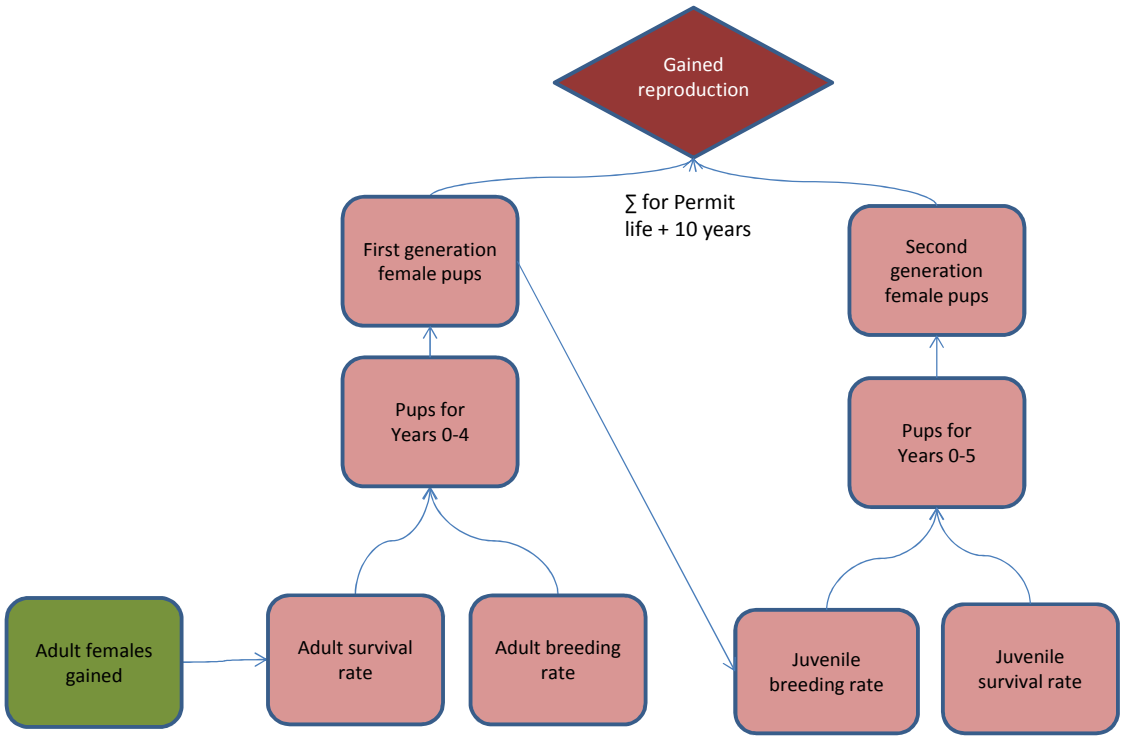


Figure 3b. A schematic showing the structure of the "Gained Reproduction" term of the Credit formula for the Ibat REA model.



Winter Habitat Protection Module

The intent of the winter habitat protection module is to give credit for protecting currently vulnerable hibernating bats from lethal human-caused disturbance. The underlying rationale is but for the gate, some portion of the hibernating bats would have died. Therefore, the gate has gained females by preventing this mortality event. The fundamental premise is that lethal disturbance is a real threat. If the disturbance does not occur, there is no gain in females associated with the hibernaculum protection project. Regrettably, there is no way to know whether the gain will be or was realized, but as explained in the beginning of this guide, we believe our approach sufficiently balances this uncertainty so that region wide the losses will indeed be offset.

The underlying assumptions specific to the Winter Habitat Protection module include:

1. Installing a bat-friendly gate will nearly eliminate the chance of lethal disturbance, and thereby, increase the number of females that survive.
2. For lethal disturbance to occur both the hibernaculum & the hibernating bats must be accessible to human disturbance.

3. The calculated background rate of lethal disturbance is a reasonable estimate of the likelihood of disturbance occurring at any overwinter site in which both the hibernaculum and the bats are accessible to human disturbance.

The output of the winter habitat protection module is the number of expected females gained (EFG). The equation is:

$$EFG = [N*Pa*p(D)]/2, \quad (5)$$

where *N* is the number of bats hibernating in target cave (derived from biennial survey data), *Pa* the percent of hibernating bats that are in accessible locations (derived from biologist's expertise of hibernating population), and *p(D)* = probability of disturbance occurring. We divide by two to get the expected number of females. The probability of disturbance is calculated by multiplying the rangewide background rate of disturbance at hibernacula by a cave-specific vulnerability factor. The background rate was derived by querying the Indiana hibernacula database for all hibernacula that list human disturbance as a threat. From this query, we searched for the subset of hibernacula that had documented evidence of lethal disturbance. Dividing the latter sum by the former gave us a probability of disturbance at caves deemed vulnerable to human disturbance. Cave-specific vulnerability is a function of 4 factors: hibernaculum accessibility, bat accessibility, clustering behavior and ceiling height. If neither the hibernaculum nor the bats are accessible, cave-specific vulnerability is 0. If the ceiling height is greater than 10 feet and the majority of the bats are not clumped in groups, then cave-specific vulnerability is 0. Otherwise, this term is assigned the value of 1 and the background rate of disturbance is applied. Figure 4a displays the concept model underlying the Winter Habitat Protection module. Figure 4b gives a stepwise visual of the model.

Figure 4a. A schematic of the factors underlying the module.

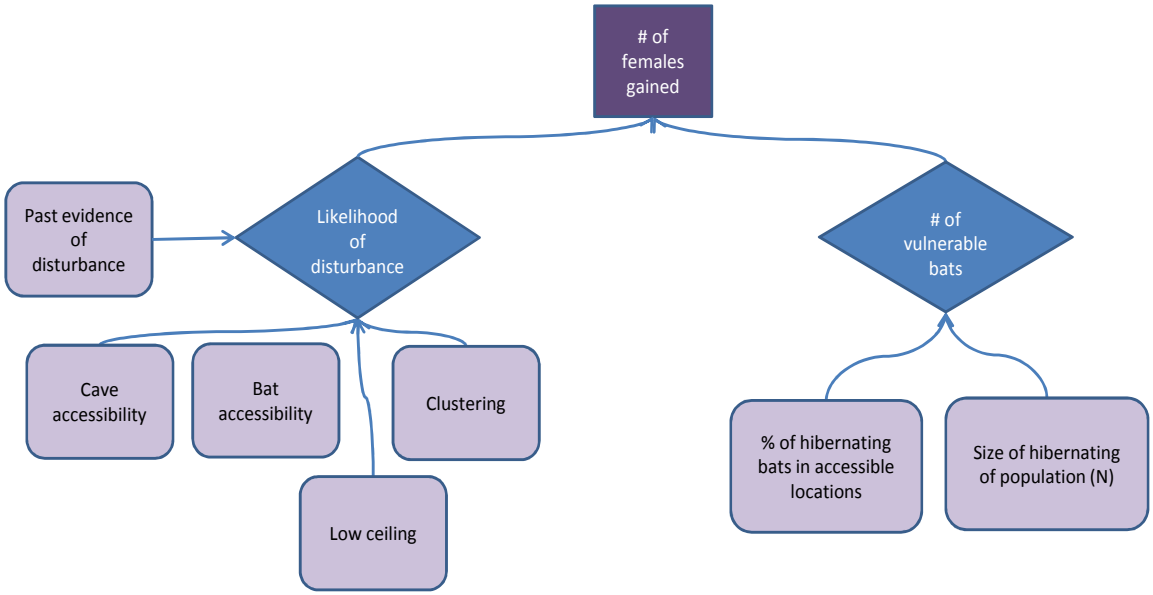
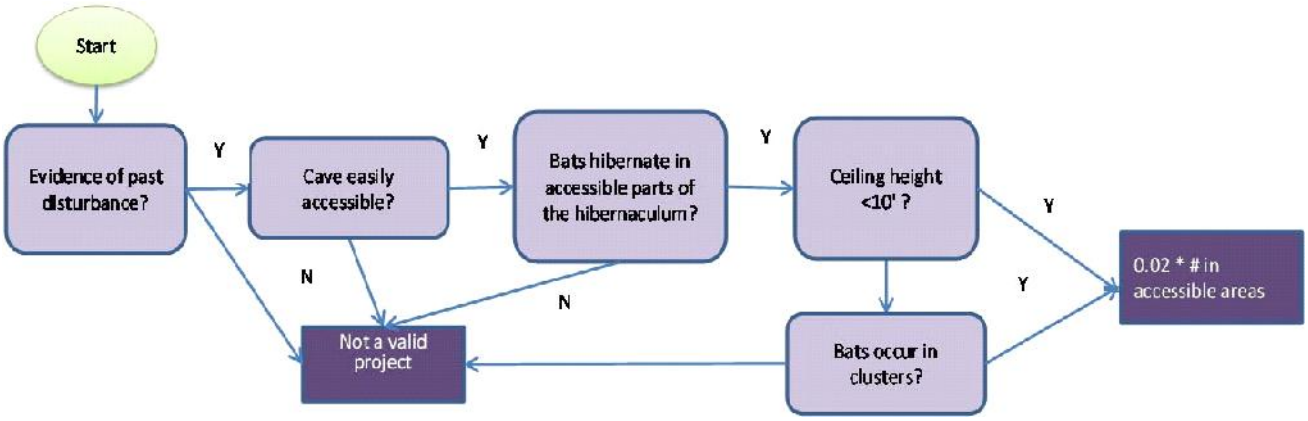


Figure 4b. A schematic of the stepwise decisions of module.



Summer Habitat Protection Module

The intent of the summer habitat protection module is to protect occupied habitat that is under threat. The underlying rationale is similar to the winter habitat protection scenario; but for the habitat protection, the suitable habitat would be degraded or destroyed thereby losing a maternity colony. By protecting the habitat, we are maintaining female productivity that would have otherwise been lost, and thus, gaining females. The fundamental premise is that there is real threat to the habitat. If the threat is not realized, there is no gain in females associated with the habitat protection project. We recognize that in some cases we will not know with certainty that the threat will be realized nor will we know the magnitude of its impact on the affected females. For this reason, and as we explained previously, we believe our approach sufficiently balances this uncertainty so that regionwide the losses will indeed be offset. Specifically, for each mitigation project, we require evidence of a threat and a minimum acreage to be protected or restored. The first condition reduces the uncertainty associated with whether a threat will occur. The second condition will lead to take being under-mitigate in some instances and over-mitigate in others, but collectively, we believe it will balance out over time.

The underlying assumptions of the summer habitat protection module include:

1. One female requires 46 acres of suitable summer habitat

2. Protecting habitat from a known threat will prevent the loss of a female Ibats' home-ranges, and thereby, maintain the reproductive potential for the affected females.

3. A minimum of 5 acres of suitable habitat will be protected

4. Protection entails both ownership or effective control of roost sites and habitat, and

bat-oriented management.

The output of the summer protection module is the number of expected females gained (EFG). The equation is:

$$EFG = K * p(D), \quad (6)$$

where *K* is the carrying capacity of the habitat to be protected and *p(D)* is the probability of a threat occurring. The degree to which providing habitat protection of existing colonies aids the population growth and viability of Indiana bats is contingent upon the impact of the threat, the likelihood of the threat occurring, and the timing of the threat. To address these uncertainties, the summer habitat protection module requires either evidence an imminent threat for which substantial loss of the maternity colony's habitat is expected within 10 years or evidence that the site severely lacking suitable habitat (i.e., less than 20% forest cover). If there is an imminent, identifiable threat to the habitat or if habitat is limited, the *p(D)* is 1, otherwise it is 0. Carrying capacity is determined by the habitat function of the habitat to be protected.

Roosting & Foraging habitat: K = # ac protected/46

Corridor habitat: K = 10 ac/46

Roosting & Foraging and Corridor: K = # ac protected/46

The roosting and foraging K formulas are scaled to the 46 ac per female metric, e.g., if 46 acres are protected, 1 female is gained. The amount of protected corridor habitat does not directly relate to the ac per female metric. We have defined a qualifying corridor project as one that protects a critical corridor; more precisely, protection of a corridor that if lost would cause a substantial impact on the colony. Thus, the anticipated gain in females is not related to the amount of corridor protected. We did not believe a corridor project should be given the value as a roosting and foraging project; we settled on a flat 10ac credit (5 ac credit for each of the two termini) for any qualifying corridor project.

Additionally, a valid corridor protection project must meet the several conditions. One, the terminus blocks must be greater than 500 feet apart. This criterion is based on the radio-telemetry data which shows that the majority of Indiana bats will not traverse open areas greater than 500 feet. Two, the occupied termini blocks must be at least 5 acres. The basis for this criterion is that for the corridor to be meaningful it must link termini that can provide some minimal habitat use for Ibats. For similar reasons, if one terminus is unoccupied, this must be at least 20 acres. Figure 5a displays the concept model underlying the Summer Habitat Protection module and Figure 5b gives a stepwise visual of the model.

Figure 5a. A schematic of the factors underlying the module.

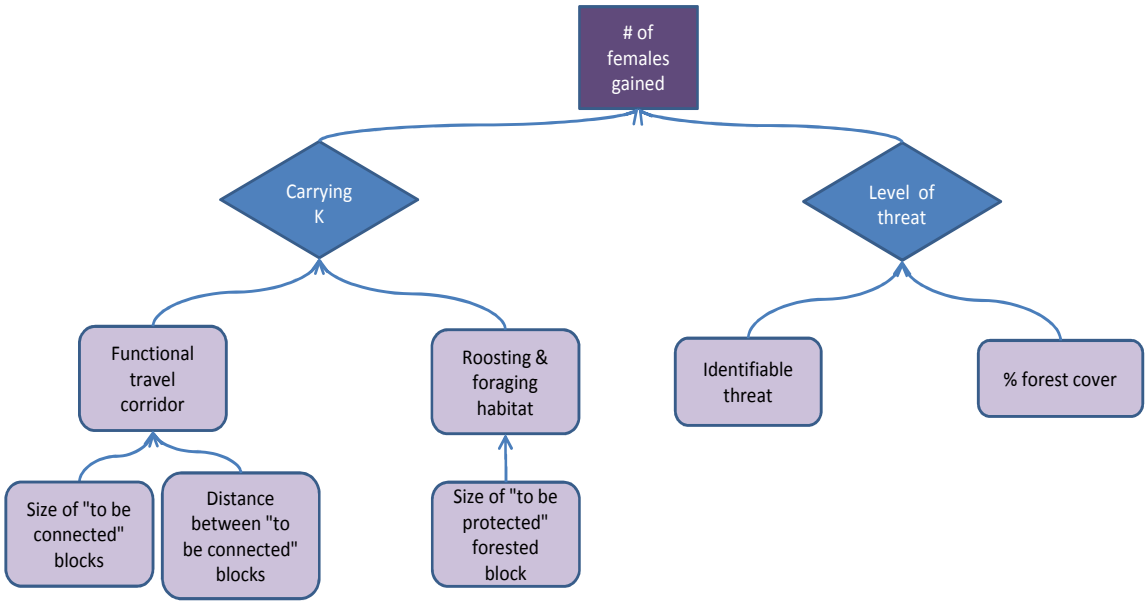
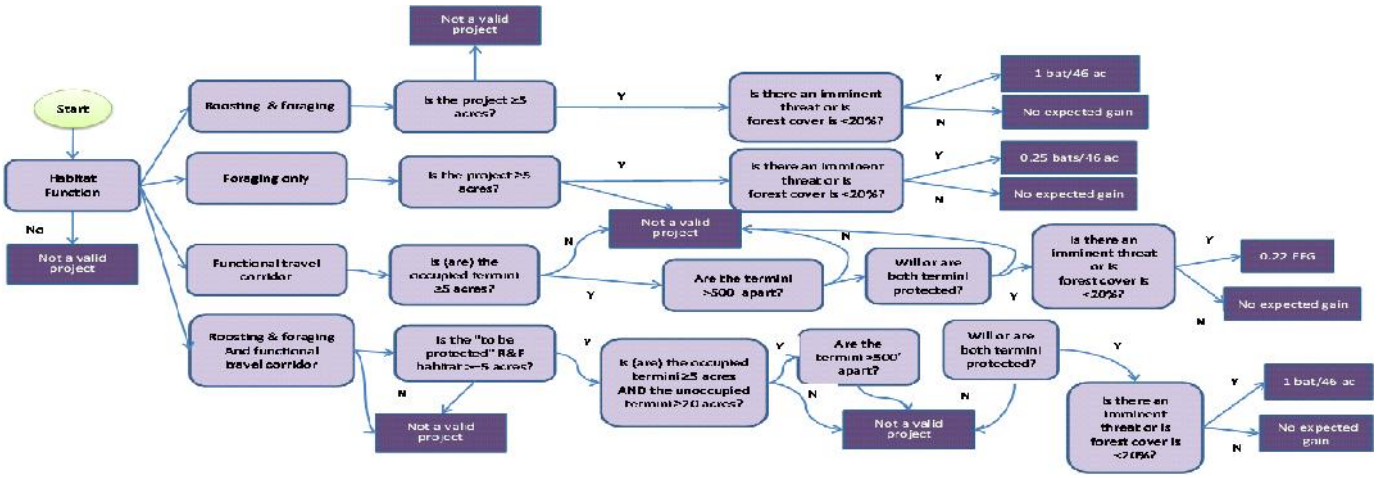


Figure 5b. A schematic of the stepwise decisions of module.



Summer Habitat Restoration Module

The intent of the summer habitat restoration module is to give credit for habitat restoration that is likely to increase the carrying capacity of a known maternity colony. The underlying premise is that restoring suitable habitat adjacent to a currently occupied

yet habitat limited site will increase the carrying capacity and thus gain females over time. Maternity colonies are the reproductive units of Indiana bat. These colonies are small and dispersed. To support the population goals for this species, there must be thousands of maternity colonies across the landscape. Increasing the number of maternity colonies is clearly a conservation need for the species. However, establishing new colonies is not likely to be a successful endeavor. Indiana bats show great site fidelity to their summer maternity areas thereby making it unlikely that restoring habitat in areas isolated (greater than 10 miles) from maternity colonies will be successfully occupied in the foreseeable future. Instead, restoration efforts must target restoring, enhancing, or creating summer habitat within or adjacent to existing colony areas.

Low survival in the first year and long life span mean that adult female survival is the key to growing the population. Adult female survivorship is high in stable or increasing populations. So opportunities to improve adult survivorship are limited to populations where survivorship is depressed. Recruitment is more variable and so offers more opportunities for improvement through management. To increase the number of recruits, it is necessary to increase the probability of mating and giving birth to a pup or to increase the carrying capacity of a maternity colony site. Both approaches entail improving the quality and quantity of maternity colony areas. Summer mitigation efforts should target sites where foraging or roosting resources are currently limited, i.e., at sites where the carrying capacity can be increased. Current data from the Indianapolis Airport HCP provide evidence that habitat creation and restoration can improve colony size, and hence, colony productivity. Thus, the summer habitat restoration module is focuses on increasing carrying capacity.

A special case involving the summer habitat restoration module occurs when the scarcity of suitable habitat may actually threaten the long-term persistence of the colony. Surveys recently conducted by the wind industry in Indiana indicate that colonies can occur in areas with minimal and fragmented habitat. We do not have enough data yet to evaluate the stability or size of this kind of colony, but our assumption for this model is that they are under severe stress. We define colonies with 20% or less forest within their home range as severely habitat limited. Under those circumstances, a multiplier of six (6) is applied to the "Expected female gain" in order to encourage restoration at those colonies, which may be in imminent danger of failing.

The underlying assumptions of the summer habitat restoration module include:

1. Female Ibats will use newly restored roosting habitat within their home range for foraging.

2. Forty-six (46) ac of restored habitat will increase K by 1 female

3. The use of restored habitat will increase over time.

4. The restoration mix will ensure short (foraging) and long-term (continued supply of roosting trees) benefits

The output of the summer habitat restoration module is the number of expected females gained (EFG). The equation is:

$$EFG = K \quad (7)$$

The formulas for carrying capacity, *K*, vary by function:

Roosting & Foraging: K = # ac restored/46

Corridor: K = 10 ac /46

Roosting & Foraging and Corridor:

K = (# ac restored+10)/46 or

K = (# ac restored + 5)/46 (if restoring at unoccupied terminus, too).

Similar to the summer habitat protection module, the roosting and foraging K formulas are scaled to the 46 ac per female metric, e.g., if 46 acres are protected, 1 female is gained. In addition to acres restored, K is also a function of existing habitat. As indicated above, a valid mitigation project entails restoring habitat at a habitat limited site, which includes, but is not restricted to, percent forest cover. Thus, we included an additional conditional factor. If existing percent forest cover is greater than 30%, the EFG is reduced by a 25%. As explained previously, the amount of protected corridor habitat does not directly relate to the ac per female metric. We used the same metric for the Corridor only option under the summer habitat protection module. For the combined option (Roosting & Foraging + Corridor) combined the metrics, i.e., the Roosting & Foraging metric + Corridor metric. The exception to this rule is that if project entails restoring habitat at an unoccupied terminus, corridor credit is only given for the only the occupied terminus. This modification is made to avoid double counting (crediting) as the acreage of unoccupied terminus is accounted for in the # of acres restored term of the equation. Figure 6a displays the concept model underlying the Summer Habitat Protection module. Figure 6b gives a stepwise visual of the model.

The timeline for accrual of credits for restoration projects are delayed. We have little data to garner insights on the timeline of use. Again, drawing from work at the Indianapolis airport, we believe that minimal foraging benefits begin to accrual at 8 years. These benefits continue to accrue at this rate (which we ascribed to 25% of the full benefits) until year 25 at which quality of the restored habitat for foraging increases and minimal roosting benefits begin to appear (which we ascribed to 50% of the full benefits). At year 37, we anticipate that roosting benefits will be improved (75% of the full benefits realized) and at year 50 full benefits are provided.

Figure 6a. A schematic of the factors underlying the module

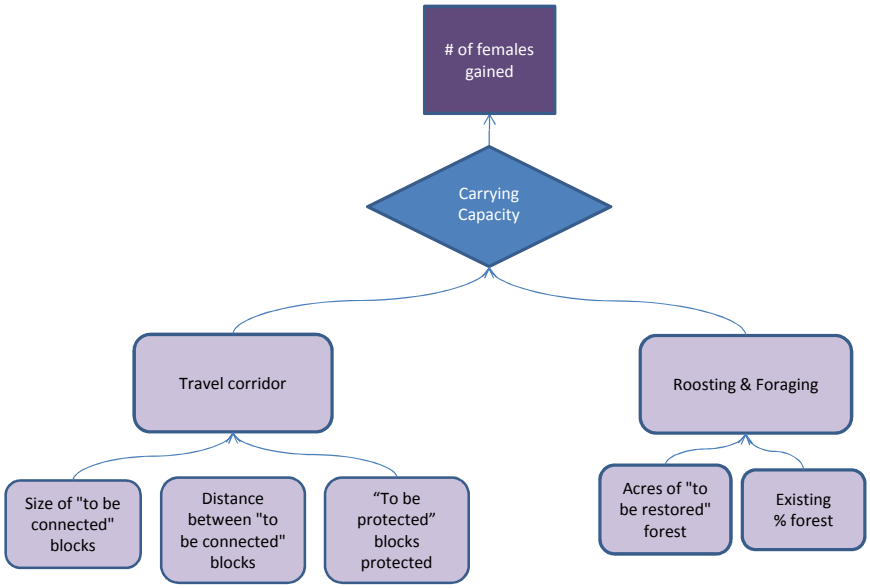
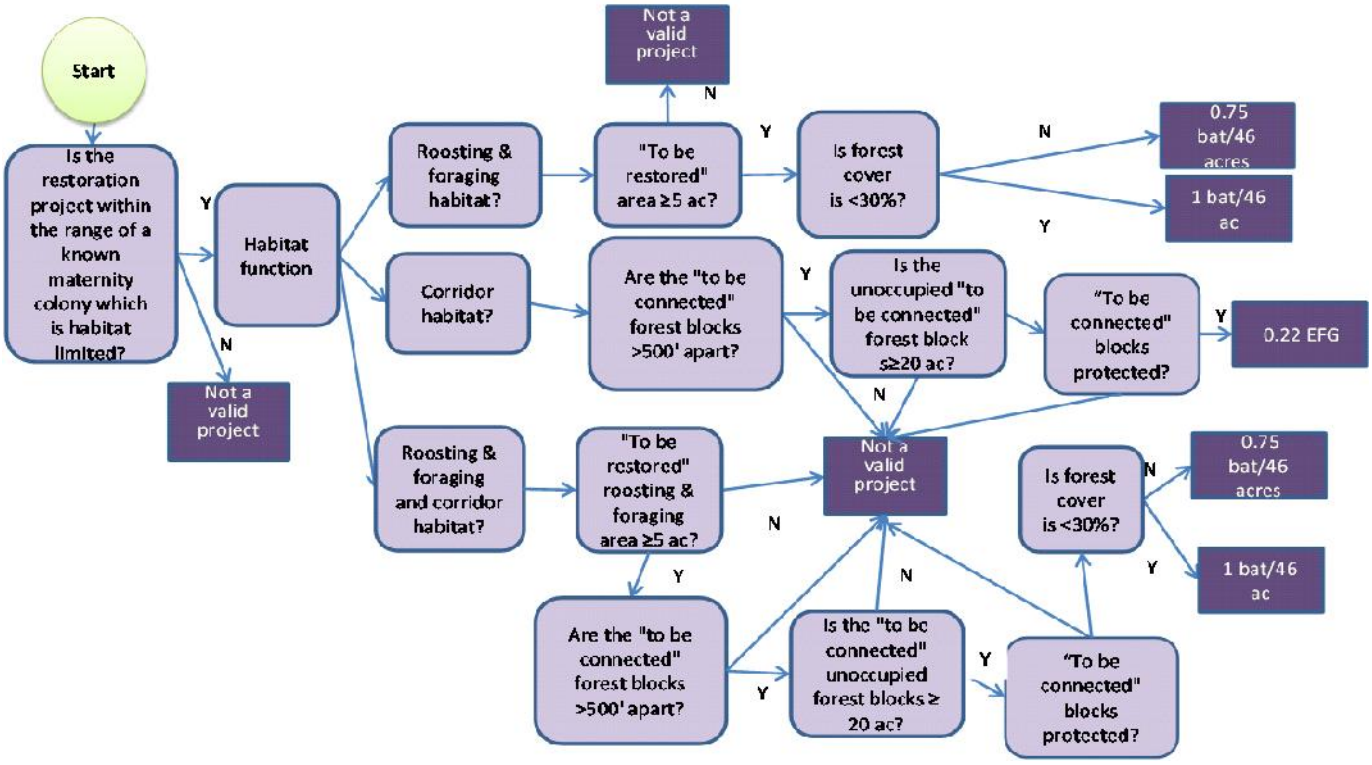


Figure 6b. A schematic of the stepwise decisions of module.



R3 Indiana Bat Mitigation Model References

Burns, Russell M., and Barbara H. Honkala, tech. coords. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol.2, 877 p.

Cole, S. 2009. How much is enough? Determining adequate levels of environmental compensation for wind power impacts using equivalency analysis. In: European Offshore Wind Conference 2009, 14-16 Sep 2009, Stockholm, Sweden.

Hawkins, J.A., J. Jaskula, A. Mann, P. Kudlu, and V. Brack, Jr. 2005. Habitat Conservation Plan: 2004 Telemetry Study of Autumn Swarming Behavior of the Indiana Bat (Myotis sodalis). Final Report. Indiana Department of Natural Resources Division of Forestry, Indianapolis, Indiana. 25pp. plus appendices.

Jones, C., and K. Pease. 1997. Restoration-based compensation measures in natural resource liability statutes. *Contemporary Economic Policy*, 4: 111-123.

Kiser, J.D. and C.L. Elliot. 1996. Foraging habitat, food habits, and roost tree characteristics of the Indiana bat (*Myotis sodalis*) during autumn in Jackson County, Kentucky. Final Report, Nongame Program, Kentucky Department of Fish and Wildlife Resources, Frankfort.

Skrabis, K. E. 2005. Compendium of resource equivalency analyses: New Carissa oil spill. Report for the Bureau of Land Management and U.S. Fish and Wildlife Service by Office of Policy Analysis, U.S. Department of the Interior, Washington D.C., USA.

Skrabis, K. E. 2011. Using resource equivalency analysis to develop a framework of compensatory mitigation for potential takes of Golden Eagles from wind energy development. Appendix F of Draft Eagle Conservation Plan. U.S. Fish & Wildlife Service, Arlington, Virginia, USA.

Sperduto, M., Hebert, M. Donlan, and S. Thompson. 1999. Injury quantification and restoration scaling for marine birds killed as a result of the North Cape Oil Spill. U.S. Fish and Wildlife Service.

Thogmartin, et al. *in press*. White-nose syndrome is likely to extirpate the endangered Indiana bat over large parts of its range.

Unsworth, R., and R. Bishop. 1994. Assessing natural resource damages using environmental annuities. *Ecological Economics* 11:35-41.