Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Western Yellow Bat (*Lasiurus xanthinus*) (WYBA) Basic Conceptual Ecological Model for the Lower Colorado River

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U.S. DEPARTMENT OF THE INTERIOR
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September 2015

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Lower Colorado River Multi-Species Conservation Program

Western Yellow Bat (*Lasiurus xanthinus*) (WYBA) Basic Conceptual Ecological Model for the Lower Colorado River

Prepared by:

Jaymee Marty, Ph.D. and Robert Unnasch, Ph.D.

Sound Science, LLC

Lower Colorado River
Multi-Species Conservation Program
Bureau of Reclamation
Lower Colorado Region
Boulder City, Nevada
http://www.lcrmscp.gov

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ACRONYMS AND ABBREVIATIONS

CEM	conceptual ecological model
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
Reclamation	Bureau of Reclamation
WYBA	western yellow bat (*Lasiurus xanthinus*)

Symbols

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Definitions

For the purposes of this document, vegetation layers are defined as follows:

Canopy – The canopy is the uppermost strata within a plant community. The canopy is exposed to the sun and captures the majority of its radiant energy.

Understory – The understory comprises plant life growing beneath the canopy without penetrating it to any extent. The understory exists in the shade of the canopy and usually has lower light and higher humidity levels. The understory includes subcanopy trees and the shrub and herbaceous layers.

Shrub layer – The shrub layer is comprised of woody plants between 0.5 and 2.0 meters in height.

Herbaceous layer – The herbaceous layer is most commonly defined as the forest stratum composed of all vascular species that are 0.5 meter or less in height.

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1 Species Conceptual Ecological Model Methodology for the Lower Colorado River Multi-Species Conservation Program

2 Western Yellow Bat Habitat Data

Foreword

The Lower Colorado River Multi-Species Conservation Program (LCR MSCP) Habitat Conservation Plan requires the creation, and long-term stewardship, of habitat for 20 covered species. This is both an exciting and daunting challenge – exciting, in that success would mean a major conservation achievement in the lower Colorado River landscape, and daunting, in that we need to simultaneously manage our lands for the benefit of 20 species in a mosaic of land cover types. To do so, we need to develop a common understanding of the habitat requirements of each species and the stewardship required to meet those needs.

To provide a framework to capture and share the information that forms the foundation of this understanding, conceptual ecological models (CEMs) for each covered species have been created under the LCR MSCP's Adaptive Management Program. The LCR MSCP's conceptual ecological models are descriptions of the functional relationships among essential components of a species' life history, including its habitat, threats, and drivers. They tell the story of "what's important to the animal" and how our stewardship and restoration actions can change those processes or attributes for the betterment of their habitat. As such, CEMs can provide:

- A synthesis of the current understanding of how a species' habitat works. This synthesis can be based on the published literature, technical reports, or professional experience.

- Help in understanding and diagnosing underlying issues and identifying land management opportunities.

- A basis for isolating cause and effect and simplifying complex systems. These models also document the interaction among system drivers.

- A common (shared) framework or "mental picture" from which to develop management alternatives.

- A tool for making qualitative predictions of ecosystem responses to stewardship actions.

- A way to flag potential thresholds from which system responses may accelerate or follow potentially unexpected or divergent paths.

- A means by which to outline further restoration, research, and development and to assess different restoration scenarios.

- A means of identifying appropriate monitoring indicators and metrics.

- A basis for implementing adaptive management strategies.

Most natural resource managers rely heavily upon CEMs to guide their work, but few explicitly formulate and express the models so they can be shared, assessed, and improved. When this is done, these models provide broad utility for ecosystem restoration and adaptive management.

Model building consists of determining system parts, identifying the relationships that link these parts, specifying the mechanisms by which the parts interact, identifying missing information, and exploring the model's behavior (Heemskerk et al. 2003[1]). The model building process can be as informative as the model itself, as it reveals what is known and what is unknown about the connections and causalities in the systems under management.

It is important to note that CEMs are not meant to be used as prescriptive management tools but rather to give managers the information needed to help inform decisions. These models are conceptual and qualitative. They are not intended to provide precise, quantitative predictions. Rather, they allow us to virtually "tweak the system" free of the constraints of time and cost to develop a prediction of how a system might respond over time to a variety of management options; for a single species, a documented model is a valuable tool, but for 20 species, they are imperative. The successful management of multiple species in a world of competing interests (species versus species), potentially conflicting needs, goals, and objectives, long response times, and limited resources, these models can help land managers experiment from the safety of the desktop. Because quantitative data can be informative, habitat parameters that have been quantified in the literature are presented (in attachment 2) in this document for reference purposes.

These models are intended to be "living" documents that should be updated and improved over time. The model presented here should not be viewed as a definitive monograph of a species' life history but rather as a framework for capturing the knowledge and experience of the LCR MSCP's scientists and land stewards. While ideally the most helpful land management tool would be a definitive list of do's and don'ts, with exact specifications regarding habitat requirements that would allow us to engineer exactly what the species we care about need to survive and thrive, this is clearly not possible. The fact is, that despite years of active management, observation, and academic research on many of the LCR MSCP species of concern, there may not be enough data to support developing such detailed, prescriptive land management.

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[1] Heemskerk, M., K. Wilson, and M. Pavao-Zuckerman. 2003. Conceptual models as tools for communication across disciplines. Conservation Ecology 7(3):8. http://www.consecol.org/vol7/iss3/art8/

The CEMs for species covered under the LCR MSCP are based on, and expand upon, methods developed by the Sacramento-San Joaquin Delta Ecosystem Restoration Program (ERP): https://www.dfg.ca.gov/ERP/conceptual_models.asp. The ERP is jointly implemented by the California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. The Bureau of Reclamation (Reclamation) participates in this program. (See attachment 1 for an introduction to the CEM process.)

Many of the LCR MSCP covered species are migratory. These models only address the species' life history as it relates to the lower Colorado River and specifically those areas that are potentially influenced by LCR MSCP land management. The models DO NOT take into account ecological factors that influence the species at their other migratory locations.

Finally, in determining the spatial extent of the literature used in these models, the goals and objectives of the LCR MSCP were taken into consideration. For species whose range is limited to the Southwest, the models are based on literature from throughout the species' range. In contrast, for those species whose breeding range is continental (e.g., yellow-billed cuckoo) or west-wide, the models primarily utilize studies from the Southwest.

How to Use the Models

There are three important elements to each CEM:

(1) The narrative description of the species' various life stages, critical biological activities and processes, and associated habitat elements.

(2) The figures that provide a visual snapshot of all the critical factors and causal links for a given life stage.

(3) The associated workbooks. Each CEM has a workbook that includes a worksheet for each life stage.

This narrative document is a basic guide, meant to summarize information on the species' most basic habitat needs, the figures are a graphic representation of how these needs are connected, and the accompanying workbook is a tool for land managers to see how on-the-ground changes might potentially change outcomes for the species in question. Reading, evaluating, and using these CEMs requires that the reader understand all three elements; no single element provides all the pertinent information in the model. While it seems convenient to simply read the narrative, we strongly recommend the reader have the figures and workbook open and refer to them while reviewing this document.

It is also tempting to see these products, once delivered, as “final.” However, it is more accurate to view them as “living” documents, serving as the foundation for future work. Reclamation will update these products as new information is available, helping to inform land managers as they address the on-the-ground challenges inherent in natural resource management.

The knowledge gaps identified by these models are meant to serve only as an example of the work that could be done to further complete our understanding of the life history of the LCR MSCP covered species. However, this list can in no way be considered an exhaustive list of research needs. Additionally, while identifying knowledge gaps was an objective of this effort, evaluating the feasibility of addressing those gaps was not. Finally, while these models were developed for the LCR MSCP, the identified research needs and knowledge gaps reflect a current lack of understanding within the wider scientific community. As such, they may not reflect the current or future goals of the LCR MSCP. They are for the purpose of informing LCR MSCP decisionmaking but are in no way meant as a call for Reclamation to undertake research to fill the identified knowledge gaps.

John Swett, Program Manager, LCR MSCP
Bureau of Reclamation
September 2015

Executive Summary

This document presents a conceptual ecological model (CEM) for the western yellow bat (*Lasiurus xanthinus*) (WYBA). The purpose of this model is to help the Bureau of Reclamation (Reclamation), Lower Colorado River Multi-Species Conservation Program (LCR MSCP), identify areas of scientific uncertainty concerning WYBA ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure WYBA habitat and population conditions. (Note: Attachment 1 provides an introduction to the CEM process. We recommend that those unfamiliar with this process read the attachment before continuing with this document.)

The identified research questions and gaps in scientific knowledge that are the result of this modeling effort serve as examples of topics the larger scientific community could explore to improve the overall understanding of the ecology of this species. These questions may or may not be relevant to the goals of the LCR MSCP. As such, they are not to be considered guidance for Reclamation or the LCR MSCP, nor are these knowledge gaps expected to be addressed under the program.

CONCEPTUAL ECOLOGICAL MODELS

CEMs integrate and organize existing knowledge concerning: (1) what is known about an ecological resource, with what certainty, and the sources of this information, (2) critical areas of uncertain or conflicting science that demand resolution to better guide management planning and action, (3) crucial attributes to use while monitoring system conditions and predicting the effects of experiments, management actions, and other potential agents of change, and (4) how we expect the characteristics of the resource to change as a result of altering its shaping/controlling factors, including those resulting from management actions.

The CEM applied to the WYBA expands on the methodology developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012). The model distinguishes the major life stages or events through which the individuals of a species must pass to complete a full life cycle. It then identifies the factors that shape the likelihood that individuals in each life stage will survive to the next stage in the study area and thereby shapes the abundance, distribution, and persistence of the species in that area.

Specifically, the WYBA conceptual ecological model has five core components:

- **Life stages** – These consist of the major growth stages and critical events through which an individual WYBA must pass in order to complete a full reproductive cycle.

- **Life-stage outcomes** – These consist of the biologically crucial outcomes of each life stage, including the number of individuals recruited to the next life stage or age class within a single life stage (recruitment rate), or the number of fertilized offspring produced (fertility rate).

- **Critical biological activities and processes** – These consist of activities in which the species engages and the biological processes that take place during each life stage that significantly beneficially or detrimentally shape the life-stage outcome rates for that life stage.

- **Habitat elements** – These consist of the specific habitat conditions, the abundance, spatial and temporal distributions, and other qualities of which significantly beneficially or detrimentally affect the rates of the critical biological activities and processes for each life stage.

- **Controlling factors** – These consist of environmental conditions and dynamics – including human actions – that determine the abundance, spatial and temporal distributions, and other qualities of the habitat elements for each life stage. Controlling factors are also called "drivers."

The CEM identifies the causal relationships among these components for each life stage. A causal relationship exists when a change in one condition or property of a system results in a change in some other condition or property. A change in the first condition is said to cause a change in the second condition. The CEM method applied here assesses four variables for each causal relationship: (1) the character and direction of the effect, (2) the magnitude of the effect, (3) the predictability (consistency) of the effect, and (4) the certainty of a present scientific understanding of the effect. CEM diagrams and a linked spreadsheet tool document all information on the model components and their causal relationships.

CONCEPTUAL ECOLOGICAL MODEL STRUCTURE

The WYBA conceptual ecological model addresses the WYBA population along the river and lakes of the lower Colorado River (LCR) and other protected areas. The basic sources of information for the WYBA conceptual ecological model are

Kurta and Lehr (1995), Miner and Stokes (2005), Kunz and Fenton (2003), Lacki et al. (2007), and Cryan and Veilleux (2007). These publications summarize and cite large bodies of earlier studies. Where appropriate and accessible, those earlier studies are directly cited. The CEM also integrates numerous additional sources, particularly reports and articles completed since these publications; information on current research projects; and the expert knowledge of LCR MSCP biologists. The purpose of the CEM is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

The WYBA conceptual ecological model distinguishes and assesses three life stages and their associated outcomes as follows (table ES-1):

Table ES-1.—Outcomes of each of the three life stages of WYBA

Life stage	Life-stage outcome(s)
1. Pup	• Survival
2. Juvenile	• Survival
3. Breeding adult	• Survival • Reproduction

The model distinguishes 9 critical biological activities or processes relevant to 1 or more of these 3 life stages and their outcomes, 12 habitat elements relevant to 1 or more of these 9 critical biological activities or processes for 1 or more life stages, and 9 controlling factors that affect 1 or more of these 12 habitat elements. Because the LCR is a highly regulated system, the controlling factors almost exclusively concern human activities.

The nine critical biological activities and processes identified across all life stages are: chemical stress, disease, eating, foraging, mechanical stress, predation, roost attendance, roost site selection, and thermal stress. The 12 habitat elements identified across all life stages are: anthropogenic disturbance, canopy closure, food availability, genetic diversity and infectious agents, matrix community, number of pups, parent roost attendance, patch size, predator density, temperature, tree species composition, and water availability. The nine controlling factors identified across all habitat elements are: fire management, grazing, habitat restoration, nuisance species introduction and management, pesticide/herbicide application, tree pruning, tree thinning, water storage-delivery system design and operation, and wind energy development.

RESULTS

The analysis of the causal relationships shows which critical biological activities and processes most strongly support or limit each life-stage outcome in the present system, which habitat elements most strongly affect the rates of these critical biological activities and processes, and which controlling factors most strongly affect the abundance, distribution, or condition of these habitat elements.

The analysis identifies several critical biological activities and processes, habitat elements, and controlling factors that significantly affect survivorship across one or more life stages. Highlights of the results include the following:

- Tree pruning of the dead fronds from native and non-native palm (*Washingtonia* sp.) trees has a moderate effect on canopy closure and parent roost attendance.

- Tree species composition strongly affects roost site selection.

- Roost site selection has a moderate effect on reproduction in breeding adults and is strongly affected by tree species composition.

- Tree species composition is strongly affected by the presence of nuisance species; management activities, such as fire management; grazing, and water storage-delivery system design and operation. It is moderately affected by restoration activities and tree thinning.

- Roost sites located close to or within agricultural areas where pesticides/ herbicides are being applied may increase chemical stress in WYBA and affect survival rates during all life stages as well as prey abundance.

- The rate of foraging success strongly affects the success rate of WYBA in the juvenile and breeding adult life stages.

- Roost attendance and roost site selection have a moderate impact on breeding adult reproduction.

- If wind energy development is present in areas with significant WYBA activity, mechanical stress may negatively affect WYBA juvenile and breeding adult survival.

Finally, the analysis highlights several potentially important causal relationships about which scientific understanding remains low. These may warrant attention to determine if improved understanding might provide additional management options for improving WYBA survivorship and recruitment along the LCR. Specifically, the findings suggest a need to improve the understanding of:

- The distribution of WYBA roost sites within the LCR MSCP area, with special emphasis on potential impacts of land use and associated activities within the habitat and the surrounding matrix community.

- The distribution of suitable WYBA roost habitat along the LCR and habitat use within those sites.

- The ecology of predation on WYBA and its significance on survival across all life stages, how this may vary among predator species and across different habitat settings, and whether it may be possible to manipulate these habitat conditions to improve WYBA survival even in the presence of predators.

- The presence of disease in the WYBA population and its significance in affecting survival across all life stages within the LCR.

- The impacts of pesticide/herbicide use within the LCR on the survival of WYBA across all life stages.

- WYBA movement patterns within the LCR, including any seasonal migratory movement.

The research questions and gaps in scientific knowledge identified in this modeling effort serve as examples of topics the larger scientific community could explore to improve the overall understanding of the ecology of WYBA. These questions may or may not be relevant to the goals of the LCR MSCP. As such, they are not to be considered guidance for Reclamation or the LCR MSCP, nor are these knowledge gaps expected to be addressed under the program.

Chapter 1 – Introduction

This document presents a conceptual ecological model (CEM) for the western yellow bat (*Lasiurus xanthinus*) (WYBA). The purpose of this model is to help the Bureau of Reclamation (Reclamation), Lower Colorado River Multi-Species Conservation Program (LCR MSCP), identify areas of scientific uncertainty concerning WYBA ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure WYBA habitat and population conditions. The CEM methodology follows that developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012), with modifications. (Note: Attachment 1 provides an introduction to the CEM process. We recommend that those unfamiliar with this process read the attachment before continuing with this document.)

The CEM addresses the WYBA population along the river and lakes of the lower Colorado River (LCR) and other protected areas. The model thus addresses the landscape as a whole rather than any single reach or managed area.

Due to a lack of species-specific information on several key areas of WYBA life history and ecology, some of the information provided in this report is for the southern yellow bat (*Lasiurus ega*) prior to its split into two species and mostly reflects data for eastern populations. It is assumed for the purposes of the model and this report that the information is generally applicable to WYBA. One such reference is Kurta and Lehr (1995). Other basic sources of information used for the WYBA conceptual ecological model are Miner and Stokes (2005), Williams et al. (2006), Kunz and Fenton (2003), Lacki et al. (2007), and Cryan and Veilleux (2007). These publications summarize and cite large bodies of earlier studies. The CEM also integrates numerous additional sources, particularly reports and articles completed since the aforementioned publications; information on current research projects; and the expert knowledge of LCR MSCP bat biologists. The purpose of the conceptual ecological model is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

This document is organized as follows: The remainder of chapter 1 provides an explanation of the purposes for using conceptual ecological models and introduces the underlying concepts and structure of the CEM. Succeeding chapters present and explain the model for the WYBA within the LCR and evaluate the implications of this information for management, monitoring, and research needs.

WESTERN YELLOW BAT REPRODUCTIVE ECOLOGY

There is not much known about the specific reproductive biology of the WYBA. It was taxonomically split from the southern yellow bat by Baker et al. in 1988. However, the reproductive biology of the southern yellow bat is likely very similar to the WYBA, and this description is based on that information.

WYBA copulation occurs in late summer, likely between late August and late October. Female WYBA likely store sperm until fertilization occurs in late winter. Gestation takes 60–70 days. WYBA have one to two pups, with litter sizes typically two (NatureServe 2015). Young are born in June and July, likely peaking around the second week of June (Hoffmeister 1986), and lactation takes place in June and July. There is no parental care after the female ceases lactation.

CONCEPTUAL ECOLOGICAL MODEL PURPOSES

Adaptive management of natural resources requires a framework to help managers understand the state of knowledge about how a resource "works," what elements of the resource they can affect through management, and how the resource will likely respond to management actions. The "resource" may be a population, species, habitat, or ecological complex. The best such frameworks incorporate the combined knowledge of many professionals accumulated over years of investigations and management actions. CEMs capture and synthesize this knowledge (Fischenich 2008; DiGennaro et al. 2012).

CEMs explicitly identify: (1) the variables or attributes that best characterize resource conditions, (2) the factors that most strongly shape or control these variables under both natural and altered (including managed) conditions, (3) the character, strength, and predictability of the ways in which these factors do this shaping/controlling, and (4) how the characteristics of the resource vary as a result of the interplay of its shaping/controlling factors.

By integrating and explicitly organizing existing knowledge in this way, a CEM summarizes and documents: (1) what is known, with what certainty, and the sources of this information, (2) critical areas of uncertain or conflicting science that demand resolution to better guide management planning and action, (3) crucial attributes to use while monitoring system conditions and predicting the effects of experiments, management actions, and other potential agents of change, and (4) how the characteristics of the resource would likely change as a result of altering its shaping/controlling factors, including those resulting from management actions.

A CEM thus translates existing knowledge into a set of explicit hypotheses. The scientific community may consider some of these hypotheses well tested, but others less so. Through the model, scientists and managers can identify which hypotheses, and the assumptions they express, most strongly influence management actions. The CEM thus helps guide management actions based on the results of monitoring and experimentation. These results indicate whether expectations about the results of management actions – as clearly stated in the CEM – have been met or not. Both expected and unexpected results allow managers to update the model, improving certainty about some aspects of the model while requiring changes to other aspects, to guide the next cycle of management actions and research. The CEM, through its successive iterations, becomes the record of improving knowledge and the ability to manage the system.

CONCEPTUAL ECOLOGICAL MODEL STRUCTURE FOR THE WYBA

The CEM methodology used here expands on that developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012). The expansion incorporates recommendations of Wildhaber et al. (2007), Wildhaber (2011), Kondolf et al. (2008), and Burke et al. (2009) to provide greater detail on causal linkages and outcomes as well as explicit demographic notation in the characterization of life-stage outcomes (McDonald and Caswell 1993). Attachment 1 provides a detailed description of the methodology. The resulting model is a "life history" model, as is common for CEMs focused on individual species (Wildhaber et al. 2007; Wildhaber 2011). That is, it distinguishes the major life stages or events through which the individuals of a species must pass to complete a full life cycle, including reproducing, and the biologically crucial outcomes of each life stage. These outcomes typically include the number of individuals recruited to the next life stage (e.g., juvenile to adult) or next age class within a single life stage (recruitment rate), or the number of viable offspring produced (fertility rate). It then identifies the factors that shape the rates of these outcomes in the study area and thereby shapes the abundance, distribution, and persistence of a species in that area.

The WYBA conceptual ecological model has five core components as explained further in attachment 1:

- **Life stages** – These consist of the major growth stages and critical events through which an individual of a species must pass in order to complete a full life cycle.

- **Life-stage outcomes** – These consist of the biologically crucial outcomes of each life stage, including the number of individuals recruited to the next life stage (e.g., juvenile to adult), or the number of viable offspring produced (fertility rate). The rates of the outcomes for an individual life stage depend on the rates of the critical biological activities and processes for that life stage.

- **Critical biological activities and processes** – These consist of the activities in which the species engages and the biological processes that take place during each life stage that significantly affect its life-stage outcomes rates. Examples of activities and processes for a small mammal species may include dispersal, foraging, maternal care, and avoiding predators. Critical biological activities and processes typically are "rate" variables.

- **Habitat elements** – These consist of the specific habitat conditions, the quality, abundance, and spatial and temporal distributions of which significantly affect the rates of the critical biological activities and processes for each life stage. These effects on critical biological activities and processes may be either beneficial or detrimental. Taken together, the suite of natural habitat elements for a life stage is called the "habitat template" for that life stage. Defining the natural habitat template may involve estimating specific thresholds or ranges of suitable values for particular habitat elements, outside of which one or more critical biological activities or processes no longer fully support desired life-stage outcome rates – if the state of the science supports such estimates.

- **Controlling factors** – These consist of environmental conditions and dynamics – including human actions – that determine the quality, abundance, and spatial and temporal distributions of important habitat elements. Controlling factors are also called "drivers." There may be a hierarchy of such factors affecting the system at different scales of time and space (Burke et al. 2009). For example, the availability of adequate food, cover, and roost sites depends on the presence of suitable herbaceous vegetation, which in turn may depend in part on factors such as local hydrology, which is affected by water storage-delivery system design and operation coupled with habitat restoration or other management activities.

The CEM identifies these five components and the causal relationships among them that affect life-stage outcome rates. Further, the CEM assesses each causal linkage based on four variables to the extent possible with the available information: (1) the character and direction of the effect, (2) the magnitude of the effect, (3) the predictability (consistency) of the effect, and (4) the status (certainty) of a present scientific understanding of the effect.

The CEM for each life stage thus identifies the causal relationships that most strongly support or limit the rates of its life-stage outcomes, support or limit the rate of each critical biological activity or process, and support or limit the quality, abundance, and distribution of each habitat element (as these affect other habitat elements or affect critical biological activities or processes). In addition, the model for each life stage highlights areas of scientific uncertainty concerning these causal relationships, the effects of specific management actions aimed at these relationships, and the suitability of the methods used to measure habitat and population conditions. Attachment 1 provides further details on the assessment of causal relationships, including the use of diagrams and a spreadsheet tool to record the details of the CEM and summarize the findings.

Chapter 2 – WYBA Life Stage Model

A life stage consists of a biologically distinct portion of the life cycle of a species during which individuals undergo distinct developments in body form and function, engage in distinct behaviors, use distinct sets of habitats, and/or interact with their larger ecosystems in ways that differ from those associated with other life stages. This chapter proposes a life stage model for WYBA within the LCR on which to build the CEM.

INTRODUCTION TO THE WYBA LIFE CYCLE

The WYBA was formerly considered a subspecies of the southern yellow bat. It was recognized as a distinct species based on genetic work by Baker et al. (1988). Little is known about the breeding biology of WYBA. Much of the information available is for the southern yellow bat and may be somewhat different from WYBA given their different ecological setting and potentially different seasonal activity patterns.

WYBA LIFE STAGE 1 – PUP

We consider the pup stage to be the first stage in the life cycle of the WYBA. It begins when a pup is born and ends when it has fledged (becomes volant) and becomes independent of the mother. Lasiurines are thought to develop more slowly than the young of crevice-roosting bat species because their foliage roosts do not offer as much thermal protection as bark or tree hollows, leading to a greater use of torpor (Carter and Menzel 2007). The estimated time of young to fly and become fully independent is approximately 2 months (Adams 2003).

WYBA LIFE STAGE 2 – JUVENILE

This life stage begins when a pup has fledged and becomes independent from the mother and ends when the individual reaches sexual maturity. The precise timing of this life stage for WYBA is unknown. For the southern yellow bat, Kurta and Lehr (1995) speculate that both males and females breed in their first year. While there is a tremendous amount of overlap in the biological activities and processes, habitat elements, and controlling factors affecting both WYBA in the juvenile and breeding adult life stages, we felt that the differences in behavior and the way in which WYBA in these life stages interact with the environment were potentially significantly different enough to warrant the split.

WYBA LIFE STAGE 3 – BREEDING ADULT

This life stage begins when a bat reaches sexual maturity and ends when it stops reproducing. It is estimated that adult WYBA reach sexual maturity within their first year. Mating probably occurs in late summer to autumn. Sperm storage is assumed to be similar to that utilized by the closely related southern yellow bat (Adams 2003). Only scattered records of pregnant and lactating females exist, but these indicate that females give birth during spring or early summer. In the United States, pregnant southern yellow bats are known to exist from April through June (Kurta and Lehr 1995). The number of embryos carried by pregnant females varies from one to four. The lactation period is at least 60 days (Kurta and Lehr 1995).

LIFE STAGE MODEL SUMMARY

Based on this information, the WYBA conceptual ecological model distinguishes three life stages and their associated life-stage outcomes as shown in table 1 and figure 1. The life stages are numbered sequentially beginning with the pup life stage.

Table 1.—WYBA life stages and outcomes in the LCR ecosystem

Life stage	Life-stage outcome(s)
1. Pup	• Survival
2. Juvenile	• Survival
3. Breeding adult	• Survival • Reproduction

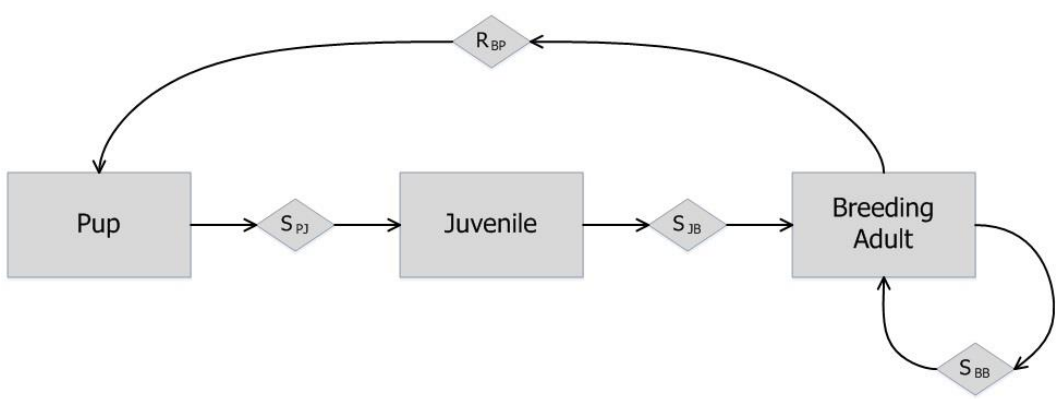


Figure 1.—Proposed WYBA life history model.
Squares indicate the life stage, and diamonds indicate the life-stage outcomes. SP_{PJ} = survivorship rate, pup; S_{JB} = survivorship rate, juveniles; S_{BB} = survivorship rate, breeding adults; and R_{PB} = reproduction rate, breeding adults.

Chapter 3 – Critical Biological Activities and Processes

Critical biological activities and processes consist of activities in which the species engages and biological processes that take place during each life stage that significantly shape the rate(s) of the outcome(s) for that life stage. Critical biological activities and processes are "rate" variables (i.e., the rate [intensity] of these activities and processes, taken together, determine the rate of recruitment of individuals from one life stage to the next).

The CEM identifies nine critical biological activities and processes that affect one or more WYBA life stages. Some of these activities or processes differ in their details among life stages. However, grouping activities or processes across all life stages into broad types makes it easier to compare the individual life stages to each other across the entire life cycle. Table 2 lists the nine critical biological activities and processes and their distribution across life stages.

Table 2.—Distribution of WYBA critical biological activities and processes among life stages
(Xs indicate that the critical biological activity or process is applicable to that life stage.)

Life stage ➔ / **Critical biological activity or process 🡻**	**Pup**	**Juvenile**	**Breeding adult**
Chemical stress	X	X	X
Disease	X	X	X
Eating	X		
Foraging		X	X
Mechanical stress		X	X
Predation	X	X	X
Roost attendance			X
Roost site selection			X
Thermal stress	X	X	X

The basic sources of information used to identify the critical biological activities and processes are Kurta and Lehr (1995), Miner and Stokes (2005), Williams et al. (2006), Kunz and Fenton (2003), Lacki et al. (2007), and Cryan and Veilleux (2007). The identification also integrates information from both older and more recent works as well as the expert knowledge of LCR MSCP bat biologists. The following paragraphs discuss the nine critical biological activities and processes in alphabetical order.

CHEMICAL STRESS

WYBA in every life stage are vulnerable to stress and mortality due to exposure to harmful chemicals, including pesticides/herbicides used in agriculture. Environmental contaminants are known to have negative impacts on bat populations due to the bioaccumulation of these chemicals (O'Shea and Clark, Jr. 2002). WYBA in the juvenile and breeding life stages are especially at risk of poisoning from insecticides because of their diet, high metabolic rates, high food intake, and high rates of fat mobilization during migration, hibernation, and lactation (Clark et al. 1988). Pups may suffer mortality by direct exposure to chemicals such as pesticides/herbicides if maternal roosts are located within an agricultural matrix. Additionally, pesticides/herbicides ingested by the mother are mobilized during lactation and transferred into the milk, and the pups can die as a result (Geluso et al. 1981). Pesticide/herbicide use in foraging areas may affect WYBA due to a loss or change in the insect prey base, but these effects are unknown. The effects of pesticides/herbicides would be most prominent in roost sites close to agricultural lands and areas where pesticide/herbicide use is common (Pierson et al. 2006).

DISEASE

The prevalence of disease as a source of bat mortality is poorly known for most species and is difficult to separate from other causes of mortality (Messenger et al. 2003). However, rabies has been suspected as a cause of high mortality in some bat species (Constantine 1967). In addition to concerns of direct mortality from disease, the fact that bats harbor strains of rabies and possibly other viruses affecting humans makes them a human health hazard and thus a potential target for extermination efforts (Fenton 1997).

EATING

This process only applies to the pup life stage because pups must eat to stay alive and develop but do not actively forage within their environment in the same way

as the juveniles and adults. A pup's ability to eat is determined by the foraging and provisioning rate of its mother. Some elements, such as siblings, number of pups in the roost, and genetic diversity, are not traditionally considered aspects of habitat but are included in this section because of their effects on critical biological activities and processes.

FORAGING

WYBA are insectivores and appear to select prey by size rather than taxonomic group (e.g., in contrast to bats that are moth specialists). A fecal analysis performed by O'Farell et al. (2004) identified the following insect orders as WYBA prey: Coleoptera (beetles), Diptera (flies), Hemiptera (cicadas and leaf hoppers), Lepidoptera (moths), and Orthoptera (crickets and grasshoppers). Foraging is done by juveniles and breeding adults, but it is important to note that foraging by the parents affects the provisioning rate to pups and roost attendance by adults.

In a study of riparian habitat use by bats in southern Nevada, Williams et al. (2006) found that WYBA were most active (foraging) in riparian woodland habitat compared to other habitat types (riparian marsh, mesquite bosque, and riparian shrubland). This riparian habitat was dominated by palm (*Washingtonia* sp.) trees. In a study conducted along a stretch of the LCR from southwestern Arizona to southeastern California, Vizcarra et al. (2010) found a high probability of WYBA use in cottonwood-willow (*Populus fremontii*, *Salix* sp.) habitat.

MECHANICAL STRESS

The primary source of mechanical stress on WYBA juveniles and breeding adults considered here is collisions with wind energy facilities. Bat fatalities related to wind energy facilities have been on the rise for the past 30 years (Hayes 2013). While wind energy facilities are not currently located along the LCR, mortality from wind energy facilities in areas where WYBA may migrate to and from have been recorded (Kunz et al. 2007).

PREDATION

Little specific information is available on WYBA predators. The WYBA's preference for palm trees as roost habitat puts them in closer proximity to humans; therefore, domestic dogs (*Canis lupis*) and cats (*Felis catus)* are major predators of this species (Kurta and Lehr 1995). Woodpeckers (Picidae) and

raccoons (*Procyon lotor*) have been observed disturbing other tree-roosting bat species at their roosting sites (Sparks et al. 2003). Since jays (Corvidae), raccoons, and opossums (*Didelphis virginianus*) also thrive in human-dominated settings, it is likely that predation from these species is higher when roost sites are close to these areas.

Predation risk may impact a number of aspects of bat behavior, including roost site selection, the nature of sleep and torpor, evening roost departures, and landscape-related movement patterns (Lima and O'Keefe 2013).

ROOST ATTENDANCE

Adequate maternal roost attendance is important for successful reproduction. Female WYBA are solely responsible for feeding of the young. Lactating females attend the roost, and this affects the survival of pups.

ROOST SITE SELECTION

WYBA preferentially roost in the skirt of dead fronds of native and non-native palm trees (Kurta and Lehr 1995; Mirowsky 1997). In a study of bat roost site habitat conducted at the LCR, WYBA were documented to use Mexican fan palms (*Washingtonia robusta*) almost exclusively and did not exhibit roost-switching behavior. Roost locations were consistently found to be in dead frond skirts below the live crowns of trees (Diamond 2012). Higginbotham et al. (1999) cite examples of studies in which WYBA are found roosting in cottonwood forests.

Roost site selection by breeding females is important for reproductive success. Roost success varies spatially as a result of food availability, hydrology, predator types and densities, vegetation characteristics, and other factors (Kunz and Lumsden 2003).

THERMAL STRESS

The costs associated with thermoregulation influence the energy available for growth and reproduction of WYBA in all life stages (Barclay and Harder 2003). While not documented in WYBA, extremes in cold and heat are known to be causes of mortality in other bat species and should be considered a threat. Although lasiurines are capable of withstanding freezing temperatures for short periods (< 1 month) (Cryan and Veilleux 2007), WYBA may be especially vulnerable, as they are relatively exposed in their forest roosts. Pups may be

particularly susceptible to temperature extremes. Jones et al. (2009) provide evidence of the effects of extreme cold and heat on various bat species, including a massive die off of bat pups documented in Australia in 2006. Similarly, extreme heat was responsible for a massive die off of over 3,500 individuals of a mixed-species colony in New South Wales in 2002. Thermal stress may affect WYBA in different life stages and reproductive statuses differentially.

Chapter 4 – Habitat Elements

Habitat elements consist of specific habitat conditions that ensure, allow, or interfere with critical biological activities and processes. These elements consist of anything in the environment from the perspective of the individual and thus should not be restricted to a traditional definition. For example, number of pups is a habitat element that may affect an individual pup.

This chapter identifies 12 habitat elements that affect 1 or more critical biological activities or processes across the 3 WYBA life stages. Some of these habitat elements differ in their details among life stages. Table 3 lists the 12 habitat elements and the 9 critical biological activities and processes that they *directly* affect across all WYBA life stages.

Table 3.—Distribution of WYBA habitat elements and the critical biological activities and processes they directly affect across all life stages
(Xs indicate that the habitat element is applicable to that critical activity or process.)

Critical activity or process ➔ / **Habitat element 🡻**	**Chemical stress**	**Disease**	**Eating**	**Foraging**	**Mechanical stress**	**Predation**	**Roost attendance**	**Roost site selection**	**Thermal stress**
Anthropogenic disturbance				X			X		
Canopy closure							X	X	X
Food availability				X				X	
Genetic diversity and infectious agents		X							
Matrix community	X			X	X			X	
Number of pups				X			X		
Parent roost attendance			X						
Patch size				X		X		X	
Predator density				X		X		X	
Temperature								X	X
Tree species composition				X				X	
Water availability								X	

The diagrams and other references to habitat elements elsewhere in this document identify the habitat elements by a one-to-three-word short name. However, each short name in fact refers to a longer, complete name. For example, the habitat element "patch size" is the short name for "the size of riparian habitat patches." The following paragraphs provide the full name for each habitat element and a detailed definition, addressing the elements in alphabetical order. As with all tabulations of habitat associations, inferences that particular habitat characteristics are critical to a species or life stage require evidence and CEMs for why each association matters to species' viability (Rosenfeld 2003; Rosenfeld and Hatfield 2006.)

ANTHROPOGENIC DISTURBANCE

Full name: **Human activity within or surrounding a given habitat patch, including noise, pollution, and other disturbances associated with human activity**. This element refers to the existence and level of human disturbance near WYBA roosting habitat. The disturbance of roost sites may be a cause for bat decline along the LCR in areas that are near development and/or areas that receive varying levels of human use. The cosmetic pruning of palm trees in particular is a major threat to roosting WYBA (Miner and Stokes 2005; Reclamation 2008). Human talking and walking around roost sites does not appear to substantially disturb bats, but any attempt to handle them may (Constantine 1959).

CANOPY CLOSURE

Full name: **The density of foliage in the overstory**. This element refers to the percent cover of canopy vegetation in the vicinity of a WYBA roost site. Since few observations have been made of WYBA roosting in native riparian habitat, it is difficult to assess the exact requirements of canopy closure for roosting WYBA in this habitat type. WYBA are more commonly found roosting in native and non-native palm trees where an extensive cover of dead palm fronds exists below the live foliage of the tree (Kurta and Lehr 1995; Mirowsky 1997; Diamond 2012). In a study of WYBA roost habitat along the LCR, Diamond (2012) estimates the percent of dead crown cover in WYBA roosting trees (Mexican fan palms) at approximately 40 percent. Reduced canopy closure may affect the availability of appropriate roosts, which could increase energetic demands or displace bats to areas with increased competition for food and roosts (Ormsbee et al. 2007).

FOOD AVAILABILITY

Full name: **The abundance of food available for adults and their young**. This element refers to the taxonomic and size composition of the invertebrates that an individual WYBA will encounter during the juvenile and adult stages as well as the density and spatial distribution of the food supply near the roost location. The abundance and condition of the food supply affects adult health as well as the growth and development of the young during the pup and juvenile stages. Although pups rely on the mother for nutrition, food availability still affects the foraging behavior and success of the mother and therefore indirectly affects the survival of the pup.

GENETIC DIVERSITY AND INFECTIOUS AGENTS

Full name: **The genetic diversity of WYBA individuals and the types, abundance, and distribution of infectious agents and their vectors**. The genetic diversity component of this element refers to the genetic homogeneity versus heterogeneity of a population during each life stage. The greater the heterogeneity, the greater the possibility that individuals of a given life stage will have genetically encoded abilities to survive their encounters with the diverse stresses presented by their environment and/or take advantage of the opportunities presented. The infectious agent component of this element refers to the spectrum of viruses, bacteria, fungi, and parasites that individual WYBA are likely to encounter during each life stage.

MATRIX COMMUNITY

Full name: **The type of habitat surrounding habitat patches used by WYBA**. This element refers to the types of plant communities and land use activities surrounding the habitat patches used by WYBA. For example, adjacent agricultural landscapes may have elevated pesticide/herbicide loads, which may affect foraging and survival of adult and juvenile WYBA. Williams (2005) notes that WYBA are known to roost in date palm (*Phoenix dactylifera*) and other orchards. Orchards, in particular, can be a significant source of pesticide/herbicide contamination of prey consumed by WYBA. The proximity to development and the planting of non-native palm trees has likely aided in the northern expansion of WYBA populations and provides important roost habitat for the species (Williams et al. 2006).

NUMBER OF PUPS

Full name: **The number of pups in a roost**. This element refers to the number of pups that a mother must rear. Lasiurine bats are unusual in that they typically produce more than 1 pup (average 2.3) per year (LaVal and LaVal 1979). WYBA are known to have from one to four pups per year (Kurta and Lehr 1995). The number of pups in a roost is related to maternal health, and the well-being of the mother depends in part on the availability of sufficient food resources in close proximity to the roost as well as other factors such as predator density.

PARENT ROOST ATTENDANCE

Full name: **The ability of a mother to care for young during the pup stage**. This element refers to the capacity of a mother to tend to the young. It is affected by the presence of predators, food availability, and the ability to thermoregulate.

PATCH SIZE

Full name: **The size of riparian habitat patches**. This element refers to the areal extent of a given patch of riparian vegetation. Native riparian vegetation along the LCR has been reduced by 94 percent, and prior to the LCR MSCP, the remaining riparian habitat was scattered in patches less than 4 hectares in size (Calvert and Neiswenter 2012). No studies are available that address the effect of patch size on WYBA activity or survival; however, it is assumed to be an important factor, as it is for the western red bat (*L. blossevillii)*.

PREDATOR DENSITY

Full name: **The abundance and distribution of predators that affect WYBA during the pup, juvenile, and breeding adult stages**. This element refers to a set of closely related variables that affect the likelihood that different kinds of predators will encounter and successfully prey on WYBA during all life stages. The variables of this element include the species and size of the fauna that prey on WYBA during different life stages, the density and spatial distribution of these fauna in the habitat used by WYBA, and whether predator activity may vary in relation to other factors (e.g., time of day, patch size and width, matrix community type, etc.).

TEMPERATURE

Full name: **The mean temperature in a habitat patch or roost site**. This element refers to the average temperature in the roosting habitat. Thermal regulation is necessary for survival of WYBA in all life stages. Tree-roosting bats, in general, are more exposed to temperature fluctuations than cave- and mine- dwelling bats. They may hibernate or migrate to the southern part of their range in winter (O'Farell et al. 2004). Extreme temperatures in the LCR region in the summer may kill pups or roosting adult WYBA.

TREE SPECIES COMPOSITION

Full name: **The composition of tree species in a plant community**. This element refers to the tree composition of a plant community where WYBA are active. WYBA have been found to be more active (foraging) in riparian habitat compared to other natural habitat types (Williams et al. 2006), but they tend to preferentially roost in native and non-native palm trees (Kurta and Lehr 1995; Mirowsky 1997). Williams (2005) notes that WYBA are known to roost in date palm and other orchards. Pierson et al. (2006) list concerns over orchards being a population sink for tree-roosting bat species. In a study of bat roost site habitat conducted along the LCR, WYBA were documented to roost in Mexican fan palms almost exclusively (Diamond 2012). Higginbotham et al. (1999) cite examples of studies in which WYBA are found roosting in cottonwood forests.

WATER AVAILABILITY

Full name: **The availability of water, including groundwater and the distance to standing water, or the presence of adjacent water bodies**. This element refers to the presence of water near roost sites, particularly in the summer breeding season. The proximity of open water and wetlands to appropriate roost habitat may be an important landscape-scale factor for WYBA roost site selection. This element affects WYBA indirectly by affecting the availability of prey as well as the availability of roosting habitat (Hagen and Sabo 2012). Groundwater declines have been linked to changes in the riparian vegetation community, with declines in cottonwood and willow species and increases in non-native tamarisk (*Tamarix* spp.) (Stromberg 1998).

Chapter 5 – Controlling Factors

Controlling factors consist of environmental conditions and dynamics, both natural and anthropogenic, which significantly affect the abundance, spatial and temporal distributions, and quality of critical habitat elements. They may also significantly directly affect some critical biological activities and processes. A hierarchy of such factors exists, with long-term dynamics of climate and geology at the top. However, this CEM focuses on nine immediate controlling factors that are within the scope of potential human manipulation. The nine controlling factors identified in this CEM do not constitute individual variables; rather, each identifies a category of variables (including human activities) that share specific features that make it useful to treat them together. Table 4 lists the nine controlling factors and the habitat elements they directly affect.

Table 4.—Habitat elements directly affected by controlling factors

Controlling factor ➔ / **Habitat element 🡻**	**Fire management**	**Grazing**	**Habitat restoration**	**Nuisance species introduction and management**	**Pesticide/herbicide application**	**Tree pruning**	**Tree thinning**	**Water storage-delivery system design and operation**	**Wind energy development**
Anthropogenic disturbance	N/A*								
Canopy closure	X		X			X	X		
Food availability					X				
Genetic diversity and infectious agents	N/A*								
Matrix community			X						X
Number of pups	N/A*								
Parent roost attendance						X			
Patch size	X	X	X						
Predator density	N/A*								
Temperature	N/A*								
Tree species composition	X	X	X	X			X		
Water availability								X	

* N/A values suggest that none of the identified controlling factors *directly* affect the habitat element.

FIRE MANAGEMENT

This factor addresses any fire management (whether prescribed fire or fire suppression) that may occur along the LCR that could affect WYBA or their habitat. Effects may include the creation of habitat that supports or excludes WYBA, a reduction in the food supply of invertebrates, or support of species that pose threats to WYBA such as predators, competitors, or carriers of infectious agents. Although typically not a major threat in most riparian habitats, fire has been shown to affect WYBA roosting habitat along the LCR by facilitating the replacement of large cottonwood trees by non-native species such as tamarisk (*Tamarix ramosissima*) and arrowweed (*Tessaria sericea*) (Busch 1995). Fire could affect WYBA roosting sites if it carries into the dead frond skirts preferred as roosting habitat.

Climate change is also projected to affect fire frequency along the LCR (U.S. Fish and Wildlife Service 2013).

GRAZING

This factor addresses the grazing activity on habitats along the LCR and in surrounding areas that could affect WYBA or their habitat. Grazing may thin the understory or even prevent the establishment of cottonwood and willow seedlings (Kauffman et al. 1997). This factor includes grazing by wild, domesticated, and feral animals. Currently, grazing is minimal in LCR MSCP restoration sites. (Note: Reclamation staff and researchers have observed mule deer (*Odocoileus hemionus)* browsing on LCR sites, which may become an issue if populations are not managed).

HABITAT RESTORATION

This factor addresses the active program to restore cottonwood-willow riparian habitat along the LCR and includes both the community planted as well as the manner in which it is planted within restoration areas (e.g., density, age, and patch size). It also includes avoiding the removal of native palm trees to maintain roost habitat for WYBA.

NUISANCE SPECIES INTRODUCTION AND MANAGEMENT

This factor addresses the intentional or unintentional introduction of nuisance species (animals and plants) and their control that affects WYBA survival and reproduction. A nuisance species may infect, prey on, compete with, or present alternative food resources for WYBA during one or more life stages, cause other alterations to the riparian food web that affect WYBA, or affect physical habitat features such as canopy or shrub cover.

PESTICIDE/HERBICIDE APPLICATION

This factor addresses biocide applications that may occur on or adjacent to WYBA habitat in the LCR region. Environmental contaminants are known to have negative impacts on bat populations due to the bioaccumulation of these chemicals (O'Shea and Clark, Jr. 2002). WYBA in the juvenile and breeding life stages are especially at risk of poisoning from insecticides because of their diet, high metabolic rates, high food intake, and high rates of fat mobilization during migration, hibernation, and lactation (Clark et al. 1988). Pierson et al. (2006) suggest that if there are negative impacts of agricultural pesticides/herbicides on tree-roosting bats either directly (mortality or reduced fecundity) or indirectly (through reduction in prey base), then orchards may be a population sink.

TREE PRUNING

This factor addresses the removal of vegetation (live and dead), mostly for cosmetic purposes, from individual native and non-native palm trees within the LCR region by mechanical means. WYBA only roost in the ring of dead fronds that encircle the live foliage on palm trees (Mirowsky 1997). Effects may include destruction of WYBA roosting habitat and/or direct mortality of adult and immature WYBA during pruning activities.

TREE THINNING

This factor addresses the removal of trees from areas within the LCR region by either mechanical or natural means. Effects may include the creation of habitat that supports or excludes WYBA or support of species that pose threats to WYBA such as predators, competitors, or carriers of infectious agents. This factor includes the thinning of vegetation within both riparian and matrix communities.

WATER STORAGE-DELIVERY SYSTEM DESIGN AND OPERATION

This factor addresses the volume and spatial and temporal variation of flow in the LCR. The LCR consists of a chain of reservoirs separated by flowing reaches. The water moving through this system is highly regulated for storage and delivery (diversion) to numerous international, Federal, State, Tribal, and municipal users and for hydropower generation. The dynamic nature of a free-flowing river creates a mosaic of riparian habitats, and thus, a natural flow regime may be beneficial to WYBA.

WIND ENERGY DEVELOPMENT

This factor addresses the development of wind energy facilities near foraging areas and migratory routes of WYBA. While there are currently no wind turbines located along the LCR, it is likely that bats foraging near active wind turbines, including WYBA migrating to and from the LCR, could be killed. Lasiurines tend to be disproportionately affected by these facilities (Arnett 2005; Kunz et al. 2007; Hayes 2013).

Chapter 6 – Conceptual Ecological Model by Life Stage

This chapter contains three sections, each presenting the CEM for a single WYBA life stage. The text and diagrams identify the critical biological activities and processes for each life stage, the habitat elements that support or limit the success of these critical biological activities and processes, the controlling factors that determine the abundance and quality of these habitat elements, and the causal links among them. The CEM sections specifically refer to the river and lakes of the LCR and other protected areas managed as WYBA habitat and thus address this landscape as a whole rather than any single reach or managed area.

The CEM for each life stage assesses the character and direction, magnitude, predictability, and scientific understanding of each causal link based on the following definitions (see attachment 1 for further details):

- **Character and direction** categorizes a causal relationship as positive, negative, or complex. "Positive" means that an increase in the causal node results in an increase in the affected node, while a decrease in the causal node results in a decrease in the affected node. "Negative" means that an increase in the causal node results in a decrease in the affected element, while a decrease in the causal node results in an increase in the affected node. Thus, "positive" or "negative" here do ***not*** mean that a relationship is beneficial or detrimental. The terms instead provide information analogous to the sign of a correlation coefficient. "Complex" means that there is more going on than a simple positive or negative relationship. Positive and negative relationships are further categorized based on whether they involve any response threshold in which the causal agent must cross some value before producing an effect. In addition, the "character and direction" attribute categorizes a causal relationship as uni- or bi-directional. Bi-directional relationships involve a reciprocal relationship in which each node affects the other.

- **Magnitude** refers to "…the degree to which a linkage controls the outcome *relative to other drivers*" (DiGennaro et al. 2012). Magnitude takes into account the spatial and temporal scale of the causal relationship as well as the strength (intensity) of the relationship at any single place and time. The present methodology separately rates the intensity, spatial scale, and temporal scale of each link on a three-part scale from "Low" to "High" and assesses overall link magnitude by averaging the ratings for these three. If it is not possible to estimate the intensity, spatial scale, or temporal scale of a link, the subattribute is rated as "Unknown" and ignored in the averaging. If all three subattributes are "Unknown," however, the overall link magnitude is rated as "Unknown." Just as the

terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link magnitude provide information analogous to the size of a correlation coefficient.

- **Predictability** refers to "…the degree to which current understanding of the system can be used to predict the role of the driver in influencing the outcome. Predictability … captures variability… [and recognizes that] effects may vary so much that properly measuring and statistically characterizing inputs to the model are difficult" (DiGennaro et al. 2012). A causal relationship may be unpredictable because of natural variability in the system or because its effects depend on the interaction of other factors with independent sources for their own variability. Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link predictability provide information analogous to the size of the range of error for a correlation coefficient. The present methodology rates the predictability of each link on a three-part scale from "Low" to "High." If it is not possible to rate predictability due to a lack of information, then the link is given a rating of "Unknown" for predictability.

- **Scientific understanding** refers to the degree of agreement represented in the scientific literature and among experts in understanding how each causal relationship works—its character, magnitude, and predictability. Link predictability and understanding are independent attributes. A link may be highly predictable but poorly understood or poorly predictable but well understood. The present methodology rates the state of scientific understanding of each link on a three-part scale from "Low" to "High."

The CEM for each life stage thus identifies the causal relationships that most strongly support or limit life-stage outcomes, support or limit the rate of each critical biological activity or process, and support or limit the quality of each habitat element, as that element affects other habitat elements or affects critical biological activities or processes.

A separate spreadsheet is used to record the assessment of the character and direction, magnitude, predictability, and scientific understanding for each causal link along with the underlying rationale and citations for each life stage. The CEM for each life stage, as cataloged in its spreadsheet, is illustrated with diagrams showing the controlling factors, habitat elements, critical biological activities and processes, and causal links identified for that life stage. A diagram may also visually display information on the character and direction, magnitude, predictability, and/or scientific understanding of every link. The diagrams use a common set of conventions for identifying the controlling factors, habitat elements, critical biological activities and processes, and life-stage outcomes as well as for displaying information about the causal links. Figure 2 illustrates these conventions.

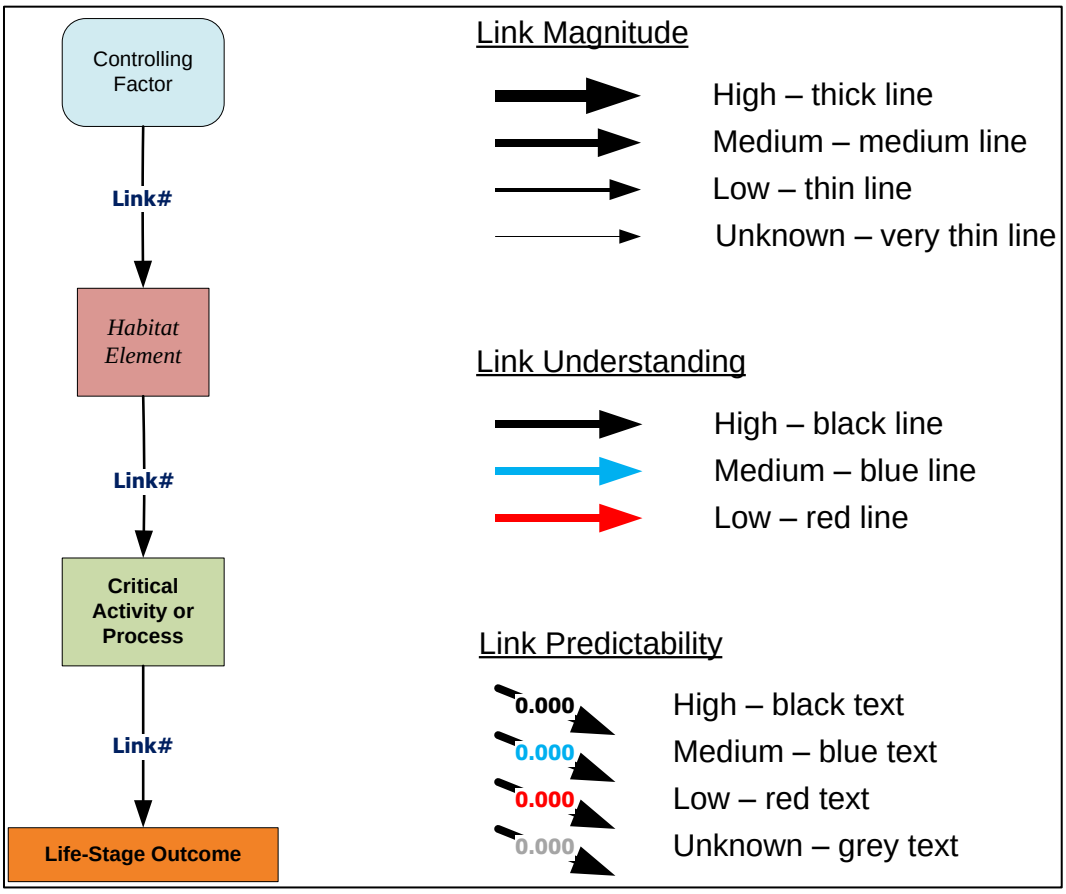


Figure 2.—Diagram conventions for LCR MSCP conceptual ecological models.

The discussion of each life stage includes an analysis of the information contained in the spreadsheet. The analyses highlight causal chains that strongly affect survivorship, identify important causal relationships with different levels of predictability, and identify important causal relationships with high scientific uncertainty. The latter constitutes topics of potential importance for adaptive management investigation.

The causal relationships between controlling factors and habitat elements are essentially identical across all three life stages. For this reason, the discussion of controlling factor-habitat element linkages across all three life stages appears in a subsequent chapter.

WYBA LIFE STAGE 1 – PUP

We consider the pup stage to be the first stage in the life cycle of WYBA. It begins when a pup is born and ends when it has fledged and becomes independent from the mother. Success during this life stage – successful transition to the next stage – involves pup survival, maturation, and flight.

The CEM (figures 3 and 4) recognizes five (of nine) critical biological activities and processes for this life stage, ordered as they appear on the following figures:

1. **Chemical Stress** – Pups may suffer mortality by direct exposure to chemicals such as pesticides/herbicides if maternal roosts are located within an agricultural matrix. Additionally, pesticides/herbicides ingested by the mother are mobilized during lactation and transferred into the milk, and the pups can die as a result (Geluso et al. 1981). There is no literature on the effects of chemical stress on WYBA in LCR open environments, although the impacts have been identified as a topic of concern.

   The CEM identifies the matrix community surrounding a roost site as a secondary habitat element affecting chemical stress.

2. **Disease** – Although the literature does not emphasize disease as affecting population levels of WYBA, we believe that disease bears mentioning. It has been recommended as an area for further research for bat species in general (Messenger et al. 2003).

   The CEM recognizes genetic diversity and infectious agents as a secondary habitat element affecting disease.

3. **Eating** – The pup must eat in order to maintain metabolic processes.

   The CEM recognizes the number of pups and parent roost attendance as secondary habitat elements affecting disease.

4. **Predation** – Predation may affect the survival of pups. Tree-roosting bat species are particularly susceptible to roost predation, although nothing is known about how great a threat predation poses to WYBA along the LCR.

   The CEM recognizes patch size and predator density as secondary habitat elements affecting predation.

5. **Thermal Stres***s* – Pup growth and survival depends on maintaining an optimum temperature.

   The CEM recognizes canopy closure, parent roost attendance, and temperature as secondary habitat elements affecting thermal stress.

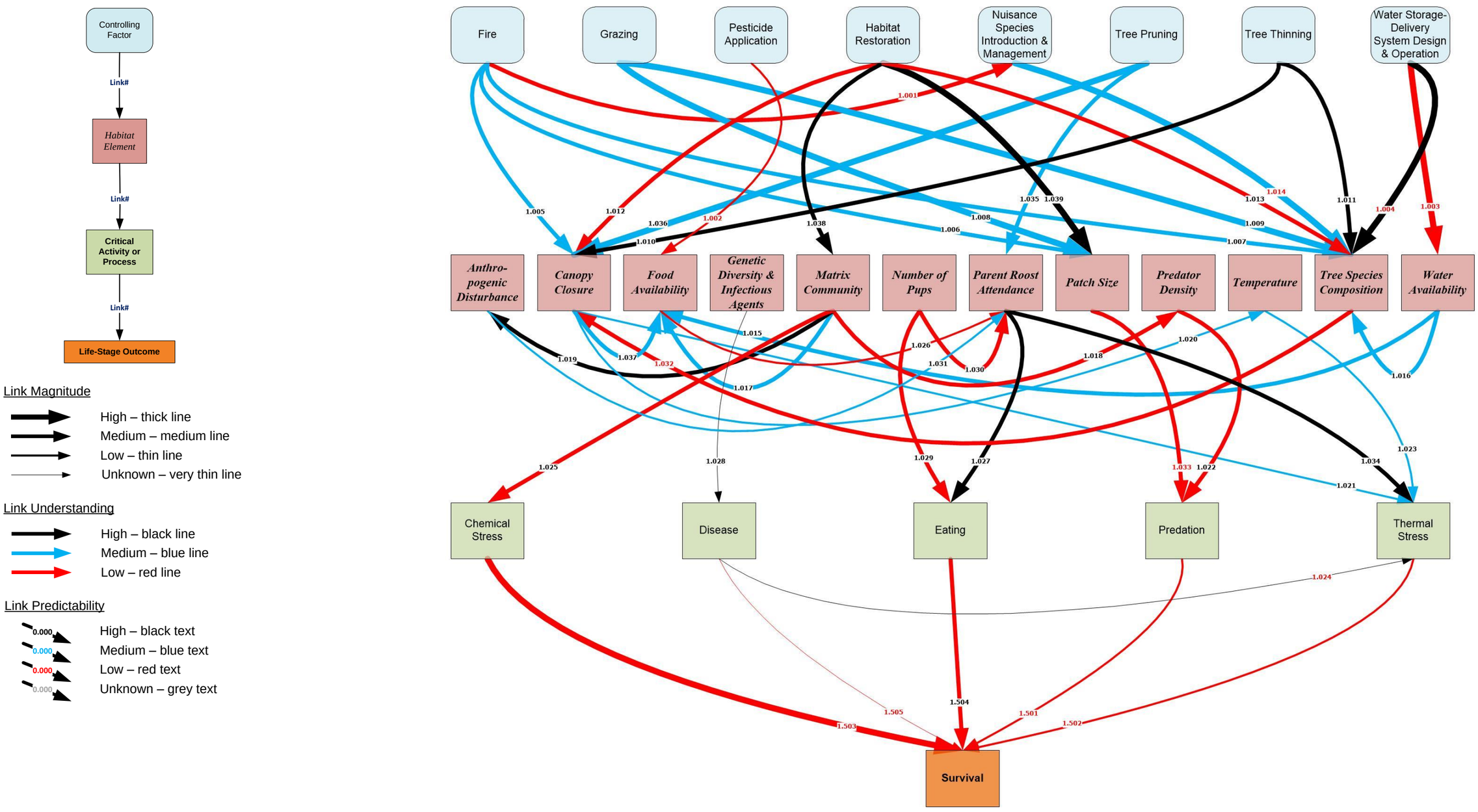


Figure 3.—WYBA life stage 1 – pup, basic CEM diagram showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

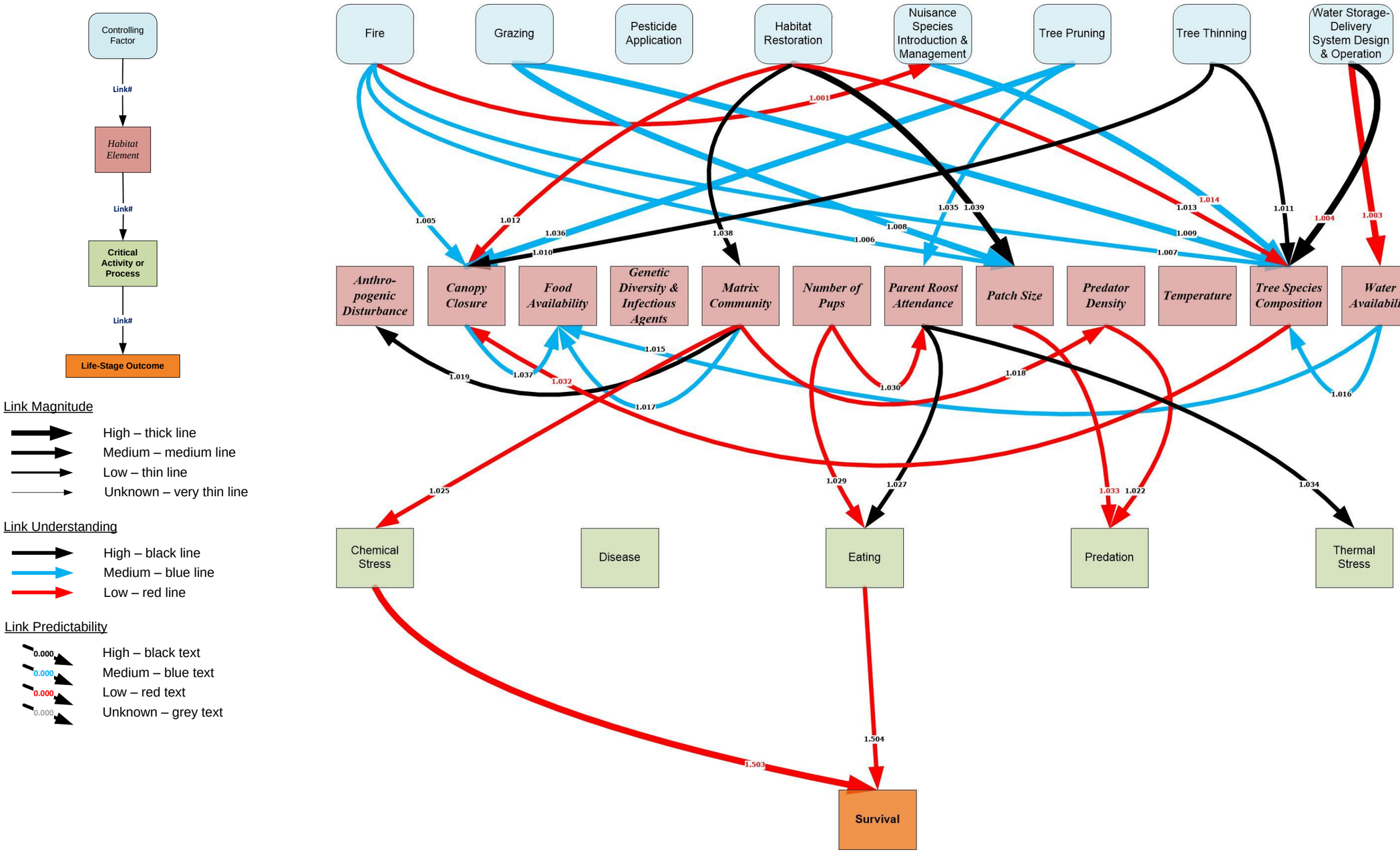


Figure 4.—WYBA life stage 1 – pup, high- and medium-magnitude relationships, showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

WYBA LIFE STAGE 2 – JUVENILE

The juvenile life stage begins when a pup has fledged and becomes independent from the mother and ends when the individual reaches sexual maturity. Success during this life stage – successful transition to the next stage – involves organism survival and maturation.

The CEM (figures 5 and 6) recognizes six (of nine) critical biological activities and processes for this life stage, ordered as they appear on the following figures:

1. **Chemical Stress** – Environmental contaminants are known to have negative impacts on bat populations due to the bioaccumulation of these chemicals (O'Shea and Clark, Jr. 2002). WYBA in the juvenile and breeding life stages are especially at risk of poisoning from insecticides because of their diet, high metabolic rates, high food intake, and high rates of fat mobilization during migration, hibernation, and lactation (Clark et al. 1988). There is no literature on the effects of chemical stress on WYBA in LCR open environments, although the impacts have been identified as a topic of concern.

   Additionally, pesticide/herbicide use in foraging areas may affect WYBA due to a loss or change in the insect prey base, but these effects are unknown. The effects of pesticides/herbicides would be most prominent in roost sites close to orchards and other agricultural lands (Pierson et al. 2006).

   The CEM identifies the matrix community surrounding a roost site as a secondary habitat element affecting chemical stress.

2. **Disease** – Although the literature does not emphasize disease as affecting population levels of WYBA, we believe that disease bears mentioning. It has been recommended as an area for further research for bat species in general (Messenger et al. 2003).

   The CEM recognizes genetic diversity and infectious agents as a secondary habitat element affecting disease.

3. **Foraging** – Juvenile WYBA must forage effectively to feed themselves and maintain metabolic processes.

   The CEM recognizes anthropogenic disturbance, food availability, the matrix community, patch size, predator density, and tree species composition as secondary habitat elements affecting foraging.

4. **Mechanical Stress** – The primary source of mechanical stress on WYBA juveniles considered here is collisions with wind energy facilities. While there are currently no wind turbines located along the LCR, it is likely that bats foraging near active wind turbines, including WYBA migrating to and from the LCR, could be killed. Lasiurines tend to be disproportionately affected by these facilities (Arnett 2005; Kunz et al. 2007; Hayes 2013).

   The CEM recognizes the matrix community as a secondary habitat element affecting mechanical stress.

5. **Predation** – Predation may affect the survival of juvenile WYBA. Tree-roosting bat species are particularly susceptible to predation because of their exposed roosts, although little is known about how great a threat predation poses to WYBA along the LCR.

   The CEM recognizes patch size and predator density as secondary habitat elements affecting predation.

6. **Thermal Stress** – Juvenile growth and survival depend on maintaining an optimum temperature.

   The CEM recognizes canopy closure and temperature as secondary habitat elements affecting thermal stress.

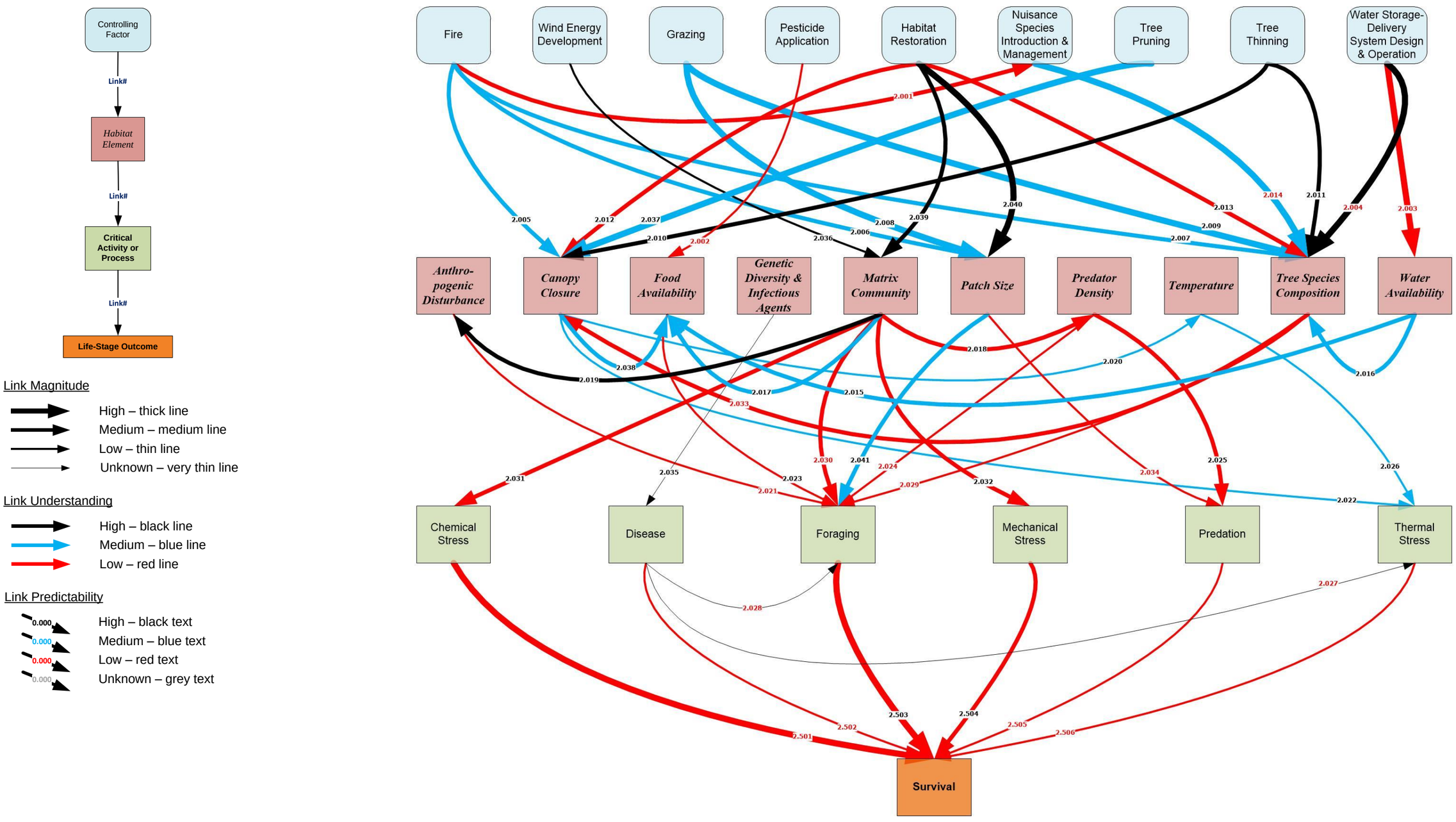


Figure 5.—WYBA life stage 2 – juvenile, basic CEM diagram showing the relevant controlling factors, habitat elements and critical biological activities and processes at this life stage.

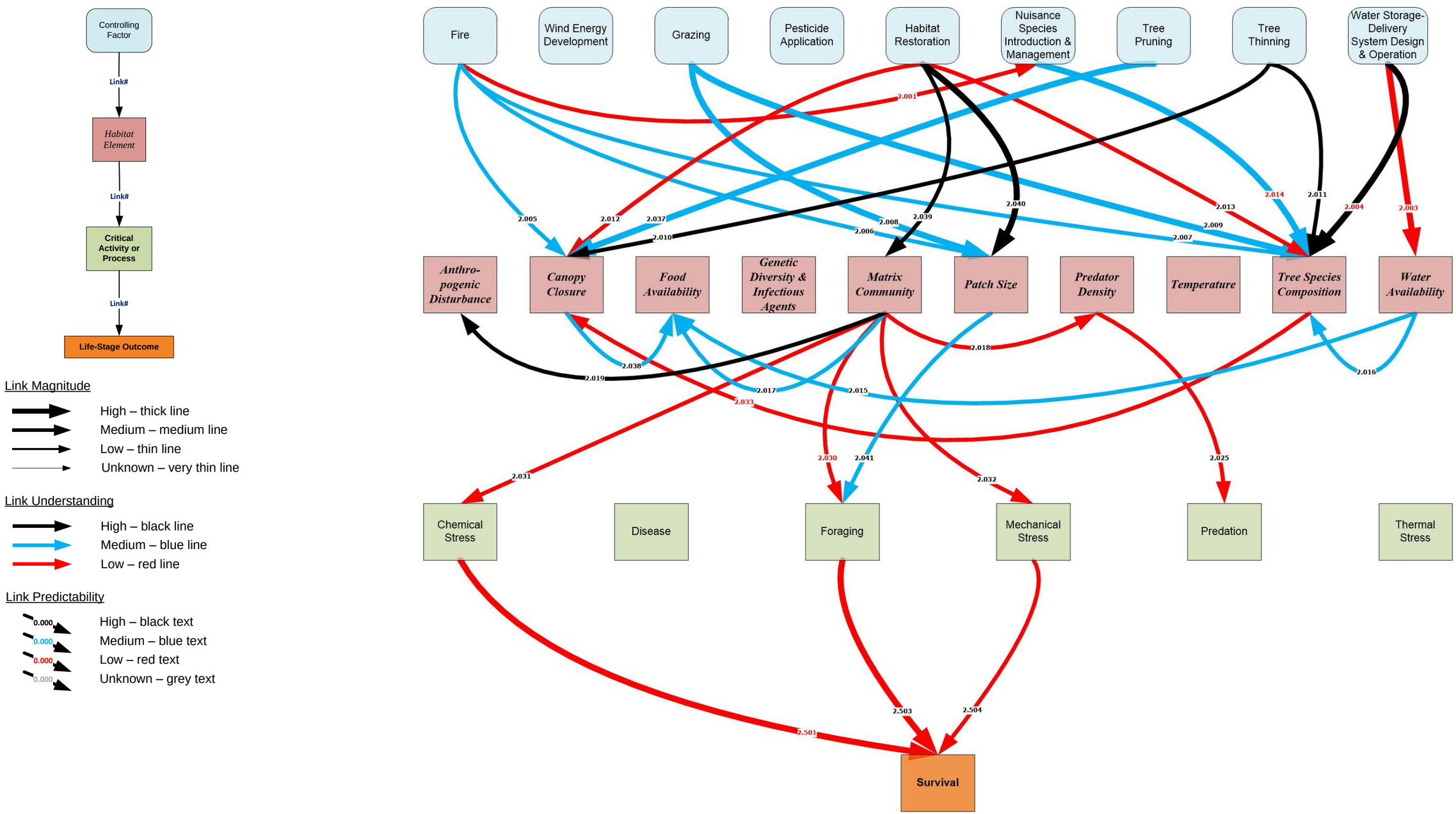


Figure 6.—WYBA life stage 2 – juvenile, high- and medium-magnitude relationships showing the relevant controlling factors, habitat elements, and critical biological processes at this life stage.

WYBA STAGE 3 – BREEDING ADULT

The breeding adult life stage begins when a bat reaches sexual maturity and ends when it stops reproducing. Success during this life stage involves organism survival and breeding.

The CEM (figures 7 and 8) recognizes eight (of nine) critical biological activities and processes for this life stage, ordered as they appear on the following figures:

1. **Chemical Stress** – Environmental contaminants are known to have negative impacts on bat populations due to the bioaccumulation of these chemicals (O'Shea and Clark, Jr. 2002). WYBA in the juvenile and breeding life stages are especially at risk of poisoning from insecticides because of their diet, high metabolic rates, high food intake, and high rates of fat mobilization during migration, hibernation, and lactation (Clark et al. 1988). There is no literature on the effects of chemical stress on WYBA in LCR open environments, although the impacts have been identified as a topic of concern.

   Additionally, pesticide/herbicide use in foraging areas may affect WYBA due to a loss or change in the insect prey base, but these effects are unknown. The effects of pesticides/herbicides would be most prominent in roost sites close to orchards and other agricultural lands (Pierson et al. 2006).

   The CEM identifies the matrix community surrounding a roost site as a secondary habitat element affecting chemical stress.

2. **Disease** – Although the literature does not emphasize disease as affecting population levels of WYBA, we believe that disease bears mentioning. It has been recommended as an area for further research for bat species in general (Messenger et al. 2003).

   The CEM recognizes genetic diversity and infectious agents as a secondary habitat element affecting disease.

3. **Foraging** – Adult WYBA must forage effectively to feed themselves and their young.

   The CEM recognizes anthropogenic disturbance, food availability, the number of pups, the matrix community, patch size, predator density, and tree species composition as secondary habitat elements affecting foraging.

4. **Mechanical Stress** – The primary source of mechanical stress on WYBA adults considered here is that of collisions with wind energy facilities. While there are currently no wind turbines located along the LCR, it is likely that bats foraging near active wind turbines, including WYBA migrating to and from the LCR, could be killed. Lasiurines tend to be disproportionately affected by these facilities (Arnett 2005; Kunz et al. 2007; Hayes 2013).

   The CEM recognizes the matrix community as a secondary habitat element affecting mechanical stress.

5. **Roost Site Selection** – This process involves roost site selection by breeding females and is important for reproductive success.

   The CEM recognizes anthropogenic disturbance, canopy closure, the matrix community, patch size, temperature, tree species composition, and water availability as secondary habitat elements affecting roost site selection.

6. **Predation** – Predation may affect the survival of adult WYBA. Tree-roosting bat species are particularly susceptible to predation because of their exposed roosts, although nothing is known about how great a threat predation poses to WYBA along the LCR.

   The CEM recognizes patch size and predator density as secondary habitat elements affecting predation.

7. **Thermal Stress** – Breeding adult survival depends on maintaining an optimum temperature.

   The CEM recognizes canopy closure and temperature as secondary habitat elements affecting thermal stress.

8. **Roost Attendance** – Breeding adults must attend to the roost to protect and feed the young.

   The CEM recognizes the number of pups in the roost as a secondary habitat element affecting roost attendance.

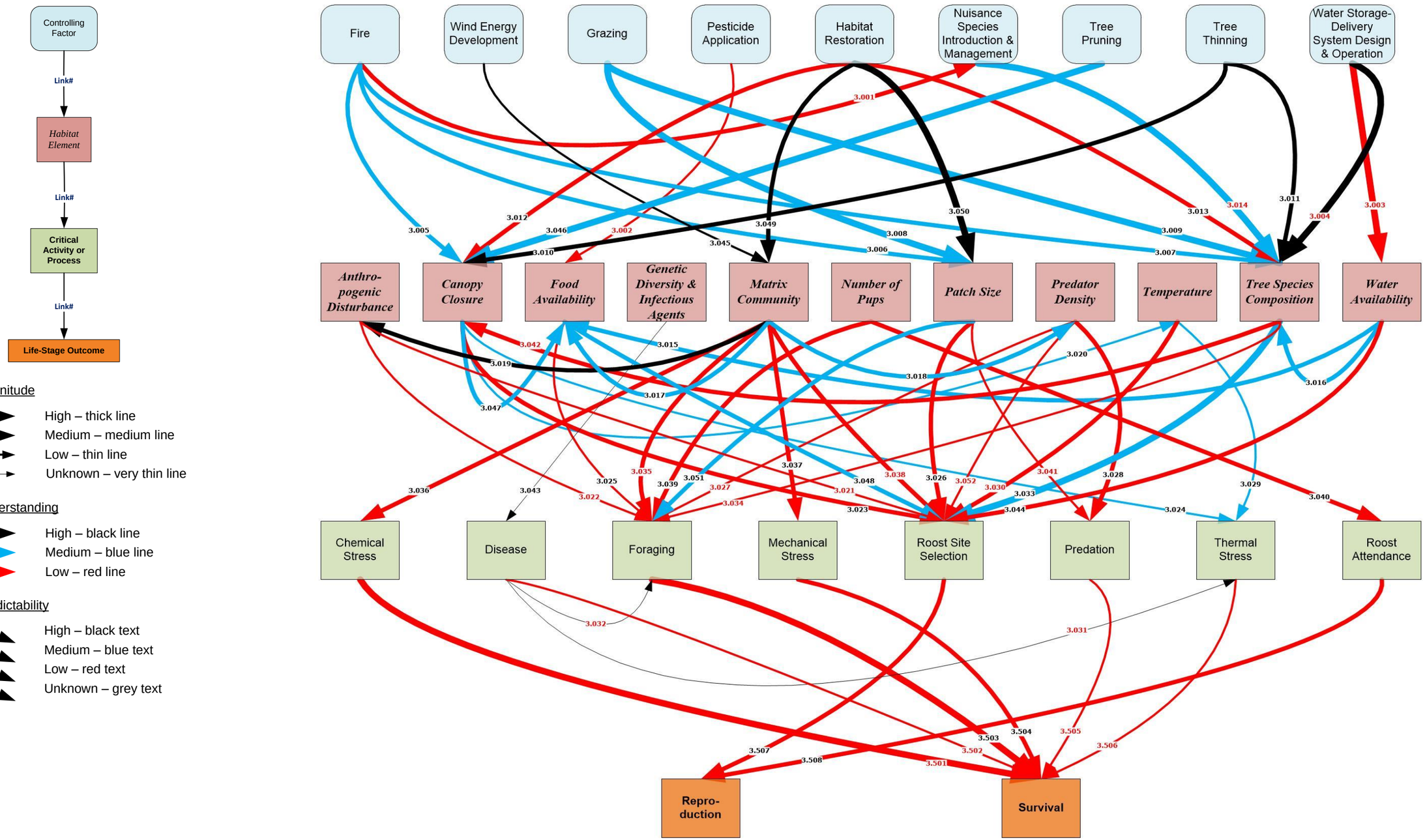
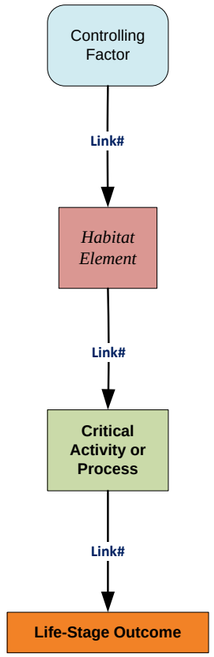
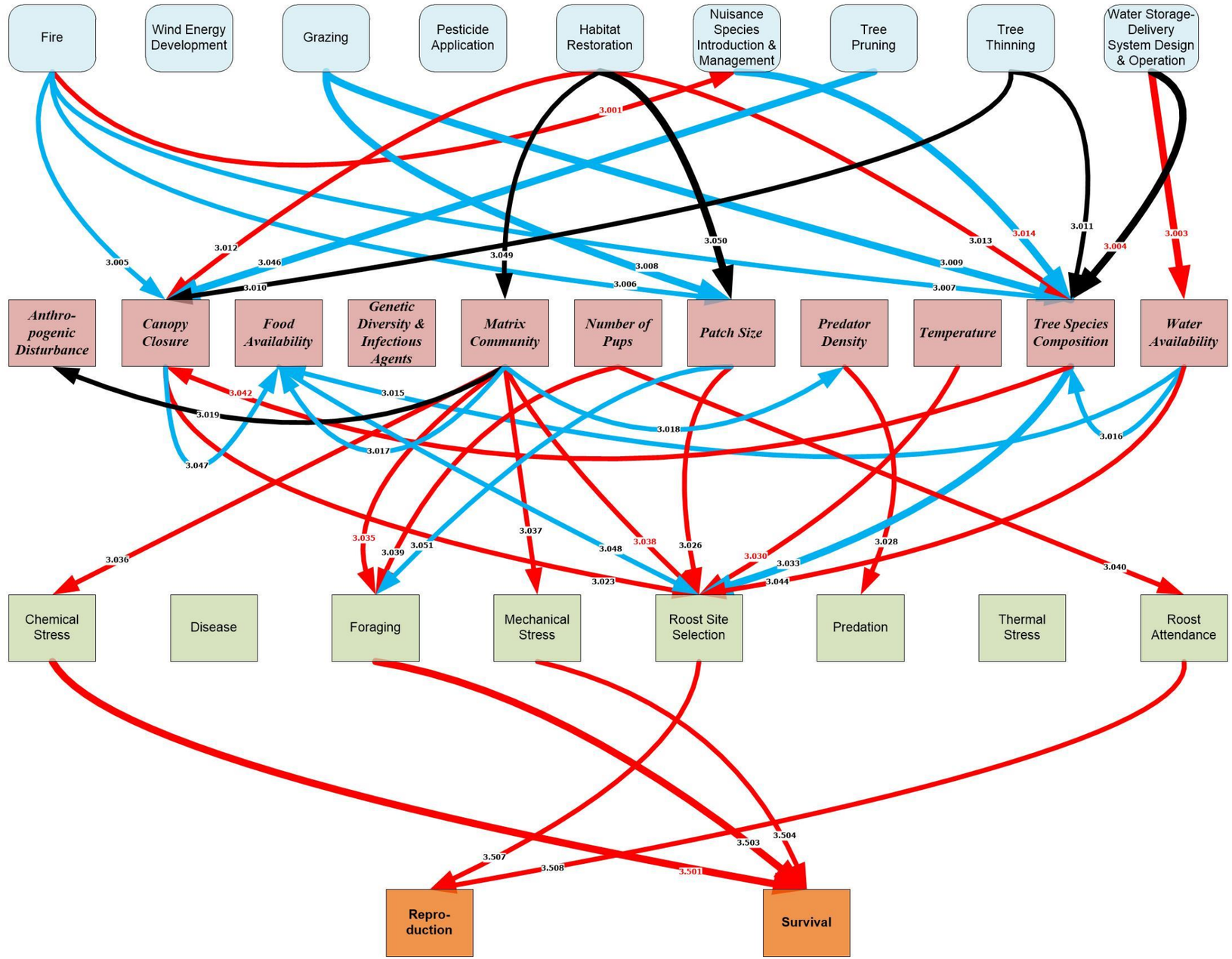


Figure 7.—WYBA life stage 3 – breeding adult, basic CEM diagram showing the relevant controlling factors, habitat elements, and critical biological activities processes at this life stage.





Link Magnitude

- High – thick line
- Medium – medium line
- Low – thin line
- Unknown – very thin line

Link Understanding

- High – black line
- Medium – blue line
- Low – red line

Link Predictability

- 0.000 High – black text
- 0.000 Medium – blue text
- 0.000 Low – red text
- 0.000 Unknown – grey text

Figure 8.—WYBA life stage 3 – breeding adult, high- and medium-magnitude relationships showing the relevant controlling factors, habitat elements, and critical biological processes at this life stage.

Chapter 7 – Causal Relationships Across All Life Stages

The nine controlling factors discussed in chapter 5 have the same influence on the same habitat elements for all life stages for which those habitat elements matter. Table 5 shows the magnitudes of *direct* influence of the nine controlling factors on 7 of the 12 habitat elements. The structure of table 5 is the same as for table 4, but table 5 shows the magnitudes of the relationships instead of just their presence/absence. The paragraphs following the table discuss the relative effects of the different controlling factors on each habitat element.

Table 5.—Magnitude of influence of controlling factors on habitat elements

Controlling factor ➔ / **Habitat element ⬇**	**Fire management**	**Grazing**	**Habitat restoration**	**Nuisance species introduction and management**	**Pesticide/herbicide application**	**Tree pruning**	**Tree thinning**	**Water storage-delivery system design and operation**	**Wind energy development**
Anthropogenic disturbance	N/A*								
Canopy closure	**Med**		**Med**			**Med**	**Med**		
Food availability					**Low**				
Genetic diversity and infectious agents	N/A*								
Matrix community			**Med**						**Low**
Number of pups	N/A*								
Parent roost attendance						**Med**			
Patch size	**Med**	**High**	**High**						
Predator density	N/A*								
Temperature	N/A*								
Tree species composition	**Med**	**High**	**Med**	**High**			**Med**	**High**	
Water availability								**High**	

* N/A values suggest that none of the identified controlling factors *directly* affect the habitat element.

CANOPY CLOSURE

The controlling factors that directly affect canopy closure include fire management, habitat restoration, tree pruning, and tree thinning.

Fire affects many aspects of vegetation structure and composition, including canopy closure. Little evidence exists that burning was extensive in flood plain environments historically in the Southwest. Native riparian vegetation is not well adapted to fire, so lightning and human-induced fires can severely alter riparian and, thus, WYBA habitat (Busch 1995).

Habitat restoration increases canopy closure, and tree thinning, either mechanical or natural, may either reduce or increase it. The extent of closure increase from restoration efforts depends on the types and ages of plants and the configuration in which they are planted.

The pruning of dead fronds from native and non-native palm trees reduces the cover of preferred roosting habitat for WYBA (Mirowsky 1997).

Tree thinning alters the species composition in riparian and urban habitats used by WYBA when thinning operations target certain species.

FOOD AVAILABILITY

The primary controlling factor affecting food availability is pesticide/herbicide application. Pesticides/herbicides, by design, reduce insect abundance and therefore prey for bats (Pierson et al. 2006).

MATRIX COMMUNITY

A controlling factor affecting the matrix community and mechanical stress on WYBA is wind energy development. This factor addresses the development of wind energy facilities near foraging areas and migratory routes of WYBA. While there are currently no wind turbines along the LCR, it is highly likely that migrating bats foraging near active wind turbines could be killed. Lasiurines tend to be disproportionately affected by these facilities (Arnett 2005; Kunz et al. 2007; Hayes 2013). Restoration may also change the matrix community if type conversion occurs (e.g., from farmed fields to riparian forests).

PARENT ROOST ATTENDANCE

The controlling factor that directly affects parent roost attendance is tree pruning. Cosmetic tree pruning may be one of the main threats to WYBA along the LCR (Williams 2005; Reclamation 2008). WYBA only roost in palm trees that have a ring of dead fronds that encircle the area below the live foliage (Mirowsky 1997). Parent roost attendance will be negatively affected by tree pruning that occurs when pups are in the roost.

PATCH SIZE

The controlling factors that directly affect patch size include fire management and grazing.

Fire affects many aspects of vegetation structure and composition, and severe fire may reduce overall patch size (Busch 1995).

Grazing may affect patch size as well if an overgrazed condition exists and inhibits the growth of tree species (Kauffman et al. 1997). Restoration would increase overall patch size.

TREE SPECIES COMPOSITION

The controlling factors that directly affect tree species composition include fire management, grazing, habitat restoration, nuisance species introduction and management, tree thinning, and water storage-delivery system design and operation.

Fire affects many aspects of vegetation structure and composition. Little evidence exists that burning was extensive in flood plain environments historically in the Southwest. Native riparian vegetation is not well adapted to fire, so lightning and human-induced fires can severely alter riparian species composition and, thus, WYBA habitat (Busch 1995). Some evidence exists that fire in riparian habitats can increase the cover of some nuisance species like tamarisk (Di Tomaso 1998).

Grazing effects on riparian tree species composition depends on the species of the grazer and grazing intensity among other factors. Grazing thins the understory and may even prevent the establishment of cottonwood and willow seedlings (Kauffman et al. 1997).

Habitat restoration along the LCR may improve habitat conditions for WYBA by altering riparian tree species composition and increasing patch size. WYBA have

been found to be more active (foraging) in riparian habitat compared to other natural habitat types (Williams et al. 2006; Vizcarra et al. 2010), but they tend to preferentially roost in native and non-native palm trees (Kurta and Lehr 1995; Mirowsky 1997). In a study of bat roost site habitat conducted along the LCR, WYBA were documented to use Mexican fan palms almost exclusively (Diamond 2012), though Higginbotham et al. (1999) cite examples of studies in which WYBA are found roosting in cottonwood forests.

Nuisance species can change the structure of entire communities, with lasting effects. Although the effects are experienced at a patch level, invasive species can spread across entire regions, and their effects can last decades unless a complete transformation of the community type occurs.

Tree thinning alters the species composition in riparian and urban habitats used by WYBA when thinning operations target certain species.

Water movement in the LCR is highly regulated, and this has disrupted the natural flows that shape riparian habitat in the system. Water storage-delivery system design and operation affects water availability in riparian habitat and determines where various tree species can grow.

WATER AVAILABILITY

A controlling factor affecting water availability in the LCR is water storage-delivery system design and operation. The amount of water released or stored affects water levels and, therefore, distance to water, soil moisture, and other hydrological conditions within WYBA habitat.

Chapter 8 – Discussion and Conclusions

This chapter summarizes the findings of this assessment in three ways by posing three questions: (1) which critical biological activities and processes most strongly affect the individual across all life stages, (2) which habitat elements, in terms of their abundance, distribution, and quality, most strongly affect the most influential activities and processes, and (3) which of these causal relationships appear to be the least understood in ways that could affect their management?

MOST INFLUENTIAL ACTIVITIES AND PROCESSES ACROSS ALL LIFE STAGES

Figure 9 identifies the critical biological activities and processes that the assessment found most strongly directly affect the success of each life stage (high or medium magnitude). The findings presented in this diagram may be summarized as follows:

- Tree pruning (removal of the dead fronds from native and non-native palm trees) has a high effect on canopy closure, parent roost attendance, and thermal stress among all life stages.

- Roost site selection has a moderate effect on reproduction of breeding adults and is strongly affected by tree thinning.

- At roost sites located close to or within agricultural areas where biocides are being applied, bats may experience increased chemical stress, which can reduce WYBA survival rates in all life stages as well as prey abundance.

- Relative foraging success strongly affects the success rate of juvenile and breeding adult WYBA in all life stages.

- Roost attendance and roost site selection have a moderate effect on breeding adult reproduction.

- If wind energy development is present in areas with significant WYBA activity, mechanical stress may negatively affect WYBA juvenile and breeding adult survival.

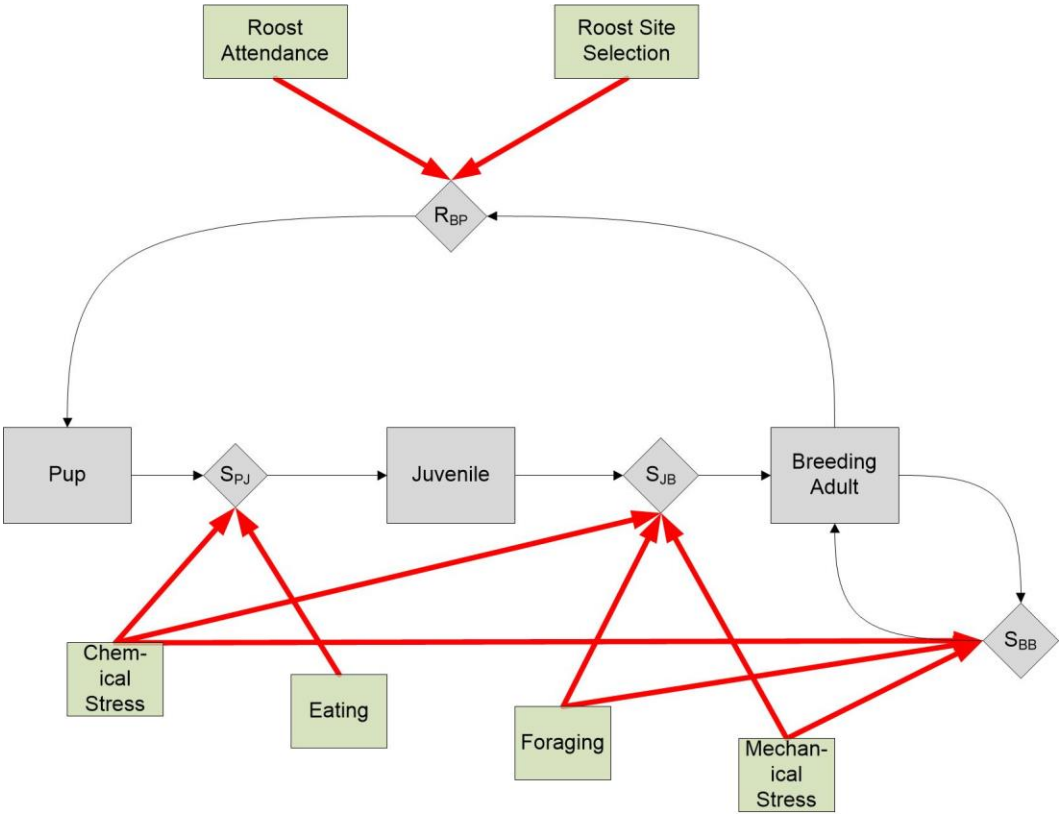


Figure 9.—Most influential biological activities and processes affecting each life stage of WYBA. Only elements with high- or medium-magnitude connections are presented. The legend is provided on figure 2.

POTENTIALLY PIVOTAL ALTERATIONS TO HABITAT ELEMENTS

Figure 10 identifies the habitat elements that this assessment indicates most strongly directly affect the critical biological activities and processes identified on figure 9 across all life stages (high or medium magnitude). The findings presented in this diagram may be summarized as follows:

- The habitat elements that most influenced critical biological processes and activities and WYBA breeding success include the matrix community, patch size, and tree species composition. All these elements affect the foraging success of adults and juveniles and provisioning (aka eating) of pups. WYBA preferentially forage over riparian forests, and maintaining these forests in a healthy state will maximize prey density.

- The matrix community can play a significant role in the survival and reproductive success of WYBA. While WYBA preferentially forage over riparian forest communities, they will forage over agricultural lands as well. Because the bats preferentially roost in palm trees, which along the LCR are found within an matrix of agricultural lands, they are likely to be exposed to a variety of biocides. This exposure can result in chemical stress to WYBA in all life stages.

In addition, the following controlling factors were important habitat element determinants:

- Water storage-delivery system design and operation is a significant driver of canopy closure, tree species composition, and thus food availability. Prey abundance during lactation and juvenile stages plays an important role in both adult reproductive success and survival of WYBA in all life stages. Thus, Reclamation's water management at its restoration sites can play a significant role in the persistence of WYBA.

- Habitat restoration, especially increasing the size of riparian forest habitat, plays a significant role in providing foraging patches for WYBA. As these habitat patches become larger, the likelihood of WYBA foraging over agricultural lands is lessened, reducing exposure to biocides that can reduce both reproductive success and survival.

GAPS IN UNDERSTANDING

Figures 9 and 10 use the conventional color coding of individual causal relationships to identify relationships that a CEM identifies as having high, intermediate, or low levels of scientific confirmation. As noted in attachment 1, "low" scientific understanding of a relationship means that it is "… subject to wide disagreement or uncertainty in peer-reviewed studies from within the ecosystem of concern and in scientific reasoning among experts familiar with the ecosystem." In many cases, the scientific principles are well understood, but the factual details are insufficiently understood within the LCR conservation areas. The figures highlight that the level of understanding of how the various controlling factors affect the habitat elements is fairly well understood. However, the large numbers of red arrows for relationships between habitat elements and biological activities and processes indicate that these relationships have a low level of scientific understanding. Each of these red arrows identifies a causal relationship that may warrant further field, laboratory, or literature investigation. The following paragraphs highlight some potentially important areas of low understanding; however, these are not meant to represent

Western Yellow Bat (*Lasiurus xanthinus*) (WYBA)
Basic Conceptual Ecological Model for the Lower Colorado River

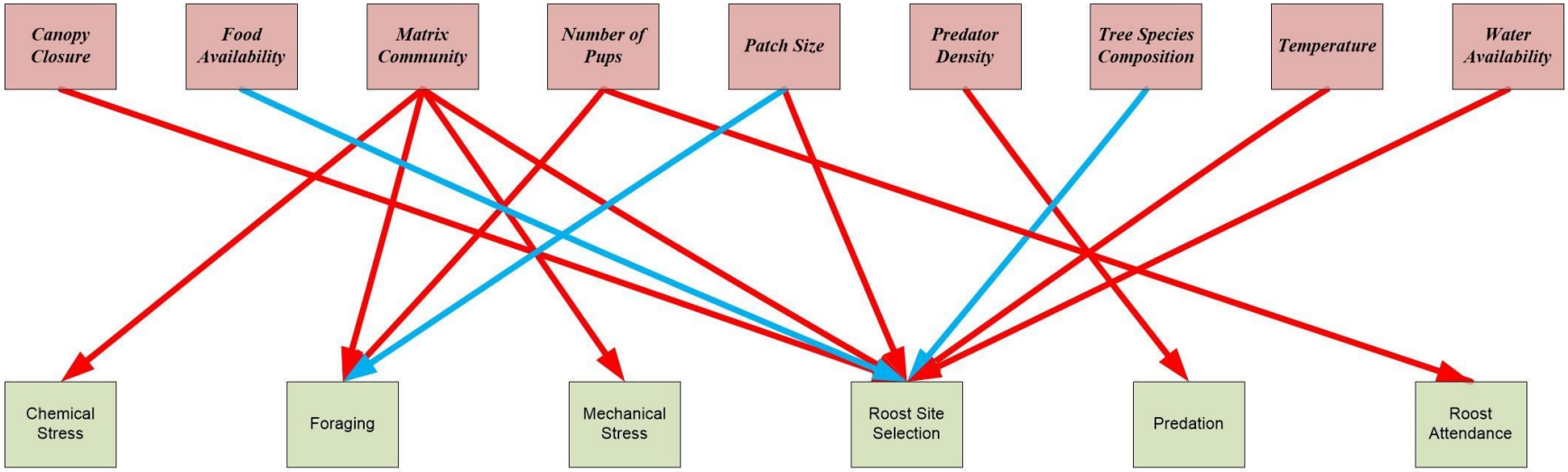


Figure 10.—Habitat elements that directly affect the most influential biological activities and processes across all life stages of WYBA. Only elements with high- or medium-magnitude connections within this life stage are presented. The legend is provided on figure 2.

a list of required or even feasible areas for research. Decisions about which research issues to pursue will be determined by LCR MSCP staff based on a variety of factors.

Specifically, the findings suggest a need to improve the understanding of:

- The distribution of WYBA roost sites within the LCR MSCP area, with special emphasis on potential impacts of land use and associated activities within the habitat and the surrounding matrix community

- The distribution of suitable WYBA roost habitat along the LCR and habitat use within those sites

- The ecology of predation on WYBA and its significance on survival across all life stages, how this may vary among predator species and across different habitat settings, and whether it may be possible to manipulate these habitat conditions to improve WYBA survival even in the presence of predators

- The presence of disease in the WYBA population and its significance in affecting survival of WYBA across all life stages within the LCR

- The impacts of biocide use within the LCR and its impact on the survival of WYBA across all life stages

- WYBA movement patterns within the LCR, including any seasonal migratory movement

This list of uncertainties is not meant to be exhaustive but only to highlight topics the literature identifies as potentially pivotal to WYBA recruitment along the LCR and to identify important knowledge gaps in these publications. They are not in any way to be considered guidance for Reclamation or the LCR MSCP, nor are these knowledge gaps expected to be addressed under the program.

LITERATURE CITED

Adams, R.A. 2003. Bats of the Rocky Mountain West: Natural History, Ecology, and Conservation. University Press of Colorado, Boulder.

Arnett, E.B. 2005. Relationships Between Bats and Wind Turbines in Pennsylvania and West Virginia: An Assessment of Bat Fatality Search Protocols, Patterns of Fatality, and Behavioral Interactions with Wind Turbines. Final report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International, Austin, Texas. 187 p.

Baker, R.J., J.C. Patton, H.H. Genoways, and J.W. Bickham. 1988. Genic Studies of *Lasiurus* (Chiroptera: Vespertilionidae). Occasional Papers, The Museum, Texas Tech University 117:1–15.

Barclay, R.M. and L.D. Harder. 2003. Life histories of bats: life in the slow lane. Pages 209–253 *in* T.H. Kunz and M.B. Fenton (editors). Bat Ecology. University of Chicago Press, Chicago, Illinois.

Bureau of Reclamation (Reclamation). 2008. Species Accounts for the Lower Colorado River Multi-Species Conservation Program. September 2008. http://www.lcrmscp.gov

Burke, M., K. Jorde, and J. Buffington. 2009. Application of a hierarchical framework for assessing environmental impacts of dam operation: changes in streamflow, bed mobility and recruitment of riparian trees in a western North American river. Journal of Environmental Management 90:S224–S236.

Busch, D.E. 1995. Effects of fire on southwestern riparian plant community structure. The Southwestern Naturalist 40(3):259–267.

Calvert, A.W. and S.A. Neiswenter. 2012. Bats in riparian-restoration sites along the lower Colorado River, Arizona. The Southwestern Naturalist 57(3):340–342.

Carter, T.C. and J.M. Menzel. 2007. Behavior and day-roosting ecology of North American foliage-roosting bats. Pages 61–81 *in* Bats in Forests: Conservation and Management. M.J. Lacki, J.P. Hayes, and A. Kurta (editors). Johns Hopkins University Press, Baltimore, Maryland.

Clark, D.R., Jr., F.M. Bagley, and W.W. Johnson. 1988. Northern Alabama colonies of the endangered gray bat *Myotis grisescens*: organochlorine contamination and mortality. Biological Conservation 43:213–225.

Constantine, D.G. 1959. Ecological observations on lasiurine bats in the north bay area of California. Journal of Mammalogy 40:131–15.

_____. 1967. Bat rabies in the southwestern United States. Public Health Reports 82(10):867–888.

Cryan, P.M. and J.P. Veilleux. 2007. Migration and use of autumn, winter and spring roosts by tree bats. Pages 153–175 *in* Bats in Forests: Conservation and Management. M.J Lacki, J.P. Hayes, and A. Kurta (editors). Johns Hopkins University Press, Baltimore, Maryland.

Diamond, J.M. 2012. Distribution and Roost Site Habitat Requirements of Western Yellow (*Lasiurus xanthinus*) and Western Red (*Lasiurus blossevillii*) Bats: 2011 Summary of Findings. Submitted to the Bureau of Reclamation, Lower Colorado River Multi-Species Conservation Program, Lower Colorado Region, Boulder City, Nevada.

Di Tomaso, J.M. 1998. Impact, biology, and ecology of saltcedar (*Tamarix* spp.) in the southwestern United States. Weed Technology 12:326–336.

DiGennaro, B., D. Reed, C. Swanson, L. Hastings, Z. Hymanson, M. Healey, S. Siegel, S. Cantrell, and B. Herbold. 2012. Using conceptual models and decision-support tools to guide ecosystem restoration planning and adaptive management: an example from the Sacramento-San Joaquin Delta, California. San Francisco Estuary and Watershed Science 10(3):1–15. http://escholarship.org/uc/item/3j95x7vt

Fenton, M.B. 1997. Science and the conservation of bats. Journal of Mammalogy 78(1):1–14.

Fischenich, J.C. 2008. The Application of Conceptual Models to Ecosystem Restoration. U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), Ecosystem Management and Restoration Research Program (EMRRP), Technical Note ERDC/EBA TN-08-1, February 2008. Vicksburg, Mississippi. http://cw-environment.usace.army.mil/webinars/09jan27-cmPublicationEBA.pdf

Geluso, K., J. Altenbach, and D. Wilson. 1981. Organochlorine residues in young Mexican free-tailed bats from several roosts. American Midland Naturalist 105(2):249–257.

Hagen, E.M. and J.L. Sabo. 2012. Influence of river drying and insect availability on bat activity along the San Pedro River, Arizona (USA). Journal of Arid Environments 84:1–8.

Hayes, M.A. 2013. Bats killed in large numbers at United States wind energy facilities. Bioscience 63(12):975–979.

Heemskerk, M., K. Wilson, and M. Pavao-Zuckerman. 2003. Conceptual models as tools for communication across disciplines. Conservation Ecology 7(3):8. http://www.consecol.org/vol7/iss3/art8/

Higginbotham, J.L., L.K. Ammerman, and M.T. Dixon. 1999. First record of *Lasiurus xanthinus* (Chiroptera: Vespertilionidae) in Texas. Southwestern Naturalist 44:343–347.

Hoffmeister, D.F. 1986. Mammals of Arizona. University of Arizona Press, Tucson.

Jones, G., D.S. Jacobs, T.H. Kunz, M.R. Willig, and P.A. Racey. 2009. Carpe noctem: the importance of bats as bioindicators. Endangered Species Research 8(1-2):93–115.

Kauffman, J.B., R.L. Beschta, N. Otting, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. Fisheries 22:12–24.

Kondolf, G.M., J.G. Williams, T.C. Horner, and D. Milan. 2008. Assessing physical quality of spawning habitat. Pages 249–274 *in* D.A Sear and P. DeVries (editors). Salmonid Spawning Habitat in Rivers: Physical Controls, Biological Responses, and Approaches. American Fisheries Society Symposium 65. American Fisheries Society, Bethesda, Maryland.

Kunz, T.H. and M.B. Fenton (editors). 2003. Bat Ecology. University of Chicago Press, Chicago, Illinois.

Kunz, T.H. and L.F. Lumsden. 2003. Ecology of cavity and foliage roosting bats. Pages 3–89 *in* T.H. Kunz and M.B. Fenton (editors). Bat Ecology. University of Chicago Press, Chicago, Illinois.

Kunz T.H., E.B. Arnett, W.P. Erickson, G.D. Johnson, R.P. Larkin, M.D. Strickland, R.W. Thresher, and M.D. Tuttle. 2007. Ecological impacts of wind energy development on bats: questions, hypotheses, and research needs. Frontiers in Ecology and the Environment 5:315–324.

Kurta, A. and G.C. Lehr. 1995. *Lasiurus ega*. Mammalian Species 1–7.

Lacki, M.J., J.P. Hayes, and A. Kurta (editors). 2007. Bats in Forests. Johns Hopkins University Press, Baltimore, Maryland.

LaVal, R.K. and M.L. LaVal. 1979. Notes on reproduction, behavior, and abundance of the red bat, *Lasiurus borealis*. Journal of Mammalogy 60(1):209–212.

Lima, S.L. and J.M. O'Keefe. 2013. Do predators influence the behaviour of bats? Biological Reviews 88(3):626–644.

McDonald, D.B. and H. Caswell. 1993. Matrix methods for avian demography. Pages 139–185 *in* D.M. Power (editor). Current Ornithology. Plenum Press, New York.

Messenger, S.L., C.E. Rupprecht, and J.S. Smith. 2003. Bats, emerging virus infections, and the rabies paradigm. Pages 622–679 *in* T.H. Kunz and M.B. Fenton (editors). Bat Ecology. University of Chicago Press, Chicago, Illinois.

Miner, K.L. and D.C. Stokes. 2005. Bats in the south coast ecoregion: status, conservation issues, and research needs. Pages 211–227 *in* U.S. Department of Agriculture Forest Service General Technical Report PSW-GTR-195.

Mirowsky, K. 1997. Bats in palms: precarious habitat. Bats 15:1–6.

NatureServe. 2015. NatureServe Explorer: An online encyclopedia of life [Web application]. Version 7.1. NatureServe, Arlington, Virginia. http://explorer.natureserve.org

O'Farrell, M.J., J.A. Williams, and B. Lund. 2004. Western yellow bat (*Lasiurus xanthinus*) in southern Nevada. The Southwestern Naturalist 49(4):514–518.

Ormsbee, P.C., J.D. Kiser, and S.I. Perlmeter. 2007. Importance of night roosts to the ecology of bats. Pages 129–151 *in* M.J. Lacki, J.P. Hayes, and A. Kurta (editors). Bats in Forests: Conservation and Management. Johns Hopkins University Press, Baltimore, Maryland.

O'Shea, T.J. and D.R. Clark, Jr. 2002. An overview of contaminants and bats, with special reference to insecticides and the Indiana bat. Pages 237–253 *in* The Indiana Bat: Biology and Management of an Endangered Species. Bat Conservation International, Austin, Texas.

Pierson, E.D., W.E. Rainey, and C.C. Corben. 2006. Distribution and Status of Red Bats (*Lasiurus blossevillii*) in California. California Department of Fish and Game, Habitat Conservation Planning Branch, Species Conservation and Recovery Program Report 2006-04, Sacramento, California.

Rosenfeld, J.S. 2003. Assessing the habitat requirements of stream fishes: an overview and evaluation of different approaches. Transactions of the American Fisheries Society 132:953–968.

Rosenfeld, J.S. and T. Hatfield. 2006. Information needs for assessing critical habitat of freshwater fish. Canadian Journal of Fisheries and Aquatic Sciences 63:683–698.

Sparks, D.W., M.T. Simmons, C.L. Gummer, and J.E. Duchamp. 2003. Disturbance of roosting bats by woodpeckers and raccoons. Northeastern Naturalist 10:105–108.

Stromberg, J. 1998. Dynamics of Fremont cottonwood (*Populus fremontii*) and saltcedar (*Tamarix chinensis*) populations along the San Pedro River, Arizona. Journal of Arid Environments 40:133–155.

U.S. Fish and Wildlife Service. 2013. Designation of critical habitat for southwestern willow flycatcher; final rule. Federal Register 78(2):344–534.

Vizcarra, B., L. Piest, and V. Frary. 2010. Monitoring of Covered and Evaluation Bat Species for the Lower Colorado River Multi-Species Conservation Program — 2010 Final Report. Submitted to the Bureau of Reclamation, Lower Colorado River Multi-Species Conservation Program, Lower Colorado Region, Boulder City, Nevada.

Wildhaber, M.L. 2011. Identifying structural elements needed for development of a predictive life-history model for pallid and shovelnose sturgeons. Journal of Applied Ichthyology 27:462–469.

Wildhaber, M.L., A.J. DeLonay, D.M. Papoulias, D.L. Galat, R.B. Jacobson, D.G. Simpkins, P.J. Baaten, C.E. Korschgen, and M.J. Mac. 2007. A Conceptual Life-History Model for Pallid and Shovelnose Sturgeon. U.S. Geological Survey, Circular 1315. Reston, Virginia.

Williams, J.A. 2005. *Lasiurus xanthinus*: Western Yellow Bat. Western Bat Working Group. http://wbwg.org/western-bat-species/

Williams, J.A., M.J. O'Farrell, and B.R. Riddle. 2006. Habitat use by bats in a riparian corridor of the Mojave Desert in southern Nevada. Journal of Mammalogy 87(6):1145–1153.

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ATTACHMENT 1

Species Conceptual Ecological Model Methodology for the Lower Colorado River Multi-Species Conservation Program

OVERVIEW OF METHODOLOGY

The conceptual ecological models (CEMs) for species covered by the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) Habitat Conservation Plan expand on a methodology developed by the Sacramento-San Joaquin Delta Ecosystem Restoration Program (ERP): https://www.dfg.ca.gov/ERP/conceptual_models.asp. The ERP is jointly implemented by the California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. The Bureau of Reclamation participates in this program.

The ERP methodology incorporates common best practices for constructing CEMs for individual species (Wildhaber et al. 2007; Fischenich 2008; DiGennaro et al. 2012). It has the following key features:

- It focuses on the *major life stages or events* through which each species passes and the *output(s)* of each life stage or event. Outputs typically consist of survivorship or the production of offspring.

- It identifies the *major drivers* that affect the likelihood (rate) of each output. Drivers are physical, chemical, or biological factors – both natural and anthropogenic – that affect output rates and therefore control the viability of the species in a given ecosystem.

- It characterizes these interrelationships using a "*driver-linkage-outcomes*" approach. Outcomes are the output rates. Linkages are cause-effect relationships between drivers and outcomes.

- It *characterizes each causal linkage* along four dimensions: (1) the character and direction of the effect, (2) the magnitude of the effect, (3) the predictability (consistency) of the effect, and (4) the certainty of present scientific understanding of the effect (DiGennaro et al. 2012).

The CEM methodology used for species covered by the LCR MSCP Habitat Conservation Plan species expands this ERP methodology. Specifically, the present methodology incorporates the recommendations and examples of Wildhaber et al. (2007), Wildhaber (2011), Kondolf et al. (2008), and Burke et al. (2009) for a more hierarchical approach and adds explicit demographic notation for the characterization of life-stage outcomes (McDonald and Caswell 1993). This expanded approach provides greater detail on causal linkages and outcomes. The expansion specifically calls for identifying **four** types of model components for each life stage, and the causal linkages among them, as follows:

- **Life-stage outcomes** are outcomes of an individual life stage, including the recruitment of individuals to the next succeeding life stage (e.g., juvenile to adult). For some life stages, the outcomes, alternatively or additionally, may include the survival of individuals to an older age class within the same life stage or the production of offspring. The rates of life-stage outcomes depend on the rates of the critical biological activities and processes for that life stage.

- **Critical biological activities and processes** are activities in which a species engages and the biological processes that must take place during each life stage that significantly affect life-stage outcomes. They include activities and processes that may benefit or degrade life-stage outcomes. Examples of critical activities and processes include mating, foraging, avoiding predators, avoiding other specific hazards, gamete production, egg maturation, leaf production, and seed germination. Critical activities and processes are "rate" variables. Taken together, the rate (intensity) of these activities and processes determine the rates of different life-stage outcomes.

- **Habitat elements** are specific habitat conditions that significantly ensure, allow, or interfere with critical biological activities and processes. The full suite of natural habitat elements constitutes the natural habitat template for a given life stage. Human activities may introduce habitat elements not present in the natural habitat template. Defining a habitat element may involve estimating the specific ranges of quantifiable properties of that element *whenever the state of knowledge supports such estimates*. These properties concern the abundance, spatial and temporal distributions, and other qualities of the habitat element that significantly affect the ways in which it ensures, allows, or interferes with critical activities and processes.

- **Controlling factors** are environmental conditions and dynamics – both natural and anthropogenic – that determine the quality, abundance, and spatial and temporal distributions of one or more habitat elements. In some instances, a controlling factor alternatively or additionally may directly affect a critical biological activity or process. Controlling factors are also called "drivers." A hierarchy of controlling factors will exist, affecting the system at different temporal and spatial scales. Long-term dynamics of climate and geology define the domain of this hierarchy (Burke et al. 2009). For example, the availability of suitable nest sites for a riparian nesting bird may depend on factors such as canopy closure, community type, humidity, and intermediate structure which, in turn, may depend on factors such as water storage-delivery system design and operation (dam design, reservoir morphology, and dam operations) which, in turn, is shaped by watershed geology, vegetation, climate, land use, and water demand. *The LCR MSCP conceptual ecological models focus*

on controlling factors that are within the scope of potential human manipulation, including management actions directed toward the species of interest.

The present CEM methodology also explicitly defines a "life stage" as a biologically distinct portion of the life cycle of a species. The individuals in each life stage undergo distinct developments in body form and function; engage in distinct types behaviors, including reproduction; use different sets of habitats or the same habitats in different ways; interact differently with their larger ecosystems; and/or experience different types and sources of stress. A single life stage may include multiple age classes. A CEM focused on life stages is not a demographic model per se (McDonald and Caswell 1993). Instead, it is a complementary model focused on the ecological factors (drivers) that shape population dynamics.

This expanded approach permits the consideration of **six** possible types of causal relationships, on which management actions may focus, for each life stage of a species:

(1) The effect of one controlling factor on another

(2) The effect of a controlling factor on the abundance, spatial and temporal distributions, and other qualities of a habitat element

(3) The effect of the abundance, spatial and temporal distributions, and other qualities of one habitat element on those of another

(4) The effect of the abundance, spatial and temporal distributions, and other qualities of a habitat element on a critical biological activity or process

(5) The effect of one critical biological activity or process on another

(6) The effect of a critical biological activity or process on a specific life-stage outcome

Each controlling factor may affect the abundance, spatial and temporal distributions, and other qualities of more than one habitat element and several controlling factors may affect the abundance, spatial or temporal distributions, or other qualities of each habitat element. Similarly, the abundance, spatial and temporal distributions, and other qualities of each habitat element may affect more than one biological activity or process, and the abundances, spatial or temporal distributions, or other qualities of several habitat elements may affect each biological activity or process. Finally, the rate of each critical biological activity or process may contribute to the rates of more than one life-stage outcome.

Integrating this information across all life stages for a species provides a detailed picture of: (1) what is known, with what certainty, and the sources of this information; (2) critical areas of uncertain or conflicting science that demand resolution to better guide LCR MSCP management planning and action; (3) crucial attributes to use to monitor system conditions and predict the effects of experiments, management actions, and other potential agents of change; and (4) how managers may expect the characteristics of a resource to change as a result of changes to controlling factors, including changes in management actions.

Conceptual Ecological Models as Hypotheses

The CEM for each species produced with this methodology constitutes a collection of hypotheses for that species. These hypotheses concern: (1) the species' life history; (2) the species' habitat requirements and constraints; (3) the factors that control the quality, abundance, and spatial and temporal distributions of these habitat conditions; and (4) the causal relationships among these. Knowledge about these model components and relationships may vary, ranging from well settled to very tentative. Such variation in the certainty of current knowledge always arises as a consequence of variation in the types and amount of evidence available and in the ecological assumptions applied by different experts.

Wherever possible, the information assembled for the LCR MSCP species CEMs documents the degree of certainty of current knowledge concerning each component and linkage in the model. This certainty is indicated by the quality, abundance, and consistency of the available evidence and by the degree of agreement/disagreement among the experts. Differences in the interpretations or arguments offered by different experts may be represented as alternative hypotheses. Categorizing the degree of agreement/disagreement concerning the components and linkages in a CEM makes it easier to identify topics of greater uncertainty or controversy.

Characterizing Causal Relationships

A causal relationship exists when a change in one condition or property of a system results in a change in some other condition or property. A change in the first condition is said to cause a change in the second condition. The present CEM methodology includes methods for assessing causal relationships (links) along four dimensions (attributes) adapted from the ERP methodology (DiGennaro et al. 2012):

(1) The character and direction of the effect

(2) The magnitude of the effect

(3) The predictability (consistency) of the effect

(4) The certainty of present scientific understanding of the effect

The present and ERP methodologies for assessing causal linkages differ in three ways. First, the ERP methodology assesses these four attributes for the *cumulative* effect of the entire causal chain leading up to each outcome. However, the LCR MSCP methodology recognizes six different types of causal linkages as described above. This added level of detail and complexity makes it difficult in a single step to assess the cumulative effects of all causal relationships that lead up to any one individual causal link. For example, in the present methodology, the effect of a given critical biological activity or process on a particular life-stage outcome may depend on the effects of several habitat elements on that critical biological activity or process which, in turn, may depend on the effects of several controlling factors. For this reason, the present methodology assesses the four attributes separately for each causal link *by itself* rather than attempting to assess cumulative effects of all causal linkages leading to the linkage of interest. The present methodology assesses cumulative effects instead through analyses of the data assembled on all individual linkages. The analyses are made possible by assembling the data on all individual linkages in a spreadsheet as described below.

Second, the present CEM methodology explicitly divides link magnitude into three separate subattributes and provides a specific methodology for integrating their rankings into an overall ranking for link magnitude: (1) link intensity, (2) link spatial scale, and (3) link temporal scale. In contrast, the ERP methodology treats spatial and temporal scale together and does not separately evaluate link intensity. The present methodology defines link intensity as the relative strength of the effect of the causal node on the affected node *at the places and times where the effect occurs*. Link spatial scale is the relative spatial extent of the effect of the causal node on the affected node. Link temporal scale is the relative temporal extent of the effect of the causal node on the affected node. The present methodology defines link magnitude as the average of the separate rankings of link intensity, spatial scale, and temporal scale as described below.

Third, the ERP methodology addresses a single, large landscape, while the present methodology needed the flexibility to generate models applicable to a variety of spatial scopes. For example, the present methodology needed to support modeling of a single restoration site, the LCR main stem and flood plain, or the entire Lower Colorado River Basin. Consequently, the present methodology assesses the spatial scale of cause-effect relationships only relative to the spatial scope of the model.

The LCR MSCP conceptual ecological model methodology thus defines the four attributes for a causal link as follows:

- **Link character** – This attribute categorizes a causal relationship as positive, negative, involving a threshold response, or "complex." "Positive" means that an increase in the causal node results in an increase in the affected node, while a decrease in the causal node results in a decrease in the affected node. "Negative" means that an increase in the causal node results in a decrease in the affected element, while a decrease in the causal node results in an increase in the affected node. Thus, "positive" or "negative" here do ***not*** mean that a relationship is beneficial or detrimental. The terms instead provide information analogous to the sign of a correlation coefficient. "Threshold" means that a change in the causal agent must cross some value before producing an effect. "Complex" means that there is more going on than a simple positive, negative, or threshold effect. In addition, this attribute categorizes a causal relationship as uni- or bi-directional. Bi-directional relationships involve a reciprocal relationship in which each node affects the other.

- **Link magnitude** – This attribute refers to "… the degree to which a linkage controls the outcome *relative to other drivers*" (DiGennaro et al. 2012). Magnitude takes into account the spatial and temporal scale of the causal relationship as well as the strength (intensity) of the relationship in individual locations. The present methodology provides separate ratings for the intensity, spatial scale, and temporal scale of each link, as defined above, and assesses overall link magnitude by averaging these three elements. Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link magnitude provide information analogous to the size of a correlation coefficient. Tables 1-1 through 1-4 present the rating framework for link magnitude.

- **Link predictability** – This attribute refers to "… the degree to which the current understanding of the system can be used to predict the role of the driver in influencing the outcome. Predictability … captures variability … [and recognizes that] effects may vary so much that properly measuring and statistically characterizing inputs to the model are difficult" (DiGennaro et al. 2012). A causal relationship may be unpredictable because of natural variability in the system or because its effects depend on the interaction of other factors with independent sources for their own variability. Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link predictability provide information analogous to the size of the range of error for a correlation coefficient. Table 1-5 presents the scoring framework for link predictability.

- **Link understanding** refers to the degree of agreement represented in the scientific literature and among experts in understanding how each driver is linked to each outcome. Table 1-6 presents the scoring framework for understanding. Link predictability and understanding are independent attributes. A link may be considered highly predictable but poorly understood or poorly predictable but well understood.

Conceptual Ecological Model Documentation

The documentation for each CEM provides information in three forms: (1) a narrative report, (2) causal diagrams showing the model components and their causal linkages for each life stage, and (3) a spreadsheet that is used to record the detailed information (e.g., linkage attribute ratings) for each causal linkage. The spreadsheet and diagrams, built using Microsoft Excel™ and Microsoft Visio™, respectively, are linked so that the diagrams provide a fully synchronized summary of the information in the spreadsheet.

The narrative report for each species presents the definitions and rationales for the life stages/events and their outcomes identified for the species' life history; the critical biological activities and processes identified for each life stage; the habitat elements identified as supporting or impeding each critical biological activity or process for each life stage; the controlling factors identified as affecting the abundance, spatial and temporal distributions, and other qualities of the habitat elements for each life stage; and the causal linkages among these model components.

The narrative report includes causal diagrams (*aka* "influence diagrams") for each life stage. These diagrams show the individual components or nodes of the model for that stage (life-stage outcomes, critical biological activities and processes, habitat elements, and controlling factors) and their causal relationships. The causal relationships (causal links) are represented by arrows indicating which nodes are linked and the directions of the causal relationships. The attributes of each causal link are represented by varying line thickness, line color, and other visual properties as shown on figure 1-1. The diagram conventions mostly follow those in the ERP methodology (DiGennaro et al. 2012).

The spreadsheet for each CEM contains a separate worksheet for each life stage. Each row in the worksheet for a life stage represents a single causal link. Table 1-7 lists the fields (columns) recorded for each causal link.

Link Attribute Ratings, Spreadsheet Fields, and Diagram Conventions

Table 1-1.—Criteria for rating the relative intensity of a causal relationship – one of three variables in the rating of link magnitude (after DiGennaro et al. 2012, Table 2)

Link intensity – the relative strength of the effect of the causal node on the affected node *at the places and times where the effect occurs*.	
High	Even a relatively small change in the causal node will result in a relatively large change in the affected node *at the places and times where the effect occurs*.
Medium	A relatively large change in the causal node will result in a relatively large change in the affected node; a relatively moderate change in the causal node will result in no more than a relatively moderate change in the affected node; and a relatively small change in the causal node will result in no more than a relatively small change in the affected node *at the places and times where the effect occurs*.
Low	Even a relatively large change in the causal node will result in only a relatively small change in the affected node *at the places and times where the effect occurs*.
Unknown	Insufficient information exists to rate link intensity.

Table 1-2.—Criteria for rating the relative spatial scale of a cause-effect relationship – one of three variables in the rating of link magnitude (after DiGennaro et al. 2012, Table 1)

Link spatial scale – the relative spatial extent of the effect of the causal node on the affected node. The rating takes into account the spatial scale of the cause and its effect.	
Large	Even a relatively small change in the causal node will result in a change in the affected node across a large fraction of the spatial scope of the model.
Medium	A relatively large change in the causal node will result in a change in the affected node across a large fraction of the spatial scope of the model; a relatively moderate change in the causal node will result in a change in the affected node across no more than a moderate fraction of the spatial scope of the model; and a relatively small change in the causal node will result in a change in the affected node across no more than a small fraction of the spatial scope of the model.
Small	Even a relatively large change in the causal node will result in a change in the affected node across only a small fraction of the spatial scope of the model.
Unknown	Insufficient information exists to rate link spatial scale.

Table 1-3.—Criteria for rating the relative temporal scale of a cause-effect relationship – one of three variables in the rating of link magnitude (after DiGennaro et al. 2012, Table 1)

Link temporal scale – the relative temporal extent of the effect of the causal node on the affected node. The rating takes into account the temporal scale of the cause and its effect.	
Large	Even a relatively small change in the causal node will result in a change in the affected node that persists or recurs over a relatively large span of time – decades or longer – even without specific intervention to sustain the effect.
Medium	A relatively large change in the causal node will result in a change in the affected node that persists or recurs over a relatively large span of time – decades or longer – even without specific intervention to sustain the effect; a relatively moderate change in the causal node will result in a change in the affected node that persists or recurs over only a relatively moderate span of time – one or two decades – without specific intervention to sustain the effect; a relatively small change in the causal node will result in a change in the affected node that persists or recurs over only a relatively short span of time – less than a decade – without specific intervention to sustain the effect.
Small	Even a relatively large change in the causal node will result in a change in the affected node that persists or recurs over only a relatively short span of time – less than a decade – without specific intervention to sustain the effect.
Unknown	Insufficient information exists to rate link temporal scale.

Table 1-4.—Criteria for rating the overall relative link magnitude of a cause-effect relationship based on link intensity, spatial scale, and temporal scale

Link magnitude – the overall relative magnitude of the effect of the causal node on the affected node based on the numerical average for link intensity, spatial scale, and temporal scale. (Calculated by assigning a numerical value of 3 to “High” or “Large,” 2 to “Medium,” 1 to “Low” or “Small,” and not counting missing or “Unknown” ratings.)	
High	Numerical average $\geq$ 2.67
Medium	Numerical average $\geq$ 1.67 but < 2.67
Low	Numerical average < 1.67
Unknown	No subattribute is rated High/Large, Medium, or Low/Small, but at least one subattribute is rated Unknown.

Table 1-5.—Criteria for rating the relative predictability of a cause-effect relationship (after DiGennaro et al. 2012, Table 3)

Link predictability – the statistical likelihood that a given causal agent will produce the effect of interest.	
High	Magnitude of effect is largely unaffected by random variation or by variability in other ecosystem dynamics or external factors.
Medium	Magnitude of effect is moderately affected by random variation or by variability in other ecosystem processes or external factors.
Low	Magnitude of effect is strongly affected by random variation or by variability in other ecosystem processes or external factors.
Unknown	Insufficient information exists to rate link predictability.

Table 1-6.—Criteria for rating the relative understanding of a cause-effect relationship (after DiGennaro et al. 2012, Table 3)

Understanding – the degree of agreement in the literature and among experts on the magnitude and predictability of the cause-effect relationship of interest.	
High	Understanding of the relationship is subject to little or no disagreement or uncertainty in peer-reviewed studies from within the ecosystem of concern or in scientific reasoning among experts familiar with the ecosystem. Understanding may also rest on well-accepted scientific principles and/or studies in highly analogous systems.
Medium	Understanding of the relationship is subject to moderate disagreement or uncertainty in peer-reviewed studies from within the ecosystem of concern and in scientific reasoning among experts familiar with the ecosystem.
Low	Understanding of the relationship is subject to wide disagreement, uncertainty, or lack of evidence in peer-reviewed studies from within the ecosystem of concern and in scientific reasoning among experts familiar with the ecosystem.
Unknown	(*The "Low" rank includes this condition*).

Table 1-7.—Organization of the worksheet for each life stage

Col.	Label	Content
A	Species	Identifies the species being modeled by four-letter code.
B	Link#	Contains a unique identification number for each causal link.
C	Life Stage	Identifies the life stage affected by the link.
D	Causal Node Type	Identifies whether the causal node for the link is a controlling factor, habitat element, critical biological activity or process, or life-stage outcome.
E	Causal Node	Identifies the causal node in the link.
F	Effect Node Type	Identifies whether the effect node for the link is a controlling factor, habitat element, critical biological activity or process, or life-stage outcome.
G	Effect Node	Identifies the effect node in the link.
H	Link Reason	States the rationale for including the link in the conceptual ecological model, including citations as appropriate.
I	Link Character Type	Identifies the character of the link based on standard definitions.
J	Link Character Direction	Identifies whether the link is uni- or bi-directional.
K	Link Character Reason	States the rationale for the entries for Link Character Type and Link Character Direction, including citations as appropriate.
L	Link Intensity	Shows the rating of link intensity based on the definitions in table 1-1.
M	Link Spatial Scale	Shows the rating of link spatial scale based on the definitions in table 1-2.
N	Link Temporal Scale	Shows the rating of link temporal scale based on the definitions in table 1-3.
O	Link Average Magnitude	Shows the numerical average rating of link intensity, spatial scale, and temporal scale based on the definitions in table 1-4.
P	Link Magnitude Rank	Shows the overall rating of link magnitude based on the Link Average Magnitude, grouped following the criteria in table 1-4.
Q	Link Magnitude Reason	States the rationale for the ratings for link intensity, spatial scale, and temporal scale, with citations as appropriate.
R	Link Predictability Rank	Shows the rating of link predictability based on the definitions in table 1-5.
S	Link Predictability Reason	States the rationale for the rating of link predictability, with citations as appropriate.
T	Link Understanding Rank	Shows the rating of link understanding based on the definitions in table 1-6.
U	Link Understanding Reason	States the rationale for the rating of link predictability, including comments on alternative interpretations and publications/experts associated with different interpretations when feasible, with citations as appropriate.
V	Management Questions	Briefly notes questions that appear to arise from the preceding entries for the link, focused on critical gaps or uncertainties in knowledge concerning *management actions and options*, with reasoning, including the estimate of relative importance when possible.
W	Research Questions	Brief notes that appear to arise from the preceding entries for the link, focused on critical gaps or uncertainties in *basic scientific knowledge*, with reasoning, including the estimate of relative importance when possible.
X	Other Comments	Provides additional notes on investigator concerns, uncertainties, and questions.
Y	Update Status	Provides information on the history of editing the information on this link for updates carried out after completion of an initial version.

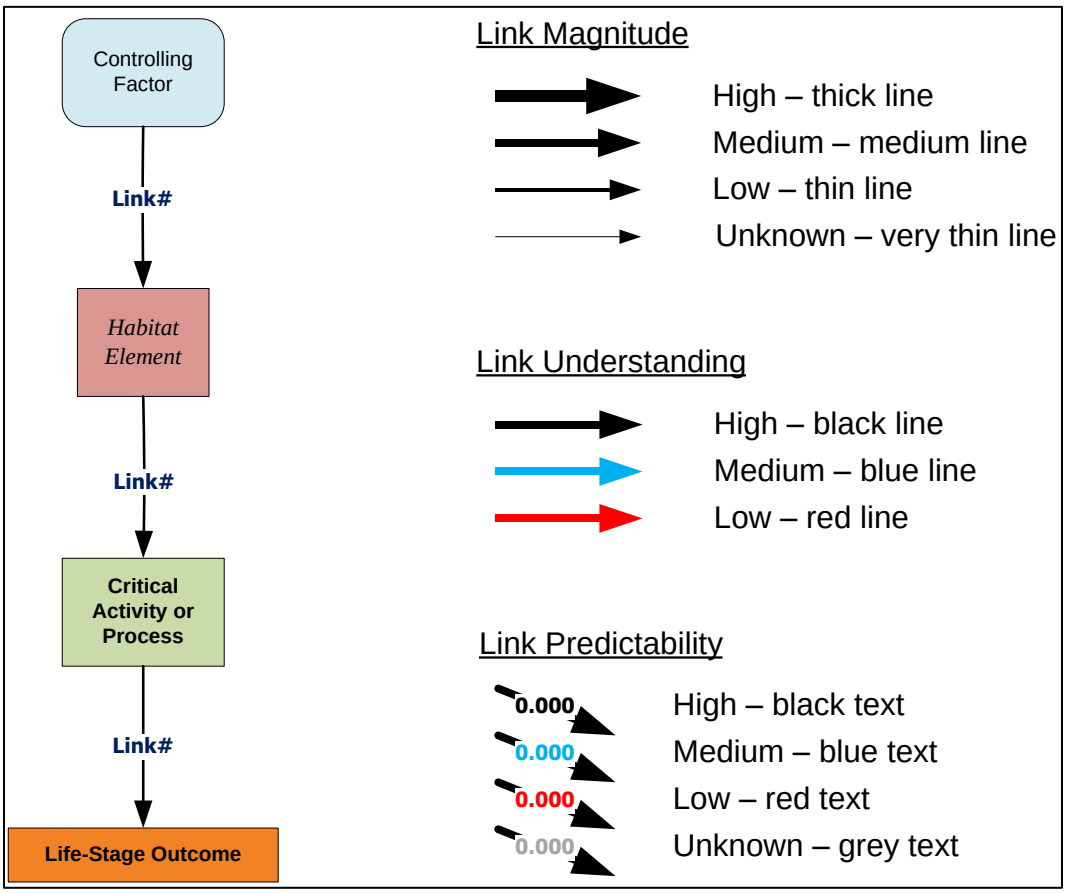

Figure 1-1.—Conventions for displaying cause and effect nodes, linkages, link magnitude, link understanding, and link predictability.

LITERATURE CITED

Burke, M., K. Jorde, and J.M. Buffington. 2009. Application of a hierarchical framework for assessing environmental impacts of dam operation: changes in streamflow, bed mobility and recruitment of riparian trees in a western North American river. Journal of Environmental Management 90:S224–S236.

DiGennaro, B., D. Reed, C. Swanson, L. Hastings, Z. Hymanson, M. Healey, S. Siegel, S. Cantrell, and B. Herbold. 2012. Using conceptual models and decision-support tools to guide ecosystem restoration planning and adaptive management: an example from the Sacramento–San Joaquin Delta, California. San Francisco Estuary and Watershed Science 10(3):1–15. http://escholarship.org/uc/item/3j95x7vt

Fischenich, J.C. 2008. The application of conceptual models to ecosystem restoration. U.S. Army Engineers, Engineer Research and Development Center (ERDC), Ecosystem Management and Restoration Research Program (EMRRP), Technical Note ERDC/EBA TN-08-1, February 2008. Vicksburg, Mississippi. http://el.erdc.usace.army.mil/publications.cfm?Topic=technote&Code=emrrp

Kondolf, G.M., J.G. Williams, T.C. Horner, and D. Milan. 2008. Assessing physical quality of spawning habitat. Pages 249–274 *in* D.A Sear and P. DeVries (editors). Salmonid Spawning Habitat in Rivers: Physical Controls, Biological Responses, and Approaches. American Fisheries Society Symposium 65. American Fisheries Society, Bethesda, Maryland.

McDonald, D.B. and H. Caswell. 1993. Matrix methods for avian demography. Pages 139–185 *in* D.M. Power (editor). Current Ornithology. Plenum Press, New York, New York.

Wildhaber, M.L. 2011. Identifying structural elements needed for development of a predictive life-history model for pallid and shovelnose sturgeons. Journal of Applied Ichthyology 27:462–469.

Wildhaber, M.L., A.J. DeLonay, D.M. Papoulias, D.L. Galat, R.B. Jacobson, D.G. Simpkins, P.J. Baaten, C.E. Korschgen, and M.J. Mac. 2007. A conceptual life-history model for pallid and shovelnose sturgeon. U.S. Geological Survey, Circular 1315. Reston, Virginia.

ATTACHMENT 2

Western Yellow Bat Habitat Data

Table 2-1.—Western yellow bat habitat data

Habitat element	Value or range	Location	Reference
Canopy closure	Crown width for roost trees: mean = 2.5 meters (range = 1–4 meters); percent dead crown cover mean = 43 percent; range = 35–75 percent	Lower Colorado River	Diamond 2012
	Crown width for roost trees: mean = 2.9 meters (range = 0.5–4.6 meters); percent dead crown cover mean = 51 percent; range = 50–55 percent	Lower Colorado River	Diamond et al. 2013
Patch size	High probability of occupancy with as little as 10 percent coverage of cottonwood-willow (*Populus fremontii*, *Salix* sp.) within 10 meters, or 0.3 hectare	Lower Colorado River	Vizcarra et al. 2010
Tree species composition	Roost in Mexican fan palms (*Washingtonia robusta*) almost exclusively	Lower Colorado River	Diamond 2012
	Roost in cottonwoods	Arizona	Higginbotham et al. 1999
	Forage in riparian woodland preferentially	Nevada	Williams et al. 2006
	Occupancy strongly associated with cottonwood-willow habitat; weak negative association with saltcedar	Lower Colorado River	Vizcarra et al. 2010

Note: The data presented in this table reflect those available in the literature at the time this model was developed. These data have not been validated.

LITERATURE CITED

Diamond, J.M. 2012. Distribution and Roost Site Habitat Requirements of Western Yellow (*Lasiurus xanthinus*) and Western Red (*Lasiurus blossevillii*) Bats: 2011 Summary of Findings. Submitted to the Bureau of Reclamation, Lower Colorado River Multi-Species Conservation Program, Lower Colorado Region, Boulder City, Nevada.

Diamond, J.M., R. Mixan, and M. Piorkowski. 2013. Distribution and Roost Site Habitat Requirements of Western Yellow (*Lasiurus xanthinus*) and Western Red (*Lasiurus blossevillii*) Bats. Submitted to the Bureau of Reclamation, Lower Colorado River Multi-Species Conservation Program, Lower Colorado Region, Boulder City, Nevada.

Higginbotham, J.L., L.K. Ammerman, and M.T. Dixon. 1999. First record of *Lasiurus xanthinus* (Chiroptera: Vespertilionidae) in Texas. Southwestern Naturalist 44:343–347.

Vizcarra, B., L. Piest, and V. Frary. 2010. Monitoring of Covered and Evaluation Bat Species for the Lower Colorado River Multi-Species Conservation Program — 2010 Final Report. Submitted to the Bureau of Reclamation, Lower Colorado River Multi-Species Conservation Program, Lower Colorado Region, Boulder City, Nevada.

Williams, J.A., M.J. O'Farrell, and B.R. Riddle. 2006. Habitat use by bats in a riparian corridor of the Mojave Desert in southern Nevada. Journal of Mammalogy 87(6):1145–1153.