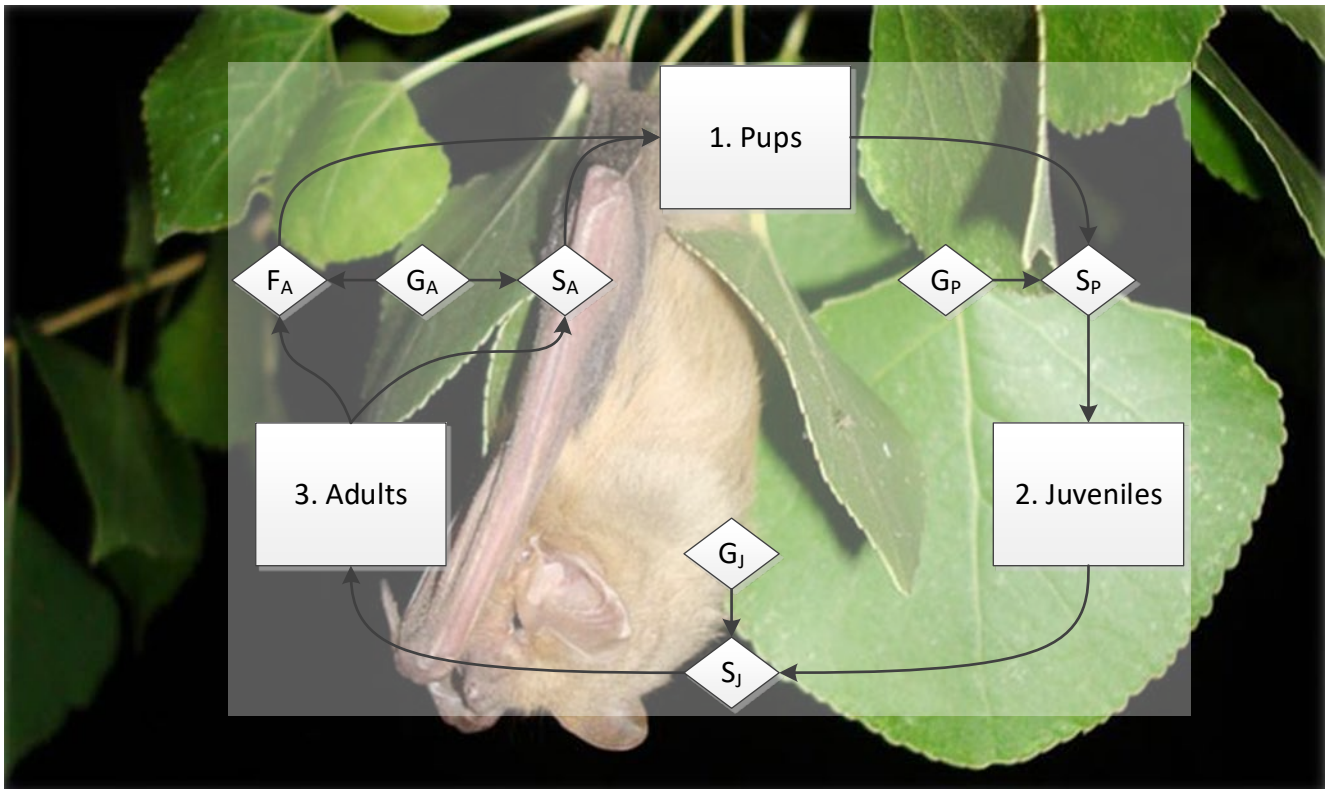
Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

2019 Updates to Western Yellow Bat (*Lasiurus xanthinus*) (WYBA) Basic Conceptual Ecological Model for the Lower Colorado River



BUREAU OF RECLAMATION

Work conducted under LCR MSCP Work Task G6

June 2020

Lower Colorado River Multi-Species Conservation Program Steering Committee Members

Federal Participant Group

Bureau of Reclamation
U.S. Fish and Wildlife Service
National Park Service
Bureau of Land Management
Bureau of Indian Affairs
Western Area Power Administration

Arizona Participant Group

Arizona Department of Water Resources
Arizona Electric Power Cooperative, Inc.
Arizona Game and Fish Department
Arizona Power Authority
Central Arizona Water Conservation District
Cibola Valley Irrigation and Drainage District
City of Bullhead City
City of Lake Havasu City
City of Mesa
City of Somerton
City of Yuma
Electrical District No. 3, Pinal County, Arizona
Golden Shores Water Conservation District
Mohave County Water Authority
Mohave Valley Irrigation and Drainage District
Mohave Water Conservation District
North Gila Valley Irrigation and Drainage District
Town of Fredonia
Town of Thatcher
Town of Wickenburg
Salt River Project Agricultural Improvement and Power District
Unit "B" Irrigation and Drainage District
Wellton-Mohawk Irrigation and Drainage District
Yuma County Water Users' Association
Yuma Irrigation District
Yuma Mesa Irrigation and Drainage District

Other Interested Parties Participant Group

QuadState Local Governments Authority
Desert Wildlife Unlimited

California Participant Group

California Department of Fish and Wildlife
City of Needles
Coachella Valley Water District
Colorado River Board of California
Bard Water District
Imperial Irrigation District
Los Angeles Department of Water and Power
Palo Verde Irrigation District
San Diego County Water Authority
Southern California Edison Company
Southern California Public Power Authority
The Metropolitan Water District of Southern California

Nevada Participant Group

Colorado River Commission of Nevada
Nevada Department of Wildlife
Southern Nevada Water Authority
Colorado River Commission Power Users
Basic Water Company

Native American Participant Group

Hualapai Tribe
Colorado River Indian Tribes
Chemehuevi Indian Tribe

Conservation Participant Group

Ducks Unlimited
Lower Colorado River RC&D Area, Inc.
The Nature Conservancy

Lower Colorado River Multi-Species Conservation Program

2019 Updates to Western Yellow Bat (*Lasiurus xanthinus*) (WYBA) Basic Conceptual Ecological Model for the Lower Colorado River

Prepared by:

David P. Braun, Ph.D. and Robert Unnasch, Ph.D.

Sound Science, LLC

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

June 2020

Braun, D.P. and R. Unnasch. 2020. 2019 Updates to Western Yellow Bat (*Lasiurus xanthinus*) (WYBA) Basic Conceptual Ecological Model for the Lower Colorado River. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada, by Sound Science, LLC, Boise, Idaho under contract No. R16PC00028.

ACRONYMS AND ABBREVIATIONS

AZGFD	Arizona Game and Fish Department
CAP	critical activity or process
CEM	conceptual ecological model
CF	controlling factor
CVCA	Cibola Valley Conservation Area
DBH	diameter at breast height
HCP	Habitat Conservation Plan
HE	habitat element
km	kilometer(s)
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
LSO	life-stage outcome
m	meter(s)
PVER	Palo Verde Ecological Reserve
Reclamation	Bureau of Reclamation
USDA-NRC	U.S. Department of Agriculture-Natural Resources Conservation Service
USFWS	U.S. Fish and Wildlife Service
WYBA	western yellow bat (*Lasiurus xanthinus* aka *Dasypterus xanthinus*)

Symbols

%	percent
±	plus or minus

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.

CONTENTS

Page

Foreword v

Updates to Chapter 1 – Introduction 1-1
Western Yellow Bat Reproductive Ecology 1-2
Conceptual Ecological Model Purposes 1-2
Conceptual Ecological Model Structure 1-2

Updates to Chapter 2 – WYBA Life-Stage Model 2-1
Proposed WYBA Life Stages and Life-Stage Outcomes 2-1
Pups 2-3
Juveniles 2-4
Adults 2-4

Updates to Chapter 3 – Critical Biological Activities and Processes 3-1
Breeding 3-1
Chemical Stress 3-2
Competition 3-3
Disease 3-4
Feeding 3-4
Foraging 3-4
Inter-Site Movement 3-5
Maternal Care 3-7
Mechanical Stress 3-7
Predation 3-7
Roosting 3-9
Thermal Stress 3-10

Updates to Chapter 4 – Habitat Elements 4-1
Anthropogenic Disturbance 4-2
Arthropod Community 4-2
Chemical Contaminants 4-4
Fire Regime 4-4
Infectious Agents 4-6
Litter Size 4-6
Maternal Care 4-6
Matrix Community 4-7
Monitoring, Capture, Handling 4-8
Palm Trees 4-9
Riparian Tree Community 4-11
Temperature 4-12
Vertebrate Community 4-13
Water Availability 4-15

Page

Updates to Chapter 5 – Controlling Factors 5-1
Conservation Monitoring and Research Programs 5-2
Fire Management 5-2
Habitat Development and Management..... 5-3
Nuisance Species Introduction and Management 5-4
Surrounding Land Use 5-4
Water Storage-Delivery System Design and Operation 5-5
Wind Energy Development..... 5-6

Updates to Chapter 6 – Conceptual Ecological Model by Life Stage..... 6-1
New Links with Controlling Factors as Causal Agents that Affect
Other Controlling Factors 6-1
New Links with Controlling Factors as Causal Agents that Affect
Habitat Elements 6-4
Deleted Links with Controlling Factors as Causal Agents 6-10
Updated Links with Controlling Factors as Causal Agents 6-14
New Links with Habitat Elements as Causal Agents that Affect
Habitat Elements 6-15
New Links with Habitat Elements as Causal Agents that Affect
Critical Activities or Processes 6-23
Deleted Links with Habitat Elements as Causal Agents..... 6-35
Updated Links with Habitat Elements as Causal Agents..... 6-37
New Links with Critical Activities and Processes as Causal Agents 6-44
Deleted Links with Critical Biological Activities or Processes as
Causal Agents 6-50
Updated Links with Critical Biological Activities or Processes as
Causal Agents 6-50
New Links with Life-Stage Outcomes as Causal Agents 6-53
Summary of Updated Terms for WYBA conceptual ecological model 6-55

Literature Cited in This Update L-1

Acknowledgments A-1

Tables

Table Page

1 (Revision of original table 1) WYBA life stages and life-stage outcomes in the LCR ecosystem 2-1
2 (Revision of original table 2) WYBA critical biological activities and processes and their distribution among life stages 3-1
3 (Revision of original table 3) WYBA habitat elements and the critical biological activities or processes they directly affect across all life stages 4-1
4 (Revision of original table 4) WYBA controlling factors and the habitat elements they directly affect 5-1
5 (New table for this update) Updated WYBA conceptual ecological model component names 6-55

Figures

Figure Page

1 (Revision of original Figure 1) Proposed WYBA life history model 3-2

Foreword

This report provides an update to the original conceptual ecological model (CEM) prepared for the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) for the western yellow bat (*Lasiurus xanthinus*) (WYBA) (Marty and Unnasch 2015). This update incorporates information reported in publications and presentations at professional meetings since the completion of the original WYBA conceptual ecological model, information from the professional experiences of LCR MSCP staff and other experts, and newer information on western yellow bat ecology more generally. An updated version of the CEM workbook incorporates the new information. This report constitutes an appendix to the original CEM. The full CEM report, including its life-stage diagrams, has not been updated. The authors of the present report updated the WYBA conceptual ecological model alongside the CEM for the western red bat (*Lasiurus blossevillii*) (WRBA) (Braun and Unnasch 2020).

The structure of the present report follows the structure of the original CEM report. Specifically, it presents and documents updates to chapters 1–6. It does not include updates to the original Executive Summary or chapters 7–8 because they were not updated.

The updates reported in this report change the WYBA conceptual ecological model in several key respects, in addition to incorporating new information on the species itself. Six sets of changes in the structure of the CEM are particularly noteworthy. (1) This update adds pup growth, juvenile growth, and adult growth as life-stage outcomes. (2) This update adds breeding, competition, and inter-site movement as new critical biological activities and processes. (3) This update eliminates genetic diversity and infectious agents as a habitat element, replacing it with simply infectious agents. (4) This update combines three habitat elements—patch size, tree species composition, and canopy cover—into a more inclusive habitat element, riparian tree community, and also distinguishes palm trees as a separate habitat element. (5) This update adds three other new habitat elements—chemical contaminants, fire regime, and monitoring, capture, handling. (6) This update adds two new controlling factors—conservation monitoring and research programs and surrounding land use—and incorporates information on the original factors, grazing, pesticide application, tree pruning, and tree thinning into the latter. The structure of the CEM for the western red bat was updated in the same ways.

This report also provides a list of all literature cited in the updates to chapters 1–6 and in the updated CEM workbook. In addition, this report provides a list of all changes made to the names of the CEM components to standardize terminology across all CEMs.

The report both explicitly and implicitly identifies possible new research and monitoring questions concerning gaps in knowledge that may bear on adaptive management of WYBA. These questions may or may not reflect the current or future goals of the LCR MCSP decision making and are in no way meant as a call for the Bureau of Reclamation to undertake research to fill the identified knowledge gaps.

Updates to Chapter 1 – Introduction

The information in the initial section of chapter 1 is updated as follows:

This document updates information in the conceptual ecological model (CEM) for the western yellow bat (*Lasiurus xanthinus* aka *Dasypterus xanthinus*)[1] (WYBA) concerning its ecology and status along the Lower Colorado River Valley. This update incorporates information concerning WYBA in the greater lower Colorado River (LCR) ecosystem that have appeared since completion of the original WYBA conceptual ecological model (Marty and Unnasch 2015) (Berry et al. (2017), Broderick (2016), Calvert (2016a, 2016b), Hill (2018), LCR MSCP 2016, Mixan and Diamond (2016, 2017a, 2017b, 2018a, 2018b, 2019a, 2019b), and Mixan et al. (2015). This update also incorporates information concerning WYBA in the greater LCR ecosystem from presentations by these authors at the annual Colorado River Terrestrial and Riparian meetings in 2015–2017,[2] including Broderick (2015), Brown (2015), Calvert (2015, 2016c, 2017), and Mixan (2015, 2016, 2017). Calvert (2017) summarizes the history of bat research and monitoring along the Lower Colorado River Valley for the Lower Colorado River Multi-species Conservation Program (LCR MSCP).

This update also incorporates information from a small number of both earlier and more recent publications concerning WYBA more generally across the northern extent of its current range in Arizona, California, Nevada, New Mexico, and Texas (Arizona Game and Fish Department [AZGFD] 2011; Eckberg and Foster 2011; NatureServe 2019a; Ortiz and Barrows 2014; Zabriskie et al. 2019). Bunkley et al. (2015), Mikula (2015), Mikula et al. (2016), and Rodhouse et al. (2016) provide pertinent information on bat ecology in general; Faria et al. (2013), Kuzmin et al. (2012), and Stuchin et al. (2018) provide information on rabies transmission and effects in WYBA; and Wonkka et al. (2018) provide new information on the effects of wildfire on cottonwood (*Populus* spp.) riparian forests.

---

[1] Baird et al. (2015, 2017) propose reclassifying all yellow bat species from the genus *Lasiurus* to *Dasypterus*. The American Society of Mammalogists (2019) now recognizes the species as *Dasypterus xanthinus*, as do Morgan et al. (2019). However, species accounts (AZGFD 2011; LCR MSCP 2016; NatureServe 2019a) and LCR MSCP authorizing documents (Reclamation 2004) use the original designation, and the present document follows their practice.

[2] The Colorado River Terrestrial and Riparian annual meetings did not take place in 2018 and 2019 due to temporary closures of the Federal Government.

WESTERN YELLOW BAT REPRODUCTIVE ECOLOGY

This update expands on the discussion of WYBA reproductive ecology in the original CEM to take note of the generalization summarized by Mikula et al. (2016) that, "In general, bats are K-strategists with long life spans and small litter sizes (Kunz and Fenton 2003), and life-history traits directly related to effective avoidance of predation (Rydell et al. 1996; Speakman 1991a, 1995)." As discussed in chapter 3 (see "Predation"), the literature on WYBA does not record any activities to drive off, distract, or misdirect predators at roosts or in the air. The species also may have only limited anti-predator defenses such as avoidance behaviors: The AZGFD (2011) specifically cites Mumford and Zimmerman (1963) that WYBA "flies steadily, in a straight line with slow wing beats." The LCR MSCP (2016) states that "Palm trees may be preferred [as roosting habitat] because dead fronds closely match the fur coloration of the species, although the bats will use any tree that gives them enough cover to be hidden while roosting." No other publications reviewed for this CEM describe WYBA coloration or behaviors as cryptic.

CONCEPTUAL ECOLOGICAL MODEL PURPOSES

This update does not include any changes to this section of chapter 1. However, when the CEMs are fully updated, chapter 1 should be revised to indicate that the CEM methodology followed here is a crucial foundation for carrying out effects analyses as described by Murphy and Weiland (2011, 2014) and illustrated by Jacobson et al. (2016).

CONCEPTUAL ECOLOGICAL MODEL STRUCTURE

No change.

Updates to Chapter 2 – WYBA Life-Stage Model

PROPOSED WYBA LIFE STAGES AND LIFE-STAGE OUTCOMES

This update standardizes the names of the WYBA life stages and life-stage outcomes and adds three new outcomes focused on pup, juvenile, and adult growth. Table 1 and figure 1 are updated accordingly. The updated version of figure 1 also appears on the cover illustration of this update.

Table 1.—(Revision of original table 1) WYBA life stages and life-stage outcomes in the LCR ecosystem

Life stage	Life-stage outcome(s)
1. Pups	• Pup survival • Pup growth
2. Juveniles	• Juvenile survival • Juvenile growth
3. Adults	• Adult survival • Adult growth • Adult fertility

This update drops the adjective, breeding, from the name of the WYBA adult life stage. The adult life stage begins with the onset of sexual maturity, and no reports suggest that WYBA cease sexual activity at some later stage of life. However, numerous reports indicate that WYBA adults may not all participate in reproduction in any single year: Bat monitoring protocols for the Lower Colorado River Valley include recording the reproductive status of both male and female adults (male testes descended or not; females pregnant, lactating, post-lactating, or not—Hill 2018). The resulting data indicate that mist netting can capture both reproductive and non-reproductive male and female WYBA at the same places and times (Calvert 2010a, 2010b, 2012a, 2012b, 2013, 2016a, 2016b; Diamond 2012; LCR MSCP 2016). Consequently, it is not appropriate to refer to all adult WYBA as breeding adults. Instead, this update adds a new critical biological activity, breeding, to address the differential year-to-year participation of WYBA adults in reproduction.

This update also adds the name of the associated life stage to the name of each life-stage outcome, for consistency with the other LCR MSCP conceptual ecological model updates, as shown in table 1 and on figure 1. Further, this

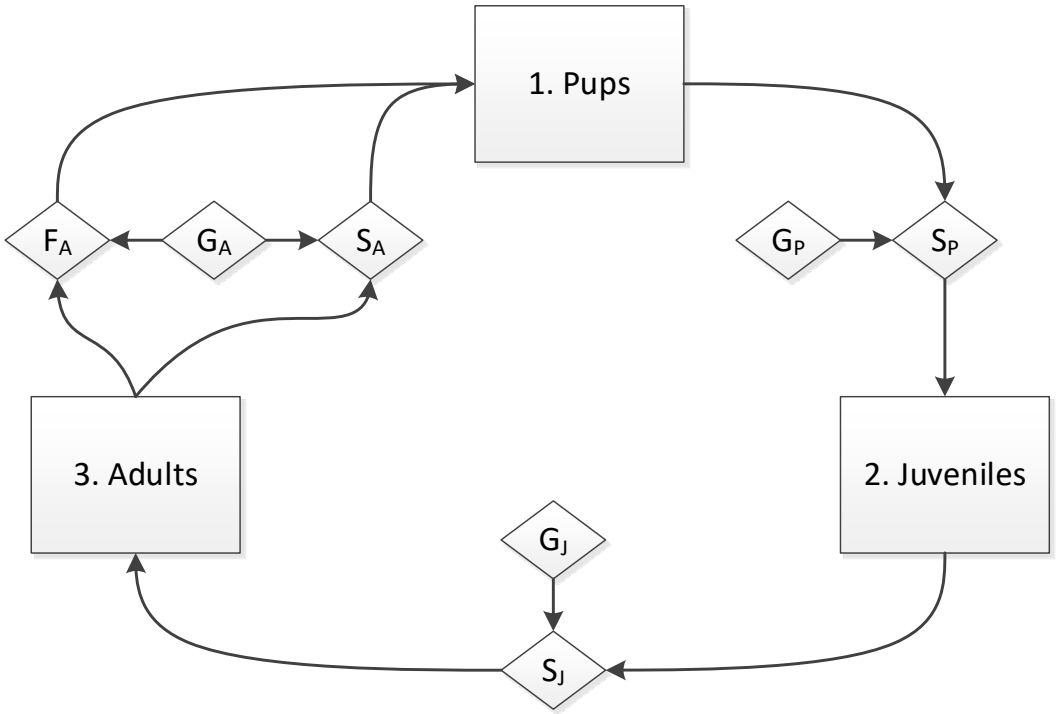


Figure 1.—(Revision of original Figure 1) Proposed WYBA life history model. Squares indicate life stages, and diamonds indicate life-stage outcomes. Life-stage outcomes are rates, as follows: S_P = survival of pups; G_P = growth of pups; S_J = survival of juveniles; G_J = growth of juveniles; S_A = annual survival of adults; F_A = fertility of adults; G_A = growth of adults.

update changes the name of the life-stage outcome for adult reproduction to adult fertility, again for consistency with the other LCR MSCP conceptual ecological updates.

Finally, this update adds life-stage outcomes for growth in all three life stages. Growth here includes both (a) morphological and physiological development and (b) the maintenance of body mass and condition (health) in the face of the stresses of daily life and fluctuations in food intake. Pup growth includes morphological and physiological maintenance and development to fledging; juvenile growth includes morphological and physiological maintenance and development to sexual maturity; and adult growth includes the maintenance and continued development of body mass as well as support of gestation and subsequent lactation in females. This update adds these outcomes to the original CEM in order to capture the ways in which (a) various types of stress potentially can affect condition and growth in all three life stages; (b) competition with siblings and the quality of maternal care potentially can affect pup growth; (c) competition and foraging success potentially can affect juvenile growth; (d) competition, foraging success, and gestating and caring for pups potentially can affect adult growth; and (e) growth, in turn, can affect survival in all three WYBA life stages.

The authors of this update also considered including an additional life-stage outcome for WYBA adults to represent the possible dynamics of WYBA migration. General species accounts for WYBA characterize the species as migratory (AZGFD 2011; NatureServe 2019a), with many individuals leaving particularly the northern portions of their current range during the colder months (see below, this chapter, "Adults" and chapter 3, "Inter-Site Movement"). WYBA detected along the Lower Colorado River Valley since 2010 may move seasonally (migrate) both through and within the valley, with adult males and females migrating separately and possibly to/from different winter destinations. However, the literature reviewed for the WYBA conceptual ecological model and this update does not provide any information on whether, why, or over what distances individual WYBA adults may migrate. This update addresses this area of uncertainty by adding a new critical biological activity, inter-site movement, to address the differential movement of WYBA both through and within the Lower Colorado River Valley rather than by adding a life-stage outcome for adult WYBA migration. On the other hand, a CEM for WYBA dynamics at a larger, regional scale might need to include seasonal migration as a life-stage outcome, as suggested by the general species accounts.

This update also expands the individual WYBA life stage descriptions as follows:

Pups

This update integrates information on the importance of thermal regulation in WYBA pups that the original WYBA conceptual ecological model (Marty and Unnasch 2015) presented separately. Chapter 2 in the original WYBA conceptual ecological model noted that 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). Further, in chapter 3 (see "Thermal Stress"), the original WYBA conceptual ecological model noted that bat pups in general are particularly susceptible to temperature extremes. Jones et al. (2009) document the effects of extreme cold and heat on various bat species, including a massive die-off of bat pups in Australia in 2006.

However, the literature reviewed for this update does not specifically address thermal regulation or tolerances in WYBA pups. The skirts of dead leaf fronds on the palm trees that WYBA prefer for roosting on (see chapter 3, "Roosting") likely provide thermal protection for roosting WYBA (Ortiz and Barrows 2014). Diamond et al. (2013) suggest that more substantial palm skirts "likely provide a suitable microclimate that is not found in those palms lacking a large dead frond skirt." However, the literature does not address how such thermal protection or its absence may affect WYBA pup survival or growth. As noted above, this update explicitly recognizes the importance of morphological and physiological growth—maturation—in the pup life stage. Slower growth necessarily results in a

smaller body size at fledging and/or a longer time between birth and fledging. This update also notes (see chapter 3, "Competition" and "Maternal Care") that WYBA pups may compete for maternal care, with larger litters likely resulting in greater competition. However, the literature does not address these possible relationships specifically for WYBA pups.

Juveniles

This update incorporates information on the timing of this life stage. Mixan and Diamond (2018a, 2018b), discussing the consistent, large peak in acoustic detections of WYBA in July and August along the Lower Colorado River Valley, specifically at habitat conservation areas, note that "… western yellow bat young typically become volant in July, which would lead to the increased activity observed in July and August." This update does not incorporate any other new information about the biology of the juvenile life stage, except to explicitly recognize the importance of morphological and physiological growth in this life stage, as well. Slower growth necessarily results in a smaller body size and/or a longer time between fledging and sexual maturity.

Adults

This update recognizes the importance of morphological and physiological growth in this life stage and incorporates additional information about the biology of the adult life stage in general, or in the Lower Colorado River Valley in particular, as follows:

- The timing of WYBA adult nighttime activity affects monitoring practices and, possibly, vulnerability to predation. AZGFD (2011) and LCR MSCP (2016) state that WYBA foraging begins at dusk, a generalization confirmed by acoustic monitoring in the Lower Colorado River Valley (Calvert 2010a, 2010b). Acoustic monitoring along the Lower Colorado River Valley routinely detects WYBA during evening (1700–2200), mid-night (2200–0200), and morning (0200–0700) monitoring periods, although the relative incidence of calls may vary among these three periods (Mixan et al. 2013). Nighttime mist netting for bats in the Lower Colorado River Valley routinely begins at least a half-hour after sunset to allow the bats time to forage before being subjected to the stresses of capture. Conversely, acoustic monitoring along the Lower Colorado River Valley begins a half-hour before sunset to ensure that recording begins with the first bats to emerge from their roosts (Hill 2018). Monitoring protocols, therefore, are compatible with the timing of WYBA adult foraging activity (see chapter 3, "Foraging" and chapter 4, "Monitoring, Capture, Handling").

- Acoustic detections and mist-net captures of WYBA have increased along the Lower Colorado River Valley since approximately 2010, although with large year-to-year variation at individual monitoring sites and possibly a slight decline in overall detections since 2015 (Broderick 2012a, 2012b, 2016; Calvert 2017; Mixan and Diamond 2019a, 2019b). This change has occurred concurrently with the maturation of Fremont cottonwood-Goodding's willow (*Populus fremontii-Salix gooddingii*) stands planted at habitat conservation areas, particularly the Beal Lake, the Cibola National Wildlife Refuge Unit #1 Conservation Area, the Cibola Valley Conservation Area (CVCA), and the Palo Verde Ecological Reserve (PVER). The woodland patches at these conservation areas have added significantly to the cottonwood-willow stands present at other protected areas along the valley, which serve as long-term, system-wide monitoring sites for the LCR MSCP. The published evidence for this increase in WYBA detections has become clear largely since the preparation of the original WYBA conceptual ecological model (Marty and Unnasch 2015). The increased availability and geographic distribution of cottonwood-willow woodlands along the valley is hypothesized to be a driving factor in the increased detections of WYBA along the valley (Broderick 2012a, 2012b; Mixan and Diamond 2019b) (see chapter 3, "Foraging").

Intensive acoustic monitoring along the Lower Colorado River Valley since fiscal year 2010, both in habitat conservation areas and in established protected areas, has detected WYBA during every season of the year (Broderick 2012a; Calvert 2016a, 2016b, 2017; Mixan 2015, 2016; Mixan and Diamond 2017a, 2017b, 2018a, 2018b, 2019a, 2019b; Mixan et al. 2015;). However, the pattern of detections appears to result from three interacting dynamics: (1) WYBA migrate up and down the Lower Colorado River Valley, northward primarily in May and southward primarily in September; (2) WYBA increasingly concentrate in July and August to forage in cottonwood-willow stands created at LCR MSCP habitat conservation areas; and (3) a few WYBA adult males may overwinter as far north as the upper Moapa Valley in southern Nevada, while WYBA females may overwinter in the Lower Colorado River Valley only as far north as the southern valley in the United States (for example, at the Mittry Lake Wildlife Area near Yuma, Arizona). Elsewhere in its range, the northward seasonal migration of WYBA in New Mexico "… may coincide with the blooming of agave and perhaps yucca" (NatureServe 2019a) (see chapter 3, "Inter-Site Movement").

- Investigations along the LCR and Bill Williams River valleys, and along multiple river valleys in central and southeastern Arizona, have compared WYBA roosting sites with non-roosting sites, both in natural protected areas and created habitat (Calvert 2017; Mixan 2015; Mixan et al. 2015). Mixan et al. (2015) report that most radio-tracked WYBA in one investigation (93% of 29 tracked) roosted in fan palms (*Washingtonia* spp.), with the remainder in date palms (*Phoenix dactylifera*). These findings statistically confirm the pattern described

in the original WYBA conceptual ecological model (Marty and Unnasch 2015) and in AZGFD (2011) and LCR MSCP (2016). However, it should be noted that reports on fan palms in which WYBA have been observed to roost, including along the LCR and Bill Williams River valleys, identify the trees variously as the non-native Mexican fan palm (*W. robusta*), the native but sometimes possibly intentionally planted California fan palm (*W. filifera*), a hybrid of the two (*W. filifera* x *robusta*), or simply as *Washingtonia* spp. Chapter 4 (see "Palm Trees") discusses the identification and native versus non-native status of fan palms in the Lower Colorado River Valley. Mixan et al. (2015) further note, "While it was not tested in this study, anecdotal observations indicate that Mexican fan palms had a much higher availability than date palms, and this trend is likely responsible for the roost use described above." Ortiz and Barrows (2014) report WYBA at palm oases in the Colorado Desert subdivision of the Sonoran Desert in southern California consistently roosting specifically in native California fan palms. Zabriskie et al. (2019) report on four apparently torpid WYBA found roosting in hybrid fan palm trees (*W. filifera* x *robusta*) in Las Cruces, New Mexico. Numerous publications (see summaries in AZGFD 2011; Brown 2006; LCR MSCP 2016; NatureServe 2019a) also note that WYBA may also roost in native riparian trees such as mature cottonwood, hackberry *(Celtis occidentalis)*, and sycamore (*Platanus occidentalis)* trees and in tall yucca species with long masses (skirts) of dead fronds below their crowns such as the giant dagger yucca (*Yucca carnerosana*) (see chapter 3, "Roosting").

- The investigations reported by Mixan et al. (2015) along the LCR and Bill Williams River valleys and along multiple river valleys in central and southeastern Arizona, comparing WYBA roosting sites with non-roosting sites, both in natural protected areas and created habitat, also collected measurements of roosting versus non-roosting trees. The data indicate that WYBA consistently (and statistically significantly) roosted in the tallest palm trees available at any given site. Diamond (2012) also notes for a separate study exclusively in the Lower Colorado River Valley, "Yellow bat tree roosts had a significantly higher live crown base and percentage of dead crown. Roost trees with a high live crown base and a high percentage of dead crown indicate the presence of a wide and deep dead palm frond skirt. These palm skirts likely provide a suitable microclimate that is not found in those palms lacking a large dead frond skirt" (see chapter 3, "Roosting"). Ortiz and Barrows (2014), studying palm oases in southern California, compared oases where WYBA roosted versus oases where they did not and found that the statistically preferred oases were located at higher elevations and had higher numbers of palms greater than 10 feet tall with moderate to long frond skirt lengths. The WYBA at these oases avoided palms from which fire had destroyed large portions of the frond skirt. Ortiz and Barrows (2014) also found that WYBA preferred oases in which the majority of palms exhibited new growth and avoided oases in which the palms lacked such new growth.

WYBA adults do not necessarily forage in the immediate vicinity of their roosting sites but instead may travel up to several kilometers (km) (e.g., 6 km) to forage preferentially in areas with native riparian woodland vegetation and over water (Diamond et al. 2013; LCR MSCP 2016; Mixan and Diamond 2019a, 2019b) (see chapter 3, "Foraging").

Updates to Chapter 3 – Critical Biological Activities and Processes

This update identifies 12 critical biological activities and processes that affect 1 or more WYBA life stages. The original WYBA conceptual ecological model (Marty and Unnasch 2015) identified nine. Table 2 lists the 12 critical biological activities and processes in this update, and their distribution across life stages, and indicates which are new to this update or renamed from the original WYBA conceptual ecological model.

Table 2.—(Revision of original Table 2) WYBA critical biological activities and processes and their distribution among life stages
(Xs indicate the critical biological activities or processes that apply to each life stage.)

Life stage ➔ **Critical biological activity or process 🡻**	**Pups**	**Juveniles**	**Adults**
Breeding (*new*)			**X**
Chemical stress	**X**	**X**	**X**
Competition (*new*)	**X**	**X**	**X**
Disease	**X**	**X**	**X**
Feeding (*replaces eating*)	**X**		
Foraging		**X**	**X**
Inter-site movement (*new*)			**X**
Maternal care (*replaces roost attendance*)			**X**
Mechanical stress	**X**	**X**	**X**
Predation	**X**	**X**	**X**
Roosting (*replaces roost site selection*)		**X**	**X**
Thermal stress	**X**	**X**	**X**

BREEDING

This update adds this critical biological activity or process to the original WYBA conceptual ecological model to recognize the possibility that some adult WYBA

may not participate in reproduction in a given year. Breeding here concerns the activities and processes of mating and gestation, but not maternal care, which is its own critical biological activity or process.

As noted in chapter 2 (see "Proposed WYBA Life Stages and Life-Stage Outcomes"), data on WYBA adults captured in mist nets indicate that only some WYBA adults participate in reproduction in any single year. Specifically, data on the reproductive status of mist-netted adult male and female WYBA (male testes descended or not; females pregnant, lactating, post-lactating, or not—Hill 2018) indicate that both reproductive and non-reproductive male and female WYBA may occur together at the same places and times (Calvert 2010a, 2010b, 2012a, 2012b, 2013, 2016a, 2016b; Diamond 2012; LCR MSCP 2016). However, the reasons why some adult WYBA participate in reproductive activities in a given year while others do not have not been studied.

CHEMICAL STRESS

The definition of this critical biological activity or process is updated with two additions. First, WYBA roost preferentially in native (California), non-native (Mexican), and hybrid fan palms, which often occur as intentionally planted ornamentals in residential and commercial areas, including urban areas (Bazelman 2016; LCR MSCP 2016; Ortiz and Barrows 2014; Zabriskie et al. 2019). In the Lower Colorado River Valley in particular, such palm trees typically occur in the yards of houses interspersed in areas of agricultural use (Berry et al. 2017; Brown 2006; Diamond 2012; Diamond et al. 2013; LCR MSCP 2016; Mixan et al. 2012, 2013, 2015). As noted in chapter 2 (see "Adults"), WYBA in the Lower Colorado River Valley also may roost in the crowns of date palms, which are planted in orchards in the valley. The interspersal of residential and commercial sites with fan palms across the agricultural areas of the Lower Colorado River Valley, and the concentration of date palms in orchards, potentially expose WYBA at their roost sites to a wide range of agricultural chemicals (see chapter 4, "Chemical Contaminants").

Second, locations with or potentially suitable for WYBA foraging habitat, such as the PVER and CVCA, occur in former agricultural areas or adjacent to presently actively farmed lands. Both conservation areas incorporate former agricultural fields and lie immediately adjacent to farmlands actively in use to produce crops such as alfalfa and cotton. More generally, Mixan et al. (2015) note that all sites in the Lower Colorado River Valley where the LCR MSCP has planted riparian woodland habitat "… are adjacent to highly manipulated residential and agricultural lands."

As noted in the original WYBA conceptual ecological model (Marty and Unnasch 2015) and also by NatureServe (2019a), exposure to pesticides from agricultural fields and orchards—potentially may harm WYBA and its food resources. As recently emphasized by the European Food Safety Authority (Hernández-Jerez et al. 2019), pesticide exposure poses a risk to all insectivorous bats worldwide. The literature reviewed for the WYBA conceptual ecological model and this update do not report any specific instances in which contaminants from adjacent farmlands are known or suspected to have affected any WYBA roosting or foraging areas. Nevertheless, the CEM must at least recognize the possibility of such interactions.

COMPETITION

This update adds this critical biological activity or process to the original WYBA conceptual ecological model to address an important ecological process that the original WYBA conceptual ecological model did not cover. The process is defined for the WYBA conceptual ecological model as follows:

Basic biological principles suggest that WYBA pups may compete with each other for maternal care, particularly for their mother's milk. The larger the litter, presumably, the greater such competition. Basic biological principles also suggest that WYBA juveniles and adults may compete for food with each other as well as with other bats, insectivorous birds and other vertebrates, and possibly predatory insects. Finally, basic biological principles suggest WYBA juveniles and adults may also compete with each other or with other species for favorable roosting habitat. Chapter 4 (see "Vertebrate Community") identifies species that possibly could compete with WYBA for roosting habitat. The possibility of competition among WYBA for roosting habitat is enhanced by the fact that WYBA roost singly (with or without pups), as discussed below, this chapter (see "Roosting"). None of these possible interactions has been studied in WYBA. The literature also does not make any mention of whether WYBA must compete for access to water or whether WYBA compete for mates during breeding.

At least three mammals may compete with WYBA adults for habitat. As discussed in chapter 4 (see "Vertebrate Community"), beavers (*Castor canadensis*), mule deer (*Odocoileus hemionus*), and non-native cattle (*Bovidae*) and burros (*Equus asinus*) can alter riparian vegetation communities in the Southwestern United States by removing cottonwood (*Populus* spp.) and willow (*Salix* spp.) or preventing the establishment of their seedlings.

DISEASE

The definition of this critical biological activity or process is updated to note that WYBA may host the rabies virus (Faria et al. 2013; Kuzmin et al. 2012; Stuchin et al. 2018), including specifically WYBA in Arizona (Kuzmin et al. 2012). However, the literature does not document the incidence of illness in WYBA hosts due to a rabies infection.

FEEDING

This update renames the original critical biological activity or process, eating, to clarify the terminology for the pup life stage: Lactating WYBA feed their offspring. The pups therefore are passive recipients of their food, while juveniles and adults actively forage for their food. As noted in the original WYBA conceptual ecological model (Marty and Unnasch 2015), feeding success for a pup depends on the foraging success and provisioning rate of its mother (see below, this chapter, "Maternal Care") and competition from siblings in the same litter (see above, this chapter, "Competition" and chapter 4, "Litter Size").

FORAGING

The literature reviewed for this update contains no new information on WYBA prey preferences or the details of WYBA foraging behaviors, both of which remain largely unstudied. However, the definition and discussion of this critical biological activity or process can be updated in four areas:

First, this update assumes that foraging among WYBA juveniles presumably closely resembles foraging among WYBA adults.

Second, as noted in chapter 2 (see "Adults"), WYBA foraging in the Lower Colorado River Valley and elsewhere begins at dusk (AZGFD 2011; Calvert 2010a, 2010b; LCR MSCP 2016). Acoustic monitoring along the Lower Colorado River Valley routinely detects WYBA during evening (1700–2200), mid-night (2200–0200), and morning (0200–0700) monitoring periods, although the relative incidence of WYBA calls may vary among these three periods (Mixan et al. 2013). The timing of foraging affects the spectrum of prey available and vulnerability to predation, and it affects decisions on monitoring practices. Otherwise, the definition of this critical biological activity or process remains the same as in the original WYBA conceptual ecological model (Marty and Unnasch 2015).

Third, evidence accumulated since preparation of the original WYBA conceptual ecological model (Marty and Unnasch 2015) reinforces the inference that WYBA forage significantly more in riparian habitat—and more particularly in cottonwood-willow woodland patches compared to marsh, riparian shrubland, mesquite bosque, saltcedar (*Tamarix* spp.), or agricultural habitat—and over water than in or over any other type of habitat (Broderick 2012a, 2012b; Calvert 2017; LCR MSCP 2016; Mixan et al. 2015; NatureServe 2019a; Vizcarra et al. 2010)—even if that target habitat lies some distance from suitable roosting sites (see immediately below). Broderick (2012b) further notes that WYBA foraged far more in more mature cottonwood patches at the PVER and CVCA habitat creation sites compared to sapling cottonwood patches, although the more mature patches at that time were only 2–3 years old and not fully mature, and therefore were termed "intermediate" cottonwood habitat.

Finally, as noted in chapter 2 (see "Adults") and immediately above, WYBA adults do not appear to select roost sites for their proximity to preferred foraging habitat. Diamond et al. (2013) report tracking two subadult WYBA moving between foraging and roosting sites over distances of approximately 6 km from the CVCA and 8 km from the PVER, respectively. However, no information is available with which to assess the representativeness of these observations.[3] No report(s) yet provide a tabulation or analysis of radio tracking data for WYBA in the Lower Colorado River Valley or an assessment of possible relationships between habitat conditions or prey density and WYBA travel distances between roosting and foraging sites.

INTER-SITE MOVEMENT

This update adds inter-site movement as a critical biological activity or process to capture the dynamics of shifting WYBA adult occupancy and movement among sites into, out of, and within the Lower Colorado River Valley from day to day, season to season, and year to year. As discussed in chapter 2 (see "Adults"), intensive acoustic monitoring in both habitat conservation areas and established protected areas along the Lower Colorado River Valley since fiscal year 2010 has detected WYBA during every season of the year (Broderick 2010, 2012a; Calvert 2016a, 2016b, 2017; Diamond 2012; Mixan 2015, 2016; Mixan and Diamond 2017a, 2017b, 2018a, 2018b, 2019a, 2019b; Mixan et al. 2013, 2015; Vizcarra et al. 2010). Observations of WYBA in southern Nevada complement these

[3] NatureServe (2019a), in discussing WYBA foraging, cites an example of a radio-tagged individual in Texas tracked for more than 22 km from its roost site; however, the report in fact does not indicate whether the individual was migrating or moving to a new roost site, not foraging.

observations along the Lower Colorado River Valley (O'Farrell et al. 2004; Williams et al. 2006). The pattern of detections appears to result from three interacting dynamics:

1. WYBA migrate up and down the Lower Colorado River Valley, northward primarily in May and southward primarily in September. The literature on WYBA in the Lower Colorado River Valley typically describes these movements as migratory "pulses."

2. WYBA roost and forage at low density throughout the LCR and lower Bill Williams River valleys during the warmer months but increasingly concentrate their foraging in July and August in cottonwood-willow stands created at LCR MSCP habitat conservation areas. During these months they may also move from one roosting site to another.

3. A few WYBA, mostly males, may overwinter as far north as the upper Moapa Valley in southern Nevada, while WYBA females may overwinter in the Lower Colorado River Valley only as far north as the southern valley in the United States (for example, at the Mittry Lake Wildlife Area near Yuma, Arizona).

Mixan et al. (2015) used radio tracking data to assess WYBA travel distances between roosts. Among six WYBA that moved between tree roosts, "The maximum movement between roosts was 5.17 km, and the minimum was 3 m. Western yellow bats moved a mean of 1.16 km between roosts, with a median of 0.093 km." As noted above, this chapter (see "Foraging"), scattered observations record WYBA traveling as much as 6–8 km between roosting and foraging locations in the Lower Colorado River Valley. Ortiz and Barrows (2014) found in southern California that palm oases occupied by WYBA for roosting had a mean distance to water of 1.886 ± 0.648 km.

The possible causes of WYBA adult movement among sites into, out of, and within the Lower Colorado River Valley, discussed in the works cited in the preceding paragraphs concerning inter-site movement, are poorly understood. Hypotheses in these works concerning possibly causes include the strong preference of WYBA to roost in trees (fan palms) that do not necessarily occur in or even particularly close to the habitat settings in which they prefer to forage (see above, this chapter, "Foraging" and below, this chapter, "Roosting"); changes in roosting habitat quality following, for example, a fire (Ortiz and Barrows 2014); changes in the availability of prey associated with the maturation of created cottonwood-willow woodlands along the Lower Colorado River Valley or the blooming of different plants (e.g., agave and perhaps yucca in New Mexico); use of some sites as stopovers rather than as areas of seasonal residence; and seasonal changes in temperature (NatureServe 2019a).

Changes in the distribution of predators conceivably might also affect inter-site movement. Ortiz and Barrows (2014) found in southern California that WYBA were scarce or absent in palm oases where owls (species not identified) were present. Such a pattern might result either from WYBA avoiding oases where owls are present, or fleeing after owls arrive, or from highly effective predation by owls on WYBA at sites where the two occur together.

MATERNAL CARE

This update renames the critical biological activity or process, parent roost attendance, for terminological clarity. This critical biological activity or process specifically concerns maternal care of pups—lactation, nursing, cleaning, guarding, etc.—rather than attendance to the roost site. Maternal care of pups affects adult fertility because more and/or higher-quality maternal care improves pup survival; however, maternal care also has energetic costs that may affect adult growth and survival. Using the term, "maternal," also signifies that WYBA males play no role in the care of pups.

MECHANICAL STRESS

The definition of this critical biological activity or process is updated to note that WYBA juveniles and adults may experience mechanical stress when captured and handled during mist-net monitoring, when investigators attach radio transmitters to some captured individuals for subsequent tracking, and potentially also when they escape direct contact with predators. The protocols for bat monitoring in the Lower Colorado River Valley are designed to minimize mechanical stress during capture, handling, and release (Brown 2006; Hill 2018).

PREDATION

No new literature addresses predation on WYBA in the Lower Colorado River Valley or elsewhere. The subject remains largely unstudied; however, studies of predation on bats in general (Mikula 2015; Mikula et al. 2016) provide guidance for updating the WYBA conceptual ecological model.

This update revises the definition of this critical biological activity or process to note that predators may attack WYBA in three settings: (1) in their roosts, (2) from the air during foraging and inter-site movement, and (3) from the ground, when WYBA foraging activities bring them close to the ground. Further, because WYBA forage and travel only at night, their vulnerability to predation in the latter

two settings occurs only at night. Chapter 4 (see "Arthropod Community" and "Vertebrate Community") discusses the species that potentially could prey on WYBA in each of these three settings.

The dense frond skirts of fan palms potentially attract a wide range of vertebrates and arthropods while also providing dense cover for WYBA. Briefly, species that could prey on WYBA in their roosts include birds, climbing mammals, and climbing carnivorous reptiles. As noted above, for example (see this chapter, "Inter-Site Movement"), Ortiz and Barrows (2014) found that WYBA in southern California were scarce or absent in palm oases where owls (species not identified) were present. This could indicate either that WYBA avoid oases where owls are present, or leave when owls arrive, or that owls are highly effective predators on WYBA in palm oases. The possibility also exists that pressure from nocturnal predators could cause WYBA to avoid foraging during nights illuminated strongly by moonlight, a pattern of behavior known as "lunar phobia." This pattern of avoidance is documented among some bats around the world and interpreted to be a result of selective pressure from nocturnal predatory birds (Lang et al. 2006; Mikula et al. 2016; Saldaña-Vázquez and Munguía-Rosas 2013). However, investigators along the Lower Colorado River Valley and elsewhere have not found evidence for lunar phobia among WYBA or any other bat species of concern to the LCR MSCP other than the California leaf-nosed bat (*Macrotus californicus*) (Andersen and Geluso 2018; Brown 2006, 2010, 2013, 2015; Ortiz and Barrows 2014; Rogers et al. 2006; Vizcarra and Piest 2010). In fact, Vizcarra and Piest (2010) found a positive statistical relationship between moon phase and bat call minutes, including for WYBA, in acoustic monitoring data across dozens of sites in the Lower Colorado River Valley in 2008–10. They suggest that this relationship results from a higher level of nocturnal insect activity during times of greater moonlight, which in turn attracts greater foraging activity among insectivorous bats.

Studies elsewhere have noted that large spiders (Nyffeler and Knörnschild 2013) and large centipedes (Molinari et al. 2005) also may prey on roosting bats; however, no spiders or centipedes in the region of the Lower Colorado River Valley are known to do so.

Avian predators are the main threat to bats in the aforementioned second of the three settings (Mikula et al. 2016). In fact, Mikula et al. (2016) suggest:

> *Attacks on bats by diurnal raptors were found to be distributed globally and were present in the majority of extant raptor lineages. Attacks on bats by other diurnal birds were also occasionally recorded. Furthermore, the majority of extant bat families featured as prey. These results strongly suggest that predation by birds may act as a major factor affecting the scarcity of daytime activity in bats and as a driver in the evolution of bat nocturnality.*

Species that could prey on WYBA at ground level may include domestic dogs (*Canis lupis*) and cats *(Felis catus*). As noted in the original WYBA conceptual ecological model, the preference of WYBA for palm trees as roost habitat puts them in closer proximity to humans and therefore to their pets. Mikula (2015) also suggests that fish and amphibians can prey on bats at ground level when they come down to drink.

ROOSTING

This critical biological activity or process replaces the original, roosting site selection, to clarify the terminology: Roosting includes roosting site selection and also addresses other behaviors such as roosting time(s) of day and persistence and size (area, density) of site occupancy.

This update incorporates additional information on WYBA roosting behavior and roost site preferences. Several studies assess WYBA roosting along the LCR and Bill Williams River valleys and several river valleys in central and southeastern Arizona (Calvert 2017; Mixan 2015; Mixan et al. 2015), at oases in southern California (Ortiz and Barrows 2014), and in southern New Mexico (Zabriskie et al. 2019) (see chapter 2, "Adults"). These studies confirm the pattern described in the original WYBA conceptual ecological model (Marty and Unnasch 2015) and in AZGFD (2011) and LCR MSCP (2016): WYBA overwhelmingly roost solitarily in the dead frond skirts of Washington fan palms (*Washingtonia* spp., either the Mexican fan palm or the California fan palm). Chapter 4 (see "Palm Trees") discusses the evidence for whether the fan palms along the Lower Colorado River Valley are the Mexican or California species and possible implications of the distinction. The literature also records WYBA occasionally roosting in date palm orchards and in native cottonwood, sycamore, and hackberry trees and in tall yucca species with long masses (skirts) of dead fronds below their crowns such as the giant dagger yucca (AZGFD 2011; Brown 2006; LCR MSCP 2016; NatureServe 2019a; Zabriskie et al. 2019). However, the one published tally of WYBA radio tracked from foraging sites to roost sites in the Lower Colorado River Valley (Mixan et al. 2015) found that 29 of 31 tracked WYBA roosted in fan palms and only 2 in nearby date palm orchards (orchard distance[s] not reported).

Several studies (Diamond 2012; Diamond et al. 2013; Mixan et al. 2015; Vizcarra et al. 2010) report on studies along the LCR and Bill Williams River valleys and along multiple river valleys in central and southeastern Arizona that allow comparisons of WYBA roosting sites with non-roosting sites, and roosting versus non-roosting trees within these sites, both in natural protected areas and created habitat. These studies specifically collected data that could be used to assess WYBA affinities for roosting habitat characteristics at four spatial scales: (1) the individual trees in which WYBA roost and their immediate vicinities within a riparian woodland patch, (2) the trees immediately surrounding those selected for

roosting, (3) the overall riparian woodland patch within which the roosting trees occur, and (4) the larger landscape that includes and surrounds these patches. Analyses completed to date have found only three statistically significant relationship for WYBA at any of these four scales: WYBA roost in the tallest palm trees available at any given site, as measured by total height and the height of the live crown, and in trees with the highest percentage of dead crown (Diamond 2012; Mixan et al. 2015). Diamond (2012) specifically notes that "Roost trees with a high live crown base and a high percentage of dead crown indicate the presence of a wide and deep dead palm frond skirt. These palm skirts likely provide a suitable microclimate that is not found in those palms lacking a large dead frond skirt." The studies along the Lower Colorado River Valley also found that WYBA seek out sites for roosting regardless of their surroundings: WYBA along the valley have been observed roosting in fan palms not only along the Bill Williams River within a national wildlife refuge (Mixan and Diamond 2014; Mixan et al. 2012, 2013), but also in the densely residential Parker Strip (Berry et al. 2017), as well as in date palm orchards (Mixan et al. 2015). Bazelman (2016) cites evidence of WYBA occupancy in the densely urban Phoenix, Arizona, metropolis.

As discussed in chapter 2 (see "Adults"), Ortiz and Barrows (2014) collected data to compare palm oases in southern California where WYBA roosted versus oases where they did not. The results demonstrate that WYBA statistically preferred oases located at higher elevations with greater numbers of fan palms greater than 10 feet tall with moderate to high percentages of frond skirt length as a percentage of total palm height. As further confirmation of the importance of skirt length, the study found that the WYBA at these oases avoided palms from which fire had eliminated large portions of the frond skirt. The study also found that WYBA preferred oases in which the majority of palms exhibited new growth and avoided oases in which the palms lacked such new growth.

As discussed above, this chapter (see "Inter-Site Movement"), this update also incorporates new information on the distances WYBA may travel between foraging and roosting sites. Similarly, as also discussed in chapter 2 (see "Adults"), this update incorporates new information on the times of day when WYBA leave and return to their roosts. Otherwise, the literature reviewed for this update does not provide new information on WYBA roosting behaviors such roosting time(s) of day or persistence and size (area, density) of site occupancy.

THERMAL STRESS

The definition of this critical biological activity or process is updated to note that WYBA cope with cold air temperatures in four ways that may bear on their presence along the Lower Colorado River Valley, near the northern geographic limit of their range:

1. WYBA "wrap themselves in their tail membrane for added thermal regulation while roosting" (AZGFD 2011). Pups clinging to their mother presumably benefit from the maternal warmth.

2. Most WYBA migrate southward and/or to lower elevations during the colder months, with females moving farther (e.g., farther southward) than males, as discussed above, this chapter (see "Inter-Site Movement").

3. WYBA that remain in seasonally colder locations and/or are caught in cold spells become torpid, thereby conserving bodily heat (Mixan and Diamond 2014; Mixan et al. 2013; Zabriskie et al. 2019).

4. The skirts of dead fan palm fronds, in which WYBA roost (see above, this chapter, "Roosting"), likely provide them some thermal protection. Diamond et al. (2013) suggest that more substantial fan palm skirts that WYBA select for roosting along the Lower Colorado River Valley "likely provide a suitable microclimate that is not found in those palms lacking a large dead frond skirt." Ortiz and Barrows (2014) offer a similar hypothesis for WYBA roosting at palm oases in southern California. Adams (2003) and others further hypothesize that WYBA "has expanded its range northward in response to the planting of palms along the LCR, using the river as a corridor" (see also AZGFD 2011; Brown 2006; Diamond 2012; Diamond et al. 2013; LCR MSCP 2016; Mixan et al. 2015). However, other factors likely also have shaped the expansion. Chapter 4 (see "Palm Trees") further discusses the geographic distribution of fan palms along the LCR.

Updates to Chapter 4 – Habitat Elements

This update identifies 14 habitat elements that affect 1 or more critical biological activities or processes across the 3 WYBA life stages. The original WYBA conceptual ecological model (Marty and Unnasch 2015) identified 12 habitat elements. This update adds four completely new habitat elements, chemical contaminants, fire regime, monitoring, capture, handling, and palm trees. At the same time, this update integrates three original habitat elements (canopy cover, patch size, and tree species composition) into another new habitat element, riparian tree community; and renames four original habitat elements (food availability, genetic diversity and infectious agents, parent roost attendance, and predator density) to arthropod community, infectious agents, maternal care, and vertebrate community, respectively. Table 4 lists the 14 habitat elements in this update, indicates the critical biological activities and processes they *directly* affect across all WYBA life stages, and indicates which habitat elements are new to this update or renamed from the original WYBA conceptual ecological model.

Table 3.—(Revision of original table 3) WYBA habitat elements and the critical biological activities or processes they directly affect across all life stages
(Xs indicate the habitat elements that affect each critical biological activity or process.)

Critical biological activity or process ➔ / **Habitat element 🡻**	Breeding	Chemical stress	Competition	Disease	Feeding	Foraging	Inter-site movement	Maternal care	Mechanical stress	Predation	Roosting	Thermal stress
Anthropogenic disturbance						X		X	X		X	
Arthropod community (*renamed*)						X	X			X	X	
Chemical contaminants (*new*)		X					X					
Fire regime (*new*)												X
Infectious agents(*renamed*)				X								
Litter size (*renamed*)			X			X		X				
Maternal care (*renamed*)					X							X
Matrix community						X					X	
Monitoring, capture, handling (*new*)									X			
Palm trees (*new*)							X			X	X	X
Riparian tree community (*new*)						X	X			X	X	
Temperature							X				X	X
Vertebrate community (*renamed*)			X				X			X	X	
Water availability		X									X	

ANTHROPOGENIC DISTURBANCE

The definition and discussion of this habitat element is updated as follows:

Full name: **Noise and other physical disturbances associated with human activity in and around existing or potential WYBA roosting and foraging habitat**. This element refers to the existence and level of human disturbance near WYBA roosting or foraging habitat, including physical contact with WYBA, agitation of vegetation, and noise. 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. Human activities may affect lasiurine bat roosting and reproduction, especially if pregnant and lactating females are roosting in orchards subject to high levels of human activity (Constantine 1959). Human talking and walking around roost sites does not appear to substantially disturb lasiurine bats. WYBA readily occupy fan palms in areas with substantial human activity, such as residential areas and orchards, as noted in chapter 3 (see "Roosting"). However, any attempt to handle lasiurine bats may disturb them. Active work in habitat where WYBA are roosting potentially may disrupt reproduction (e.g., tending of young during early development phases) (Dudek and ICF International 2012). Studies elsewhere (Bunkley et al. 2015) have found that noise at night can disrupt bat nocturnal activities in general and that these effects may differ depending on the frequency of the noises and the call frequencies of the bats in the area.

ARTHROPOD COMMUNITY

This is a new habitat element in the CEM, included so that the CEM better distinguishes different broad categories of food resources for WYBA juveniles and adults, competitors with WYBA for food resources, potential predators on WYBA, and species that may shape the environment in and around WYBA roosting sites.

Full name: **The taxonomic composition, size range, spatial and temporal distributions, and abundance of the arthropod community in and around existing or potential WYBA roosting and foraging habitat**. The arthropods of concern may include ants, beetles, butterflies and moths, centipedes, spiders, and other insects that WYBA may consume. or that may compete with or prey on WYBA, or otherwise contribute to ecological dynamics in and around WYBA roosting or foraging sites. This new habitat element addresses aspects of habitat that the original WYBA conceptual ecological model (Marty and Unnasch 2015) addressed under food availability and also partially under predator density. Additionally, this new habitat element recognizes that predatory arthropods may

also compete with WYBA juveniles and adults for prey, and that herbivorous arthropods in general may affect ecological—particularly vegetation—dynamics in and around WYBA roosting sites and foraging areas.

A review of the literature and data on the arthropod communities at and around WYBA roosting sites in and immediately around the Lower Colorado River Valley (compared to similar sites without WYBA roosts) (Anderson 2012; Andersen and Nelson 2013; Eckberg 2011, 2012; Nelson 2009; Nelson and Wydoski 2013; Nelson et al. 2015; Ohmart et al. 1988; Pratt and Wiesenborn 2009, 2011; Trathnigg and Phillips 2015; Wiesenborn 2010, 2012, 2013, 2014a, 2014b; Wiesenborn et al. 2008) is beyond the scope of this update. Holmquist et al. (2011) found that California fan palms support distinct arthropod communities, although their study focused on Death Valley National Park, California, near the Nevada border, where the California fan palm is not native. The HOSTS Database of the World's Lepidopteran Hostplants (Robinson et al. 2019) identifies a single moth species that uses the California fan palm as its host in California and Arizona, the palm flower moth (*Litoprosopus Coachella*), the larvae of which feed on the fan palm flowers.

The original WYBA conceptual ecological model (Marty and Unnasch 2015) stated that "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'Farrell 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)." Calvert et al. (2010) state that WYBA preferentially eat moths, but they do not cite specific studies for supporting data.

Predatory arthropods such as mantises, spiders, and wasps that prey on other arthropods may compete with WYBA for food resources. Further, they may prey on these shared food resources by preying on their eggs and larvae or when the adult prey are resting on the ground or in vegetation. As noted above, a review of the literature and data on the arthropod communities at and around WYBA roosting sites in and immediately around the Lower Colorado River Valley (compared to similar sites without WYBA roosts) is beyond the scope of this update.

Conceivably, some carnivorous arthropods potentially could prey on WYBA as noted in chapter 3 (see "Predation"). There are no data on such interactions affecting WYBA or any other bat species in the region. The CEM merely notes the possibility based on general ecological concepts.

Arthropods, particularly insects, can significantly affect vegetation dynamics in all ecosystems, presumably including riparian communities. The effects of the non-native northern tamarisk beetle (*Diorhabda carinulata*) on saltcedar (*Tamarix* spp.) along the Colorado River valley provides one particularly clear

example. Resource managers intentionally released the beetle in 2001 in the Upper Colorado River basin as a biocontrol for the invasive saltcedar (Bean and Dudley 2018). The beetle has spread widely, including down the Colorado River valley into the LCR ecosystem, where it currently occurs as far south as the Imperial National Wildlife Refuge as of January 2019 (RiversEdge West 2019). Repeated defoliation by the beetle usually causes the canopy to die back within one to four years, and can cause individual plant death within 2 years or more, with overall mortality rates up to 40%, depending on the site (Bean and Dudley 2018). The literature reviewed for this update does not document effects of native arthropods on riparian vegetation along the Lower Colorado River Valley, and a review of such information is beyond the scope of this update.

CHEMICAL CONTAMINANTS

The original WYBA conceptual ecological model (Marty and Unnasch 2015) did not propose a separate habitat element for chemical contaminants. However, the original WYBA conceptual ecological model did note that WYBA are vulnerable to chemical stress (see chapter 3) and identified some possible sources of contaminants that could result in such stress. This update adds this new habitat element so that the CEM better identifies the causal chains that could result in chemical stress to WYBA in any life stage.

Full name: **The concentrations of chemical contaminants in the air, on plant surfaces, and/or on the ground in and around existing or potential WYBA roosting and foraging habitat**. This element includes chemicals that may contaminate arthropods on which WYBA juveniles and adults feed, drift in the air or leach into the groundwater to reach WYBA habitat, or occur at WYBA habitat sites restored from former land uses. In principal, the element includes biocides, fertilizers, and industrial wastes. The literature reviewed to prepare this update does not identify any specific chemical contaminants of potential concern for WYBA food resources or habitat sites, and a full review of the potential literature on chemical contaminants that could affect WYBA or their food resources in the Lower Colorado River Valley is beyond the scope of this update. Chapter 3 (see "Chemical Stress") provides additional information on the types of contaminants that could result in chemical stress to WYBA along the Lower Colorado River Valley.

FIRE REGIME

The original WYBA conceptual ecological model (Marty and Unnasch 2015) did not propose a separate habitat element for the fire regime, but it did note several

ways in which wildfire and prescribed fire can affect WYBA habitat. This update adds this new habitat element so that the CEM better identifies the causal chains through which wildfire and prescribed fire can affect WYBA habitat.

Full name: **The frequency, timing, spatial extent, and intensity of fire in and around existing or potential WYBA roosting and foraging habitat**. Wildfire is a natural type of disturbance in the plant communities across the geographic range of WYBA, including the Lower Colorado River Valley, and wildfires today also occur through human causes (Conway et al. 2010; LCR MSCP 2014; Meyer 2005; Stromberg et al. 2009). The LCR MSCP sometimes uses prescribed fire as a tool for habitat management (LCR MSCP 2014).

Ortiz and Barrows (2014) report that fire at palm oases in southern California can reduce—sometimes severely—the length and volume of California fan palm frond skirts. Further, WYBA avoid fan palms and oases that experience significant damage from such fires, presumably until regrowth restores sizeable frond skirts. At the same time, fire may be beneficial to fan palms on a larger geographic scale (Howard 1992). The U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) (2002) reports specifically for the California fan palm that:

> *Native Americans historically and prehistorically enhanced palm populations through firing palm stands and planting seeds. Palm stands were burned to control infestations of the palm boring beetle (Dinapate wrightii), to improve access to the palms and their fruit by clearing underbrush, and to increase the production and enhance the quality of fruit. Furthermore, these fires encouraged seed production, increasing the density of palms on favorable sites.*

Wonkka et al. (2018) provide a recent review of the literature on the effects of fire on riparian communities containing both cottonwood and saltcedar in the Western United States. Fire can affect these communities along the LCR—in which WYBA forage—by facilitating the replacement of large cottonwood trees by non-native species such as saltcedar and arrowweed (*Tessaria sericea*) (Busch 1995). Mixan and Diamond (2017b) describe the effects of a fire at the Cibola National Wildlife Refuge-Island site in August, 2011, which burned cottonwood-willow vegetation that may have provided foraging habitat for WYBA. Mixan and Diamond (2016), discussing WYBA detections at the site following the fire, note "… a downward trend beginning in 2012 (the year after the fire). There seems to be an abundance of suitable palm tree roosts within the vicinity of CNWR-Island, so it may be that the fire disturbed the prey base in the area, resulting in the bats going elsewhere to forage." As noted in chapter 3 (see "Predation"), WYBA may become more active when nocturnal moonlight is greater (Vizcarra and Piest 2010), possibly because greater moonlight results in greater nocturnal insect activity. However, the findings of Mixan and Diamond (2016), following the 2011 fire at CNWR-Island site, point in the opposite direction–that the opening up

of the habitat by the fire depressed WYBA use of the area. Fire at WYBA monitoring sites can also damage monitoring equipment installed at these sites (Mixan et al. 2013) or create openings useful for placing mist nets (Hill 2018).

INFECTIOUS AGENTS

The original WYBA conceptual ecological model (Marty and Unnasch 2015) included genetic diversity and infectious agents under the label of a single habitat element. However, the literature reviewed for the original CEM and this update does not provide any information on WYBA genetic diversity, threats to WYBA genetic diversity, or effects of genetic diversity (or its impairment) on WYBA ecology. This update therefore simplifies the CEM by setting aside concerns about genetic diversity. On the other hand, the WYBA conceptual ecological model does need to address infectious agents as a habitat element in order to characterize the causal chains affecting the incidence of disease.

Full name: **The species, abundances, spatial and temporal distributions, and activity levels of infectious agents to which WYBA are susceptible at locations in and around existing or potential WYBA roosting and foraging habitat**. WYBA in every life stage presumably are vulnerable to infection, as are all animals. Infectious agents include viruses, bacteria, fungi, and parasites. Non-lethal infections may make the affected individuals vulnerable to mortality from other causes. As noted in chapter 3 (see "Disease"), WYBA may host the rabies virus (Faria et al. 2013; Kuzmin et al. 2012; Stuchin et al. 2018), including specifically WYBA in Arizona (Kuzmin et al. 2012). The literature reviewed for the original WYBA conceptual ecological model and for this update does not identify any other specific infectious agents known or suspected to affect WYBA in the Lower Colorado River Valley or elsewhere.

LITTER SIZE

This update renames the habitat element in the original WYBA conceptual ecological model, number of pups, to litter size for consistency with the terminology in other bird and mammal CEMs prepared for the LCR MSCP. The definition of this habitat element otherwise remains unchanged.

MATERNAL CARE

This update renames the habitat element in the original WYBA conceptual ecological model, parent roost attendance, to maternal care for consistency with

the updated name for the critical biological activity or process with the latter name. WYBA pups experience maternal care as a habitat element, while WYBA adult females engage in maternal care as a critical biological activity or process. The definition of this habitat element otherwise remains unchanged. However, this update does recognize that, when their litter contains more than one individual, WYBA pups presumably compete for maternal care.

MATRIX COMMUNITY

The definition and discussion of this habitat element is updated as follows:

Full name: **The taxonomic composition, size range, spatial and temporal distributions, and abundances of shrubs and herbaceous plants in and around existing or potential WYBA roosting and foraging habitat**. As noted in the section on "Acronyms, Symbols, and Definitions" in the front matter to this update, the WYBA conceptual ecological model recognizes plant communities as consisting of canopy, understory, shrub, and herbaceous layers. Trees, woody vegetation greater than 2.0 m in height, make up the canopy layer and may also occur in the understory as subcanopy trees. This update addresses trees as a separate habitat element (see below, this chapter, "Riparian Tree Community"). Where trees are present, shrubs and herbaceous plants make up the understory. In the absence of trees, shrubs comprise the uppermost layer of vegetation.

The matrix community may affect WYBA foraging and roosting at two spatial scales: (1) the fan palm stands within which WYBA roost and riparian tree stands in and around which they forage and (2) the landscape surrounding these stands (see chapter 3, "Foraging"). The matrix community at these two spatial scales provides the habitat for all arthropods on which WYBA may feed, and habitat for vertebrates and arthropods that may compete with or prey on WYBA, and may provide nursery habitat for trees. The foraging range around WYBA roosting sites may also include some agricultural vegetation such as orchards. As discussed in chapter 3 (see "Inter-Site Movement"), WYBA adults do not appear to select roost sites for their proximity to preferred foraging habitat. For example, Diamond et al. (2013) report tracking two subadult WYBA moving between foraging and roosting sites over distances of approximately 6 km from the CVCA and 8 km from the PVER, respectively. However, no report(s) yet provide a tabulation or analysis of radio tracking data for WYBA in the Lower Colorado River Valley with which to assess possible relationships between habitat conditions—including matrix community conditions—or prey density and WYBA travel distances between roosting and foraging sites.

The LCR MSCP has collected data on shrub and herbaceous vegetation within and around riparian tree stands in the LCR ecosystem, both at habitat development sites and in protected areas (BIO-WEST, Inc. 2010, 2011; Calvert 2008; Nelson and Andersen 1999; Nelson et al. 2014, 2015; Parametrix, Inc., and GeoSystems Analysis, Inc. 2012, 2013, 2014, 2015; Pratt and Wiesenborn 2009; Reynolds et al. 2014). However, these investigations were carried out for other purposes and did not specifically seek to characterize the matrix community associated with WYBA foraging or roosting sites or the landscape between them.

MONITORING, CAPTURE, HANDLING

This is a new habitat element in the CEM.

Full name: **The methods, frequencies, timing, and duration of (a) monitoring of WYBA habitat and (b) monitoring, capture, and handling of WYBA during field investigations**. Adding this habitat element makes it possible for the CEM to address two topics: (1) the potential ways in which monitoring, capture, and handling can affect WYBA, for example by causing mechanical stress; and (2) the potential ways in which WYBA behaviors, such as foraging and roosting behaviors, can affect the ability of different methods to detect WYBA and affect decisions about monitoring practices. The monitoring of bats in the Lower Colorado River Valley, including WYBA, has long followed clear protocols for all monitoring practices, with routine reporting of protocols and their refinements (Berry et al. 2017; Broderick 2010, 2012a, 2012b, 2013, 2016; Brown 2006, 2010, 2013; Calvert 2010a, 2010b, 2012a, 2012b, 2013, 2016a, 2016b; Hill 2018; LCR MSCP 2008; Mixan and Diamond 2014, 2016, 2017a, 2017b, 2018a, 2018b, 2019a, 2019b; Mixan et al. 2012, 2013; Vizcarra and Piest 2009, 2010; Vizcarra et al. 2010). These protocols cover visual surveys, mist netting, the use of radio tracking devices, and acoustic monitoring and the digital processing of acoustic recordings. The protocols explicitly recognize and address needs to: (1) minimize stress and harm to bats captured in mist nets, (2) raise mist nets at specific times of the night to ensure they capture bats not as they leave their roosts but instead later during foraging, and (3) begin acoustic recording before sunset and end it after sunrise to ensure complete coverage of bat foraging activity. These protocols also require that radio tracking devices be attached only to larger individuals (weighing more than 10 grams) that can carry a device without stress (Mixan et al. 2015). Because of this latter requirement, the rate of growth in juvenile and adult WYBA affects the availability of individuals suitable for the attachment of a tracking device.

PALM TREES

This is a new habitat element in the CEM.

Full name: **The taxonomic composition, tree size and density, tree condition, spatial and temporal distributions, and abundances of stands of palm trees along the Lower Colorado River Valley and its immediate tributaries**. As noted above (see particularly chapter 2, "Adults" and chapter 3, "Roosting"), WYBA in the greater LCR ecosystem roost mostly in the dead frond skirts of either the Mexican or California fan palm and occasionally also in the frond skirts of date palms in orchards. As also noted above, WYBA appear to select palm tree stands and individual trees within them for roosting based on characteristics such as tree height, the presence and condition of living fronds in the crown, and the proportional length of the dead frond skirt (Ortiz and Barrows 2014; see chapter 3, "Roosting"). Both fan palm species require habitat with a shallow water table, although the Mexican fan palm also occurs along desert washes, suggesting that, once rooted, it can at least seasonally use groundwater at some depth below the surface (Ortiz and Barrows 2014, Simono 2012a, 2012b).

The identity of the fan palm species along the Lower Colorado River Valley may warrant some clarification. The California fan palm likely is native to the valley in California and Arizona, including in the Yuma area and on the California side of the river in canyons immediately west of Parker Dam (Ohmart et al. 1988; Simono 2012a). The Mexican fan palm, in turn, is not considered native to the valley or anywhere else in the United States (Simono 2012b).

The California fan palm may be spread by fauna such as coyote (*Canis latrans*) that consume its fruit: The USDA-NRCS (2002) notes that "… germination is very high from seeds which have passed through [coyote] digestive systems." However, its current distribution may not exclusively be the result of natural propagation. The USDA-NRCS (2002) notes that Native Americans in the region historically propagated the species, and Ohmart et al. (1988) state that at least some of the California fan palms in the Yuma area in the early 1980s were cultivated. The California fan palms in the Moapa Valley in southern Nevada may have been planted there in the 1890s or may be native or introduced by Native Americans—the topic remains controversial (Cornett 1983; Spencer 2011). The fan palms in both the Moapa Valley, Nevada, and also in Death Valley, California, are also thought to lie beyond the northern limits of the natural historic range of the species (Holmquist et al. 2011; O'Farrell et al. 2004; Provencher et al. 2005). The first record of WYBA in the Moapa Valley dates only to January 1999 (O'Farrell et al. 2004).

Investigations over the past two decades along the Lower Colorado River Valley, including reports by botanists and bat monitoring teams, report both fan palm species in and around protected areas and habitat creation sites in the valley. Anderson (2012) reports only California fan palms in an experimental field near Blythe, California; Parametrix, Inc., and GeoSystems Analysis, Inc. (2014, 2015) report encountering only California fan palms in their vegetation surveys along the valley in 2013; and Mixan et al. (2012, 2013), and Mixan and Diamond (2014) all cite a 2004 vegetation survey along the valley (BIO-WEST, Inc., and GEO/Graphics, Inc. 2006) identifying only California fan palms along the Bill Williams River in the national wildlife refuge. In contrast, reports specifically on bat monitoring in the Lower Colorado River Valley either report only Mexican fan palms (Berry et al. 2017; Diamond 2012; Diamond et al. 2013; Mixan and Diamond 2016; Mixan et al. 2015) or both or simply "*Washingtonia* spp." (Calvert 2013, 2017; Calvert et al. 2010; Mixan and Diamond 2017a, 2017b, 2018a, 2019b).

Simono (2012a, 2012b) does not recognize any of the fan palms along the Lower Colorado River Valley in California as Mexican fan palms—only as California fan palms. The California fan palm is considered a rare, protected species in Arizona (NatureServe 2019b), although not ranked in California, while the Mexican fan palm is an exotic species in both States. The two species also can hybridize; the hybrid is often called *W. filibusta*.

The identity of the fan palms along the LCR and Bill Williams River valleys may be a matter of more than taxonomic interest. Because they are different species, the two species of fan palm and their hybrids potentially could differ in their biological and ecological characteristics in ways that affect WYBA. The historic range of WYBA overlaps with the historic ranges of both fan palms; neither species can germinate or grow except in moist soils (e.g., immediately adjacent to surface water or in locations with a water table very close to the land surface), and the dead frond skirts of both are susceptible to fire (Anderson 2011; Howard 1992; Ortiz and Barrows 2014; USDA-NRCS 2002). On the other hand, the California fan palm is reported to be more cold tolerant, and to retain its dead frond skirt unless it is removed by fire or intentional pruning (USDA-NRCS 2002); and fire may be beneficial to its longevity and dissemination (Howard 1992). In contrast, the Mexican fan palm is not cold tolerant, and it drops its lowest dead fronds after approximately 2 years, resulting in a shorter skirt (Anderson 2011) and less intense burning. A detailed review of the ecology of California and Mexican fan palms—or date palms—is beyond the scope of this update.

RIPARIAN TREE COMMUNITY

This is a new habitat element in the CEM.

Full name: **The taxonomic composition, size range, vertical and horizontal structure, canopy structure, patch size, abundances, and temporal (e.g., successional) dynamics of riparian woody canopy vegetation in and around existing or potential WYBA roosting and foraging habitat**. The original WYBA conceptual ecological model (Marty and Unnasch 2015) addressed riparian woody canopy vegetation—here labeled simply the riparian tree community—and palm trees (fan and date) together under the general heading of three habitat elements: canopy cover, patch size, and tree species composition. This update treats palm trees separately from the riparian tree community and recognizes that WYBA appear to use riparian tree patches preferentially as foraging habitat but roost elsewhere. This update also recognizes that other characteristics of the riparian tree community, such as the presence of clearings within a patch, also may affect WYBA ecology. The full name of the new habitat element identifies these additional, potentially relevant characteristics. This update recognizes that ongoing studies may yet identify other characteristics that also affect WYBA ecology. Rather than expand the number of habitat elements in the WYBA conceptual ecological model focused on separate characteristics of the riparian tree community, this update addresses all such characteristics under the label of a single habitat element. This update also recognizes that many characteristics of the riparian tree community affect each other. For example, as noted in the original WYBA conceptual ecological model, riparian tree species composition and maturity affect canopy cover height and density.

As noted in the "Definitions" immediately following the acronym list in this update, the WYBA conceptual ecological model recognizes plant communities along the Lower Colorado River Valley as consisting of canopy, understory, shrub, and herbaceous layers. Trees, woody vegetation greater than 2.0 m in height, make up the canopy layer and may also occur in the understory as subcanopy trees. Where trees are absent, shrubs comprise the uppermost layer of vegetation; where trees are present, shrubs and herbaceous plants make up the understory. This update addresses the shrubs and herbaceous layers together as a separate habitat element (see above, this chapter, "Matrix Community").

As discussed in chapter 3 (see "Foraging"), WYBA forage significantly more in riparian habitat—and more particularly in cottonwood-willow patches compared to marsh, riparian shrubland, mesquite bosque, saltcedar, or agricultural habitat—and over water than in or over any other type of habitat (Broderick 2012a, 2012b; Calvert 2017; LCR MSCP 2016; Mixan et al. 2015; NatureServe 2019a; Vizcarra et al. 2010). This pattern holds even when the riparian habitat lies some distance from suitable roosting sites (see immediately below). Broderick (2012b) further

found that WYBA foraged far more in more mature cottonwood patches at the PVER and CVCA habitat creation sites compared to sapling cottonwood patches, although the more mature patches at that time were only 2–3 years old and not fully mature, and therefore were termed "intermediate" cottonwood habitat.

Broderick (2012b) found evidence that a few more specific characteristics of the preferred cottonwood-willow habitat also may affect WYBA activity in this setting. Specifically, monitoring data from the PVER and CVCA showed statistically significant positive relationships between WYBA activity (call minutes detected during acoustic monitoring) and the length of the cottonwood-willow patch edge, the distance from a point of activity to the edge of the patch in which the activity occurred, and the number of layers in the tree canopy. At the PVER, activity was also greater, the closer a patch was located relative to the Colorado River.

As discussed in chapter 3 (see "Roosting"), the literature also records WYBA occasionally roosting in cottonwood, sycamore, and hackberry trees (AZGFD 2011; Brown 2006; LCR MSCP 2016; NatureServe 2019a; Zabriskie et al. 2019). However, the literature does not identify specific characteristics of individual trees of these species that may affect WYBA roosting activity in them compared to other individual trees.

Finally, this update recognizes that interactions between the riparian tree community and fan palms could affect the availability of fan palms as potential roosting habitat. Specifically, Welch and Leppanen (2017) report that saltcedar competes with California fan palms by reducing water availability for the fan palms (see also below, this chapter, "Water Availability").

TEMPERATURE

The definition and discussion of this habitat element is updated as follows:

Full name: **The mean air temperature in and around existing or potential WYBA roosting and foraging habitat**. 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. The greater Lower Colorado River Valley also straddles the historic northern limits of the geographic range of WYBA (AZGFD 2011; NatureServe 2019a; chapter 1 (see "Adults").

As discussed in chapter 3 (see "Thermal Stress"), WYBA exhibit several adaptations for occupying the more northern portions of their geographic range, including occupancy through winter by at least WYBA males. However, the literature does not quantify the temperature limits that WYBA prefer or tolerate.

VERTEBRATE COMMUNITY

This is a new habitat element in the CEM.

Full name: **The taxonomic, functional, and size composition; abundance; activity levels; and temporal dynamics of the community of vertebrates—birds, mammals, reptiles, and amphibians—that may occur in or around existing or potential WYBA roosting and foraging habitat**. This element refers to the range of vertebrate species known or suspected to interact with WYBA or its habitat along the Lower Colorado River Valley, particularly as competitors, predators, or ecosystem engineers. The original WYBA conceptual ecological model identified a single habitat element related to the vertebrate community, predator density. This update recognizes that vertebrates not only may prey on WYBA but also may compete with WYBA for food and habitat (see chapter 3, "Competition"), and that vertebrates such as beavers, mule deer, and non-native cattle and burros can act as ecosystem engineers, altering the vegetation communities used or potentially usable by WYBA as roosting or foraging habitat. The new habitat element, vertebrate community, therefore subsumes and expands on the habitat element, predator density, included in the original WYBA conceptual ecological model.

No new literature addresses the vertebrate species that may prey on WYBA in the Lower Colorado River Valley or elsewhere. The subject remains largely unstudied. However, studies of predation on bats in general (Mikula 2015; Mikula et al. 2016) provide guidance for updating the WYBA conceptual ecological model. As noted in chapter 3 (see "Predation"), WYBA are vulnerable to predation in three settings: (1) in their roosts; (2) from the air during foraging and inter-site movement; and (3) from the ground, when WYBA foraging activities bring them close to the ground. Further, because WYBA forage and travel only at night, their vulnerability to predation in the latter two settings occurs only at night, when owls in particular are most active. However, as also noted in chapter 3 (see "Predation"), WYBA do not avoid foraging in full moonlight (i.e., do not exhibit lunar phobia), indicating that predation pressure at night has not significantly shaped their adaptation.

As noted in chapter 3 (see "Predation"), the dense frond skirts of fan palms potentially attract a wide range of vertebrates. Vertebrates that could prey on WYBA in their roosts include birds, climbing mammals, and climbing carnivorous reptiles. As noted above, this chapter, for example (see "Inter-Site Movement"), Ortiz and Barrows (2014) found that WYBA in southern California were scarce or absent in palm oases where owls (species not identified) were present. This could indicate either that WYBA avoid oases where owls are present, or leave when owls arrive, or that owls are highly effective predators on WYBA in palm oases. Rottenborn (2000), in a study in central California in

1994–95, found that red-shouldered hawks (*Buteo lineatus*) frequently nested in fan palms (*Washingtonia* spp.), but the literature does not indicate if they prey on fauna within the palm canopy.

The original WYBA conceptual ecological model also notes that woodpeckers (Picidae) and jays (Corvidae), and two climbing mammals, raccoons (*Procyon lotor*) and opossums (*Didelphis virginiana*), could also prey on roosting WYBA. However, the literature does not report any occurrences of opossums in the Lower Colorado River Valley. On the other hand, the native ringtail cat (*Bassariscus astutus*) preys on small animals and is a highly capable climber that does occur along the Lower Colorado River Valley, including in riparian habitat (Mueller 2006). The native Sonoran lyresnake (*Trimorphodon lambda*) (Brennan 2008), a climbing snake known to prey on roosting bats (Esbérard and Vrcibradic 2007)[4], also occurs in the greater Lower Colorado River Valley: An individual photographed in the Planet Ranch section of the lower Bill Williams River valley in 2014 was recently confirmed as *T. lambda* (J. Hill 2019, personal communication). Owls that potentially could prey on WYBA at night along the Lower Colorado River Valley include the barn owl (*Tyto alba*), ferruginous pygmy-owl (*Glaucidium brasilianum*), great horned owl (*Bubo virginianus*), and western screech-owl (*Otus kennicottii*) (Arizona-Sonora Desert Museum 2019). The subject of owl predation on WYBA has not been studied.

As noted in the original WYBA conceptual ecological model (Marty and Unnasch 2015), vertebrates that could prey on WYBA at ground level may include domestic dogs and cats. The preference of WYBA for palm trees as roost habitat puts them in closer proximity to humans and therefore to their pets. Mikula (2015) also suggests that fishes and amphibians can prey on bats at ground level when they come down to drink.

As noted in the discussion of competition with WYBA, in chapter 3, other bats and other insectivorous vertebrates may compete for food with WYBA adults. However, the literature reviewed for this update provides no information on such competition with WYBA for food in the Lower Colorado River Valley or elsewhere. On the other hand, the literature does identify at least three vertebrates that may compete with WYBA for habitat or otherwise modify WYBA habitat. Specifically,

- Arizona myotis (*Myotis occultus*) have been detected roosting in fan palm skirts in the Lower Colorado River Valley. Specifically, a single telemetered female was tracked to a maternity colony of over 100 Arizona myotis roosting in the skirts of two fan palm trees next to a house on Colorado River Indian Tribe land (Calvert 2016a; Diamond 2012).

[4] Esbérard and Vrcibradic (2007) specifically address *T. biscutatus*, the western lyresnake, of which the Sonoran lyresnake was until recently considered a subspecies.

Ronning (2019, personal communication) notes that, "Colonies of the Arizona myotis appeared to have disappeared from the LCR by the 1940s, but this colony and detections at our monitoring locations may mean that they are present now and potential competitors for roosts." The hooded oriole (*Icterus cucullatus*) nests on the underside of palm tree fronds and occurs in the WYBA distribution (NatureServe 2019c) and, therefore, also could compete with WYBA for roosting habitat. Such possible interactions with WYBA have not been studied.

- Beavers can alter riparian vegetation communities in the Southwestern United States by removing cottonwood and willow. The species was once common in the LCR ecosystem (Grinnell 1914; Minckley and Rinne 1985; Ohmart et al. 1988) and is increasingly active there today (Hautzinger 2010; Mueller 2006; Shafroth and Beauchamp 2006; Vizcarra and Piest 2010). Beaver activity may alter riparian vegetation communities in other ways, as well. Their activity along one section of the Bill Williams River has "… maintain[ed] fluctuating water levels and pathways, which has limited colonization of saltcedar and promoted growth of native wetland vegetation" (Cotten and Grandmaison [2013]) while simultaneously favoring colonization of saltcedar immediately around such inundated areas (Miller and Leavitt 2015; O'Donnell and Leavitt 2017a, 2017b).

Grazing by mule deer and by non-native cattle and burros across the arid Southwestern United States, in turn, can degrade riparian habitat. For example, grazing may thin the understory or prevent the establishment of cottonwood and willow seedlings (Kauffman et al. 1997). Krueper (1993) and Krueper et al. (2003) report that fencing cattle out of sensitive riparian habitats in the San Pedro Riparian National Conservation Area in southeastern Arizona led to improved habitat quality and increased riparian bird density within 4 years.

WATER AVAILABILITY

The definition and discussion of this habitat element is updated as follows:

Full name: **The spatial and temporal availability of water, particularly the presence and distance of surface water, including small pools, and the depth of the water table in and around existing or potential WYBA roosting and foraging habitat**. This element refers to the presence of surface water near foraging areas or roost sites.

As noted above, this chapter (see "Riparian Tree Community"), WYBA along the Lower Colorado River Valley preferentially forage not only in cottonwood-willow habitat but over water (Broderick 2012a, 2012b; Calvert 2017; LCR MSCP 2016; Mixan et al. 2015; NatureServe 2019a; Vizcarra et al. 2010),

and they may be more active in cottonwood-willow patches that are closer to open water (Broderick 2012b). Further, as noted above, this chapter (see "Palm Trees"), both California and Mexican fan palms can germinate and grow only in moist soils, immediately adjacent to surface water or in locations with a water table very close to the land surface (Anderson 2011; Ortiz and Barrows 2014; USDA-NRCS 2002).

Water availability potentially may affect WYBA indirectly by affecting the arthropod, matrix, riparian tree, and vertebrate communities (see above, this chapter). For example, falling water tables in the Southwestern United States have been linked to changes in the riparian vegetation community, with declines in cottonwood and willow species and increases in saltcedar (Stromberg 1998).

Updates to Chapter 5 – Controlling Factors

This update identifies seven controlling factors that affect one or more habitat elements or critical biological activities or processes across the WYBA life cycle. The original WYBA conceptual ecological model (Marty and Unnasch 2015) identified nine controlling factors. This update adds one entirely new controlling factor, conservation monitoring and research programs; integrates four original controlling factors (grazing, tree pruning, tree thinning, and pesticide application) into a new controlling factor, surrounding land use, that also addresses land uses such as agriculture, commercial and residential activities, and recreation; renames the controlling factor identified in the spreadsheet as fire to fire management; renames habitat restoration to habitat development and management; and recognizes that habitat development and management also may entail tree pruning, tree thinning, and pesticide application. Table 5 lists the seven controlling factors in this update, indicates which habitat elements they *directly* affect, and indicates which controlling factors are new to this update or renamed from the original WYBA conceptual ecological model.

Table 4.—(Revision of original Table 4) WYBA controlling factors and the habitat elements they directly affect (Xs indicate the habitat elements that affect each critical biological activity or process. Table does not show three habitat elements that are not directly affected.)

Habitat element ➔ / **Controlling factor 🡻**	Anthropogenic disturbance	Arthropod community	Chemical contaminants	Fire regime	Infectious agents	Matrix community	Monitoring, capture, handling	Palm trees	Riparian tree community	Vertebrate community	Water availability
Conservation monitoring and research programs (*new*)							X				
Fire management (*renamed in workbook*)				X							
Habitat development and management (*renamed*)	X					X			X		
Nuisance species introduction and management		X	X		X	X			X	X	
Surrounding land use (*new*)	X	X	X			X		X	X	X	
Water storage-delivery system design and operation								X			X
Wind energy development	X										

As noted in the original WYBA conceptual ecological model, a hierarchy of controlling factors exists, affecting every ecosystem, with long-term dynamics of climate and geology at the top. However, this CEM focuses on controlling factors that are within the scope of potential human manipulation. Further, as also noted in the original WYBA conceptual ecological model, the 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. The following paragraphs describe the updates to the controlling factors for the WYBA conceptual ecological model and explain the changes made to the original CEM.

CONSERVATION MONITORING AND RESEARCH PROGRAMS

This update adds this controlling factor to provide a driver for monitoring activities.

Full Name: **The types, frequencies, and duration of monitoring and research activities carried out by the LCR MSCP, U.S. Fish and Wildlife Service (USFWS), States, and Tribes focused on species and habitats of concern to their respective wildlife conservation programs**. The Habitat Conservation Plan (HCP) (LCR MSCP 2004) for the LCR mandates the LCR MSCP, in particular, to carry out conservation measures to meet the biological needs of 5 threatened or endangered species, and 19 other covered species, and to potentially benefit 5 evaluation species. The LCR MSCP carries out many of these conservation measures in partnership with other agencies. The conservation measures include monitoring of species distributions as well as several types of research investigations. The current LCR MSCP annual work plan and 5-year monitoring and research priorities specifically call for field-based research investigations to characterize habitat requirements and habitat conditions, including conditions at created and managed habitat sites, for 22 species, including WYBA (LCR MSCP 2018a, 2018b).

FIRE MANAGEMENT

This update renames this controlling factor in the WYBA conceptual ecological model workbook, where it was named simply, fire. The original WYBA conceptual ecological model used the label, fire management, in the report but only the label, fire, in the workbook. Further, the original workbook addressed both fire management and the fire regime itself under the umbrella of this controlling factor. This update separates the controlling factor, fire management,

from the habitat element, fire regime, as discussed in the updates to chapter 4. This update also revises the definition of the controlling element as follows: *Full name*: **The types, frequencies, and duration of activities intended to control and/or suppress fire in and around existing or potential WYBA roosting and foraging habitat and across lands surrounding these locations**. The LCR MSCP and other land management agencies along the LCR and Bill Williams River valleys may use prescribed fire as a management tool and actively manage wildfires through fire suppression and the construction of fire control breaks (LCR MSCP 2018a). Wildfire is a natural type of disturbance in the riparian plant communities of the Lower Colorado River Valley, and wildfires today also occur through human accidents (Conway et al. 2010; LCR MSCP 2018a). In fact, wildfires have occurred recently at LCR MSCP restoration sites (Hunters Hole and Yuma East Wetlands) and in riparian habitat at the Havasu National Wildlife Refuge and Cibola National Wildlife Refuge-Island Unit (Hill 2018; J. Hill and C. Ronning 2018, joint personal communication; LCR MSCP 2018a).

HABITAT DEVELOPMENT AND MANAGEMENT

This update renames the controlling factor in the original WYBA conceptual ecological model, habitat restoration, to habitat development and management, to clarify that the factor includes both the development and management of conservation habitat. Further, this update revises the definition of this factor as follows:

Full name: **The types, frequencies, and durations of actions taken by the LCR MCP to create and manage habitat for species conservation in and around existing or potential WYBA roosting and foraging habitat, including actions to affect the taxonomic composition, abundance, condition, and spatial distribution of vegetation**. The HCP mandates the LCR MSCP to carry out conservation measures to meet the biological needs of 5 threatened or endangered species, and 19 other covered species, and to potentially benefit 5 evaluation species. These measures include creating and managing habitat to meet these biological needs through the manipulation particularly of vegetation and hydrology. The LCR MSCP and other land managers along the LCR and Bill Williams River valleys use a range of methods to establish and manage the vegetation (see chapter 4, “Matrix Community” and “Riparian Tree Community”) on lands under their authorities, including prescribed fire, surface irrigation and subirrigation, planting, fertilizing, thinning and hand removal, disking and plowing, and the application of herbicides (LCR MSCP 2014, 2018a; LCR MSCP 2004). Agencies and irrigation and drainage districts may also remove vegetation to maintain roads and canals under their authorities. The renamed controlling factor partially incorporates two controlling factors in the original WYBA conceptual ecological model, pesticide/herbicide application and

tree thinning, to the extent that those original categories concerned actions taken to create and manage habitat for species conservation (versus taken on surrounding lands; see below).

NUISANCE SPECIES INTRODUCTION AND MANAGEMENT

The definition of this controlling factor is updated as follows:

Full name: **The introduction and management of nuisance species that potentially may interact with WYBA in and around existing or potential WYBA roosting and foraging habitat**. Nuisance species are non-native animals, plants, and micro-organisms that were not introduced and/or are not managed for recreational purposes; may poison, infect, prey on, compete with, or present alternative food resources for native species; cause other alterations to the food web that affect native species; or affect habitat features such as vegetation cover. The factor includes the legacy of past introductions and the potential for additional introductions and includes both intentional and accidental introductions. Management activities may include efforts to control the spread of nuisance species through interdiction and education and efforts to reduce the abundance and/or geographic range of species through mechanical removal, prescribed fire, applications of biocidal chemicals, and releases of biological controls. Agencies involved in nuisance species management along the LCR and Bill Williams River valleys include the Bureau of Land Management, State of Arizona, the USFWS, the Bureau of Reclamation (Reclamation), Indian Tribes, and irrigation districts.

SURROUNDING LAND USE

This update adds this new controlling factor to the original WYBA conceptual ecological model.

Full name: **The types and intensities of human activity on lands surrounding habitat conservation areas and other protected areas used or potentially usable by WYBA as roosting and/or foraging habitat**. The lands surrounding LCR MSCP habitat conservation areas and other protected areas—particularly surrounding locations used or potentially usable by WYBA as roosting sites or foraging areas—are subject to a wide range of uses. These uses include commercial and residential activities, irrigation farming, grazing, recreation, and multi-purpose range management. These uses frequently affect the taxonomic composition, abundance, condition, and spatial distribution of vegetation on these lands. Plantings around residential and commercial areas may include non-native species such as fan palms. Mixan et al. (2015) note that WYBA were detected

foraging more often at habitat creation sites along the Lower Colorado River Valley "… with a high degree of development within and adjacent to the treatment sites. This association with development likely is related to the presence of palm trees in these developed areas."

Irrigation farming specifically replaces native and otherwise uncontrolled vegetation with annual crops and orchards. Farmlands are subject to surface irrigation and subirrigation, planting, fertilizing, thinning and hand removal, disking and plowing, and the application of herbicides and pesticides. Commercial and residential areas also may be subject to irrigation and subirrigation, planting, fertilizing, vegetation thinning and pruning, and the application of herbicides and pesticides. The original WYBA conceptual ecological model specifically noted that cosmetic trimming of palm trees is a major threat to roosting WYBA. All developed lands are also subject to intensive fire management. The dead fronds of fan palms are highly flammable and pose a particular fire hazard in residential and commercial areas (Howard 1992). The renamed controlling factor partially incorporates four controlling factors in the original WYBA conceptual ecological model—grazing, pesticide/herbicide application, tree pruning, and tree thinning—to the extent that those original categories concerned human activities on surrounding lands (versus taken on sites created and managed as habitat for species conservation; see below).

WATER STORAGE-DELIVERY SYSTEM DESIGN AND OPERATION

Full name: **The design and operation of the water storage, diversion, and delivery system that regulates the elevation of surface water in and around existing or potential WYBA roosting and foraging habitat**. The Colorado River through the Lower Colorado River Valley consists of a chain of reservoirs separated by flowing reaches. The water moving through this system is highly regulated by Reclamation for storage and delivery to numerous international, Federal, State, Tribal, municipal, and agricultural holders of water rights as well as for hydropower generation. The Bill Williams River below Alamo Dam similarly is regulated by the U.S. Army Corps of Engineers for flood control, recreation, water conservation, and wildlife conservation. This system of water management and its infrastructure, together with regulated discharges from the Upper Colorado River Basin and local weather conditions, determine surface water elevations and groundwater elevations along the LCR and Bill Williams River valleys, and deliveries of water to off-channel locations, including protected areas and habitat conservation areas (LCR MSCP 2004). River regulation and entrenchment of the LCR between the reservoirs have eliminated almost all opportunities for the river to deliver pulses of water onto its former floodplain and have altered water table elevations throughout the valley. Reclamation, the

USFWS, and other agencies have rights to use some of the water in the LCR on lands managed as wildlife habitat, delivered through surface water diversions and groundwater wells (LCR MSCP 2014, 2018a).

WIND ENERGY DEVELOPMENT

The definition of this controlling factor is updated as follows:

Full name: **The construction, operation, and maintenance of wind energy facilities and their associated infrastructure in and around existing or potential WYBA roosting and foraging habitat or migratory routes**. 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; Arnett and Baerwald 2013; Hayes 2013; Kunz et al. 2007).

Updates to Chapter 6 – Conceptual Ecological Model by Life Stage

The following sections identify all changes made to the WYBA conceptual ecological model workbook other than changes that involve only updates to names. These latter changes are listed separately in table 5 (see "Summary of Updated Terms for the WYBA Conceptual Ecological Model" at the end of this chapter). The items in each section of this chapter are arranged alphabetically. The abbreviations, CF for controlling factor, HE for habitat element, CAP for critical biological activity or process, and LSO for life-stage outcome are provided to identify component types where needed. Each item also identifies the life stage(s) to which the item applies. For the sake of brevity, the descriptions below do not repeat the definitions of the controlling factors, habitat elements, critical biological activities and processes, or life-stage outcomes. Readers should refer to the definitions in chapters 3–5 as needed.

NEW LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS THAT AFFECT OTHER CONTROLLING FACTORS

- Habitat Development and Management effects on Conservation Monitoring and Research Programs (CF): The causal node in this link is an update of the controlling factor, habitat restoration, in the original WYBA conceptual ecological model. The effect node in this link is a new controlling factor added to the original CEM. LCR MSCP and partner decisions on habitat development and management determine where monitoring of WYBA should occur and also affects where research studies may occur. In addition, LCR MSCP management of habitat management sites can affect monitoring of WYBA at the sites, when the clearing of fire-control zones, thinning or removal of vegetation, or creation of linear patches affects lines of sight for visual monitors and the availability of openings for placement of mist nets or acoustic monitoring stations. The link is hypothesized to be complex and unidirectional with proposed high intensity, spatial scale, and temporal scale; high predictability; and high understanding. *Applies to all life stages*.

- Habitat Development and Management effects on Fire Management (CF): The causal node in this link is an update of the controlling factor, habitat restoration, in the original WYBA conceptual ecological model. The effect node in this link is a clarification: The original WYBA conceptual ecological model included fire management as a controlling factor in the

report but used the term, fire, for the associated controlling factor in the spreadsheet and used the latter term to cover both fire management and the fire regime itself. This update separates these two distinct topics. Managers of protected areas and habitat conservation sites that presently or potentially could support WYBA take habitat development or management objectives into account when making decisions about fire management at these sites. However, the reports reviewed for this update do not discuss how WYBA habitat development or conservation objectives are taken into account in fire management decisions. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

- Habitat Development and Management effects on Nuisance Species Introduction and Management (CF): The causal node in this link is an update of the controlling factor, habitat restoration, in the original WYBA conceptual ecological model. The effect node in this link is unchanged from the original CEM. Managers of protected areas and habitat conservation sites that presently or potentially could support WYBA take habitat development or management objectives into account when making decisions about nuisance species management at these sites. However, the reports reviewed for this update do not discuss how WYBA habitat development or conservation objectives are taken into account in decisions concerning the management of nuisance species at WYBA habitat development or conservation sites. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

- Habitat Development and Management effects on Water Storage-Delivery System Design and Operation (CF): The causal node in this link is an update of the controlling factor, habitat restoration, in the original WYBA conceptual ecological model. The effect node in this link is unchanged from the original CEM. The LCR MSCP manages water applications on known and potential WYBA habitat sites to achieve habitat development and management objectives through the exercise of its surface water and groundwater rights. The link is hypothesized to be complex and unidirectional with proposed high intensity, high spatial scale, and low temporal scale; medium predictability; and high understanding. *Applies to all life stages*.

- Surrounding Land Use effects on Fire Management (CF): The causal node in this link is a new controlling factor added to the original WYBA conceptual ecological model. The effect node in this link is a clarification: The original CEM included fire management as a controlling factor in the report but used the term, fire, for the associated controlling factor in the

spreadsheet and used the latter term to cover both fire management and the fire regime itself. This update separates these two distinct topics. Management of lands surrounding known and potential WYBA habitat sites may affect the incidence of wildfire or escaped prescribed fire on these sites, to which site fire managers must respond. Management of wildfire and use of prescribed fire are commonplace across the portions of the Lower Colorado River Valley that include WYBA habitat and are likely zones of origin of fires that could affect WYBA sites. The link is hypothesized to be complex and unidirectional with proposed medium intensity, spatial scale, and temporal scale; high predictability; and medium understanding. Although the specifics will differ from one WYBA habitat site to the next, it will always be the case that fire managers for these habitat sites will take surrounding land conditions into consideration when planning how to manage fire conditions onsite. While the principles of this relationship are well understood in general, the relationship has not been studied specifically for WYBA habitat and its surroundings along the LCR. *Applies to all life stages*.

- Surrounding Land Use effects on Wind Energy Development (CF): The causal node in this link is a new controlling factor added to the original WYBA conceptual ecological model. The effect node in this link is unchanged from the original CEM. Theoretically, the siting of wind turbines and associated access roads and utility corridors depends on the distribution of compatible land uses, and the siting of such infrastructure in turn can affect land use within their vicinities. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The reports reviewed for this update do not discuss whether or to what extent wind energy development is taking place along the Lower Colorado River Valley or how it relates to existing land uses. The information found in this link can be updated if/as wind energy development takes place along the valley. *Applies to all life stages*.

- Water Storage-Delivery System Design and Operation effects on Nuisance Species Introduction and Management (CF): The causal and effect nodes are unchanged from the original WYBA conceptual ecological model, but the original CEM did not address their interaction. Theoretically, surface water deliveries from regulated waters can carry in nuisance plant propagules and small aquatic fauna to habitat management areas, and water deliveries may be managed in part to help suppress nuisance species through intentionally prolonged inundation or drying of habitat management areas. The link is hypothesized to be complex and bi-directional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The reports reviewed for the original CEM and this update do not discuss whether or to what extent water deliveries may introduce nuisance species to known

or potential WYBA habitat along the Lower Colorado River Valley or to the extent to which water deliveries may be used by habitat managers as a tool for controlling nuisance species in such habitat. *Applies to all life stages*.

NEW LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS THAT AFFECT HABITAT ELEMENTS

- Conservation Monitoring and Research Programs effects on Monitoring, Capture, Handling (HE): Both the causal and effect nodes are new additions to the original WYBA conceptual ecological model. The HCP mandates the LCR MSCP, in particular, to carry out conservation measures to meet the biological needs of 5 threatened or endangered species, and 19 other covered species, and to potentially benefit 5 evaluation species. The HCP identifies the WYBA as a covered species (LCR MSCP 2004). The LCR MSCP carries out many of these conservation measures in partnership with other agencies. The conservation measures include monitoring of species distributions as well as several types of research investigations. The current LCR MSCP annual work plan and 5-year monitoring and research priorities specifically call for field-based research investigations to characterize habitat requirements and habitat conditions, including conditions at created and managed habitat sites, for 22 species, including WYBA (LCR MSCP 2018a, 2018b). The AZGFD has carried out several studies for the LCR MSCP to develop recommendations for best monitoring practices for WYBA management. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional, with high intensity, spatial scale, and temporal scale; high predictability; and high understanding. *Applies to all life stages*.

- Fire Management effects on the Fire Regime (HE): The causal and effect nodes in this link are clarifications: The original WYBA conceptual ecological model included fire management as a controlling factor in the report but used the term, fire, for the associated controlling factor in the spreadsheet and used the latter term to cover both fire management and the fire regime itself. This update separates these two distinct topics. Current and potential WYBA habitat sites in the Lower Colorado River Valley are located in a landscape highly managed for fire control, in which fire patterns are determined by decisions on wildfire suppression or control and on the use of prescribed fire to manage vegetation. The link is hypothesized to be complex and unidirectional with proposed high intensity, spatial scale, and temporal scale; high predictability; and

medium understanding. Fire management is the dominant determinant of the fire regime at current and potential WYBA habitat sites, both through the management of wildfire and through prescribed fire. While the principles of this relationship are well understood in general, the relationship has not been studied specifically with respect to WYBA habitat. *Applies to all life stages*.

- Habitat Development and Management effects on Anthropogenic Disturbance (HE): The causal node in this link is an update of the controlling factor, habitat restoration, in the original WYBA conceptual ecological model. The effect node in this link is unchanged from the original CEM. Activities associated with habitat development and management may result in human disturbance in areas with WYBA foraging or roosting habitat. Theoretically, human activities may affect WYBA foraging or roosting, but WYBA in fact appear to be relatively unaffected (see chapter 3, "Foraging" and chapter 4, "Anthropogenic Disturbance"). The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; high predictability; and medium understanding. The reports reviewed for this update do not discuss whether or to what extent habitat development and management at known or potential WYBA habitat sites involves human activities that could disturb WYBA activities. *Applies to all life stages*.

- Habitat Development and Management effects on the Riparian Tree Community (HE): The causal node in this link is an update of the controlling factor, habitat restoration, in the original WYBA conceptual ecological model. The effect node in this link is a new addition to the original CEM that incorporates and expands on the several separate habitat elements in the original CEM focused on the riparian tree community (see updates to chapter 4). Habitat development and management practices are the dominant factor shaping the riparian tree community at all LCR MSCP habitat sites managed for riparian vegetation to support LCR MSCP threatened and covered species. Associated habitat development and management practices include earth moving, tilling, irrigation, and mechanical pruning and thinning of vegetation, and the LCR MSCP is authorized to use prescribed fire and herbicides as management tools as well. Planting and thinning may be designed to achieve particular goals of stand composition, density, and vertical structure, and the duration of habitat development and management determines overall stand age and maturity. The link is hypothesized to be complex and unidirectional with proposed high intensity, low spatial scale, and high temporal scale. Habitat development and management regimes have the ability to greatly affect vegetation, habitat development and management decisions are made at the scale of individual habitat sites, and habitat development and management sites are heavily managed to achieve long-term objectives under the LCR MSCP HCP. The link is proposed to have high

predictability because, while other factors such as grazing, fire, water management, etc., also affect vegetation at known and potential WYBA habitat sites along the Lower Colorado River Valley, their effects are known and taken into account. The link is proposed to have medium understanding. The LCR MSCP continues to adapt its habitat development and management practices as its knowledge increases concerning what practices work better than others. *Applies to all life stages*.

- Nuisance Species Introduction and Management effects on the Arthropod Community (HE): The causal node in this link is unchanged from the original CEM. The effect node is a new addition to the original WYBA conceptual ecological model, replacing and expanding on the original habitat element, food availability (see updates to chapter 4). The arthropod community may include non-native species with food value for WYBA and/or different ecological characteristics compared to native arthropods. For example, the northern tamarisk beetle, introduced as a biocontrol agent, strongly affects vegetation through its strong impact on saltcedar. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. For example, the introduced northern tamarisk beetle has affected saltcedar stands along the Lower Colorado River Valley, but there are no data on any other possible effects of this species on the arthropod community. *Applies to all life stages*.

- Nuisance Species Introduction and Management effects on Chemical Contaminants (HE): The causal node in this link is unchanged from the original WYBA conceptual ecological model. The original CEM did not propose a separate habitat element for chemical contaminants. However, the original WYBA conceptual ecological model did note that WYBA are vulnerable to chemical stress (see chapter 3) and identified some possible sources of contaminants that could result in such stress. This update adds this new habitat element to the CEM so that it better identifies the causal chains that could result in chemical stress to WYBA in any life stage (see updates to chapter 4). Spraying of biocides (herbicides, pesticides) to control nuisance plants and insects on surrounding lands could introduce chemical contaminants into protected areas and habitat conservation sites used by WYBA. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The link is proposed as a theoretical possibility but the subject has not been studied for the Lower Colorado River Valley. *Applies to all life stages*.

- Nuisance Species Introduction and Management effects on Infectious Agents (HE): The causal node in this link is unchanged from the original WYBA conceptual ecological model CEM. The effect node in this link is

a revision to a similar habitat element in the original CEM that also nominally included but did not substantively address WYBA genetic diversity (see updates to chapter 4). Nuisance species may include or carry pathogens to which WYBA are susceptible, including the rabies virus. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional based on the assumption that the greater the number of nuisance mammal and arthropod species arriving in the Lower Colorado River Valley, the greater the chances one or more will carry or be an infectious agent for WYBA. The link has unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The subject has not been studied for the Lower Colorado River Valley or WYBA in general. *Applies to all life stages*.

- Nuisance Species Introduction and Management effects on the Matrix Community (HE): The causal and effect nodes in this link are unchanged from the original WYBA conceptual ecological model, but the original CEM did not include their interaction as a causal link. Invasive species can change the structure of entire vegetation communities. The link is hypothesized to be complex and unidirectional, with effects that vary by species and community type. The link is proposed to have high intensity, spatial scale, and temporal scale. Invasive species can significantly alter the structure of entire communities with widespread and lasting effects as they spread across entire regions and cause changes that can last decades. Predictability is low: Effects vary by species and community type, and it is usually not known how the introduction of exotic species will affect the natural community. Understanding is medium: The effects of some exotic species (e.g., saltcedar) are fairly well known in the LCR. *Applies to all life stages*.

- Nuisance Species Introduction and Management effects on the Vertebrate Community (HE): The causal node in this link is unchanged from the original WYBA conceptual ecological model. The effect node is a new addition to the original CEM, replacing and expanding on the original habitat element, predator density (see updates to chapter 4). Nuisance species in the Lower Colorado River Valley include terrestrial vertebrates such as feral pigs, burros, bullfrogs, etc., that at the very least can alter habitat for WYBA. There are no studies of how introduced terrestrial vertebrates have affected the overall structure or ecology of the Lower Colorado River Valley terrestrial vertebrate community. The link is hypothesized to be complex and unidirectional, with effects that vary by species and community type, with proposed high intensity, spatial scale, and temporal scale; high predictability; and low understanding. *Applies to all life stages*.

- Surrounding Land Use effects on Anthropogenic Disturbance (HE): The causal node in this link is a new controlling factor added to the original WYBA conceptual ecological model. The effect node in this link is unchanged from the original CEM. Surrounding land use can be an important source of anthropogenic disturbance such as noise. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional, and it assumes that the greater the intensity of surrounding land use, the greater the likelihood of anthropogenic disturbance to WYBA habitat. The link has unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Surrounding Land Use effects on the Arthropod Community (HE): The causal and effect nodes are both new additions to the original WYBA conceptual ecological model. Surrounding land uses can affect the arthropod community across WYBA habitat by fostering or suppressing the abundances of arthropods on which WYBA may feed or which may compete with WYBA for prey. The link is hypothesized to be complex and unidirectional, with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Surrounding Land Use effects on Chemical Contaminants (HE): The causal node is a new addition to the original WYBA conceptual ecological model. The effect node is an existing habitat element in the original CEM. Surrounding land uses may entail applications of herbicides, pesticides, or fertilizers or releases of other chemicals that may cause harm to WYBA if they spread into WYBA habitat. The link is hypothesized to be complex and unidirectional with medium intensity, low spatial scale, and low temporal scale. The most likely scenario involves pesticide applications at individual agricultural fields affecting nearby patches and the effects dissipating within a decade after application. Predictability and understanding are both low: The LCR MSCP does not receive information on what pesticides may be used, when pesticide applications may occur, what the target pests are, or through what landowner actions either before or after such actions take place. Pesticides harm arthropods by design, but impacts on WYBA will depend on pesticide type, mode of application, and other factors. *Applies to all life stages*.

- Surrounding Land Use effects on the Matrix Community (HE): The causal node in this link is a new addition to the original WYBA conceptual ecological model, incorporating and expanding on controlling factors in the original CEM that addressed more activities such as grazing, tree thinning, etc. The effect node in the link is unchanged from the

original CEM. Surrounding land uses, including farming, livestock grazing, residential and commercial uses, recreation, and habitat management all necessarily affect many aspects of matrix community vegetation structure and composition. The link is hypothesized to be complex and unidirectional with proposed high intensity, spatial scale, and temporal scale. Surrounding land uses, at least the general categories of land use, such as for agriculture or for residential or commercial development, are typically stable over periods of years to decades across large areas. Predictability and understanding are medium: The effects depend on the type of land use, with range and habitat management having the fewest effects and farming having the greatest. These relationships are well understood in general even if not systematically studied along the LCR. *Applies to all life stages*.

- Surrounding Land Use effects on Palm Trees (HE): The causal node in this link is a new addition to the original WYBA conceptual ecological model, incorporating and expanding on controlling factors in the original CEM that addressed more activities such as grazing, tree thinning, etc. The effect node is also a new addition to the CEM, addressing the taxonomic composition, tree size and density, tree condition, spatial and temporal distributions, and abundances of stands of palm trees along the Lower Colorado River Valley and its immediate tributaries. WYBA in the valley overwhelmingly roost in palms, mostly California and Mexican fan palms, which are often planted in and around residential areas in the valley, but occasionally also roost in date palms, which are cultivated in commercial orchards. Local fire codes may require that palms in developed areas have their skirts removed regularly to reduce fire hazards. The link is hypothesized to be complex and unidirectional with proposed medium intensity, medium spatial scale, and high temporal scale. Surrounding intensive land use, such as for orchards or residential use, strongly shape the distribution of palm trees along the LCR and Bill Williams River valleys, but they are not the only drivers at work. Predictability is medium but understanding low: The literature does not provide any systematic assessments of the distribution or condition of palm trees in the valley in relation to land use. *Applies to all life stages*.

- Surrounding Land Use effects on the Riparian Tree Community (HE): The causal node in this link is a new addition to the original WYBA conceptual ecological model, incorporating and expanding on controlling factors in the original CEM that addressed more specific activities such as grazing, tree thinning, etc. The effect node in the link also is a new addition to the CEM, incorporating and expanding on habitat elements in the CEM that addressed more specific aspects of tree community structure and composition. Surrounding land uses, including grazing, tree thinning, tree pruning, and pesticide use may affect riparian tree community vegetation structure and composition, canopy cover, and patch size at and around WYBA foraging habitat, by intruding into this habitat

(e.g., livestock or defoliant drift) or altering the surroundings in ways that affect dynamics within this habitat. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Surrounding Land Use effects on the Vertebrate Community (HE): The causal node in this link is a new addition to the original WYBA conceptual ecological model, incorporating and expanding on controlling factors in the original CEM that addressed more specific activities such as grazing, tree thinning, etc. The effect node in the link also is a new addition to the CEM, incorporating and expanding on an single habitat element in the original related to the vertebrate community, predator density. Surrounding land uses, including farming, livestock grazing, residential and commercial development, and recreation may affect the abundance and composition of the vertebrate community at and around WYBA foraging and roosting habitat. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Wind Energy Development effects on Anthropogenic Disturbance (HE): The causal and effects nodes in this link are unchanged from the original WYBA conceptual ecological model. However, the original CEM did not recognize the causal relationship between the two, one of the primary mechanisms by which the construction and operation of wind energy infrastructure can affect bats. Noise, unusual winds and turbulence, and electromagnetic disturbances associated with wind turbine installation and operation are thought to pose hazards to bats, although these possible relationships have not been studied for the Lower Colorado River Valley or WYBA in particular. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

DELETED LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS

- Effects of Fire on Nuisance Species Introduction and Management (CF). This update corrects the original WYBA conceptual ecological model spreadsheet use of the label, fire, to refer to either the controlling factor, fire management, or the habitat element, fire regime, depending on the

details of the causal relationship. Further, this update clarifies that fire management does not directly affect nuisance species management. Instead, fire management affects the fire regime, which both affects and is affected by the composition and structure of various vegetation communities, which in turn both affect and are affected by nuisance species introduction and management. *Applies to all life stages*.

- Effects of Fire on Canopy Cover (HE). This update corrects the original WYBA conceptual ecological model spreadsheet use of the term, fire, to refer to either the controlling factor, fire management, or the habitat element, fire regime, depending on the details of the causal relationship. This update also incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Fire on Patch Size (HE). This update corrects the original WYBA conceptual ecological model spreadsheet use of the term, fire, to refer to either the controlling factor, fire management, or the habitat element, fire regime, depending on the details of the causal relationship. This update also incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Fire on Tree Species Composition (HE). This update corrects the original WYBA conceptual ecological model spreadsheet use the term, fire, to refer to either the controlling factor, fire management, or the habitat element, fire regime, depending on the details of the causal relationship. This update also incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Grazing on Patch Size (HE). This update incorporates the original controlling factor, grazing, into the new controlling factor, surrounding land use, which also addresses several other activities such as tree thinning and pesticide application formerly also addressed as separate controlling factors. This update also incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Grazing on Tree Species Composition (HE). This update incorporates the original controlling factor grazing, into the new controlling factor, surrounding land use, which also addresses several other activities such as tree thinning and pesticide application formerly also addressed as separate controlling factors. This update also incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Habitat Restoration on Canopy Cover (HE). This update incorporates the original controlling factor, habitat restoration, into the new controlling factor, habitat development and management, which also incorporates specific vegetation management practices such as "tree thinning," that the original WYBA conceptual ecological model treated as a separate controlling factor. This update also incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Habitat Restoration on Patch Size (HE). This update incorporates the original controlling factor, habitat restoration, into the new controlling factor, habitat development and management, which also incorporates specific vegetation management practices such as "tree thinning," that the original WYBA conceptual ecological model treated as a separate controlling factor. This update also incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, tree community. *Applies to all life stages*.

- Effects of Habitat Restoration on Tree Species Composition (HE). This update incorporates the original controlling factor, habitat restoration, into the new controlling factor, habitat development and management, which also incorporates specific vegetation management practices such as "tree thinning," that the original WYBA conceptual ecological model treated as a separate controlling factor. This update also incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Nuisance Species Introduction and Management on Tree Species Composition (HE). This update incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Pesticide Application on Food Availability (HE). This update incorporates the original controlling factor, pesticide use, into the new controlling factor, surrounding land use, which also addresses several other activities such as grazing, tree thinning, and pruning formerly also addressed as separate controlling factors. This update also incorporates the original habitat element, food availability, into the more inclusive element, arthropod community. *Applies to juvenile and adult life stages*.

- Effects of Tree Pruning on Canopy Cover (HE). This update incorporates the original controlling factor, grazing, into the new controlling factor, surrounding land use, which also addresses several other activities such as tree thinning and pesticide application formerly also addressed as separate controlling factors. This update also incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Tree Thinning on Canopy Cover (HE). This update incorporates the original controlling factor, grazing, into the new controlling factor, surrounding land use, which also addresses several other activities such as tree thinning and pesticide application formerly also addressed as separate controlling factors. This update also incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Tree Thinning on the Tree Community (HE). This update incorporates the original controlling factor, grazing, into the new controlling factor, surrounding land use, which also addresses several other activities such as tree thinning and pesticide application formerly also addressed as separate controlling factors. This update also incorporates originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Water Storage-Delivery System Design and Operation on Tree Species Composition (HE). This update incorporates the originally separate habitat elements, canopy cover, patch size, and tree species composition into the new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Wind Energy Development on the Matrix Community (HE). This update drops this link because the impacts of wind energy development on the matrix community do not appear to be ecologically sufficiently relevant to include. They are not known to be occurring, and if they were to occur, they would likely be too small in spatial scale to affect WYBA ecology. *Applies to juvenile and adult life stages*.

UPDATED LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS

- Effects of Nuisance Species Introduction and Management on the Riparian Tree Community (HE). This update replaces the originally separate habitat elements, canopy cover, patch size, and tree species composition with the new habitat element, riparian tree community. Invasive species can change the structure of entire vegetation communities, as has occurred in the Lower Colorado River Valley with the spread of saltcedar. The link is hypothesized to be complex and unidirectional with effects that vary by species and community type. The link is proposed to have high intensity, spatial scale, and temporal scale. Invasive species can significantly alter the structure of entire communities with widespread and lasting effects as they spread across entire regions and cause changes that can last decades. Predictability is low: Effects vary by species and community type, and it is usually not known how the introduction of exotic species will affect the natural community. Understanding is medium: The effects of some exotic species (e.g., saltcedar) are fairly well known in the LCR. *Applies to all life stages*.

- Habitat Development and Management effects on the Matrix Community (HE): The causal node in this link is an update of the original controlling factor, habitat restoration, incorporating and expanding on the original definition to include several activities such as tree thinning that the original WYBA conceptual ecological model handled separately. The effect node in this link is unchanged from the original CEM. Habitat development and management at known or potential WYBA habitat sites may change the matrix community significantly by replacing other vegetation types with riparian vegetation or by managing the composition of the matrix community itself such as through the removal of nuisance species. The link is hypothesized to be complex and unidirectional with proposed medium intensity, medium spatial scale, and high temporal scale. Spatially, habitat development and management decisions are made at the scale of individual habitat sites. Temporally, habitat development and management sites are heavily managed to achieve long-term objectives under the LCR MSCP Habitat Conservation Plan. The proposed link predictability is high: Other factors, such as grazing and fire and water management, also affect vegetation at known and potential WYBA habitat sites along the Lower Colorado River Valley, but their effects are also well understood. The proposed link understanding is medium: The LCR MSCP continues to adapt its habitat development and management practices as its knowledge increases concerning what practices work better than others. *Applies to all life stages*.

NEW LINKS WITH HABITAT ELEMENTS AS CAUSAL AGENTS THAT AFFECT HABITAT ELEMENTS

- Arthropod Community effects on Palm Trees (HE): This update incorporates the original habitat element, food availability, into the more inclusive element, arthropod community, and adds the new habitat element, palm trees. Arthropods presumably may graze on palm tree wood, leaves, flowers, and fruit, causing harm, and presumably may assist in their pollination. In turn, palm trees provide habitat for many arthropods. The link is hypothesized to be complex and bi-directional, with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Chemical Contaminants effects on the Arthropod Community (HE): The original WYBA conceptual ecological model did not propose a separate habitat element for chemical contaminants. However, the original CEM did note that WYBA are vulnerable to chemical stress (see chapter 3) and identified some possible sources of contaminants that could result in such stress. This update adds "chemical contaminants" as a new habitat element so that the CEM better identifies the causal chains that could result in chemical stress to WYBA in any life stage (see updates to chapter 4). The effect node also is a new addition to the original CEM, replacing and expanding on the original habitat element, "food availability" (see updates to chapter 4). Chemical contaminants in and around WYBA roosting and foraging habitat presumably can affect the abundance of arthropods and the composition of the arthropod community there, either directly when directly harmful to arthropods or indirectly when the contaminants affect the vegetation. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Chemical Contaminants effects on the Matrix Community (HE): The original WYBA conceptual ecological model did not propose a separate habitat element for chemical contaminants. However, the original CEM did note that pesticide use within WYBA habitat or on surrounding lands could alter habitat conditions that affect WYBA. This update adds chemical contaminants as new habitat element so that the CEM better identifies the causal chains that could result in such effects on WYBA habitat (see updates to chapter 4). Chemical contaminants on lands

surrounding WYBA roosting and foraging habitat presumably might affect the density and composition of the matrix community there either by directly affecting the vegetation or by affecting fauna (arthropods, vertebrates) that help shape the community. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Chemical Contaminants effects on Palm Trees (HE): The original WYBA conceptual ecological model did not propose a separate habitat element for chemical contaminants. This update also adds the new habitat element, palm trees, and recognizes that chemical contaminants potentially can harm palm trees. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Chemical Contaminants effects on the Riparian Tree Community (HE): The original WYBA conceptual ecological model did not propose a separate habitat element for chemical contaminants. However, the original CEM did note that pesticide use within WYBA habitat or on surrounding lands could alter habitat conditions that affect WYBA. This update adds "chemical contaminants" as a new habitat element so that the CEM better identifies the causal chains that could result in such effects on WYBA habitat (see updates to chapter 4). The effect node in this link is a new addition to the CEM that incorporates and expands on the several separate habitat elements in the original CEM focused on the tree community (see updates to chapter 4). Chemical contaminants in and around WYBA foraging habitat presumably can affect the density, structure, patch sizes, and composition of the riparian tree community there either by directly affecting the vegetation or by affecting fauna (arthropods, vertebrates) that help shape the community. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Chemical Contaminants effects on the Vertebrate Community (HE): The original WYBA conceptual ecological model did not propose a separate habitat element for chemical contaminants. However, the original CEM did note that pesticide use within WYBA habitat or on surrounding lands could alter habitat conditions that affect WYBA. This update adds chemical contaminants as a new habitat element so that the CEM better identifies the causal chains that could result in such effects on WYBA habitat (see updates to chapter 4). The effect node in this link is a new

addition to the CEM, incorporating and expanding on an single habitat element related to the vertebrate community, predator density. Chemical contaminants in and around WYBA roosting and foraging habitat presumably can affect the density and composition of the vertebrate community there either by directly affecting the fauna or by affecting the vegetation in ways that affect the fauna. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Fire Regime effects on the Arthropod Community (HE): The original WYBA conceptual ecological model included fire management as a controlling factor in the report but used the term, fire, for the associated controlling factor in the spreadsheet and used the latter term to cover both fire management and the fire regime itself. This update separates these two distinct topics (see updates to chapter 4). The effect node in the present link also is a new addition to the original CEM, replacing and expanding on the original habitat element, "food availability" (see updates to chapter 4). The fire regime in and around WYBA roosting and foraging habitat presumably can affect the density and composition of the arthropod community there either by directly affecting the arthropods or by affecting the vegetation in ways that affect the arthropods. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Fire Regime effects on the Matrix Community (HE): The original WYBA conceptual ecological model included fire management as a controlling factor in the report but used the term, fire, for the associated controlling factor in the spreadsheet and used the latter term to cover both fire management and the fire regime itself. This update separates these two distinct topics (see updates to chapter 4). The effect node is unchanged from the original CEM. Fire affects many aspects of vegetation structure and composition. The link is hypothesized to be complex and unidirectional with proposed high intensity, medium spatial scale, and medium temporal scale. Fire can have great effects on vegetation structure, but these effects vary in spatial scale, and the persistence of effects depending on their timing and severity. Spatial and temporal scales here are rated "intermediate" to represent this variability. The CEM proposes rating link predictability and link understanding as medium. The effects of fire on vegetation are at least broadly predictable and understood both in general and in the Lower Colorado River Valley. *Applies to all life stages*.

- Fire Regime effects on the Palm Trees (HE): The original WYBA conceptual ecological model included fire management as a controlling factor in the report but used the term, fire, for the associated controlling factor in the spreadsheet and used the latter term to cover both fire management and the fire regime itself. This update separates these two distinct topics (see updates to chapter 4). The CEM also adds the new habitat element, palm trees. The dead frond skirts on fan palms, in particular, are highly flammable, and fire can remove all or most of the skirt on individual trees. Fan palm frond skirts are recognized as a fire hazard for adjacent buildings but, at least in the Lower Colorado River Valley, fan palms are not common enough outside developed areas to affect the fire regime at the landscape scale. Fire may also be beneficial in promoting at least California fan palm propagation (see chapter 4, "Palm Trees"). The link is hypothesized to be complex and unidirectional with high intensity, medium spatial scale, and high temporal scale: Wherever they occur in the Lower Colorado River Valley, palm trees presumably are susceptible to damage from fire, but palm tree occurrences are scattered, and date palm orchards are presumably carefully managed to avoid harmful fires. The CEM proposes rating link predictability as unknown, and understanding low: The subject has not been studied in the Lower Colorado River Valley. *Applies to all life stages*.

- Fire Regime effects on the Riparian Tree Community (HE): The original WYBA conceptual ecological model included fire management as a controlling factor in the report but used the term, fire, for the associated controlling factor in the spreadsheet and used the latter term to cover both fire management and the fire regime itself. This update separates these two distinct topics (see updates to chapter 4). The effect node in this link is a new addition to the original CEM that incorporates and expands on the several separate habitat elements focused on the riparian tree community (see updates to chapter 4). Fire affects many aspects of vegetation structure and composition and can destroy WYBA habitat (Busch 1995). Reciprocally, riparian tree community conditions such as species composition, density, and moisture levels affect the fire regime. The link is hypothesized to be complex and unidirectional with proposed high intensity, medium spatial scale, and medium temporal scale. The CEM proposes rating link predictability and link understanding as medium. The effects of fire on southwestern riparian vegetation are at least broadly predictable and understood both in general and in the Lower Colorado River Valley. *Applies to all life stages*.

- Fire Regime effects on the Vertebrate Community (HE): The original WYBA conceptual ecological model included fire management as a controlling factor in the report but used the term, fire, for the associated controlling factor in the spreadsheet and used the latter term to cover both fire management and the fire regime itself. This update separates these

two distinct topics (see updates to chapter 4). The effect node in this link is a new addition to the original CEM, incorporating and expanding on an single habitat element related to the vertebrate community, predator density. The fire regime in and around WYBA roosting and foraging habitat presumably can affect the density and composition of the vertebrate community there either by directly affecting the vertebrates or by affecting the vegetation in ways that affect the vertebrates. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Infectious Agents effects on Palm Trees (HE): The causal node in this link simplifies the habitat element from the original WYBA conceptual ecological model that included both genetic diversity and infectious agents. The effect node is a new addition to the original CEM, addressing the taxonomic composition, tree size and density, tree condition, spatial and temporal distributions, and abundances of stands of palm trees along the Lower Colorado River Valley and its immediate tributaries. Technically the habitat element, infectious agents, refers to agents that can infect WYBA. However, it is useful to note that palm trees are susceptible to their own infectious agents. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The subject has not been studied in the Lower Colorado River Valley, but publications on the cultivation of fan palms routinely note that they are susceptible to a range of infections. *Applies to all life stages*.

- Matrix Community effects on the Arthropod Community (HE): The causal node is unchanged from the original WYBA conceptual ecological model. The effect node in this link replaces the original habitat element, food availability. The original CEM posited a link between these two original habitat elements, but the new habitat element, arthropod community, significantly expands the meaning of this node and changes the contents of several fields in the spreadsheet entry, resulting in a new, rather than simply an updated, link. The density and composition of the matrix community surrounding roost habitat affect the abundance and composition of the arthropod community in the matrix vegetation community. Reciprocally, the abundance and composition of the arthropod community may affect the density and composition of the matrix vegetation community through herbivory, pollination, etc. The link is hypothesized to be complex and bi-directional with unknown intensity, medium spatial scale, and medium temporal scale; medium predictability; and low understanding. There are no studies of these interactions for the Lower Colorado River Valley. An effect of a change in the matrix community would likely persist over a medium time scale. *Applies to all life stages*.

- Matrix Community effects on the Vertebrate Community (HE): The causal node is unchanged from the original WYBA conceptual ecological model. The effect node in this link replaces the original habitat element, predatory density. The original CEM posited a link between these two original habitat elements, but the new habitat element, vertebrate community, significantly expands the meaning of this node and changes the contents of several fields in the spreadsheet entry, resulting in a new, rather than simply an updated, link. The density and composition of the matrix community affects the abundance and composition of the vertebrate community in the matrix vegetation community. Reciprocally, the abundance and composition of the vertebrate community may affect the density and composition of the matrix vegetation community through herbivory. The link is hypothesized to be complex and bi-directional with unknown intensity, medium spatial scale, and medium temporal scale; medium predictability; and low understanding. There are no studies of these interactions for the Lower Colorado River Valley. An effect of a change in the matrix community would likely persist over a medium time scale. *Applies to all life stages*.

- Riparian Tree Community effects on the Arthropod Community (HE): The causal node in this link is a new addition to the original WYBA conceptual ecological model that incorporates and expands on the several separate habitat elements in the original CEM focused on the tree community (see updates to chapter 4). The effect node in this link is a new addition to the CEM, incorporating and expanding on the original habitat element, food availability. The density and composition of the riparian tree community at WYBA foraging habitat affects the abundance and composition of the arthropod community there. Reciprocally, the abundance and composition of the arthropod community may affect the density and composition of the riparian tree community through herbivory. The link is hypothesized to be complex and bi-directional with proposed medium intensity, spatial scale, and temporal scale; medium predictability; and low understanding. Factors other than riparian tree community composition may affect arthropod abundance and vice versa, and these factors have received little study in the Lower Colorado River Valley. *Applies to all life stages*.

- Riparian Tree Community effects on the Vertebrate Community (HE): The causal node in this link is a new addition to the original WYBA conceptual ecological model that incorporates and expands on the several separate habitat elements in the original CEM focused on the riparian tree community (see updates to chapter 4). The effect node in this link is a new addition to the CEM, incorporating and expanding on the original habitat element, predator density. The patch size, density, composition, and vertical structure of the riparian tree community at WYBA foraging habitat affects the abundance, composition, and patterns of activity of the

vertebrate community there. Since most vertebrates are highly mobile, the status of the vertebrate community in riparian habitat affects the vertebrate community across the larger landscape as well. Reciprocally, the abundance and composition of the vertebrate community may affect the density and composition of the riparian tree community through herbivory. The link is hypothesized to be complex and bi-directional with proposed medium intensity, spatial scale, and temporal scale; medium predictability; and low understanding. Factors other than riparian tree community composition may affect vertebrate abundance and vice versa, and these factors have received little study in the Lower Colorado River Valley. *Applies to all life stages*.

- Temperature effects on the Fire Regime (HE): The causal node in this link is unchanged from the original WYBA conceptual ecological model, but the original CEM did not include a link for its effects on the fire regime. The original WYBA conceptual ecological model included fire management as a controlling factor in the report but used the term, fire, for the associated controlling factor in the spreadsheet and used the latter term to cover both fire management and the fire regime itself. This update separates these two distinct topics (see updates to chapter 4). Air temperatures affect the likelihood and intensity of fires. The link is hypothesized to be complex and unidirectional with proposed high intensity, spatial scale, and temporal scale; high link predictability; and high understanding. The relationships are well studied and predictable. *Applies to all life stages*.

- Temperature effects on Palm Trees (HE): The causal node in this link is unchanged from the original WYBA conceptual ecological model. The effect node is a new addition to the original CEM, addressing the taxonomic composition, tree size and density, tree condition, spatial and temporal distributions, and abundances of stands of palm trees along the Lower Colorado River Valley and its immediate tributaries. Fan and date palms do not tolerate cold weather, although California fan palms reportedly are more cold tolerant than Mexican fan palms. Water availability, rather than maximum temperature ranges, appears to limit fan palm distributions at lower elevations. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The subject has not been studied in the Lower Colorado River Valley, but publications on the cultivation of fan palms routinely note that they are not cold tolerant, with the California fan palm being slightly more tolerant than the Mexican species. *Applies to all life stages*.

- Vertebrate Community effects on Palm Trees (HE): This update incorporates the original habitat element, predator density, into the much more inclusive element, vertebrate community, and adds the new habitat element, palm trees. Fan palm propagation reportedly benefits from the consumption of its fruits by coyotes. A very high proportion of California

fan palm seeds germinate successfully after passing through a coyote digestive system. Coyotes that defecate the seeds away from the site where they ate them assist in disseminating the seeds. The link is hypothesized to be complex and bi-directional, with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The propagation of California fan palm seeds in coyote feces is reportedly anecdotally, and the subject otherwise has not been studied in the Lower Colorado River Valley. *Applies to all life stages*.

- Water Availability effects on the Matrix Community (HE): The original WYBA conceptual ecological model included both of these two habitat elements but did not address their interaction. The timing, duration, magnitude, and consistency of water availability affect the density of the matrix community and its composition (Stromberg 1998). The link is hypothesized to be complex and unidirectional with proposed high intensity, spatial scale, and temporal scale; high predictability; and low understanding. This is a key and increasingly well-understood set of relationships shaping riparian vegetation throughout the Southwest. *Applies to all life stages*.

- Water Availability effects on Palm Trees (HE): The original WYBA conceptual ecological model included the causal node, and this update adds the effect node as a new habitat element, palm trees. Palm trees require abundant, but not saturated soil water, as occurs naturally along streams and around springs and seeps, and occurs artificially in irrigated locations. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with high intensity, spatial scale, and temporal scale; high predictability; and high understanding. The interaction is well understood, both in general terms and specifically among landscapers and orchard growers, who cultivate the species. *Applies to all life stages*.

- Water Availability effects on the Vertebrate Community (HE): The causal node in this link is unchanged from the original WYBA conceptual ecological model. The effect node in this link is a new addition to the original CEM, incorporating and expanding on an single habitat element related to the vertebrate community, predator density. The timing, duration, magnitude, and consistency of water availability affect the abundance of vertebrates and the composition of the vertebrate community in and around WYBA habitat. The link is hypothesized to be complex and unidirectional with proposed high intensity, medium spatial scale, and medium temporal scale. Most vertebrates get their water by drinking rather than through the foods they consume, but many desert fauna can travel to reach water and, their distributions therefore, are not limited to surface water occurrences. The CEM proposes rating link predictability as medium because other factors also may affect vertebrate abundance, and

link understanding as low because there is little information on the factors affecting vertebrate abundance studied along the Lower Colorado River Valley. *Applies to all life stages*.

NEW LINKS WITH HABITAT ELEMENTS AS CAUSAL AGENTS THAT AFFECT CRITICAL ACTIVITIES OR PROCESSES

- Anthropogenic Disturbance effects on Foraging (CAP): The original WYBA conceptual ecological model included both nodes but did not address their interaction. Anthropogenic disturbance, such as farming, recreational use, and forestry, may impact foraging activity in WYBA. The link is hypothesized to be negative with no (or unknown) threshold and unidirectional with low intensity and unknown spatial and temporal scales. Other factors, such as food availability and the matrix community, affect foraging. Link predictability and understanding are low: While understood in principle, there are no data on the subject in the LCR. *Applies to the juvenile and adult life stages*.

- Anthropogenic Disturbance effects on Maternal Care (CAP): The causal node in this link is unchanged from the original WYBA conceptual ecological model. The effect node in this link replaces the original critical biological activity, parent roost attendance. The original CEM also did not include a link representing the interaction between these two nodes during the adult life stage. Maternal care is a critical biological activity or process for WYBA adults in this update but a habitat element for WYBA pups. Anthropogenic disturbance may impact roost attendance in WYBA. Active work in habitat where WYBA are roosting may adversely affect roosting individuals and could potentially disrupt reproduction (e.g., tending of young during early development phases) (Dudek and ICF International 2012). The link is hypothesized to be negative with no (or unknown) threshold and unidirectional with proposed medium intensity and unknown spatial and temporal scales. The literature suggests this could be a medium to strong effect, but there are no data on its possible spatial or temporal occurrence in the Lower Colorado River Valley or elsewhere in the WYBA range. Link predictability correspondingly is unknown and link understanding low. *Applies only to the adult life stage*.

- Anthropogenic Disturbance effects on Mechanical Stress (CAP): The causal and effect nodes in this link are unchanged from the original WYBA conceptual ecological model, but the original CEM did not address their interactions. Encounters with artificial wind turbulence and capture and handling during monitoring and research can result in mechanical stress to bats unless precautions are taken to avoid or

minimize harmful encounters. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Anthropogenic Disturbance effects on Roosting (CAP): The causal node in this link is unchanged from the original WYBA conceptual ecological model. The effect node in this link replaces the original critical biological activity, roost site selection. The original CEM also did not include a link representing the interaction between these two nodes during the juvenile life stage. This relationship is posited based on evidence that active work in the habitat where WYBA are roosting may disturb roosting individuals (Dudek and ICF International 2012). One possible response to such disturbance would be to move to another roosting location. On the other hand, years of field experience have not shown that human activity, at least during the daytime, around roosting WYBA disturb them and cause them to flee. The link is hypothesized to be negative with no (or unknown) threshold and unidirectional with low intensity, spatial scale, and temporal scale. The link operates on the scale of the patch and the roost site, and other factors affect roost site selection. Anthropogenic disturbance would likely be short term, except in areas with agricultural activities near roost sites. The link has low predictability and low understanding because of the lack of information available on the prevalence of human disturbance near WYBA roost sites within the LCR. *New link applies only to the juvenile life stage (link already included in the original CEM for the adult life stage)*.

- Arthropod Community effects on Foraging (CAP): The causal node is a new addition to the original WYBA conceptual ecological model, replacing and expanding on the original habitat element, food availability (see updates to chapter 4). The effect node is unchanged from the original CEM. The species of arthropods present at night around WYBA roosting sites, and their abundances, necessarily must affect WYBA foraging success. The link is hypothesized to be complex and unidirectional: A greater abundance of nocturnal, flying arthropods should result in greater foraging success, but only if the arthropods are palatable to and nutritious for WYBA juveniles or adults. The link is proposed to have high intensity, spatial scale, and temporal scale; medium predictability; and low understanding. Other factors than arthropod abundance and species composition also may affect WYBA foraging activity. Further, while this relationship is understood in principle, there are no data on the subject in the Lower Colorado River Valley. *Applies only to the juvenile and adult life stages*.

- Arthropod Community effects on Inter-Site Movement (CAP): The causal node is a new addition to the original WYBA conceptual ecological model, replacing and expanding on the original habitat element, food availability (see updates to chapter 4). The effect node also is a new addition to the original CEM (see updates to chapter 3). The possible causes of WYBA adult (and presumably also juvenile) movement among sites into, out of, and within the Lower Colorado River Valley are poorly understood. Hypotheses include the strong preference of WYBA to roost in trees (fan palms) that do not necessarily occur in or are even particularly close to the habitat settings in which they prefer to forage; changes in roosting habitat quality following, for example, a fire; changes in the availability of prey associated with the maturation of created cottonwood-willow woodlands along the Lower Colorado River Valley or the blooming of different plants (e.g., agave and perhaps yucca in New Mexico); use of some sites as stopovers rather than as areas of seasonal residence; and seasonal changes in temperature. Changes in the distribution of predators conceivably might also affect inter-site movement; however, the subject has not been studied along the Lower Colorado River Valley. The link is hypothesized to be complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies only to the juvenile and adult life stages*.

- Arthropod Community effects on Predation (CAP): The causal node is a new addition to the original WYBA conceptual ecological model, replacing and expanding on the original habitat element, food availability (see updates to chapter 4). The effect node is unchanged from the original CEM. Theoretically, some arthropods may prey on WYBA (see updates to chapter 3). Greater predator density and diversity presumably are associated with greater predation rates in general. There is no information on whether any arthropods in the LCR ecosystem actually do prey on WYBA in any life stage. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Arthropod Community effects on Roosting (CAP): The causal node is a new addition to the original WYBA conceptual ecological model, replacing and expanding on the original habitat element, food availability (see updates to chapter 4). The effect node in this link replaces the original critical biological activity, roost site selection. The original CEM also did not include a link representing the interaction between food availability and roost site selection in the juvenile life stage. Adult and presumably also juvenile WYBA may select a roost site that is close to areas with higher food availability. The link is hypothesized to be positive

with no (or unknown) threshold and unidirectional with proposed medium intensity, spatial scale, and temporal scale; medium predictability; and medium understanding. The possible interaction has not been studied for WYBA anywhere, and other factors affect roost site selection. Selection of roost sites likely occurs at the patch scale. Factors in addition to food availability likely also affect roost site selection, particularly factors related to the vegetation, but the effects of food availability have not been studied. *Applies only to the juvenile and adult life stages*.

- Chemical Contaminants effects on Chemical Stress (CAP): The original WYBA conceptual ecological model did not propose a separate habitat element for chemical contaminants. However, the original WYBA conceptual ecological model did note that WYBA are vulnerable to chemical stress (see updates to chapter 3) and identified some possible sources of contaminants that could result in such stress. This update adds chemical contaminants as a new habitat element so that the CEM better identifies the causal chains that could result in chemical stress to WYBA in any life stage (see updates to chapter 4). The effect node is unchanged from the original CEM. Chemical contaminants are often hypothesized to be causes of harm to bats, although the subject has not been studied specifically for WYBA or for the LCR ecoregion or adjacent regions. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

- Chemical Contaminants effects on Inter-Site Movement (CAP): The original WYBA conceptual ecological model did not propose a separate habitat element for chemical contaminants. However, the original CEM did note that WYBA are vulnerable to chemical stress (see updates to chapter 3) and identified some possible sources of contaminants that could result in such stress. The possible causes of WYBA adult (and presumably also juvenile) movement among sites into, out of, and within the Lower Colorado River Valley are poorly understood. Hypotheses include the strong preference of WYBA to roost in trees (fan palms) that do not necessarily occur in or are even particularly close to the habitat settings in which they prefer to forage, changes in roosting habitat quality following, for example, a fire; changes in the availability of prey associated with the maturation of created cottonwood-willow woodlands along the Lower Colorado River Valley or the blooming of different plants (e.g., agave and perhaps yucca in New Mexico); use of some sites as stopovers rather than as areas of seasonal residence; and seasonal changes in temperature. Changes in the distribution of predators conceivably might also affect inter-site movement. This link further hypothesizes that WYBA may also move to a different site to remove themselves from localities where they have encountered noxious chemicals in order to

avoid chemical stress. The subject has not been studied along the Lower Colorado River Valley. The link is hypothesized to complex and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to the juvenile and adult life stages*.

- Fire Regime effects on Thermal Stress (CAP): The original WYBA conceptual ecological model included fire management as a controlling factor in the report but used the term, fire, for the associated controlling factor in the spreadsheet and used the latter term to cover both fire management and the fire regime itself. This update separates these two distinct topics (see updates to chapter 4). The effect node is unchanged from the original CEM. Even if not directly harmed by fire and smoke, WYBA presumably could be harmed simply through exposure to the high temperatures associated with fires. The frequency and severity of fires, therefore, could affect the frequency and severity of thermal stress in WYBA. The subject has not been studied. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

- Litter Size effects on Competition (CAP): The original WYBA conceptual ecological model included the number of pups as a habitat element; this update renames this habitat element as litter size. This update also adds competition as a critical biological activity or process. Litter size affects the intensity of competition WYBA pups experience for food and other aspects of maternal care. The larger the liter, presumably the greater the intensity of such competition. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with proposed unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. Larger litter sizes should entail greater competition, in principle, but there are no data on the intensity of this relationship among WYBA anywhere. *Applies only to the pup life stage*.

- Matrix Community effects on Roosting (CAP): The causal node is unchanged from the original WYBA conceptual ecological model. The effect node in this link replaces the original critical biological activity, roost site selection. The original CEM also did not include a link representing the interaction between these two nodes during the juvenile life stage. Theoretically, the matrix community around WYBA roosting sites or between roosting and foraging sites could affect roost site selection or persistence of use by WYBA juveniles or adults; however, the literature presents no evidence of such interaction. WYBA cross a wide variety of landscape conditions to reach foraging areas from roost sites (and vice versa) and do not appear to avoid roost sites in areas with

highly altered matrix conditions (e.g., do not avoid urban or otherwise residential areas or orchards). The link is hypothesized to be complex and unidirectional with proposed low intensity and unknown spatial and temporal scales; low predictability; and low understanding. *Applies only to the juvenile life stage (link already included in the original CEM for the adult life stage)*.

- Monitoring, Capture, Handling effects on Mechanical Stress (CAP): The causal node in this link is a new addition to the original WYBA conceptual ecological model (see updates to chapter 4). The effect node is unchanged from the original CEM. Capture and handling during monitoring and research potentially can cause mechanical stress to WYBA. Pups are rarely captured or handled, but for later life stages, LCR MSCP and partner field protocols explicitly recognize and address needs to minimize stress and harm to bats captured in mist nets and subsequently handled for measurement, collection of tissue samples, and/or attachment of radio tracking devices, if any (see updates to chapter 4). The link is hypothesized to be positive with no (or unknown) threshold and unidirectional. In principle, the greater the frequency and intensity of capture and handling of WYBA during monitoring or research, the greater the potential for mechanical stress. Field protocols are designed to minimize any such stress (Brown 2006; Hill 2018). The link has unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. LCR MSCP and partner field protocols are designed to minimize the incidence or severity of mechanical stress during monitoring and handling; however, no data are available on the success of such efforts. On the other hand, the field protocols for minimizing the incidence and severity of mechanical stress during monitoring and handling were developed through years of experience and testing not only with WYBA but with numerous bat species across the Western United States, suggesting that they are effective and well understood. *Applies to all life stages*.

- Palm Trees effects on Inter-Site Movement (CAP): The causal node is a new addition to the original WYBA conceptual ecological model, addressing the taxonomic composition, tree size and density, tree condition, spatial and temporal distributions, and abundances of stands of palm trees along the Lower Colorado River Valley and its immediate tributaries. The effect node also is a new addition to the original CEM. The possible causes of WYBA adult (and presumably also juvenile) movement among sites into, out of, and within the Lower Colorado River Valley are poorly understood. Hypotheses include the strong preference of WYBA to roost in trees (fan palms) that do not necessarily occur in or even particularly close to the habitat settings in which they prefer to forage; changes in roosting habitat quality following, for example, a fire; changes in the availability of prey associated with the maturation of

created cottonwood-willow woodlands along the Lower Colorado River Valley or the blooming of different plants (e.g., agave and perhaps yucca in New Mexico); use of some sites as stopovers rather than as areas of seasonal residence; and seasonal changes in temperature. Changes in the distribution of predators conceivably might also affect inter-site movement, as may encounters with noxious chemical contaminants. However, the subject has not been studied along the Lower Colorado River Valley. The link is hypothesized to be complex and unidirectional with unknown intensity and spatial and temporal scales; unknown predictability; and low understanding. *Applies to the juvenile and adult life stages*.

- Palm Trees effects on Predation (CAP): The causal node is a new addition to the original WYBA conceptual ecological model, addressing the taxonomic composition, tree size and density, tree condition, spatial and temporal distributions, and abundances of stands of palm trees along the Lower Colorado River Valley and its immediate tributaries. The effect node is unchanged from the original CEM. The frond skirt on fan palms is presumed to provide dense cover for roosting WYBA, and presumably also can provide cover for predators foraging for WYBA pups, and presumably the amount of cover varies with the height, width, and density of the skirt.; however, these relationships have not been studied. The link is hypothesized to be complex and bi-directional with unknown intensity and spatial and temporal scales; unknown predictability; and low understanding. *Applies to the juvenile and adult life stages*.

- Palm Trees effects on Roosting (CAP): The causal node is a new addition to the original WYBA conceptual ecological model, addressing the taxonomic composition, tree size and density, tree condition, spatial and temporal distributions, and abundances of stands of palm trees along the Lower Colorado River Valley and its immediate tributaries. The effect node in this link replaces the original critical biological activity, roost site selection. WYBA juveniles and adults in the LCR and Bill Williams River valleys overwhelmingly roost in the frond skirts of fan palms, with a small proportion roosting in date palm frond masses. Elsewhere across its range, WYBA also roost in mature cottonwood, sycamore, hackberry, and giant dagger yucca. Further, WYBA roost in the tallest palm trees available at any given site, as measured by total height and the height of the live crown, and in trees with the highest percentage of dead crown. WYBA seek out sites for roosting regardless of their surroundings, from within wildlife refuges to within orchards and urban and residential areas at distances up to at least 6 km from where they forage. Ortiz and Barrows (2014) also found for palm oases in southern California that WYBA statistically preferred oases located at higher elevations, with greater numbers of fan palms greater than 10 feet tall with moderate to high percentages of frond skirt length as a percentage of total palm height,

avoided palms from which fire had eliminated large portions of the frond skirt or palms with little or no new growth and avoided oases where owls were present. The link is hypothesized to be complex and unidirectional with high intensity, spatial scale, and temporal scale; high predictability; and medium understanding. Investigations along the LCR and Bill Williams Rivers and in southern California palm oases have identified some statistical relationships, but the sample sizes are still small. Radio tracking data are limited to 2–3 dozen tracked individuals and have not yet been fully reported. *Applies to the juvenile and adult life stages*.

- Palm Trees effects on Thermal Stress (CAP): The causal node is a new addition to the original WYBA conceptual ecological model, addressing the taxonomic composition, tree size and density, tree condition, spatial and temporal distributions, and abundances of stands of palm trees along the Lower Colorado River Valley and its immediate tributaries. The effect node is unchanged from the original CEM. The frond skirt on fan palms is assumed to provide some thermal insulation for WYBA, presumably including pups. Further, the insulation value presumably varies with the volume and density of the skirt. The link is hypothesized to be complex and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. The relationship is proposed on basic principles but has not been studied for the LCR. *Applies to all life stages*.

- Riparian Tree Community effects on Foraging (CAP): The causal node in this link is a new addition to the original WYBA conceptual ecological model that incorporates and expands on several originally separate habitat elements focused on the tree community (see updates to chapter 4). The effect node in this link is unchanged from the original CEM. Several aspects of tree community composition and structure may affect WYBA foraging behavior. WYBA forage significantly more in riparian habitat—and more particularly in cottonwood-willow woodland patches compared to marsh, riparian shrubland, mesquite bosque, saltcedar, or agricultural habitat—and over water than in or over any other type of habitat (Broderick 2012a, 2012b; Calvert 2017; LCR MSCP 2016; Mixan et al. 2015; NatureServe 2019a; Vizcarra et al. 2010) even if that target habitat lies some distance from suitable roosting sites. Broderick (2012b) further notes that WYBA foraged far more in more mature cottonwood patches at the PVER and CVCA habitat creation sites compared to sapling cottonwood patches, although the more mature patches at that time were only 2–3 years old and not fully mature, and therefore were termed "intermediate" cottonwood habitat. Additionally, Broderick (2012b) found evidence that a few more specific characteristics of the preferred cottonwood-willow habitat also may affect WYBA activity in this setting. Specifically, monitoring data from the PVER and CVCA showed statistically significant positive relationships between WYBA activity (call minutes detected during acoustic monitoring) and the length of

cottonwood-willow patch edge, distance from a point of activity to the edge of the patch in which the activity occurred, and the number of layers in the tree canopy. At the PVER, activity was also greater the closer a patch was located relative to the Colorado River. The link is hypothesized to be complex and unidirectional with high intensity, medium spatial scale, and high temporal scale; medium predictability; and medium understanding. Other factors, such as food availability, affect foraging, and the information on WYBA foraging is relatively recent and primarily concerns adults. Here, the CEM assumes that juveniles follow a similar pattern, but there are not sufficient data to test this assumption. *Applies only to the juvenile and adult life stages*.

- Riparian Tree Community effects on Inter-Site Movement (CAP): The causal node in this link is a new addition to the original WYBA conceptual ecological model that incorporates and expands on several originally separate habitat elements focused on the tree community (see updates to chapter 4). The effect node in this link is a new addition to the original CEM. The possible causes of WYBA adult (and presumably also juvenile) movement among sites into, out of, and within the Lower Colorado River Valley are poorly understood. Hypotheses include the strong preference of WYBA to roost in trees (fan palms) that do not necessarily occur in or are even particularly close to the habitat settings in which they prefer to forage; changes in roosting habitat quality following, for example, a fire; changes in the availability of prey associated with the maturation of created cottonwood-willow woodlands along the Lower Colorado River Valley or the blooming of different plants (e.g., agave and perhaps yucca in New Mexico); use of some sites as stopovers rather than as areas of seasonal residence; and seasonal changes in temperature. Changes in the distribution of predators conceivably might also affect inter-site movement, as may encounters with noxious chemical contaminants. The subject has not been studied along the Lower Colorado River Valley. The link is hypothesized to be complex and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Riparian Tree Community effects on Roosting (CAP): The causal node in this link is a new addition to the original WYBA conceptual ecological model that incorporates and expands on several originally separate habitat elements focused on the tree community (see updates to chapter 4). Elsewhere across its range, WYBA juveniles and adults may roost in mature cottonwood, sycamore, hackberry, and crown dagger yucca. However, in the LCR and Bill Williams River valleys, they overwhelmingly roost in the frond skirts of fan palms, with a small proportion roosting in date palm frond masses. The LCR and Bill Williams River valleys provide opportunities for WYBA to roost in riparian hardwoods, but none of the small number of individuals tracked to date has done so. The distance of riparian tree stands—where WYBA

juveniles and adults may forage—from their preferred roosting sites does not appear to affect roosting site selection. The link is hypothesized to be complex and unidirectional with low intensity, spatial scale, and temporal scale; unknown predictability; and medium understanding. The sample size for radio-tracked WYBA is too small to determine what factors cause WYBA to avoid roosting in riparian trees or in entire riparian tree stands unless fan palms are present. *Applies only to the juvenile and adult life stages*.

- Temperature effects on Inter-Site Movement (CAP): The causal node is unchanged from the original WYBA conceptual ecological model. The effect node is a new addition to the original CEM (see updates to chapter 3). The possible causes of WYBA adult (and presumably also juvenile) movement among sites into, out of, and within the Lower Colorado River Valley are poorly understood. Hypotheses include the strong preference of WYBA to roost in trees (fan palms) that do not necessarily occur in or are even particularly close to the habitat settings in which they prefer to forage; changes in roosting habitat quality following, for example, a fire; changes in the availability of prey associated with the maturation of created cottonwood-willow woodlands along the Lower Colorado River Valley or the blooming of different plants (e.g., agave and perhaps yucca in New Mexico); use of some sites as stopovers rather than as areas of seasonal residence; and seasonal changes in temperature. Changes in the distribution of predators conceivably might also affect inter-site movement, as may encounters with noxious chemicals; however, the subject has not been studied along the Lower Colorado River Valley. The link is hypothesized to be complex and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Temperature effects on Roosting (CAP): The causal node is unchanged from the original. The effect node in this link replaces the original critical biological activity, roost site selection. The original WYBA conceptual ecological model also did not include a link representing the interaction between these two nodes during the juvenile life stage. WYBA juveniles may seek roosting site locations that provide safe temperature ranges. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with proposed medium intensity, spatial scale, and temporal scale. While the effect of temperature on either juvenile or adult roosting may be important on a regional scale across the overall geographic range of WYBA, there may not be a wide enough range of variation in thermal conditions along the Lower Colorado River Valley to affect roosting site selection other than as affected by vegetation. The link is proposed to have low predictability and understanding. While understood in principle, no analyses of the subject have been carried out with data from the LCR. *Applies only to the juvenile life stage (link already included in the original CEM for the adult life stage)*.

- Vertebrate Community effects on Competition (CAP): The causal node in this link is a new addition to the original WYBA conceptual ecological model, incorporating and expanding on an single habitat element in the original CEM related to the vertebrate community, predator density. The effect node is a completely new addition to the CEM (see updates to chapter 3). Theoretically, other bat species, as well as nocturnal insectivorous birds, may compete with WYBA for food items in the Lower Colorado River Valley. The subject has not been studied, and WYBA may be sufficiently generalized in their prey selection that competition is kept low. The link is hypothesized to be complex and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Vertebrate Community effects on Inter-Site Movement (CAP): The causal node in this link is a new addition to the original WYBA conceptual ecological model, incorporating and expanding on the original habitat element, predator density. The effect node is a new addition to the original CEM (see updates to chapter 3). The possible causes of WYBA adult (and presumably also juvenile) movement among sites into, out of, and within the Lower Colorado River Valley are poorly understood. Hypotheses include the strong preference of WYBA to roost in trees (fan palms) that do not necessarily occur in or are even particularly close to the habitat settings in which they prefer to forage; changes in roosting habitat quality following, for example, a fire; changes in the availability of prey associated with the maturation of created cottonwood-willow woodlands along the Lower Colorado River Valley or the blooming of different plants (e.g., agave and perhaps yucca in New Mexico); use of some sites as stopovers rather than as areas of seasonal residence; and seasonal changes in temperature. Changes in the distribution of predators conceivably might also affect inter-site movement, as may encounters with noxious chemicals, however, the subject has not been studied along the Lower Colorado River Valley. The link is hypothesized to be complex and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Vertebrate Community effects on Roosting (CAP): The causal node in this link is a new addition to the original WYBA conceptual ecological model, incorporating and expanding on the original habitat element, predator density. The effect node in this link replaces the original critical biological activity, roost site selection. Further, the original CEM did not include a link representing the interaction between predator density and roost site selection during the juvenile life stage. Conceivably, WYBA may select roost sites that have fewer threats from predators. 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). Ortiz and Barrows (2014) found that WYBA in southern California avoided palm oases where owls were present. The link is hypothesized to be complex and unidirectional. Conceivably, the greater the abundance and species diversity of vertebrates present in and around potential roosting sites, the greater the effect on WYBA roosting behaviors, but along several dimensions of behavior. The link is hypothesized to have unknown intensity and spatial and temporal scales, unknown predictability, and low understanding. Factors other than predator density affect roost site selection, and nothing is known about predation of WYBA on the LCR. *Applies only to the juvenile life stage; the CEM already included this link for the adult life stage*.

- Water Availability effects on Chemical Stress (CAP): The causal and effect nodes are unchanged from the original WYBA conceptual ecological model, but the original CEM did not posit a link between the two nodes. The link pertains only to WYBA juveniles and adults because WYBA pups obtain all of their water from their mothers by nursing (see chapter 4, "Maternal Care"). Lack of adequate hydration results in chemical stress in all vertebrates; however, WYBA select roost sites in part for the availability of water (see link from water availability to roosting) and conceivably may move to other sites if water availability is not adequate at a site. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with low intensity, spatial scale, and temporal scale; low predictability; and medium understanding. The relationship is understood in principle, and some data are available. *Applies only to the juvenile and adult life stages*.

- Water Availability effects on Roosting (CAP): The causal node in this link is unchanged from the original WYBA conceptual ecological model. The effect node in this link replaces the original critical biological activity, roost site selection. The original CEM did not include a link representing the interaction between water availability and roost site selection during the juvenile life stage. The proximity of open water and wetlands to appropriate roost habitat may be an important landscape-scale factor for WYBA protection; however, palm trees require surface water or a very shallow water table and, therefore, almost always occur close to surface water. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with high intensity, low spatial scale, and medium temporal scale. Water availability is one of several factors that affects roost site selection. It operates at the local scale and over the period of time that the roost is active. Link predictability and understanding are low: The subject has not been studied for WYBA in the Lower Colorado River Valley, although Ortiz and Barrows (2014) did not find a strong association between oasis occupancy and proximity to open water. *Applies only to the juvenile life stage; the CEM already included this link for the adult life stage*.

DELETED LINKS WITH HABITAT ELEMENTS AS CAUSAL AGENTS

- Effects of Anthropogenic Disturbance on Parent Roost Attendance (HE) for the pup life stage. This update renames the original habitat element for the pup life stage, parent roost attendance, to maternal care, and addresses all drivers of maternal care under the CEM for the adult life stage. *Applies only to the pup life stage*.

- Effects of Canopy Cover on Food Availability (HE): This update replaces the original habitat element, canopy cover, with the more inclusive habitat element, riparian tree community, and replaces the original habitat element, food availability, with the more inclusive habitat element, arthropod community. *Applies only to the juvenile and adult life stages*.

- Effects of Canopy Cover on Temperature (HE): This update replaces the original habitat element, canopy cover, with the more inclusive habitat element, tree community. *Applies to all life stages*.

- Effects of the Food Availability on Parent Roost Attendance (HE) for the pup life stage: This update incorporates the original habitat element, food availability, into arthropod community; renames the original habitat element for the pup life stage, parent roost attendance, to maternal care; and addresses all drivers of maternal care under the CEM for the adult life stage. *Applies only to the pup life stage*.

- Effects of Pesticide Application on Food Availability (HE): This update treats pesticide application as a potential aspect of habitat management and surrounding land use that can result in the introduction of chemical contaminants. Further, this update treats food availability as an effect of the abundance and composition of the arthropod community. This update then recognizes that chemical contaminants may affect the arthropod community. *Applies to all life stages*.

- Effects of Tree Species Composition on Canopy Cover (HE): This update incorporates both of these nodes into a single new habitat element, riparian tree community. *Applies to all life stages*.

- Effects of Canopy Cover on Roost Site Selection (CAP): This update replaces the original habitat element, canopy cover, with the more inclusive habitat element, riparian tree community, and replaces the original critical biological activity, roost site selection, with the more inclusive critical biological activity or process, roosting. *Applies only to the juvenile and adult life stages*.

- Effects of Canopy Cover on Thermal Stress (CAP): This update replaces the original habitat element, canopy cover, with the more inclusive habitat element, riparian tree community, and recognizes that the causal chain implied in the original WYBA conceptual ecological model involves two steps, involving the effects of vegetation on temperature, and the effects of temperature on thermal stress. This update breaks out these separate steps. *Applies to all life stages*.

- Effects of the Matrix Community on Anthropogenic Disturbance (CAP): This update replaces this original link with a new one recognizing the effects of surrounding land use on anthropogenic disturbance in order to capture the full causal chain. *Applies to all life stages*.

- Effects of the Matrix Community on Chemical Stress (CAP): This update replaces this original link with a sequence of links from surrounding land use to chemical contaminants to chemical stress in order to capture the full causal chain. *Applies to all life stages*.

- Effects of the Matrix Community on Mechanical Stress (CAP): This update replaces this original link with a sequence of links from wind energy development to anthropogenic disturbance to mechanical stress in order to capture the full causal chain. *Applies only to the juvenile and adult life stages*.

- Effects of Number of Pups on Eating (CAP): This update replaces the original habitat element, number of pups, with litter size, and replaces the original critical biological activity for pups, eating, with feeding. More importantly, it replaces this original link with a link recognizing the effects of litter size on competition among pups. *Applies only to the pup life stage*.

- Effects of Number of Pups on Parent roost attendance (CAP): This update replaces the original habitat element, number of pups, with litter size, and replaces the original critical biological activity, parent roost attendance, with maternal care. More importantly, this update recognizes that litter size affects competition among pups, not maternal care per se. Further, this update does not recognize any drivers of maternal care in the pup life stage, only in the adult life stage. *Applies only to the pup life stage*.

- Effects of Patch Size on Foraging (CAP): This update replaces the original habitat element, patch size, with the more inclusive habitat element, riparian tree community. *Applies only to the juvenile and adult life stages*.

- Effects of Patch Size on Roost Site Selection (CAP): This update replaces the original habitat element, patch size, with the more inclusive habitat element, the riparian tree community, and replaces the original critical biological activity, roost site selection, with the more inclusive, roosting. *Applies only to the juvenile and adult life stages*.

- Effects of Predator Density on Foraging (CAP): This update replaces the original habitat element, predator density, with the more inclusive habitat element, vertebrate community, and recognizes that the relevant causal relationship here is the effect of predation on foraging. *Applies only to the juvenile and adult life stages*.

- Effects of Tree Species Composition on Foraging (CAP): This update replaces the original habitat element, tree species composition, with the more inclusive, riparian tree community. *Applies only to the juvenile and adult life stages*.

- Effects of Tree Species Composition on Roost Site Selection (CAP): This update replaces the original habitat element, tree species composition, with the more inclusive, riparian tree community, and replaces the original critical biological activity, roost site selection, with the more inclusive, roosting. *Applies only to the juvenile and adult life stages*.

UPDATED LINKS WITH HABITAT ELEMENTS AS CAUSAL AGENTS

- Anthropogenic Disturbance effects on Roosting (CAP): The causal node in this link is unchanged from the original WYBA conceptual ecological model. The effect node in this link replaces the original critical biological activity, roost site selection. (The original CEM also did not include a link representing the interaction between these two nodes during the juvenile life stage—see new link above). This update revises the reasoning and ratings for the link (for the adult life stage) as follows: This relationship is posited based on evidence that active work in the habitat where WYBA are roosting may disturb roosting individuals (Dudek and ICF International 2012). One possible response to such disturbance would be to move to another roosting location. On the other hand, years of field experience have not shown that human activity, at least during the daytime, around roosting WYBA disturb them and cause them to flee. The link is hypothesized to be negative with no (or unknown) threshold and unidirectional with low intensity, spatial scale, and temporal scale. The link operates on the scale of the patch and the roost site, and other factors affect roost site selection. Anthropogenic disturbance would likely be short term, except in areas with agricultural activities near roost sites.

The link has low predictability and low understanding because of the lack of information available on the prevalence of human disturbance near WYBA roost sites within the LCR. *Update applies only to the adult life stage (see new link for the juvenile life stage)*.

- Infectious Agents effects on Disease (CAP): The causal node in this link is updated and simplified from the original critical biological activity or process, genetic diversity and infectious agents. The effect node is unchanged from the original WYBA conceptual ecological model. Infectious agents cause disease; the greater the diversity of infectious agents present in the environment to which WYBA may be exposed, the greater the likelihood of infection. The definition of disease in the original CEM is updated to note that WYBA may host the rabies virus (Faria et al. 2013; Kuzmin et al. 2012; Stuchin et al. 2018), including specifically WYBA in Arizona (Kuzmin et al. 2012). However, the literature does not document the incidence of illness in WYBA hosts due to a rabies infection. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. Disease is not well studied among WYBA. *Applies to all life stages*.

- Litter Size effects on Foraging (CAP): The causal link in this relationship renames the original habitat element, number of pups. The effect link is unchanged. The reasoning and ratings are updated as follows: Litter size affects the amount of time the mother must spend foraging to provision not only herself but her litter prior to their weaning. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional: The larger the number of pups, the more demand is placed on the mother to provision the young prior to weaning, on top of provisioning for herself. The link is hypothesized to have high intensity and spatial scale, and low temporal scale: Pressure on female WYBA to provision for their pre-volant young can be intense, but it occurs only during the time when the pups depend on the mother for food. Predictability is rated medium: The magnitude likely depends on resource levels. Understanding is rated low: Little research has been done regarding provisioning rates of WYBA. *Applies only to the adult life stage*.

- Litter Size effects on Maternal Care (CAP): The causal link in this relationship renames the original habitat element, number of pups. The effect link in this relationship renames the original critical biological activity, parent roost attendance. The reasoning for the link is updated as follows: Litter size affects the amount of time and effort the mother must spend nursing, grooming, and providing thermal and other types of protection to her litter. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional: The larger the number of pups,

the more demand (on time and energy) is placed on the mother to nurse, groom, and provide thermal and other types of protection to her litter. The link is hypothesized to have high intensity and spatial scale and low temporal scale: Pressure on female WYBA to care for their pups can be intense, but it occurs only until the pups are weaned and young are dependent on the mother for food. Predictability is rated medium: The magnitude likely depends on resource levels. Understanding is rated low: Little research has been done regarding provisioning rates of WYBA. *Applies only to the adult life stage*.

- Maternal Care effects on Feeding (CAP): This link pertains only to the pup life stage. The name of the causal node in this relationship replaces the original term, parent roost attendance. The literature mentions only maternal care of pups, not paternal care. As in the original WYBA conceptual ecological model, the causal node functions as a habitat element for pups but as a critical biological activity or process for adults. The node in question here concerns feeding for the pup life stage. The name of the effect node in this relationship replaces the term, eating, in the original CEM. The reasoning for the link also is updated as follows: Prior to weaning, WYBA pups obtain their food exclusively in the form of milk from their mothers. Prior to weaning, the pups cannot feed in the absence of maternal care. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional: Maternal care includes feeding the pups. Higher quality maternal care would include greater feeding success for pups. The link is proposed to have high intensity, spatial scale, and temporal scale; high predictability; and high understanding. Pups completely rely on their mother for food. This is a basic aspect of WYBA biology. *Applies only to the pup life stage*.

- Maternal Care effects on Thermal Stress (CAP): This link pertains only to the pup life stage. The name of the causal node in this relationship replaces the original term, parent roost attendance. The literature mentions only maternal care of pups, not paternal care. As in the original WYBA conceptual ecological model, the causal node functions as a habitat element for pups but as a critical biological activity or process for adults. The node in question here concerns feeding for the pup life stage. The effect node in this relationship is unchanged from the original CEM. The reasoning for the link also is updated as follows: Pups are born completely hairless and thus rely on the mother to maintain their body temperature initially. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional: Maternal care includes providing thermal protection for the pups. Higher quality maternal care would entail greater success in thermal protection. The link is proposed to have high intensity, spatial scale, and temporal scale; high predictability; and high understanding. Maternal care is crucial to temperature regulation for the very young pups, but that need tapers down as the pups grow in a matter of weeks. This is a basic feature of WYBA biology. *Applies only to the pup life stage*.

- Matrix Community effects on Foraging (CAP): The causal and effect nodes are unchanged from the original WYBA conceptual ecological model, but the reasoning is updated as follows: WYBA may prefer to forage in open areas without taller trees. Consequently, the spatial structure of the matrix community may affect foraging behaviors and rates of success. The link is hypothesized to be complex and unidirectional with medium intensity, spatial scale, and temporal scale. Matrix communities, by definition, operate at scales larger than an individual patch. Any effect of a change in the matrix community affecting WYBA foraging behaviors would likely persist over a medium time scale. Link predictability is unknown and understanding low: The subject has not been studied systematically. *Applies only to the juvenile and adult life stages*.

- Matrix Community effects on Roosting (CAP): The causal node is unchanged from the original WYBA conceptual ecological model. The effect node in this link replaces the original critical biological activity, roost site selection. The original CEM did not include a link representing the interaction between these two nodes during the juvenile life stage but did do so for the adult life stage. The link reasoning for the adult life stage is updated as follows: Theoretically, the matrix community around WYBA roosting sites or between roosting and foraging sites could affect roost site selection or persistence of use. However, the literature presents no evidence of such interaction. WYBA cross a wide variety of landscape conditions to reach foraging areas from roost sites (and vice versa) and do not appear to avoid roost sites in areas with highly altered matrix conditions (e.g., do not avoid urban or otherwise residential areas or orchards). The link is hypothesized to be complex and unidirectional with proposed low intensity and unknown spatial and temporal scales. The link is proposed to have low predictability and low understanding. *Applies only to the adult life stage*.

- Effects of the Riparian Tree Community on Predation (CAP): This update replaces the original habitat element, patch size, with the more inclusive, riparian tree community, while retaining the recognition that the size and shape of riparian woodland patches may affect predation rates because of its effects on the proportion of edge to area. A larger patch size should have fewer edge predators, hence less risk of predation for WYBA while foraging. However, the fan palms where WYBA roost may be located away from the riparian vegetation patches where they forage, and their travel routes between the two types of habitat may still expose them to edge predators as they fly between the two. *Applies only to the juvenile and adult life stages*.

- Temperature effects on Roosting (CAP): The causal node is unchanged from the original WYBA conceptual ecological model. The effect node in this link replaces the original critical biological activity, roost site selection. The original CEM did not include a link representing the interaction between these two nodes during the juvenile life stage but did do so for the adult life stage. The link reasoning for the adult life stage is updated as follows: WYBA adult females may seek roosting site locations that provide safe temperature ranges for rearing pups and also for simply survival outside the birthing and rearing season. High temperatures may kill pups and, therefore, affect roost site selection (Jones et al. 2009). Females across the WYBA geographic range are often reported to seek lower-elevation, and, therefore, presumably warmer, roosting sites during the birthing and rearing season. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with medium intensity and spatial scale and low temporal scale. While the effect of temperature on either juvenile or adult roosting may be important on a regional scale across the overall geographic range of WYBA, there may not be a wide enough range of variation in thermal conditions along the Lower Colorado River Valley to affect roosting site selection other than as affected by vegetation. Link predictability and understanding are rated low: While understood in principle, no analyses of the subject have been carried out with data from the LCR. *Applies only to the adult life stage)*.

- Temperature effects on Thermal Stress (CAP): The causal and effect nodes in this link are unchanged from the original WYBA conceptual ecological model. The link reasoning is updated as follows: WYBA in any life stage will experience thermal stress if exposed to excessively high or low temperatures for excessively long periods without recourse to means for reducing their exposure. The link is hypothesized to be complex and unidirectional with medium intensity and low spatial and temporal scales: The likelihood of thermal stress increases with the severity of departure from tolerable temperatures and the duration of exposure. Temperature is affected by patch and microhabitat conditions. Temperatures fluctuate often, so a given change in temperature will likely be short-lived. Predictability is medium: Juveniles and adults can move to seek more tolerable temperatures, and mothers will carry their pups with them when they do so. Other factors affect the level of thermal stress experienced by WYBA and may include humidity, clustering in roosts, maternal care for pups, and fat stores. Understanding is medium: While understood in principle, there are no data on the subject in the LCR. *Applies to all life stages*.

- Vertebrate Community effects on Predation (CAP): The causal node in this link is a new addition to the original WYBA conceptual ecological model, incorporating and expanding on an single habitat element in the original CEM related to the vertebrate community, predator density (see

updates to chapter 4). The effect node in this link is unchanged from the CEM. The reasoning and ratings for the link are updated as follows: The LCR ecosystem supports several vertebrate species that potentially prey on WYBA (see updates to chapter 3). Greater predator density and diversity presumably are associated with greater predation rates in general; however, there is no information on which vertebrates in the LCR ecosystem actually prey on WYBA in any life stage. The link is hypothesized to be complex and unidirectional with unknown intensity, high spatial scale, and high temporal scale; unknown predictability; and low understanding. There are no data on which vertebrates in the LCR ecosystem may prey on WYBA in any life stage, but there are several likely candidates, all of which would be active year round throughout the valley (see updates to chapter 3). Further, even though there are no data on which vertebrates prey on WYBA (in general or in the Lower Colorado River Valley in particular), predation by vertebrates is highly predictable based on what is known about eastern and western yellow bat ecology in general. *Applies to all life stages*.

- Vertebrate Community effects on Roosting (CAP): The causal node in this link is a new addition to the original WYBA conceptual ecological model, incorporating and expanding on an single habitat element in the original CEM related to the vertebrate community, predator density. The effect node in this link replaces the original critical biological activity, roost site selection. The CEM included a link representing the interaction between predator density and roost site selection during the adult life stage, but it did not do so for the juvenile life stage. The reasoning and ratings for the link for the adult life stage are updated as follows (see above, this chapter, "New Links with Habitat Elements as Causal Agents that Affect Critical Activities or Processes" for information on the juvenile life stage). Conceivably, WYBA may select roost sites that have fewer threats from predators. 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). Ortiz and Barrows (2014) found that WYBA in southern California avoided palm oases where owls were present. The link is hypothesized to be complex and unidirectional. Conceivably, the greater the abundance and species diversity of vertebrates present in and around potential roosting sites, the greater the effect on WYBA roosting behaviors, but along several dimensions of behavior. The link is hypothesized to have unknown intensity and spatial and temporal scales, unknown predictability, and low understanding. Factors other than predator density affect roost site selection, and nothing is known about predation of WYBA on the LCR. *Applies only to the adult life stage; this update includes a new link for the juvenile life stage*.

- Water Availability effects on the Arthropod Community (HE): The causal node in this link is unchanged from the original WYBA conceptual ecological model. The effect node in this link is a new addition to the original CEM, incorporating and expanding on a single habitat element related to the arthropod community, food availability. Link reasoning and ratings are updated as follows: The timing, duration, magnitude, and consistency of water availability affect the abundance of arthropods and the composition of the arthropod community (Hagen and Sabo 2012). The link is hypothesized to be complex and unidirectional with proposed high intensity, medium spatial scale, and low temporal scale. Areas near water likely serve as arthropod population sources, influencing insect abundance at a landscape scale (Pierson et al. 2006). However, because of the fluctuating nature of water availability in the arid southwest, the temporal effect is limited. The CEM proposes rating link predictability as medium, because other factors also may affect arthropod abundance, and link understanding as low because there is little information on the factors affecting arthropod abundance studied along the Lower Colorado River Valley. *Applies to all life stages*.

- Water Availability effects on the Riparian Tree Community (HE): The causal node in this link is unchanged from the original WYBA conceptual ecological model. The effect node in this link is a new addition to the original CEM that incorporates and expands on the several separate habitat elements focused on the tree community (see updates to chapter 4)—canopy cover, patch size, and tree species composition. Link reasons and ratings are updated to combine the effects on these three original habitat elements as well as other aspects of the riparian tree community as follows: The timing, duration, magnitude, and consistency of water availability affect the density of the tree community at WYBA habitat and its composition (Stromberg 1998). For example, groundwater declines have been linked to changes in the riparian vegetation community across the Southwestern United States with declines in cottonwood and willow species and increases in the non-native saltcedar (Stromberg 1998). The link is hypothesized to be complex and unidirectional with proposed high intensity, medium spatial scale, and high temporal scale; medium predictability; and high understanding. This is a key and increasingly well-understood set of relationships shaping riparian vegetation throughout the Southwest, but other factors such as substrate, propagule availability, elevation, and management (to name a few) can also affect riparian tree species composition and other properties of the community. *Applies to all life stages*.

- Water Availability effects on Roosting (CAP): The causal node in this link is unchanged from the original WYBA conceptual ecological model. The effect node in this link replaces the original critical biological activity, roost site selection. The original CEM did not include a link representing

the interaction between water availability and roost site selection during the juvenile life stage, but it did do so for the adult life stage. The link reasoning for the adult life stage is updated as follows: The proximity of open water and wetlands to appropriate roost habitat may be an important landscape-scale factor for WYBA protection. However, palm trees require surface water or a very shallow water table and, therefore, almost always occur close to surface water. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional, with high intensity, low spatial scale, and medium temporal scale. Water availability is one of several factors that affects roost site selection; it operates at the local scale and over the period of time that the roost is active. Link predictability and understanding are low: The subject has not been studied for WYBA in the Lower Colorado River Valley, but Ortiz and Barrows (2014) did not find a strong association between oasis occupancy and proximity to open water. *Applies only to the adult life stage*.

NEW LINKS WITH CRITICAL ACTIVITIES AND PROCESSES AS CAUSAL AGENTS

- Foraging effects on Monitoring, Capture, Handling (HE): The causal node in this proposed link is unchanged from the original WYBA conceptual ecological model. The effect node is a new addition to the original CEM (see updates to chapter 4). Bat foraging behaviors, including WYBA foraging behaviors, affect monitoring practices by dictating several aspects of monitoring protocols: The protocols explicitly recognize and address needs to: (1) minimize stress and harm to bats captured in mist nets, (2) raise mist nets at specific times of the night to ensure they capture bats not as they leave their roosts but instead later during foraging, and (3) begin acoustic recording before sunset and end it after sunrise, to ensure complete coverage of bat foraging activity. The link is hypothesized to be complex and unidirectional with medium intensity, spatial scale, and temporal scale; medium predictability; and high understanding. LCR MSCP and partner field protocols are designed specifically to address this interaction. Long experience among Reclamation and partner scientists has led to the evolved protocols in use. *Applies only to the juvenile and adult life stages*.

- Competition effects on Feeding (CAP): This link pertains only to the pup life stage. The causal node is a new addition to the original WYBA conceptual ecological model. The effect node replaces the original critical biological activity for pups, eating. Competition for maternal care (nursing) presumably can affect feeding success in WYBA pups, although

the subject has not been studied. The link is hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the pup life stage*.

- Disease effects on Feeding (CAP): This link pertains only to the pup life stage. The causal node is unchanged from the original WYBA conceptual ecological model. The effect node replaces the original critical biological activity for pups, eating. Illness presumably can affect feeding success in WYBA pups, although the subject has not been studied. The link is hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the pup life stage*.

- Foraging effects on Maternal Care (CAP): The causal node in this proposed link is unchanged from the original WYBA conceptual ecological model. The effect link replaces the original critical biological activity or process, parent roost attendance. The original CEM did not include a link between these two nodes. Maternal care is a critical biological activity or process for WYBA adults in this update but a habitat element for WYBA pups. Foraging success affects the ability of the mother to provision her young and attend the roost. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with high intensity, spatial scale, and temporal scale; medium predictability; and medium understanding. Pressure on the mother to provision young can be intense, but the effect only acts during the time when young are dependent on the mother for food. Further, other factors than food availability may affect roost attendance, and little research has been done regarding provisioning rates of WYBA. *Applies only to the adult life stage*.

- Inter-Site Movement effects on Chemical Stress (CAP): The causal node in this proposed link is a new addition to the original WYBA conceptual ecological model. The effect node is unchanged from the original CEM. If WYBA juveniles or adults change their locations for foraging or roosting in response to the presence of chemical contaminants (see link from chemical contaminants to inter-site movement), then the resulting movement will affect the occurrence and intensity of chemical stress the WYBA experience. However, the subject has not been studied along the Lower Colorado River Valley. The link is hypothesized to be complex and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Inter-Site Movement effects on Foraging (CAP): The causal node in this proposed link is a new addition to the original WYBA conceptual ecological model. The effect node is unchanged from the original CEM. If WYBA juveniles or adults change their locations for foraging or roosting in response to variation in the availability of prey (see link from arthropod community to inter-site movement), then the resulting movement will affect WYBA foraging. However, the subject has not been studied along the Lower Colorado River Valley. The link is hypothesized to be complex and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Inter-Site Movement effects on Predation (CAP): The causal node in this proposed link is a new addition to the original WYBA conceptual ecological model. The effect node is unchanged from the original CEM. If WYBA juveniles or adults change their locations for foraging or roosting in response to variation in the presence and activity of predators (see link from vertebrate community to inter-site movement), then the resulting movement will affect the occurrence and intensity of predation the WYBA experience. However, the subject has not been studied along the Lower Colorado River Valley. The link is hypothesized to be complex and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Inter-Site Movement effects on Roosting (CAP): The causal node in this proposed link is a new addition to the original WYBA conceptual ecological model. The effect node replaces and expands on the critical biological activity or process, roost site selection, in the original CEM. If WYBA juveniles or adults change their locations for roosting in response to variation in the availability of suitable roosting habitat (see link from palm trees to inter-site movement), then the resulting movement will affect WYBA roosting. However, the subject has not been studied along the Lower Colorado River Valley. The link is hypothesized to be complex and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Inter-Site Movement effects on Thermal Stress (CAP): The causal node in this proposed link is a new addition to the original WYBA conceptual ecological model. The effect node is unchanged from the original CEM. If WYBA juveniles or adults change their locations for foraging or roosting in response to the presence of unsuitable temperatures (see link from temperature to inter-site movement), then the resulting movement will affect the occurrence and intensity of thermal stress WYBA experience. However, the subject has not been studied along the Lower Colorado River Valley. The link is hypothesized to be complex and

unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Predation effects on Foraging (CAP): The causal and effect nodes in this proposed link are unchanged from the original WYBA conceptual ecological model, but the original CEM did not posit a link between the two. Conceivably, WYBA that detect prowling predators while the WYBA are foraging may seek shelter or alter their foraging behaviors to reduce the chances of becoming a meal for another species. However, the subject has not been studied in WYBA anywhere. The link is hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Predation effects on Mechanical Stress (CAP): The causal and effect nodes in this proposed link are unchanged from the original WYBA conceptual ecological model, but the original CEM did not posit a link between the two. Unsuccessful predator attacks can cause injury to the escaped prey if the predator makes contact with but fails to capture its prey, and, presumably, the likelihood of such interactions increases with the intensity of predator pressure. However, there are no data available on the subject for WYBA in the Lower Colorado River Valley or elsewhere. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

- Breeding effects on Adult Fertility (LSO): The causal node in this proposed link is a new addition to the original WYBA conceptual ecological model. The effect node replaces the original life-stage outcome, reproduction. The rate of participation of WYBA adults in breeding and their breeding success (fecundity), together with adult survival, determine WYBA adult fertility. However, there are no data available on the subject for WYBA in the Lower Colorado River Valley or elsewhere. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the adult life stage*.

- Chemical Stress effects on (1) Pup Growth, (2) Juvenile Growth, and (3) Adult Growth (LSO): The causal node in these three proposed links is unchanged from the original WYBA conceptual ecological model. The three similar effect nodes are new life-stage outcomes added to the original CEM. Chemical stress can impair growth in any life stage of any animal species. Presumably, the higher the level of chemical stress

experienced by WYBA, the lower their likely rate of growth. However, there are no data available on the subject for WYBA in the Lower Colorado River Valley or elsewhere. The links are hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

- Disease effects on (1) Pup Growth, (2) Juvenile Growth, and (3) Adult Growth (LSO): The causal node in these three proposed links is unchanged from the original WYBA conceptual ecological model. The three similar effect nodes are new life-stage outcomes added to the original CEM. Illness can impair growth in any life stage of any animal species. The higher the frequency and severity of illness experienced by WYBA, the lower their likely rate of growth. However, there are no data available on the subject for WYBA in the Lower Colorado River Valley or elsewhere. The links are hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

- Feeding effects on Pup Growth (LSO): The causal node in this proposed link replaces eating as a critical biological activity for pups in the original WYBA conceptual ecological model. The effect node is a new addition to the original CEM. Obtaining food is essential for growth. Pups need to eat enough to maintain metabolic processes and support growth. If a pup does not eat well, it will grow more slowly. However, the provisioning rate of WYBA adult females and its effects on pup growth have not been studied either along the LCR or elsewhere. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with unknown intensity, high spatial scale, and high temporal scale; high predictability; and low understanding. *Applies only to the pup life stage*.

- Foraging effects on (1) Juvenile Growth and (2) Adult Growth (LSO): The causal node in these two proposed links is unchanged from the original WYBA conceptual ecological model. The two similar effect nodes are new life-stage outcomes added to the original CEM. Obtaining food is essential for juvenile and adult growth. If a bat does not eat well, it will grow more slowly. However, the incidence of sufficient versus insufficient feeding among WYBA is unknown, either in the Lower Colorado River Valley or elsewhere, and there are no studies of WYBA growth rates in relation to foraging. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with unknown intensity, high spatial scale, and high temporal scale; high predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Mechanical Stress effects on (1) Pup Growth, (2) Juvenile Growth, and (3) Adult Growth (LSO): The causal node in these three proposed links is unchanged from the original WYBA conceptual ecological model. The three similar effect nodes are new life-stage outcomes added to the original CEM. Injuries presumably can impair WYBA growth in any life stage by diverting metabolic resources to repairing the injury. However, there are no data available on the incidence or effects of injury to WYBA in any life stage in the Lower Colorado River Valley or elsewhere. The links are hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

- Mechanical Stress effects on Pup Survival (LSO): The causal node in this proposed link is unchanged from the original WYBA conceptual ecological model. The effect node is a new life-stage outcome added to the original CEM. The CEM recognized the possible effects of mechanical stress on juvenile and adult survival but did not include an equivalent link for the pup life stage. Injuries presumably can result in pup mortality. However, there are no data available on the incidence or effects of injury to WYBA pups in the Lower Colorado River Valley or elsewhere. The links are hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the pup life stage*.

- Thermal Stress effects on (1) Pup Growth, (2) Juvenile Growth, and (3) Adult Growth (LSO): The causal node in these three proposed links is unchanged from the original WYBA conceptual ecological model. The three similar effect nodes are new life-stage outcomes added to the original CEM. Thermal stress can impair growth in any life stage of any animal species. The higher the level of such stress experienced by WYBA juveniles or adults, presumably the lower their likely rate of growth. However, there are no data available on the subject for WYBA in the Lower Colorado River Valley or elsewhere. The links are hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

DELETED LINKS WITH CRITICAL BIOLOGICAL ACTIVITIES OR PROCESSES AS CAUSAL AGENTS

Updating the WYBA conceptual ecological model did not result in the deletion of any links with critical activities and processes as the causal agents.

UPDATED LINKS WITH CRITICAL BIOLOGICAL ACTIVITIES OR PROCESSES AS CAUSAL AGENTS

- Chemical Stress effects on (1) Pup Survival, (2) Juvenile Survival, and (3) Adult Survival (LSO): The causal node in these three proposed links is unchanged from the original WYBA conceptual ecological model. The three similar effect nodes replace the shared life-stage outcome, survival, in the original CEM to differentiate survival in the three life stages. Only the link reason is updated, as follows, with all other spreadsheet fields unchanged: Chemical stress can result in death in any life stage of any animal species. The higher the level of chemical stress experienced by WYBA in a given life stage, the lower their likely rate of survival. *Applies to all life stages*.

- Disease effects on (1) Pup Survival, (2) Juvenile Survival, and (3) Adult Survival (LSO): The causal node in these three proposed links is unchanged from the original WYBA conceptual ecological model. The three similar effect nodes replace the shared life-stage outcome, survival, in the original CEM to differentiate survival in the three life stages. Only the link reason is updated, as follows, with all other spreadsheet fields unchanged: Illness can result in death in any life stage of any animal species. The higher the frequency and severity of illness experienced by WYBA in a given life stage, the lower their likely rate of survival. *Applies to all life stages*.

- Disease effects on Thermal Stress (CAP): The causal node and effect node are unchanged from the original WYBA conceptual ecological model. Diseases may have a range of effects, which may affect many activities or processes. Reciprocally, thermally stressed bats may be more susceptible to disease. The subject has not been studied for WYBA. The link is hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

- Feeding effects on Pup Survival (LSO): The causal node in this proposed link replaces eating as a critical biological activity for pups in the original WYBA conceptual ecological model. The effect node simply differentiates pup survival from survival in other life stages. Obtaining food is essential for survival. Pups presumably can die if they do not obtain sufficient food to maintain basic metabolic processes. However, the incidence of sufficient versus insufficient feeding among WYBA is unknown, either in the Lower Colorado River Valley or elsewhere. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with unknown intensity, high spatial scale, and high temporal scale; high predictability; and low understanding. *Applies only to the pup life stage*.

- Foraging effects on (1) Juvenile Survival and (2) Adult Survival (LSO): The causal node in these two proposed links is unchanged from the original WYBA conceptual ecological model. The two similar effect nodes simply differentiate survival in each life stage from survival in other life stages. Obtaining food is essential for survival. The higher the foraging success among WYBA juveniles or adults, presumably the higher their survival rate, other things being equal. WYBA juveniles or adults that do not forage effectively simply die or suffer higher levels of predation. This relationship is posited to be significant and applicable at all times and locations in the LCR ecosystem and, theoretically, should be a predictable relationship; however, there do not appear to be any studies assessing rates or effects of foraging success versus failure among WYBA or related species. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with high intensity, high spatial scale, and high temporal scale; high predictability; and low understanding. *Applies only to the juvenile and adult life stages*.

- Maternal Care effects on Adult Fertility (LSO): The original WYBA conceptual ecological model included the critical biological activity or process, parent roost attendance, which this update renames as maternal care. The original CEM also included the life-stage outcome, reproduction, which this update renames to adult fertility. The reasoning and ratings for the link remain largely the same. Maternal care includes guarding the roost and nursing young and therefore increases fecundity. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with high intensity, high spatial scale, and low temporal scale. The causal relationship applies to the maternal care of every WYBA litter. Variation in roost attendance likely occurs at the patch scale, and effects likely only last for a generation. Predictability is high, but understanding is low, because the effects of roost attendance on fecundity of WYBA along the LCR have not been studied. *Applies only to the adult life stage*.

- Mechanical Stress effects on (1) Juvenile Survival and (2) Adult Survival (LSO): The causal node in these two proposed links is unchanged from the original WYBA conceptual ecological model. The two similar effect nodes replace the shared life-stage outcome, survival, in the original CEM to differentiate survival in the three life stages. Injuries presumably can result in juvenile and adult mortality. However, there are no data available on the incidence or effects of injury to WYBA in any life stage in the Lower Colorado River Valley or elsewhere. The link is hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale. The primary source of mechanical stress on WYBA juveniles and adults considered here is that of collisions with wind energy facilities. While wind energy facilities are not currently located along the Lower Colorado River Valley, mortality from wind energy facilities in areas where WYBA may migrate to and from have been recorded (Kunz et al. 2007). The link has high predictability given the likelihood that bats foraging in proximity to active wind turbines will be killed (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). On the other hand, link understanding is low: While understood in principle, there are no data on the subject in the LCR or nearby. *Applies only to the juvenile and adult life stages*.

- Predation effects on (1) Pup Survival, (2) Juvenile Survival, and (3) Adult Survival (LSO): The causal node in these three proposed links is unchanged from the original WYBA conceptual ecological model. The three similar effect nodes replace the shared life-stage outcome, survival, in the original CEM to differentiate survival in the three life stages. Predation can be a direct cause of mortality in all animal species. The higher the rate of predation on WYBA in any life stage, the lower their rate of survival, other things being equal. Birds and mammals that are known to prey on WYBA are present throughout the riparian areas along the LCR. However, no information exists on the effect of predators on WYBA juvenile or adult survival in the Lower Colorado River Valley. The links are hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

- Roosting effects on Adult Fertility (LSO): The causal node in this proposed link replaces the original critical activity, roost site selection. The effect node replaces reproduction in the original WYBA conceptual ecological model. The reasoning for the link is also updated as follows: Successful roosting, including site selection and movement when needed (with pups clinging to the mother's back), is crucial to successful rearing. Roosting site selection should strongly affect fecundity, and WYBA select

roosting sites at multiple and large scales. Although this is a tenet of habitat selection theory, it has not been directly assessed for WYBA along the LCR. The link is hypothesized to be complex and unidirectional with high intensity, spatial scale, and temporal scale; high predictability; and low understanding. *Applies only to the adult stage*.

- Thermal Stress effects on (1) Pup Survival, (2) Juvenile Survival, and (3) Adult Survival (LSO): The causal node in these three proposed links is unchanged from the original WYBA conceptual ecological model. The three similar effect nodes replace the shared life-stage outcome, survival, in the original CEM to differentiate survival in the three life stages. The link reasoning is updated as follows: Thermal stress can result in death in any life stage of any animal species. The higher the level of such stress experienced by WYBA in any life stage, the lower their likely rate of survival. However, there are no data available on the subject for WYBA in the Lower Colorado River Valley or elsewhere. The links are hypothesized to be negative with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies to all life stages*.

NEW LINKS WITH LIFE-STAGE OUTCOMES AS CAUSAL AGENTS

- Adult Growth effects on Breeding (CAP): The causal and effect nodes are new additions to the original WYBA conceptual ecological model and apply specifically to the adult life stage. Theoretically, prolonged or delayed growth or loss of healthy condition in any animal species could lower their rate of participation in breeding. Reciprocally, individuals that grow well and at a healthy pace and/or maintain good health presumably have higher rates of participation in breeding. However, there are no data available on the subject for WYBA in the Lower Colorado River Valley or elsewhere. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the adult life stage.*

- Pup Growth effects on Pup Survival (LSO): The causal node is a new addition to the original WYBA conceptual ecological model and applies specifically to the pup life stage. The effect node simply differentiates pup survival from survival in other life stages. Theoretically, prolonged or delayed growth in the young of any animal species could increase the exposure of the affected individuals to threats to their survival over a longer span of time. Reciprocally, young that grow well and at a healthy pace presumably have greater rates of survival. However, there are no

data available on the subject for WYBA in the Lower Colorado River Valley or elsewhere. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the pup life stage.*

- Juvenile Growth effects on Juvenile Survival (LSO): The causal node is a new addition to the original WYBA conceptual ecological model and applies specifically to the juvenile life stage. The effect node simply differentiates juvenile survival from survival in other life stages. Theoretically, prolonged or delayed growth or loss of healthy condition in any animal species could increase the exposure of the affected individuals to threats to their survival over a longer span of time. Reciprocally, individuals that grow well and at a healthy pace and/or maintain good health presumably have greater rates of survival. However, there are no data available on the subject for WYBA in the Lower Colorado River Valley or elsewhere. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the juvenile life stage.*

- Adult Growth effects on Adult Survival (LSO): The causal node is a new addition to the original WYBA conceptual ecological model and applies specifically to the adult life stage. The effect node simply differentiates adult survival from survival in other life stages. Theoretically, prolonged or delayed growth or loss of healthy condition in any animal species could increase the exposure of the affected individuals to threats to their survival over a longer span of time. Reciprocally, individuals that grow well and at a healthy pace and/or maintain good health presumably have greater rates of survival. However, there are no data available on the subject for WYBA in the Lower Colorado River Valley or elsewhere. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the adult life stage.*

- Adult Survival effects on Adult Fertility (LSO): The causal node simply differentiates adult survival from survival in other life stages. The effect node replaces reproduction from the original WYBA conceptual ecological model. Adult survival, together with the rate of participation of WYBA adults in breeding and their breeding success (fecundity), determine WYBA adult fertility. However, there are no data available on the subject for WYBA in the Lower Colorado River Valley or elsewhere. The link is hypothesized to be positive with no (or unknown) threshold and unidirectional with unknown intensity, spatial scale, and temporal scale; unknown predictability; and low understanding. *Applies only to the adult life stage.*

SUMMARY OF UPDATED TERMS FOR THE WYBA CONCEPTUAL ECOLOGICAL MODEL

Table 5.—(New table for this update) Updated WYBA conceptual ecological model component names
Blue indicates new or revised items; orange indicates replaced items; italicized entries are explanatory comments.

WYBA conceptual ecological model updated terms, 2019	WYBA conceptual ecological model original terms, 2016
Life stages	
Pup	Pup
Juvenile	Juvenile
Adult	Breeding Adult
Life-stage outcomes	
Pup Survival	[Pup] Survival
Pup Growth	*(new)*
Juvenile Survival	[Juvenile] Survival
Juvenile Growth	*(new)*
Adult Survival	[Breeding Adult] Survival
Adult Fertility	[Breeding Adult] Reproduction
Adult Growth	*(new)*
Critical biological activities and processes	
Breeding *(applies only to adults)*	*(new)*
Chemical Stress	Chemical Stress
Competition	*(new)*
Disease	Disease
Feeding *(applies only to pups)*	Eating
Foraging *(applies only to juveniles and adults)*	Foraging
Inter-Site Movement	*(new)*
Maternal Care *(applies only to adults)*	Roost Attendance
Mechanical Stress	Mechanical Stress
Predation	Predation
Roosting *(applies only to juveniles and adults)*	Roost Site Selection
Thermal Stress	Thermal Stress
Habitat elements	
Anthropogenic Disturbance	Anthropogenic Disturbance
Arthropod Community	Food Availability
Chemical Contaminants	*(new)*
Fire Regime	*(new)*
Infectious Agents	*(new)*
(eliminated; see infectious agents)	Genetic Diversity and Infectious Agents
Litter Size	Number of Pups
Maternal Care *(applies only to pups)*	Parent Roost Attendance
Matrix Community	Matrix Community
Monitoring, Capture, Handling	*(new)*
Palm Trees	*(new)*
Riparian Tree Community	*(new)*
Temperature	Temperature
(eliminated; see riparian tree community)	Patch Size
(eliminated; see palm trees, riparian tree community)	Tree Species Composition
(eliminated; see riparian tree community)	Canopy Cover
Vertebrate Community	Predator Density
Water Availability	Water Availability
Controlling factors	
Conservation Monitoring and Research Programs	*(new)*
Fire Management	Fire[1]
(eliminated; see surrounding land use)	Grazing
Habitat Development and Management	Habitat Restoration
Nuisance Species Introduction and Management	Nuisance Species Introduction and Management
(eliminated; see habitat development and management, surrounding land use)	Pesticide Application
(eliminated; see habitat development and management, surrounding land use)	Tree Pruning
(eliminated; see habitat development and management, surrounding land use)	Tree Thinning
Surrounding Land Use	*(new)*
Water Storage-Delivery System Design & Operation	Water Storage-Delivery System Design and Operation
Wind Energy Development	Wind Energy Development

[1] The original WYBA conceptual ecological model used the term, fire, in its workbook to refer to both fire management and the fire regime itself, but the report only discussed fire management. This update corrects the terminology.

LITERATURE CITED IN THIS UPDATE

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

American Society of Mammalogists. 2019. Mammal Species List. http://www.mammalsociety.org/mammals-list

Anderson, P.J. 2011. Identifying Commonly Cultivated Palms. In A Resource for Pests and Diseases of Cultivated Palms. Florida Department of Agriculture and Consumer Service, Division of Plant Industry and Identification Technology Program, CPHST, PPQ, APHIS, USDA; Fort Collins, Colorado. http://idtools.org/id/palms/palmid/

Anderson, B.W. 2012. Four Decades of Research on the Lower Colorado River. AVVAR Books, Bulletin of the Revegetation and Wildlife Management Center, Volume 5, Number 1. Blythe, California.

Andersen, B.R. and K. Geluso. 2018. Roost characteristics and clustering behavior of western red bats (*Lasiurus blossevillii*) in southwestern New Mexico. Western North American Naturalist 78:174–183.

Andersen, D.C. and S.M. Nelson. 2013. Floral ecology and insect visitation in riparian *Tamarix* sp. (saltcedar). Journal of Arid Environments 94:105–112.

Arizona Game and Fish Department (AZGFD). 2011. Animal Abstract, *Lasiurus xanthinus*. Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, Arizona.

Arizona-Sonora Desert Museum. 2019. Owls. Arizona-Sonora Desert Museum, Tucson, Arizona. https://www.desertmuseum.org/books/nhsd_owls.php

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.

Arnett, E.B. and E.F. Baerwald. 2013. Impacts of wind energy development on bats: implications for conservation. Pages 435–456 *in* R.A. Adams and S.C. Pedersen (editors). Bat Evolution, Ecology, and Conservation. Springer Science & Business Media, New York.

AZGFD (see Arizona Game and Fish Department).

Baird, A.B., J.K. Braun, M.A. Mares, J.C. Morales, J.C. Patton, C.Q. Tran and J.W. Bickham. 2015. Molecular systematic revision of tree bats (Lasiurini): doubling the native mammals of the Hawaiian Islands. Journal of Mammalogy 96(6):1255–1274.

Baird, A.B., J.K. Braun, M.D. Enstrom, A.C. Hulbert, M.G. Huerta, B.K. Lim, M.A. Mares, J.C. Patton, and J.W. Bick ham. 2017. Nuclear and mtDNA phylogenetic analyses clarify the evolutionary history of two species of native Hawaiian bats and the taxonomy of Lasiurini (Mammalia: Chiroptera). PLoS One 12 (10), e0186085. 1–27.

Bazelman, T.C. 2016. Effects of urbanization on bat habitat use in the Phoenix Metropolitan Region, Arizona, USA: a multi-scale landscape analysis. Master's Thesis. Arizona State University, Tempe, Arizona.

Bean, D. and T. Dudley. 2018. A synoptic review of *Tamarix* biocontrol in North America: tracking success in the midst of controversy. BioControl:1–16.

Berry, R., P. Brown, W. Rainey, and S. Broderick. 2017. Acoustic Monitoring for Lower Colorado River Bat Species, September 2002 to May 2007. Prepared by the Bureau of Reclamation and submitted to the Lower Colorado River Multi-Species Conservation Program, Boulder City, Nevada.

BIO-WEST, Inc.. 2010. 2009 Vegetation Plot Monitoring Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2011. 2010 Vegetation Monitoring Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

BIO-WEST, Inc., and GEO/Graphics, Inc. 2006. 2004 Lower Colorado Region Vegetation Type Mapping, Backwaters Delineation, Orthophotograpy, and GIS Development. Prepared for the Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada.

Braun, D.P. and R. Unnasch. 2020. 2019 Updates to Western Red Bat (*Lasiurus blossevillii*) (WRBA) Basic Conceptual Ecological Model for the Lower Colorado River. Submitted to the Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada, by Sound Science, LLC, Boise, Idaho.

Brennan, T.C. 2008. Online Field Guide to the Reptiles and Amphibians of Arizona. http://www.reptilesofaz.org/

Broderick, S. 2010. Post-Development Bat Monitoring 2008 Acoustic Surveys. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2012a. Post-Development Bat Monitoring, 2007–2010 Intensive Acoustic Surveys – Completion Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2012b. Post-Development Bat Monitoring 2009 Acoustic Surveys. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2013. Post-Development Bat Monitoring of Habitat Creation Areas Along the Lower Colorado River – 2011 Acoustic Surveys. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2015. Post-Development Acoustic Bat Monitoring–2014. Presentation, Colorado River Terrestrial and Riparian (CRTR) meeting, Laughlin, Nevada. January 2015. https://www.lcrmscp.gov/crtr/crtr.html

_____. 2016. Post-Development Acoustic Bat Monitoring, 2012–2014 Results. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

Brown, P.E. 2006. Lower Colorado River Bat Monitoring Protocol. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2010. Roost Surveys and Monitoring for Lower Colorado River Bat Species. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2013. Roost Surveys and Monitoring for Lower Colorado River Bat Species, 2013 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2015. Monitoring Colorado River Mine-Roosting Bats and Determining Their Foraging Ranges. Presentation, Colorado River Terrestrial and Riparian (CRTR) meeting, Laughlin, Nevada. January 2015. https://www.lcrmscp.gov/crtr/crtr.html

Bunkley, J.P., C.J.W. McClure, N.J. Kleist, C.D. Francis, and J.R. Barber. 2015. Anthropogenic noise alters bat activity levels and echolocation calls. Global Ecology and Conservation 3:62–71.

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

Calvert, A. 2008. Riparian Habitat Monitoring at the Cibola NWR Nature Trail Site: 2006. Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2010a. Post-Development Bat Monitoring of Habitat Creation Areas Along the Lower Colorado River – 2008 Capture Surveys. Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2010b. Post-Development Bat Monitoring of Habitat Creation Areas Along the Lower Colorado River – 2009 Capture Surveys. Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2012a. Post-Development Bat Monitoring of Habitat Creation Areas Along the Lower Colorado River – 2010 Capture Surveys. Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2012b. Post-Development Bat Monitoring of Habitat Creation Areas Along the Lower Colorado River – 2011 Capture Surveys. Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2013. Post-Development Bat Monitoring of Habitat Creation Areas Along the Lower Colorado River – 2012 Capture Surveys. Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2015. Eight Years of Bat Capture Surveys at Riparian Restoration Areas. Presentation, Colorado River Terrestrial and Riparian (CRTR) meeting, Laughlin, Nevada. January 2015. https://www.lcrmscp.gov/crtr/crtr.html

_____. 2016a. Post-Development Bat Monitoring of Conservation Areas and the ‘Ahakhav Tribal Preserve Along the Lower Colorado River – 2013–2014 Capture Surveys. Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2016b. Post-Development Bat Monitoring of Conservation Areas and the ‘Ahakhav Tribal Preserve Along the Lower Colorado River – 2015 Capture Surveys. Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2016c. Bat Monitoring at Riparian Habitat Creation Areas. Presentation, Colorado River Terrestrial and Riparian (CRTR) meeting, Laughlin, Nevada. January 2016. https://www.lcrmscp.gov/crtr/crtr.html

_____. 2017. LCR MSCP Bat Research and Monitoring: Where Did We Start, Where Are We Now? Presentation, Colorado River Terrestrial and Riparian (CRTR) meeting, Laughlin, Nevada. January 2017. https://www.lcrmscp.gov/crtr/crtr.html

Calvert, A.W., S.C. Broderick, and T.M. Olson. 2010. Bat Monitoring at Habitat Creation Areas as Part of the Lower Colorado River Multi-Species Conservation Program. Pages 245–256 *in* T.S. Melis, J.F. Hamill, G.E. Bennett, J. Lewis G. Coggins, P.E. Grams, T.A. Kennedy, D.M. Kubly, and B.E. Ralston (editors). Proceedings of the Colorado River Basin Science and Resource Management Symposium, November 18–20, 2008, Scottsdale, Arizona: Coming Together: Coordination of Science and Restoration Activities for the Colorado River Ecosystem. Scientific Investigations Report, 2010–5135. U.S. Geological Survey, Reston, Virginia.

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

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

Conway, C.J., C.P. Nadeau, and L. Piest. 2010. Fire helps restore natural disturbance regime to benefit rare and endangered marsh birds endemic to the Colorado River. Ecological Applications 20:2024–2035.

Cornett, J.W. 1983. The occurrence of the desert fan palm, *Washington filifera*, in southern Nevada. Desert Plants 5(3):169–172.

Cotten, T. and D. Grandmaison. 2013. Lowland Leopard Frog and Colorado River Toad Distribution and Habitat Use in the Greater Lower Colorado River Ecosystem, 2012 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

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 Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, 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 Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

Dudek and ICF International. 2012. Draft Desert Renewable Energy Conservation Plan (DRECP) Baseline Biology Report. Prepared for California Energy Commission, Sacramento, California.

Eckberg, J.R. 2011. Las Vegas Wash Invertebrate Inventory, 2000–2010. Las Vegas Wash Coordination Committee, Las Vegas, Nevada.

_____. 2012. Las Vegas Wash Invertebrate Inventory, 2000–2011. Las Vegas Wash Coordination Committee, Las Vegas, Nevada.

Eckberg, J.R. and M.E. Foster. 2011. Habitat and Food Preferences of Bats Along the Las Vegas Wash. Southern Nevada Water Authority, Las Vegas, Nevada.

Esbérard, C.E. and D. Vrcibradic. 2007. Snakes preying on bats: new records from Brazil and a review of recorded cases in the Neotropical region. Revista Brasileira de Zoologia 24(3):848–853.

Faria, N.R., M.A. Suchard, A. Rambaut, D.G. Streicker, and P. Lemey. 2013. Simultaneously reconstructing viral cross species transmission history and identifying the underlying constraints. Philosophical Transactions of the Royal Society B: Biological Sciences 368.

Grinnell, J. 1914. An account of the mammals and birds of the Lower Colorado Valley with especial reference to the distributional problems presented. University of California Publications in Zoology 12:51–294.

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.

Hautzinger, A. 2010. Ecological Flows on the Bill Williams River. Presentation, Colorado River Terrestrial and Riparian (CRTR) meeting, Laughlin, Nevada. January 2010. https://www.lcrmscp.gov/crab/crab.html

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

Hernández-Jerez, A., P. Adriaanse, A. Aldrich, P. Berny, T. Coja, S. Duquesne, A.L. Gimsing, M. Marina, M. Millet, O. Pelkonen, S. Pieper, A. Tiktak, I. Tzoulaki, A. Widenfalk, G. Wolterink, D. Russo, F. Streissl, and C. Topping. 2019. Scientific statement on the coverage of bats by the current pesticide risk assessment for birds and mammals. EFSA Journal 17(7):5758.

Hill, J. 2018. Post-Development Bat Monitoring of Conservation Areas and the ‘ Ahakhav Tribal Preserve Along the Lower Colorado River – 2013–2014 Capture Surveys. Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2019. Jeff Hill, Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada, personal communication. September 2019.

Hill, J. and C. Ronning. 2018. Jeff Hill and Carolyn Ronning, Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada, joint personal communication. February 2018.

Holmquist, J.G., J. Schmidt-Gengenbach, and M.R. Slaton. 2011. Influence of invasive palms on terrestrial arthropod assemblages in desert spring habitat. Biological Conservation 144:518–525.

Howard, J.L. 1992. Species: *Washingtonia filifera*. Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Fort Collins, Colorado. https://www.fs.fed.us/database/feis//plants/tree/wasfil/all.html

Jacobson, R.B., M.L. Annis, M.E. Colvin, D.A. James, T.L. Welker, and M.J. Parsley. 2016. Missouri River *Scaphirhynchus albus* (Pallid Sturgeon) Effects Analysis—Integrative Report 2016. Scientific Investigations Report 2016–5064. U.S. Geological Survey, Reston, Virginia.

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.

Krueper, D.J. 1993. Effects of land use practices on western riparian ecosystems. Pages 321–330 *in* D.M. Finch and P.W. Stangel (editors). Status and Management of Neotropical Migratory Birds. Rocky Mountain Forest and Range Experiment Station GTR RM-229.

Krueper, D.J., J. Bart, and T.D. Rich. 2003. Response of vegetation and breeding birds to the removal of cattle on the San Pedro River, Arizona. Conservation Biology 17:607–615.

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.

Kuzmin, I.V., M. Shi, L.A. Orciari, P.A. Yager, A. Velasco-Villa, N.A. Kuzmina, D.G. Streicker, D.L. Bergman, and C.E. Rupprecht. 2012. Molecular inferences suggest multiple host shifts of rabies viruses from bats to mesocarnivores in Arizona during 2001–2009. PLoS Pathogens 8(6): e1002786.

Lang, A.B., E.K.V. Kalko, H. Römer, C. Bockholdt, and D.K.N. Dechmann. 2006. Activity levels of bats and katydids in relation to the lunar cycle. Oecologia 146:659–666.

LCR MSCP (see Lower Colorado River Multi-Species Conservation Program).

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

Lower Colorado River Multi-Species Conservation Program (LCR MSCP). 2004. Lower Colorado River Multi-Species Conservation Program, Volume II: Habitat Conservation Plan, Final. December 17 (J&S 00450.00). Sacramento, California.

_____. 2008. Post-Development Bat Monitoring of Habitat Creation Areas Along the Lower Colorado River – 2007 Acoustic Surveys. Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada.

_____. 2014. Final Implementation Report, Fiscal Year 2015 Work Plan and Budget, Fiscal Year 2013 Accomplishment Report. Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada.

_____. 2016. Western Yellow Bat (*Lasiurus xanthinus*). Pages 295–303 *in* Species Accounts for the Lower Colorado River Multi-Species Conservation Program. Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada.

_____. 2018a. Final Implementation Report, Fiscal Year 2019 Work Plan and Budget, Fiscal Year 2017 Accomplishment Report. Bureau of Reclamation, Lower Colorado Region, Lower Colorado River, Boulder City, Nevada.

_____. 2018b. Five-Year Monitoring and Research Priorities for the Lower Colorado Multi-Species Conservation Program, 2018–2022. Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada.

Marty, J. and R. Unnasch 2015. Western Yellow Bat (*Lasiurus xanthinus*) (WYBA) Basic Conceptual Ecological Model for the Lower Colorado River. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada, by Sound Science, LLC, Boise, Idaho.

Meyer, R. 2005. Species: *Atriplex lentiformis*. Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Fort Collins, Colorado. https://www.fs.fed.us/database/feis/plants/shrub/atrlen/all.html

Mikula, P. 2015. Fish and amphibians as bat predators. European Journal of Ecology 1:71–80.

Mikula, P., F. Morelli, R.K. Lučan, D.N. Jones, and P. Tryjanowski. 2016. Bats as prey of diurnal birds: a global perspective. Mammal Review 46:160–174.

Miller, J.D. and D J. Leavitt. 2015. Development and Implementation of a Repeatable Monitoring Plan for Lowland Leopard Frogs and Colorado River Toads on the Lower Colorado River, 2015 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

Minckley, W.L. and J.N. Rinne. 1985. Large woody debris in hot-desert streams: a historical review. Desert Plants 7:142–153.

Mixan, R.J. 2015. Acoustic Monitoring at Non-Restoration Sites Along the LCR. Presentation, Colorado River Terrestrial and Riparian (CRTR) meeting, Laughlin, Nevada. January 2015. https://www.lcrmscp.gov/crtr/crtr.html

_____. 2016. MSCP System Wide Acoustic Monitoring Along the LCR. Presentation, Colorado River Terrestrial and Riparian (CRTR) meeting, Laughlin, Nevada. January 2016. https://www.lcrmscp.gov/crtr/crtr.html

_____. 2017. MSCP Conservation Area and System Wide Acoustic Monitoring. Presentation, Colorado River Terrestrial and Riparian (CRTR) meeting, Laughlin, Nevada. January 2017. https://www.lcrmscp.gov/crtr/crtr.html

Mixan, R.J. and J.M. Diamond. 2014. Monitoring of LCR MSCP Bat Species as Determined by Acoustic Sampling, 2013 Summary Findings. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2016. 2015 System-Wide Acoustic Monitoring of LCR MSCP Bat Species. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2017a. 2014 System-Wide Acoustic Monitoring of LCR MSCP Bat Species. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2017b. 2016 System-Wide Acoustic Monitoring of LCR MSCP Bat Species. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2018a. 2017 System-Wide Acoustic Monitoring of LCR MSCP Bat Species. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2018b. Post-Development Acoustic Monitoring of LCR MSCP Bat Species, 2015–2016 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2019a. Post-Development Acoustic Monitoring of LCR MSCP Bat Species, 2017 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2019b. 2018 System-Wide Acoustic Monitoring of LCR MSCP Bat Species. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

Mixan, R.J., J. M. Diamond, and L. Piest. 2012. Monitoring of LCR MSCP Bat Species as Determined by Acoustic Sampling – Summary Findings 2011. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

Mixan, R.J., J.M. Diamond, and M. Piorkowski. 2013. Monitoring of LCR MSCP Bat Species as Determined by Acoustic Sampling, 2012 Summary Findings. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

Mixan, R.J., J.M. Diamond, M.D. Piorkowski, and D.P. Sturla. 2015. Distribution and Roost Site Habitat Requirements of the Western Yellow Bat (*Lasiurus blossevillii*) and the Western Yellow Bat (*Lasiurus xanthinus*). Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

Molinari, J., E.E. Gutiérrez, A.A. De Ascenção, J.M. Nassar, A. Arends, and R.J. Márquez. 2005. Predation by giant centipedes, *Scolopendra gigantea*, on three species of bats in a Venezuelan cave. Caribbean Journal of Science 41:340–346.

Morgan, C.N., L.K. Ammerman, K.D. Demere, J.B. Doty, Y.J. Nakazawa, and M.R. Mauldin. 2019. Field Identification Key and Guide for Bats of the United States of America. Occasional Papers of the Texas Technical University Museum 360. Lubbock, Texas.

Mueller, G.A. 2006. Ecology of Bonytail and Razorback Sucker and the Role of Off-Channel Habitats in Their Recovery. Scientific Investigations Report 2006-5065. U.S. Geological Survey, Reston, Virginia.

Mumford, R.E. and D.A. Zimmerman. 1963. The southern yellow bat in New Mexico. Journal of Mammalogy 44:417–418.

Murphy, D.D. and P.S. Weiland. 2011. The route to best science in implementation of the Endangered Species Act's consultation mandate: the benefits of structured effects analysis. Environmental Management 47:161–72.

_____. 2014. Science and structured decision making: Fulfilling the promise of adaptive management for imperiled species. Journal of Environmental Studies and Sciences 4:200–207.

NatureServe. 2019a. Species Comprehensive Report - *Lasiurus xanthinus*. NatureServe Explorer: An online encyclopedia of life [Web application]. Version 7.1. NatureServe, Arlington, Virginia. http://explorer.natureserve.org

_____. 2019b. Species Comprehensive Report – *Washingtonia filifera*. NatureServe Explorer: An online encyclopedia of life [Web application]. Version 7.1. NatureServe, Arlington, Virginia. http://explorer.natureserve.org

_____. 2019c. Species Comprehensive Report – *Icterus cucullatus*. NatureServe Explorer: An online encyclopedia of life [Web application]. Version 7.1. NatureServe, Arlington, Virginia. http://explorer.natureserve.org

Nelson, S.M. 2009. Comparison of Terrestrial Invertebrates Associated with Las Vegas Wash Exotic Vegetation and Planted Native Vegetation Sites. Technical Memorandum No. 86-68220-09-11. U.S. Department of the Interior, Bureau of Reclamation Denver, Colorado.

Nelson, S.M. and D.C. Andersen. 1999. Butterfly (Papilionoidea and Hesperioidea) assemblages associated with natural, exotic, and restored riparian habitats along the lower Colorado River, USA. Regulated Rivers: Research & Management 15:485–504.

Nelson, S.M. and R. Wydoski. 2013. Butterfly assemblages associated with invasive Tamarisk (*Tamarix* spp.) sites: comparisons with tamarisk control and native vegetation reference sites. Journal of Insects 2013: Article ID 561617.

Nelson, S.M., R. Wydoski, and S.F. Pucherelli. 2014. Survey and Habitat Characterization for MacNeill's Sootywing, 2013 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

Nelson, S.M., R. Wydoski, and J. Keele. 2015. Monitoring MacNeill's Sootywing and its Habitats. Submitted to the Lower Colorado Region, Lower Colorado River Multi-Species Conservation Program, Boulder City, Nevada.

Nyffeler, M. and M. Knörnschild. 2013. Bat predation by spiders. PLoS One 8:e58120.

O'Donnell, R.P. and D.J. Leavitt. 2017a. Development and Implementation of a Repeatable Monitoring Plan for Lowland Leopard Frogs and Colorado River Toads on the Lower Colorado River, 2016 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2017b. Development and Implementation of a Repeatable Monitoring Plan for Lowland Leopard Frogs and Colorado River Toads on the Lower Colorado River. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

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.

Ohmart, R.D., B.W. Anderson, and W.C. Hunter. 1988. The Ecology of the Lower Colorado River from Davis Dam to the Mexico-United States International Boundary: A Community Profile. Biological Report 85(7.19). U.S. Department of the Interior, U.S. Fish and Wildlife Service, Research and Development, Washington, D.C.

Ortiz, D.D. and C.W. Barrows. 2014. Occupancy patterns of western yellow bats (*Lasiurus xanthinus*) in palm oases in the lower Colorado Desert. The Southwestern Naturalist 59:381–388.

Parametrix, Inc., and GeoSystems Analysis, Inc.. 2012. Lower Colorado River Vegetation Monitoring 2011 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2013. Lower Colorado River Vegetation Monitoring, 2012 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2014. Lower Colorado River Vegetation Monitoring, 2013 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2015. Lower Colorado River Vegetation Monitoring, 2014 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

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

Pratt, G.F. and W.D. Wiesenborn. 2009. MacNeill's sootywing (*Hesperopsis gracielae*) (Lepidoptera: Hesperiidae) behaviors observed along transects. Proceedings of the Entomological Society of Washington 111:698–707.

_____. 2011. Geographic distribution of MacNeill's sootywing (*Hesperopsis gracielae*) (Lepidoptera: Hesperiidae) along the lower Colorado River floodplain. Proceedings of the Entomological Society of Washington 113:31–41.

Provencher, L., S. Wainscott, and R. Andress. 2005. Integrated Science Assessment for the Upper Muddy River, Clark County, Nevada. Final report prepared by The Nature Conservancy, Reno, Nevada, for the Clark County Multiple Species Habitat Conservation Plan, Reno, Nevada.

Reclamation (see Bureau of Reclamation).

Reynolds, L.V., P.B. Shafroth, and P.K. House. 2014. Abandoned floodplain plant communities along a regulated dryland river. River Research and Applications 30:1084–1098.

RiverEedge West. 2019. 2007–2018 Distribution of Tamarisk Beetle (*Diorhabda* spp.). RiversEdge West, Grand Junction, Colorado. https://riversedgewest.org/events/tamarisk-beetle-maps

Robinson, G.S., P.R. Ackery, I.J. Kitching, G.W. Beccaloni, and L.M. Hernández. 2019. HOSTS—A Database of the World's Lepidopteran Hostplants. Natural History Museum, London, United Kingdom. http://www.nhm.ac.uk/our-science/data/hostplants/

Rodhouse, T.J., T.E. Philippi, W.B. Monahan, and K.T. Castle. 2016. A macroecological perspective on strategic bat conservation in the U.S. National Park Service. Ecosphere 7:e01576.

Rogers, D.S., M.C. Belk, M.W. González, and B.L. Coleman. 2006. Patterns of habitat use by bats along a riparian corridor in northern Utah. The Southwestern Naturalist 51:52–58.

Ronning, C. 2019. Carolyn Ronning, Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada, personal communication. November 2019.

Rottenborn, S.C. 2000. Nest-site selection and reproductive success of urban red-shouldered hawks in central California. Journal of Raptor Research 34:18–25.

Saldaña-Vázquez, R.A. and M.A. Munguía-Rosas. 2013. Lunar phobia in bats and its ecological correlates: a meta-analysis. Mammalian Biology 78:216–219.

Shafroth, P.B. and V.B. Beauchamp. 2006. Defining Ecosystem Flow Requirements for the Bill Williams River, Arizona. Open File Report 2006-1314. U.S. Geological Survey, Reston, Virginia.

Simono, S. 2012a. *Washingtonia filifera*, California Fan Palm. Jepson eFlora. Jepson Flora Project, Jepson Herbarium, University of California, Berkeley, California. https://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=48512

_____. 2012b. *Washingtonia robusta*, Mexican Fan Palm. Jepson eFlora. Jepson Flora Project, Jepson Herbarium, University of California, Berkeley, California. https://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=48514

Spencer, W. 2011. The removal of wild palms in Moapa Warm Springs, Nevada & why we should care! http://www.xeri.com/moapa/

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.

Stromberg, J.C., T.J. Rychener, and M.D. Dixon. 2009. Return of fire to a free-flowing desert river: effects on vegetation. Restoration Ecology 17:327–338.

Stuchin, M., C.M. Machalaba, K.J. Olival, M. Artois, R.G. Bengis, P. Caceres, F. Diaz, E. Erlacher-Vindel, S. Forcella, F.A. Leighton, K. Murata, M. Popovic, P. Tizzani, G. Torres, and W.B. Karesh. 2018. Rabies as a threat to wildlife. Revue Scientifique et Technique (International Office of Epizootics) 37:341–357.

Trathnigg, H.K. and F.O. Phillips. 2015. Importance of native understory for bird and butterfly communities in a riparian and marsh restoration project on the lower Colorado River, Arizona. Ecological Restoration 33:395–407.

U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS). 2002. Plant Guide, Fan Palm, *Washingtonia filifera* (L. Linden) H. Wendl. U.S. Department of Agriculture NRCS National Plant Data Center, Plant Sciences Department, University of California, Davis, California.

Vizcarra, B. and L. Piest. 2009. Monitoring of Covered and Evaluation Bat Species for the LCR MSCP: 2008 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2010. Monitoring of Covered and Evaluation Bat Species for the Lower Colorado River Multi-Species Conservation Program — 2009 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

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 Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

Welch, J.N. and C. Leppanen. 2017. The threat of invasive species to bats: a review. Mammal Review 47:277–290.

Wiesenborn, W.D. 2010. Effects of Abiotic Factors on Insect Populations in Riparian Restoration Sites, 2008 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2012. Effects of Abiotic Factors on Insect Populations in Riparian Restoration Sites 2009 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2013. Effects of Abiotic Factors on Insect Populations in Riparian Restoration Sites 2010 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2014a. Effects of Abiotic Factors on Insect Populations in Riparian Restoration Sites 2011 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

_____. 2014b. Effects of Abiotic Factors on Insect Populations in Riparian Restoration Sites, 2012 Annual Report. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada.

Wiesenborn, W.D., S.L. Heydon, and K. Lorenzen. 2008. Pollen loads on adult insects from tamarisk flowers and inferences about larval habitats at Topock Marsh, Arizona. Journal of the Kansas Entomological Society 81:50–60.

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.

Wonkka, C.L., D. Twidwell, C.H. Bielski, C.R. Allen, and M.C. Stambaugh. 2018. Regeneration and invasion of cottonwood riparian forest following wildfire. Restoration Ecology 26:456–465.

Zabriskie, J.E., P.L. Cutler, and J.N. Stuart. 2019. Range extension of the western yellow bat (*Dasypterus xanthinus*) in New Mexico. Western Wildlife 6:1–4.

ACKNOWLEDGMENTS

The authors of the original WYBA conceptual ecological model in 2015 acknowledged Allen Calvert and Jeff Hill, biologists with the LCR MSCP; Carolyn Ronning, Wildlife Group Manager, LCR MSCP; and Sonja Kokos, Adaptive Management Group Manager, LCR MSCP, who provided invaluable technical feedback and guidance during the development of the model process and production of that original report. They also acknowledged John Swett, Program Manager, LCR MSCP, for his leadership and support of the LCR MSCP conceptual ecological modeling effort.

The authors of this update acknowledge additional invaluable technical feedback from Jeff Hill and Carolyn Ronning, and also from Jenny Smith, biologist, LCR MSCP; Becky Blasius, Adaptive Management Specialist, LCR MSCP; and Jimmy Knowles, Adaptive Management Group Manager, LCR MSCP.

The authors also thank Christine Wisnewski and Cindy Salo, Sound Science, LLC, for their editorial assistance and feedback.