Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

2019 Updates to Vermilion Flycatcher (*Pyrocephalus rubinus*) (VEFL) Basic Conceptual Ecological Model for the Lower Colorado River

Photo courtesy of Robert Miller

September 2020

Work conducted under LCR MSCP Work Task G6

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Lower Colorado River Multi-Species Conservation Program

2019 Updates to Vermilion Flycatcher (*Pyrocephalus rubinus*) (VEFL) Basic Conceptual Ecological Model for the Lower Colorado River

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ACRONYMS AND ABBREVIATIONS

CAP	critical biological activity or process
CEM	conceptual ecological model
CF	controlling factor
GBBO	Great Basin Bird Observatory
HE	habitat element
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
LSO	life-stage outcome
USFWS	U.S. Fish and Wildlife Service
VEFL	vermilion flycatcher (*Pyrocephalus rubinus*)

Symbols

ºC	temperature in degrees Celsius (*aka* Centigrade)
%	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.

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Attachment

1 Vermilion Flycatcher (*Pyrocephalus rubinus*) Habitat Data

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 vermilion flycatcher (*Pyrocephalus rubinus*) (VEFL) (Miller et al. 2016). This update incorporates information reported in publications and presentations at professional meetings since the completion of the original VEFL conceptual ecological model and also incorporates information from the professional experiences of LCR MSCP staff and other experts. 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 structure of this update 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 these were not updated.

The updates reported in this report change the VEFL conceptual ecological model in several ways. The terminology used has been updated and standardized in many parts of the CEM to be consistent across species as much as possible. Two critical biological activities and processes were split into separate activities and processes to better reflect their effects on different life stages and for consistency with other CEMs. Many changes were made to habitat elements: (1) addition of one element for consistency, (2) deletion of one element by merging into another habitat element for consistency and simplification, (3) separation of two former combined habitat elements into two separate elements each to better reflect different components of habitat, and (4) combination of two formerly separated habitat elements into one for simplification. No controlling factors were added or removed, but several have had major updates to reflect more analysis and recent information. These major changes have created numerous edits and adjustments throughout the CEM text and workbook.

This report also provides a list of all literature cited in the updates to chapters 1–6. In addition, it provides a list of all changes made to the name of the CEM components in order to standardize terminology across all CEMs.

This report both explicitly and implicitly identifies possible new research and monitoring questions concerning gaps in knowledge that may bear on adaptive management of VEFL. These questions may or may not reflect the current or future goals of LCR MCSP decision making, and they 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 paragraph 3 in the initial section of chapter 1 is updated as follows:

The most widely used sources of information for the vermilion flycatcher (*Pyrocephalus rubinus*) (VEFL) conceptual ecological model are Brand et al. (2010), Ellison et al. (2020), Great Basin Bird Observatory (GBBO) (2011, 2018), Myers (2008), Raulston (2013), and Rosenberg et al. (1991). These publications summarize and cite large bodies of earlier studies; where appropriate and accessible, those earlier studies are directly cited. The CEM also integrates numerous additional sources, particularly reports and articles completed since the aforementioned publications; information on current research projects; and the expert knowledge of Lower Colorado River Multi-Species Conservation Program (LCR MSCP) avian biologists. In addition, sources of information for VEFL in other areas of the Southwest were consulted to supplement research along the lower Colorado River (LCR). The purpose is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

Update to Vermilion Flycatcher Reproductive Ecology

The VEFL is considered an incomplete migrant, with many populations remaining resident, but some northern populations migrating south for winter (Ellison et al. 2020). Authors have suggested a combination of resident, breeding, and wintering birds occur within the LCR (Ellison et al. 2020; GBBO 2018; Phillips et al. 1964; Raulston 2013; Rosenberg et al. 1991; Small 1994). If so, wintering VEFL may depart the LCR by mid-April, whereas breeding birds may return to the LCR from their wintering grounds in late-February to mid-March to begin the breeding season (Rosenberg et al. 1991; Small 1994). Male birds arrive before females, with courtship beginning immediately upon the arrival of the females. Nest building commences soon after pairing, with the first egg laid shortly after nest completion (Rosenberg et al. 1991). Although Rosenberg et al. (1991) suggest nesting sites are limited, habitat restoration along the LCR and the species' propensity to use certain human-modified habitats (e.g., parks, golf courses) suggests that this may no longer be a critical factor (Ellison et al. 2020; Raulston 2013).

VEFL nest sites are located in riparian woodlands, residential areas, and along the margins of agriculture with water nearby (GBBO 2011, 2018; Rosenberg et al. 1991). Rosenberg et al. (1991) suggest that nesting within the LCR is usually in

Fremont cottonwoods (*Populus fremontii*) (hereafter cottonwoods) or Goodding willows (*Salix gooddingi*). However, recent studies have found VEFL also use dry honey mesquite (*Prosopis glandulosa*), similar to that in eastern and southern Arizona (GBBO 2011). The male VEFL suggests nests sites to the female during the courtship ritual (Ellison et al. 2020). The VEFL female builds the nest on a horizontal branch, usually in a fork. The typical clutch consists of two to three eggs, occasionally four, with two broods common during the breeding season (Rosenberg et al. 1991). Extra-pair copulation and intraspecific brood parasitism are known to occur (Ríos-Chelén et al. 2008). Brood parasitism by brown-headed cowbirds (*Molothrus ater*) ranges from 19 to 36% (Ellison et al. 2007).

The onset of incubation is not well known, but all eggs usually hatch within 13 days of the final egg being laid (Ellison et al. 2020). Young birds fledge from the nest in 13–16 days (Ellison et al. 2020), and dependent young remain with parents for at least 20 days after fledging (GBBO 2018).

Prey is captured using an "air sally" technique[1] (Ellison et al. 2020; Landres and MacMahon 1980). The diet of the VEFL has not been studied but likely includes bees, wasps, flies, beetles, crickets, and grasshoppers (Ellison et al. 2020; Rosenberg et al. 1991). Although VEFL have been observed feeding on fishes on a few occasions (Andrews et al. 1996), prey other than invertebrates appears to be a rare component of their diet (Ellison et al. 2020).

CONCEPTUAL ECOLOGICAL MODEL PURPOSES

This update does not propose 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 FOR VEFL

No change. This will not be updated for the existing CEMs.

[1] The air sally technique is a foraging method in which prey are captured in air or on the ground while the bird is in flight, often initiated when the bird is on a perch that is generally elevated and/or exposed (Fitzpatrick 1980; Remsen and Robinson 1990).

Updates to Chapter 2 – VEFL Life-Stage Model

This update standardizes the names of VEFL life stages by switching to the plural noun form for each name for consistency with the other LCR MSCP conceptual ecological model updates. The names of the original life-stage outcomes are standardized as follows: Survivors changes to Survival for all three life stages; Offspring and Reproduction change to Fertility; and the update drops the word "rate" from the names of life-stage outcomes because all life-stage outcomes are rate variables by definition. Table 1 and figure 1 are updated accordingly (see the end of this chapter).

UPDATE TO INTRODUCTION TO THE VEFL LIFE CYCLE

In the development of the CEM for VEFL, we could not find a complete demographic study of the species; therefore, we chose to represent VEFL with a three-stage model to be consistent with other species documented within the LCR MSCP and to be most useful to management.

In many studies of avian demography, nest survival is considered integral in the reproduction of adults because adults are heavily invested in the care of eggs and nestlings (Etterson et al. 2011). We treat the eggs/nestlings stage as separate from adult reproduction due to the specific factors influencing the nest, the common creation of multiple broods by this species, and the fit with the life-stage outcome modelling structure used in this CEM process.

We have chosen to combine the egg and nestling phases of development into an eggs/nestlings life stage because both the eggs and nestlings occupy the same nest; therefore, management focused on the nest will cover eggs and nestlings. Further, most research conducted on VEFL breeding has focused on the number of young fledged and not on the number of eggs hatched—meaning that most of the available information is on the habitat characteristics and management actions associated with success of the nest through both incubation and brooding periods.

The CEM is complicated by the lack of knowledge of the migratory behavior of the VEFL population occupying the LCR. Authors have suggested a combination of resident, breeding, and wintering birds occur within the LCR (Ellison et al. 2020; GBBO 2018; Phillips et al. 1964; Raulston 2013; Rosenberg et al. 1991; Small 1994). The conservation needs for the species within the LCR are likely highest for the breeding birds; thus, we focus the model on three life stages normally associated with the breeding season—eggs/nestlings, juveniles, and breeding adults.

Update to VEFL Life Stage 1 – Eggs/ Nestlings

We consider the eggs/nestlings stage to be the first in the life cycle of the VEFL. It begins when the egg is laid and ends either when the young fledge or the nest fails. Eggs are usually laid in mid-March for a first brood to as late as mid-June for a second brood (Ellison 2008; Ellison et al. 2020). GBBO (2018) found the range of incubation dates in the LCR from March 25 to June 9, with the peak in late April. Incubation lasts around 13 days, and young birds fledge from the nest in 13–16 days (Ellison et al. 2020). The life-stage outcome from the eggs/nestlings stage is the survival of eggs and associated nestlings until fledging. It is important to note that the outcome of the eggs/nestlings stage is inherently tied to the behavior and condition of the parents.

Update to VEFL Life Stage 2 – Juveniles

The juveniles life stage begins at fledging and ends when the bird begins courtship activities the following spring. Juveniles are dependent upon the parents for at least 20 days after fledging (GBBO 2018). For those birds migrating out of the area, they depart as early as late August (Small 1994). The life-stage outcome from the juveniles stage is the survival of the bird from fledging until the beginning of the courtship stage of the following breeding season. There are no studies available that analyze the survival rates of juveniles in this species; however, it may be assumed to be lower than adult survival rates that have been shown to be approximately 0.48 ± 0.21 (Michel et al. 2006; Ricklefs and Shea 2007).

Update to VEFL Life Stage 3 – Breeding Adults

The breeding adults life stage begins when the bird begins courtship activities in spring after its first winter. Generally, adults initiate courtship in late February or early March, with males arriving on the territory earlier (if they left at all)—and setting up territories before females arrive (Small 1994). Rosenberg et al. (1991) suggest that males staying on territory year round may breed earlier in spring with higher success.

The male VEFL suggests nest sites to the female during the courtship ritual (Ellison et al. 2020). The VEFL female builds the nest on a horizontal branch, usually in a fork. The typical clutch consists of two to three eggs, occasionally four, with two broods common during the breeding season (Rosenberg et al. 1991). Nest building commences soon after pairing, with the first egg laid shortly after nest completion (Rosenberg et al. 1991). Rosenberg et al. (1991) suggest that nesting sites are limited, causing heightened aggression between neighboring pairs that, in some cases, has delayed breeding up to a month.

The life-stage outcomes for breeding adults are survival and fertility—here defined as the production of eggs. Most studies of bird demography define fertility—or the reproductive rates of adults—as the number of offspring fledged (Etterson et al. 2011). We have separated the eggs/nestlings stage from adult fertility to more clearly display the information regarding nest success so that it can be better assessed by management. Therefore, adult reproduction involves the acts of pairing, site selection, nest building, and the production of eggs. Annual adult survival rates have been shown to be approximately 0.48 ± 0.21 (Michel et al. 2006; Ricklefs and Shea 2007). The longevity record for VEFL, based on band recovery, is currently 5 years and 6 months (Bird Banding Laboratory 2020; Klimkiewicz and Futcher 1989).

It is important to note that the post-breeding period is a significant part of a bird's life cycle. During the post-breeding period, adults may prospect for potential future breeding areas or move into habitat types that differ from breeding areas. VEFL are observed using more open areas, including residential areas, but are still in proximity to water during the non-breeding season (Rosenberg et al. 1991). Although male and female post-breeding individuals have different goals and responsibilities on the breeding grounds, we have included them all within the breeding adults life stage because their habitat use is similar, and thus, management directed at breeding adults will likely benefit all demographics present on the breeding grounds.

UPDATE TO LIFE-STAGE MODEL SUMMARY

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

Life stage	Life-stage outcome(s)
1. Eggs/nestlings	• Eggs/nestlings survival
2. Juveniles	• Juveniles survival
3. Breeding adults	• Breeding adults survival • Fertility

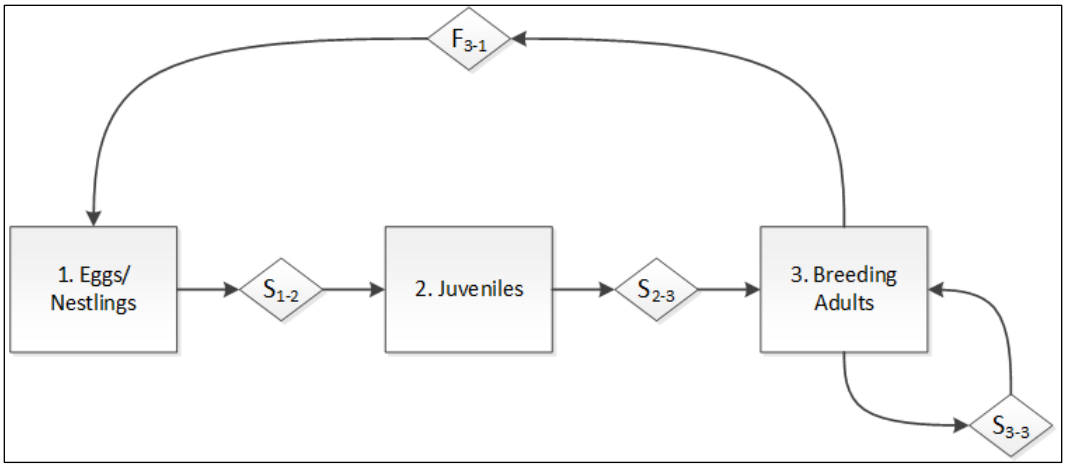

Figure 1.—(Revision of original figure 1) Proposed VEFL life history model. Squares indicate the life stages, and diamonds indicate the life-stage outcomes. S_{1-2} = Survival, Eggs/Nestlings; S_{2-3} = Survival, Juveniles; S_{3-3} = Survival, Breeding Adults; and F_{3-1} = Fertility, Breeding Adults.

Updates to Chapter 3 – Critical Biological Activities and Processes

This update identifies nine critical biological activities or processes that affect one or more VEFL life stages. The original VEFL conceptual ecological model (Miller et al. 2016) identified seven. This update changes the names of two critical biological activities and processes, Molt and Temperature Regulation, replacing them with Molting and Thermal Stress, respectively; splits one critical biological activity and process, Eating/Foraging, into two separate activities and processes, Eating and Foraging, for consistency with other LCR MSCP conceptual ecological model updates; splits one critical biological activity and process, Predation & Brood Parasitism into two separate activities and processes, Nest Predation & Brood Parasitism and Predation, for consistency with other LCR MSCP conceptual ecological model updates; and updates the discussion of five critical biological activities and processes. Table 2 lists the nine critical biological activities or processes in this update, and their distribution across life stages, and it indicates which are new to this update or renamed from the original VEFL conceptual ecological model.

Table 2.—(Revision of original table 2) Distribution of VEFL critical biological activities and processes among life stages

(Xs indicate that the critical biological activity or process is applicable to that life stage.)

Life stage ➔ **Critical biological activity or process 🡻**	**Eggs/nestlings**	**Juveniles**	**Breeding adults**
Disease	**X**	**X**	**X**
Eating (*replaces eating/foraging*)	**X**	**X**	
Foraging (*new*)		**X**	**X**
Molting (*replaces molt*)	**X**	**X**	**X**
Nest attendance			**X**
Nest predation & brood parasitism (*new*)	**X**		
Nest site selection			**X**
Predation (*replaces predation & brood parasitism*)		**X**	**X**
Thermal stress (*replaces temperature regulation*)	**X**	**X**	**X**

The most widely used sources of the information used to identify the critical biological activities and processes are Brand et al. (2010), Ellison et al. (2020), Myers (2008), Raulston (2013), and Rosenberg et al. (1991). The identification also integrates information from both older and more recent works as well as the expert knowledge of LCR MSCP biologists. The following paragraphs discuss the nine critical biological activities and processes in alphabetical order.

DISEASE

The definition of this critical biological activity or process remains unchanged. No new information was located on disease patterns or consequences among VEFL in the Lower Colorado River Valley or elsewhere.

EATING

The critical biological activity or process, formerly named Eating/Foraging, has been separated into two distinct critical biological activities or processes for consistency with other CEMs and to clarify its meaning. The discussion of Eating is revised as follows:

Eating applies to the eggs/nestlings and juveniles life stages. Juveniles are still fed by breeding adults shortly after fledging, and this feeding may be critical to their survival. The ability of nestlings and juveniles to eat is determined by the provisioning rate of its parents and competition with brood mates.

FORAGING

The critical biological activity or process, formerly named Eating/Foraging, has been separated into two distinct critical biological activities or processes for consistency with other CEMs and to clarify its meaning. The discussion of Foraging is revised as follows:

Foraging is performed by juveniles and breeding adults. Juveniles forage on their own but are still fed by adults shortly after fledging. Breeding adults must forage to feed themselves and their dependent young. Prey is captured using an “air sally” technique (Landres and MacMahon 1980). The diet of the VEFL has not been studied but likely includes bees, wasps, flies, beetles, and grasshoppers (Rosenberg et al. 1991). VEFL have been observed feeding on fishes on a few

occasions (Andrews et al. 1996). Foraging is done by juveniles and breeding adults, but it is important to note that foraging by the parents affects the provisioning rate to nestlings and nest attendance by adults.

MOLTING

This critical biological process, formerly named Molt, is renamed Molting for consistency with other CEMs. The discussion is revised as follows:

Molt is one of the most significant biological activities and processes undertaken by bird species, and successful completion of various molts during a birds' lifetime is critical to all life stages (Howell 2010). Nestling VEFL undergo a molt from natal down into juvenal plumage while in the nest. The success of this molt is dependent upon the adult provisioning rate (Howell 2010). Molting is an energetically costly process that may make nestlings more susceptible to death when resources are scarce (Gill et al. 2019; Howell 2010). Juveniles then undergo an incomplete pre-basic (pre-formative) molt in the summer geographic range from August to October (Pyle 1997). Adults undergo a complete pre-basic molt on the summer grounds from July to September every subsequent year of their lives (Pyle 1997). The existence of pre-alternate molts in adult VEFL needs confirmation, but if they do have such a molt, it is limited, occurring from February to April (Ellison et al. 2020; Pyle 1997).

NEST ATTENDANCE

The discussion of this critical biological activity or process is revised as follows:

The female VEFL does all of the incubating and brooding (Ellison et al. 2020; Taylor and Hanson 1970). After hatching, both parents feed the young, and the male occasionally feeds the brooding female (Taylor and Hanson 1970). During the days after hatching, females have been observed attending the nest 60–80% of the time (Taylor and Hanson 1970).

NEST PREDATION & BROOD PARASITISM

The critical biological activity or process, formerly named Predation & Brood Parasitism, has been separated into two distinct critical biological activities or processes for consistency with other CEMs and to clarify its meaning. The definition of this activity or process has been modified to remove predation on

juveniles and breeding adults into a standalone critical biological activity or process named Predation and is renamed Nest Predation & Brood Parasitism for consistency with other CEMs and to clarify its meaning. The discussion is updated as follows:

Nest predation and brood parasitism certainly affect the success of songbird nests within the LCR (Brand et al. 2010; Powell and Steidl 2000). Nest predator and cowbird abundance is influenced by patch size and the nest's relative proximity to a vegetation edge (Rosenberg et al. 1999; Winfree 2004). These two processes have been combined for the eggs/nestlings life stage because (1) cowbirds are both nest predators and brood parasites (Theimer et al. 2011) and (2) habitat characteristics (distance to edge, patch width, etc.) affect both processes similarly (Rosenberg et al. 1999). Intra-specific brood parasitism rates of 13–19% have been documented based on genetic analyses in VEFL (Ríos-Chelén et al. 2008). Inter-specific parasitism by brown-headed and shiny cowbirds (*Molothrus bonariensis*) has been documented, but rates are generally low. Adult VEFL exhibit aggressive behavior toward cowbirds, and the effects of cowbird parasitism are generally considered minimal (Ellison et al. 2020; Myers 2008).

NEST SITE SELECTION

The discussion of this critical biological activity or process is revised as follows:

Both breeding males and females select a nest site, with males selecting territories and females selecting the actual nest site within that territory (Ellison et al. 2020; Taylor and Hanson 1970). Nest site selection is important for reproductive success because nest success varies spatially as a result of vegetation characteristics, food availability, predator types and densities, hydrology, and unique events such as flooding (Brand et al. 2010; Ellison et al. 2020; Lima 2009; Powell and Steidl 2000).

PREDATION

The critical biological activity or process, formerly named Predation & Brood Parasitism, has been separated into two distinct critical biological activities or processes for consistency with other CEMs and to clarify its meaning. This habitat element now refers only to predation on juveniles and breeding adults. The discussion is modified as follows:

Predation is a threat to VEFL in the juveniles and breeding adults life stages; it obviously affects survival, but it has not been studied in VEFL. Predation on juveniles and breeding adults is not as easily quantified but affects both life stages and indirectly affects nestling survival through nest abandonment after predation of a breeding adult. Predation risk can result in many behavioral adaptations in passerines, including nest locations, densities, clutch size, and egg size (Lima 2009).

THERMAL STRESS

This critical biological activity or process, formerly named Temperature Regulation, is renamed Thermal Stress for consistency with other CEMs and to clarify its meaning. Further, the discussion of this critical biological activity or process is updated as follows:

Thermal stress is important to any organism inhabiting a region with temperatures as high as that along the LCR. Although overheating is possible during all life stages, most of the concern has been toward eggs and nestlings (Hunter et al. 1987a, 1987b; Rosenberg et al. 1991). The optimal temperature for egg development is 37–38 degrees Celsius (ºC), with exposure to temperatures greater than 40.5 ºC potentially lethal (Gill et al. 2019). Adults can influence the thermal stress on eggs/nestlings through their own behavior (incubating, brooding, or shading) and/or nest placement.

Updates to Chapter 4 – Habitat Elements

This update identifies 16 habitat elements that affect 1 or more critical biological activities or processes across 1 or more VEFL life stages. The original VEFL conceptual ecological model (Miller et al. 2016) identified 15 habitat elements. This update standardizes the names of three habitat elements, with Brood Size becoming Brood/Litter Size, Community Type becoming Vegetation Community Type, and Tree Size becoming Stand Height; splits one habitat element (Genetic Diversity & Infectious Agents) into two separate elements (Genetic Diversity and Infectious Agents); splits one habitat element (Predator & Cowbird Density) into two separate elements (Nest Predators and Cowbird Density & Predators); combines two habitat elements (Parental Feeding Behavior and Parental Nest Attendance) into one habitat element (Parental Care); adds one habitat element (Temperature) for consistency with other CEMs; deletes one habitat element (Water Availability) by merging it into Local Hydrology; and updates the discussions of 13 habitat elements. Table 3 lists the 16 habitat elements in this update, indicates the critical biological activities or processes they *directly* affect across all VEFL life stages, and indicates which habitat elements are new to this update or renamed from the original VEFL conceptual ecological model.

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

Critical biological activity or process ➔ / **Habitat element 🡻**	**Disease**	**Eating**	**Foraging**	**Molting**	**Nest attendance**	**Nest predation & brood parasitism**	**Nest site selection**	**Predation**	**Thermal stress**
Anthropogenic disturbance		X	X		X	X	X	X	
Brood/litter size (*replaces brood size*)		X	X		X				
Canopy closure		X	X			X	X	X	X
Food availability		X	X		X		X		
Genetic diversity (*replaces genetic diversity & infectious agents*)	X								
Infectious agents (*new*)	X								
Local hydrology							X		X
Nest predators & cowbird density (*new*)		X	X		X	X	X		
Parental care (*replaces parental feeding behavior and parental nest attendance*)		X	X			X			X
Patch size						X	X	X	
Predators (*replaces predator & cowbird density*)			X		X	X	X	X	
Soil salinity	N/A*								
Stand height (*replaces tree size*)							X		
Temperature (*new*)					X		X		X
Understory density							X		
Vegetation community type (*replaces community type*)						X	X	X	

Note: There are no habitat elements that *directly* affect molting.

* N/A value suggests that the habitat elements do not directly affect the identified critical biological activities or processes.

Anthropogenic Disturbance

The definition of this habitat element remains unchanged. No new information was located on anthropogenic disturbance among VEFL in the Lower Colorado River Valley or elsewhere.

Brood/Litter Size

This habitat element replaces the original, Brood Size, with a slightly updated definition as follows:

Full name: **The number of young in the nest**. This element refers to the number of young that the parents must rear per nest. It differs from clutch size, which refers to the number of eggs laid. Brood size is related to maternal health, and the well-being of both parents depends in part on the availability of sufficient food resources in close proximity to the breeding territory as well as other factors such as predator and cowbird density (see "Nest Predators & Cowbird Density," below). A typical VEFL clutch consists of two to three eggs, occasionally four, with two broods common during the breeding season (Rosenberg et al. 1991).

Canopy Closure

The definition of this habitat element is updated as follows:

Full name: **The percentage of ground area shaded by overhead foliage in the vicinity of the nest** (Daubenmire 1959). Canopy closure can be measured as the angular canopy closure with a field-of-view instrument, such as a camera or spherical densiometer, or as vertical canopy closure by using lidar. Both measures are related (Korhonen et al. 2011). This element refers to the percent canopy closure of canopy vegetation in the vicinity of the VEFL nest site. Canopy closure of riparian vegetation has been shown to be important to VEFL, but higher canopy densities appear to be avoided (Ellison et al. 2020). Studies conducted within the LCR have not found a predictive formula for VEFL occupancy (Raulston 2013), though open strips or patches may be important (GBBO 2018).

FOOD AVAILABILITY

The definition of this habitat element is updated as follows:

Full name: **The abundance of food available for adults and their young**. This element refers to the taxonomic and size composition of the invertebrates that an individual VEFL will encounter during each life stage as well as the density and spatial distribution of the food supply in proximity to the nest. The diet of VEFL has not been studied but likely includes bees, wasps, flies, beetles, crickets, and grasshoppers (Ellison et al. 2020; Rosenberg et al. 1991). VEFL are known insectivores, but have been observed feeding on fishes on a few occasions (Andrews et al. 1996), although it is unknown how important this resource is to the species. The abundance and condition of the food supply affects adult health, growth and development of nestlings and juveniles, the progress of molt, and the success of later stages in the annual cycle (i.e., migration). Wiesenborn (2012, 2013, 2014) recommends that maintenance of diverse insect populations, particularly in restoration habitats in the LCR, be considered in order to sustain appropriate invertebrate diets for insectivorous species such as VEFL.

GENETIC DIVERSITY

The habitat element of Genetic Diversity & Infectious Agents has been separated into two distinct habitat elements. The definition of Genetic Diversity is updated as follows:

Full name: **The genetic diversity within VEFL populations**. This element refers to the genetic homogeneity versus heterogeneity of a population during each life stage. The greater the heterogeneity, the greater the possibility that individuals of a given life stage will have genetically encoded abilities to survive their encounters with the diverse stresses presented by their environment and/or take advantage of the opportunities presented. The genetic diversity of the LCR populations of VEFL has not been studied; this is an area for future research.

INFECTIOUS AGENTS

The habitat element of Genetic Diversity & Infectious Agents has been separated into two distinct habitat elements. The definition of Infectious Agents is updated as follows:

Full name: **The types, abundance, and distribution of infectious agents and their vectors**. This element refers to the spectrum of viruses, bacteria, fungi, ecto-parasites, and endo-parasites that individual VEFL are likely to encounter during each life stage. There have been no specific studies of the infectious agents and their effects on the VEFL within the LCR. However, there is a wealth of knowledge regarding avian diseases and parasites that affect passerine birds within North America, which indicates a large number of diseases (Morishita et al. 1999) can be difficult to detect (Jarvi et al. 2002) and can have differing effects on different species (Merino et al. 2000; Palinauskas et al. 2008).

LOCAL HYDROLOGY

This habitat element now includes the former habitat element of Water Availability. The definition of this habitat element is updated as follows:

Full name: **Aspects such as the distance to standing water or the presence of adjacent water bodies, the timing and volume of floods, depth to the water table, and soil moisture levels**. This element refers to anything that affects soil moisture, such as the proximity of water to the nesting habitat, elevation, irrigation practices, and soil texture. The local hydrological conditions affect other aspects of habitat such as vegetation structure and abundance of arthropods. Wetter conditions might also provide cooler temperatures and more humid conditions necessary for egg and chick survival in desert systems (Rosenberg et al. 1991). The presence of breeding VEFL has been highly correlated with the presence of nearby surface water, either natural or artificial (GBBO 2011, 2018). Moist soil may be important, including irrigated areas such as parks and golf courses that receive moisture from sprinklers (GBBO 2018).

NEST PREDATORS & COWBIRD DENSITY

The original habitat element Predators & Cowbird Density is separated into two habitat elements, Nest Predators & Cowbird Density and Predators, to better define specific habitat elements and to be consistent with other CEMs. The definition of this habitat element is updated as follows:

Full name: **The abundance and distribution of nest predators and brood parasites**. This element refers to a set of closely related variables that affect the likelihood that different kinds of predators will encounter and successfully prey on VEFL during the eggs/nestlings life stage or that cowbirds or other nest parasites will lay eggs in the nest. The variables of this element include the species and size of the fauna that prey on VEFL during the eggs/nestlings life

stage, the density and spatial distribution of these fauna in the riparian habitat used by VEFL, and whether predator activity may vary in relation to other factors (e.g., time of day, patch size and width, matrix community type). Ellison et al. (2020) report some level of parasitism in VEFL, with rates ranging from 19% to 36%. Nest predator and cowbird density can have impacts more subtle than survival by altering nest site selection, breeding behavior, and foraging behavior (Chalfoun and Martin 2009; Lima 1998, 2009).

Parental Care

This habitat element replaces the former elements, Parental Feeding Behavior and Parental Nest Attendance, with a slightly updated definition as follows:

Full name: **The ability of both parents to care for young during the egg/incubation and nestling stages and to care for juveniles after they fledge from the nest**. This element refers to the capacity of both parents to share nesting and brood rearing responsibilities until fledging and to provision food for nestlings and recently fledged birds. It is affected by the presence of predators and competitors, food availability, number of young in the brood, and the ability to thermally regulate. Female VEFL have the sole responsibility of brooding young, but the territory is actively defended by the male (Ellison et al. 2020). Additionally, the provisioning rate is influenced by the amount of food and time spent foraging by juvenile birds.

Patch Size

The definition of this habitat element remains unchanged. No new information was located on patch size among VEFL in the Lower Colorado River Valley or elsewhere.

Predators

The original habitat element, Predators & Cowbird Density, is separated into two habitat elements, Nest Predators & Cowbird Density and Predators, to better define specific habitat elements and to be consistent with other CEMs. The definition of this habitat element is updated as follows:

Full name: **The abundance and distribution of species that depredate VEFL during the juveniles and breeding adults life stages**. This element refers to a set of closely related variables that affect the likelihood that different kinds of predators will encounter and successfully prey on VEFL during the juveniles or breeding adults life stages. The variables of this element include the species and size of the fauna that prey on VEFL during the juveniles or breeding adults life stages, the density and spatial distribution of these fauna in the riparian habitat used by VEFL, and the ways in which predator activity may vary in relation to other factors (e.g., patch size and stand characteristics) (Thompson, III 2007). Predator density can have impacts more subtle than survival by altering breeding behavior, foraging behavior, nest site selection, and prey behavior (Lima 1998, 2009).

Soil Salinity

The discussion of this habitat element is updated as follows:

Full name: **The salt content within the root zone of the soil (0–30 inches) as measured by electrical conductivity of the saturation extract value in decisiemens per meter at 25 °C** (San Joaquin River Restoration Program 2014). Salinity is one of the major ecosystem problems throughout the entire Colorado River Basin, with concentrations increasing dramatically from the headwaters to the LCR at the International Boundary with Mexico (LaHue 2017; U.S. Geological Survey 2000) and is a deterrent to successful habitat restoration (Raulston 2003). Contributors to salinity include natural sources (atmospheric deposition, erosion of geological formations), agriculture, municipal water use, and development of energy resources (LaHue 2017). Soil salinity is affected by the amount of water reaching the soil and the salinity of the water (San Joaquin River Restoration Program 2014), and it has been modified by historical changes in flooding regimes due to dam construction on the Colorado River (Briggs 1996; Raulston 2003). Soil salinity can impact the vigor of various plant species to different degrees and can ultimately influence plant community type and structure (Raulston 2003; San Joaquin River Restoration Program 2014; Shafroth et al. 1995, 2008; Stromberg 2001).

Stand Height

This habitat element is renamed from Tree Size for compatibility with other CEMs. The discussion of this habitat element is slightly updated as follows:

Full name: **The average height of the core stand area being evaluated and tree size, measured by diameter at breast height, averaged across the stand**. VEFL are known to nest in large trees within the LCR, most often cottonwoods, but also honey mesquite in lower densities (Brand et al. 2010; GBBO 2011, 2018).

TEMPERATURE

This habitat element is added for consistency with other CEMs.

Full name: **The maximum temperature in a habitat patch or nest site**. This element refers to the maximum temperature in the nesting habitat around the nest site (or during the nesting season). High temperatures typical of the LCR region in summer can kill eggs and stress young in the nest (Hunter et al. 1987b; Rosenberg 1991).

UNDERSTORY DENSITY

The definition of this habitat element is updated as follows:

Full name: **The density of the understory layer of vegetation (0–1.5 meters) (Powell and Steidl 2002)**. VEFL appear to select for low understory density, including lower vegetative coverage, lower volume, and fewer shrubs (GBBO 2011) and are not found in areas with thick honey mesquite understory (Ellison et al. 2020). A grass understory, including Bermuda grass (*Cynodon dactylon*), may be important (GBBO 2018).

VEGETATION COMMUNITY TYPE

This habitat element replaces the original, Community Type, with a slightly updated definition as follows:

Full name: **The species composition of the riparian forest patch**. This element refers to the species composition of riparian habitat used for breeding by VEFL. Research shows that VEFL are adaptable, able to use various types of native and non-native broadleaf deciduous habitats at different elevations (Brand et al. 2010). However, VEFL densities are substantially higher in native habitats such as large cottonwood stands within the LCR region (Brand et al. 2010). Per Ellison et al. (2020), VEFL nest in trees along riparian corridors, including honey mesquite,

huisache (*Acacia* spp.), cottonwoods, oak (*Quercus* spp.), willows, and Arizona sycamore (*Platanus wrightii*). VEFL are also frequently found in the LCR and elsewhere, in human-created or manipulated habitats such as parks, golf courses, and farmlands (Ellison et al. 2020; GBBO 2018; Raulston 2013).

Updates to Chapter 5 – Controlling Factors

This update identifies nine controlling factors that affect one or more habitat elements and/or critical biological activities or processes across the three VEFL life stages. The original VEFL conceptual ecological model (Miller et al. 2016) identified nine controlling factors. This update standardizes the name of one controlling factor (Pesticide/Herbicide Application) and replaces it with Pesticide Application, and it updates the discussion of seven controlling factors. Table 4 lists the nine controlling factors in this update, indicates which habitat elements they *directly* affect, and which controlling factors are new to this update or renamed from the original VEFL conceptual ecological model.

Table 4.—(Revision of original table 4) Habitat elements directly affected by controlling factors (Xs indicate that the habitat element is applicable to that controlling factor.)

Controlling factor ➔ / **Habitat element 🡻**	**Fire management**	**Grazing**	**Irrigation**	**Mechanical thinning**	**Nuisance species introduction & management**	**Pesticide application (*replaces pesticide/ herbicide application*)**	**Planting regime**	**Recreational activities**	**Water storage-delivery system design & operation**
Anthropogenic disturbance		X		X		X	X	X	
Brood/litter size	N/A*								
Canopy closure	X		X	X	X		X	X	
Food availability					X	X	X		
Genetic diversity	N/A*								
Infectious agents	N/A*								
Local hydrology			X						X
Nest predator & cowbird density					X		X	X	
Parental care								X	
Patch size	X	X		X	X		X	X	
Predators					X		X	X	
Soil salinity			X						X
Stand height	X			X	X		X		
Temperature	N/A*								
Understory density	X	X		X	X		X	X	X
Vegetation community type	X	X	X		X		X	X	

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

FIRE MANAGEMENT

This controlling factor is updated as follows:

This factor addresses any fire management (whether prescribed fire or fire suppression) that could affect VEFL or their habitat. Effects may include creation of habitat that supports or excludes VEFL, a reduction in the food supply of invertebrates, or support of species that pose threats to VEFL such as predators, competitors, or carriers of infectious agents. While fire can decrease understory vegetation to the benefit of VEFL, most of the other impacts are negative, such as decreased canopy closure, decreased patch size, decreased tree size, and increased soil temperature, which in turn decreases the food supply. Although typically not a major threat in most riparian habitats, severe wildfires have affected southwestern willow flycatcher (*Empidonax traillii extimus*) breeding sites in the past decade (Ellis et al. 2008; Graber et al. 2007; U.S. Fish and Wildlife Service [USFWS] 2002) and could affect VEFL habitats. In fact, small, contained fires have recently occurred in a few LCR restoration sites (Hunters Hole and Yuma East Wetlands), and a severe fire occurred in riparian habitat at the Havasu National Wildlife Refuge (C. Dodge and B. Raulston 2018, personal communications).

Climate change is also projected to affect fire frequency along the LCR (USFWS 2013).

GRAZING

This controlling factor is updated as follows:

This factor addresses the grazing activity on riparian habitats along the LCR and in surrounding areas that could affect VEFL or their habitat. Overgrazing by cattle (Bovidae), burros (*Equus asinus*), or mule deer (*Odocoileus hemionus*) has been a contributor to riparian habitat degradation across the arid Southwestern United States (see Belsky et al. 1999 *in* USFWS 2002; Cannon and Knopf 1984; Clary and Webster 1989; General Accounting Office 1988; Klebenow and Oakleaf 1984; Rickard and Cushing 1982; Schultz and Leininger 1990; U.S. Forest Service 1979). (*Not*e: Bureau of Reclamation staff and researchers have observed mule deer browsing on LCR sites, which may become an issue if populations increase to the point that overgrazing occurs). Grazing may thin the understory, which could benefit VEFL in the short term, but it can also prevent the establishment of cottonwood, willow, or honey mesquite seedlings (Kauffman et al. 1997; Powell and Steidl 2002). In particular, overgrazing has been an identified as a management issue in Arizona along the San Pedro River and the Verde River (S. Kokos 2014, personal communication). Krueper (1993) and

Krueper et al. (2003) report that fencing cattle out of sensitive riparian habitats in the San Pedro Riparian National Conservation Area led to improved habitat quality and increased VEFL density within 4 years. However, cattle grazing does not have much impact in the LCR habitats in which VEFL occur (C. Dodge and B. Raulston 2018, personal communications).

IRRIGATION

This controlling factor is updated as follows:

This factor addresses the human activities of artificially introducing water to the landscape to influence habitat. In many cases, this may be implemented to simulate more natural riparian processes or to manage soil salinity levels. The amount of water provided through irrigation affects the species composition and density of the riparian vegetation plant community required by VEFL. The amount of water available is also affected by management actions to reduce or terminate water applications at a site (e.g., to reallocate water to other areas within the limits of the Bureau of Reclamation's and other land management agencies' water rights).

The LCR MSCP, USFWS, and Colorado River Indian Tribes irrigate portions of several areas along the LCR Valley to create and manage habitat for general wildlife, LCR MSCP covered species, and associated wetland habitat. VEFL have been found at two restoration sites, including Colorado River Indian Tribes' 'Ahakhav Tribal Preserve Habitat Creation Area 09 and Cibola National Wildlife Refuge Unit #1 (GBBO 2011, 2018).

MECHANICAL THINNING

The definition of this controlling factor remains unchanged. No new information was located on mechanical thinning among VEFL in the Lower Colorado River Valley or elsewhere.

NUISANCE SPECIES INTRODUCTION & MANAGEMENT

This controlling factor is updated as follows:

This factor addresses the intentional or unintentional introduction of nuisance species (animals and plants) and their control that affects VEFL survival and reproduction. Nuisance species may infect, prey on, compete with, or present alternative food resources for VEFL during one or more life stages; cause other alterations to the riparian food web that affect VEFL; or affect physical habitat features such as canopy or shrub cover. For example, although VEFL successfully nest in sites dominated by invasive tamarisk (*Tamarix* spp.), they do so in lower densities, and tamarisk may negatively affect habitat in other ways (e.g., by lowering the water table) (Brand et al. 2010; Di Tomaso 1998; GBBO 2011).

The complicated nature of the relationship between tamarisk and VEFL is highlighted by another introduced species—the tamarisk beetle (*Diorhabda carinulata*). This beetle was introduced to the LCR region in order to control invasive tamarisk (Bateman et al. 2013). However, defoliation of tamarisk due to beetle infestation causes decreases in humidity and cover along with increases in temperature (Bateman et al. 2013), thereby potentially degrading areas dominated by tamarisk as habitat for VEFL. Surveys conducted in the LCR in 2013 and 2014 specifically to assess the impacts of tamarisk beetles on riparian bird species did not detect any VEFL in the plots studied (GBBO 2014); therefore, the direct impacts of the beetle on VEFL could not be determined.

Shot hole borer beetles (*Euwallacea* spp.) are invasive species from Asia that have been found in southern California. The beetles feed on a wide variety of trees, including cottonwoods and willows, as well as honey mesquite, each important riparian species on which VEFL depend (Boland 2016; Leathers 2015). As of 2018, the beetles have not been found outside of California; they may require cooler temperatures, which would prevent or slow their spread into LCR habitats (B. Raulston 2018 personal communication; University of California Agriculture and Natural Resources 2020). However, Boland (2016) reports that damage to riparian habitat in California occurred rapidly once the beetles arrived, with cottonwoods and willows having the highest infestation rates. The presence of surface water was also a factor contributing to higher infestation rates. Due to the potential threat to all riparian habitat, LCR sites should be monitored regularly for beetle spread.

In addition to non-native plants and insect pests, non-native feral swine (*Sus scrofa*) have been identified as a problem for other riparian species in California's Santa Ana River watershed habitat. Feral swine also occur on the

Havasu National Wildlife Refuge and have been sighted elsewhere in the LCR. Through their rooting and wallowing activities, they disturb soil and increase erosion, destroy vegetation, and negatively affect water quality. Swine also compete with and/or prey on native wildlife species. For these reasons, they are currently being culled from the Havasu National Wildlife Refuge (Neskey 2018; U.S. Department of the Interior 2016). Effects on VEFL and nest success, if any, would be primarily through impacts to native vegetation (C. Dodge and B. Raulston 2018, personal communications).

Pesticide Application

This controlling factor replaces the original, Pesticide/Herbicide Application; otherwise, no changes are made.

This factor addresses pesticide/herbicide applications that may occur on or adjacent to riparian habitat of the LCR region. Effects may include sublethal poisoning of VEFL via ingestion of treated insects, pollution of runoff into wetland habitats that are toxic to prey of VEFL, and a reduced invertebrate food supply.

Planting Regime

This controlling factor is updated as follows:

This factor addresses the active program to restore cottonwood-willow riparian habitat along the LCR and includes both the community planted as well as the manner in which it is planted within restoration areas (e.g., density, age, and patch size). The composition of the species planted can affect not only the vertical and horizontal structure of the vegetation but also the insect community within a given patch. Habitat creation/restoration work has been successful in generating new habitat along the LCR (Fletcher et al. 2019).

Recreational Activities

This controlling factor is updated as follows:

This factor addresses the disturbance to VEFL from recreational activities. Even non-consumptive human activity can have negative effects on wildlife (reviewed by Boyle and Samson 1985). This is a broad category that encompasses the types

of activity (e.g., boating, fishing, horseback riding, camping) as well as the frequency and intensity of those activities. The impacts may consist of disturbance and habitat alteration. However, VEFL may be less impacted than other species by some forms of recreational activities, given their use of certain human-modified habitats (e.g., parks, golf courses) (Ellison et al. 2020; Raulston 2013).

WATER STORAGE-DELIVERY SYSTEM DESIGN & OPERATION

This controlling factor is updated as follows:

Much of the habitat currently used by VEFL within the LCR is along regulated waterways. The water moving through this system is highly regulated for storage and delivery (diversion) to numerous international, Federal, State, Tribal, and municipal users and for hydropower generation.

The dynamic nature of a free-flowing river creates a mosaic of riparian habitats, and thus, a natural flow regime might be beneficial to VEFL. Natural floods can decrease understory vegetation or increase the presence of surface water, improving VEFL habitat (GBBO 2011).

Updates to Chapter 6 – Conceptual Ecological Model by Life Stage

The following sections identify all changes made to the VEFL 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 Standardization of Terms," below). 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.

New Links with Controlling Factors as Causal Agents

- Grazing to Nuisance Species Introduction & Management (CF): Link added due to new information and analysis. *Applies to all life stages*.

- Irrigation to Canopy Closure (HE): Link added due to new information and analysis. *Applies to all life stages*.

- Pesticide Application to Fertility (LSO): Link added due to the availability of new information and analysis. *Applies to the breeding adults life stage*.

- Pesticide Application to Survival (LSO): Link added due to the availability of new information and analysis. *Applies to all life stages*.

- Water Storage Delivery System Design & Operation to Irrigation (CF): Link added for compatibility with other CEMs. *Applies to all life stages*.

Deleted Links with Controlling Factors as Causal Agents

- Recreational Activities to Parental Care (HE): Link deleted due to the combination of former habitat elements, Parental Feeding Behavior and Parental Nest Attendance, into a single habitat element, Parental Care, making one of the former two links duplicative. *Applies to all life stages*.

- Water Storage Delivery System Design & Operation to Local Hydrology (HE): Link deleted due to the combination of former habitat element, Water Availability, with Local Hydrology, making one of the former two links duplicative. *Applies all life stages*.

- Water Storage Delivery System Design & Operation to Understory Density (HE): Link deleted since this is not a direct link; water storage system design and operation influences irrigation, which affects understory density. *Applies all life stages*.

- Water Storage Delivery System Design & Operation to Vegetation Community Type (HE): Link deleted because this is not a direct link; water storage system design and operation influences irrigation, which affects vegetation type. *Applies all life stages*.

UPDATED LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS

- Grazing to Anthropogenic Disturbance (HE): Link updated due to new information and analysis. *Applies to all life stages*.

- Grazing to Patch Size (HE): Link updated due to new information and analysis. *Applies to all life stages*.

- Grazing to Understory Density (HE): Link updated due to new information and analysis. *Applies to all life stages*.

- Grazing to Vegetation Community Type (HE): Link updated due to new information and analysis. *Applies to all life stages*.

- Irrigation to Local Hydrology (HE): Link updated to ensure compatibility with other CEMs. *Applies to all life stages*.

- Irrigation to Vegetation Community Type (HE): Link updated to ensure compatibility with other CEMs. *Applies to all life stages*.

- Recreational Activities to Parental Care (HE): Link updated due to the combination of former habitat elements, Parental Feeding Behavior and Parental Nest Attendance, into a single habitat element, Parental Care. *Applies to all life stages*.

- Water Storage Delivery System Design & Operation to Local Hydrology (HE): Link updated for compatibility with other CEMs. *Applies to all life stages*.

- Water Storage Delivery System Design & Operation to Soil Salinity (HE): Link updated for compatibility with other CEMs. *Applies to all life stages*.

New Links with Habitat Elements as Causal Agents

- Infectious Agents to Disease (CAP): Link updated to reflect the split of former habitat element, Genetic Diversity & Infectious Agents, into two separate habitat elements, generating a new link for Infectious Agents. *Applies to all life stages*.

- Infectious Agents to Survival (LSO): Link added due to the availability of new information and analysis. *Applies to all life stages*.

- Temperature to Nest Attendance (CAP): Link added due to the availability of new information and analysis. *Applies to the breeding adults life stage*.

- Temperature to Nest Site Selection (CAP): Link added due to the availability of new information and analysis. *Applies to the breeding adults life stage*.

- Temperature to Parental Care (CAP): Link added due to the availability of new information and analysis. *Applies to the eggs/nestlings life stage*.

- Temperature to Thermal Stress (CAP): Link added due to the availability of new information and analysis. *Applies to all life stages*.

Deleted Links with Habitat Elements as Causal Agents

- Anthropogenic Disturbance to Foraging (CAP): Link deleted to reflect the split of former critical biological activity or process, Eating/Foraging, into two separate critical biological activities or processes; Foraging does not apply to the eggs/nestlings life stage. *Applies to the eggs/nestlings life stage*.

- Brood/Litter Size to Eating (CAP): Link deleted to reflect the split of former critical biological activity or process, Eating/Foraging, into two separate critical biological activities or processes; Eating does not apply to the juveniles life stage. *Applies to the juveniles life stage*.

- Local Hydrology to Nest Site Selection (CAP): Link deleted due to the combination of former habitat element, Water availability, with Local Hydrology, making one of the former two links duplicative. *Applies to the breeding adults life stage*.

- Local Hydrology to Thermal Stress (CAP): Link deleted due to the combination of former habitat element, Water Availability, with Local Hydrology, making one of the former two links duplicative. *Applies to the juveniles and breeding adults life stages*.

- Parental Care to Eating (CAP): Link deleted to reflect the split of former critical biological activity or process, Eating/Foraging, into two separate critical biological activities or processes, creating a duplicate link. *Applies to the eggs/nestlings life stage*.

- Parental Care to Eating (CAP): Link deleted to reflect the split of former critical biological activity or process, Eating/Foraging, into two separate critical biological activities or processes; Eating does not apply to the juveniles life stage. *Applies to the juveniles life stage*.

- Parental Care to Foraging (CAP): Link deleted to remove the duplicate link created by the combination of former habitat elements, Parental Feeding Behavior and Parental Nest Attendance, into a single habitat element, Parental Care. *Applies to the breeding adults life stage*.

- Parental Care to Foraging (CAP): Link deleted because Parental Care only applies to the eggs/nestlings and juveniles life stages. *Applies to the breeding adults life stage*.

- Parental Care to Predation (CAP): Link deleted because brood parasitism and nest predation only apply to the eggs/nestlings life stage. *Applies to the breeding adults life stage*.

Updated Links with Habitat Elements as Causal Agents

- Genetic Diversity to Disease (CAP): Link updated to reflect the split of former habitat element, Genetic Diversity & Infectious Agents, into two separate habitat elements. *Applies to all life stages*.

- Local Hydrology to Nest Site Selection (CAP): Link updated due to the combination of former habitat element, Water Availability, with Local Hydrology. *Applies to the breeding adults life stage*.

- Local Hydrology to Thermal Stress (CAP): Link updated due to the combination of former habitat element, Water Availability, with Local Hydrology. *Applies to all life stages*.

New Links with Critical Activities/ Processes as Causal Agents

- Disease to Foraging (CAP): Link added to reflect the split of former critical biological activity or process, Eating/Foraging, into two separate critical biological activities or processes. *Applies to the juveniles life stage*.

- Foraging to Molting (CAP): Link added to reflect the split of former critical biological activity or process, Eating/Foraging, into two separate critical biological activities or processes. *Applies to the juveniles life stage*.

- Foraging to Survival (LSO): Link added to reflect the split of former critical biological activity or process, Eating/Foraging, into two separate critical biological activities or processes. *Applies to the juveniles life stage*.

Deleted Links with Critical Activities/ Processes as Causal Agents

No change.

Updated Links with Critical Activities/ Processes as Causal Agents

No change.

New Links with Life-Stage Outcomes as Causal Agents

No change.

SUMMARY OF STANDARDIZATION OF TERMS

Table 5.—(New table for this update) Updated CEM component names
(Blue indicates new or revised items; orange indicates replaced items.)

VEFL conceptual ecological model updated terms, 2019	VEFL conceptual ecological model original terms, 2016
Life stages	
Eggs/Nestlings *(renamed)*	Nest
Juveniles *(renamed)*	Juvenile
Breeding Adults *(renamed)*	Breeding Adult
Life-stage outcomes	
Survival	Survival
Fertility *(renamed)*	Reproduction
Critical biological activities and processes	
Disease	Disease
Eating	Eating/Foraging *(see Eating)*
Foraging	Eating/Foraging *(see Foraging)*
Molting *(renamed)*	Molt
Nest Attendance	Nest Attendance
Nest Predation & Brood Parasitism	Predation & Brood Parasitism *(see Nest Predation & Brood Parasitism*
Nest Site Selection	Nest Site Selection
Predation *(new)*	
Thermal Stress *(renamed)*	Temperature Regulation *(see Thermal Stress)*
Habitat elements	
Anthropogenic Disturbance	Anthropogenic Disturbance
Brood/Litter Size *(renamed)*	Brood Size
Canopy Closure	Canopy Closure
Food Availability	Food Availability
Genetic Diversity *(new)*	Genetic Diversity & Infectious Agents *(see Genetic Diversity; see Infectious Agents)*
Infectious Agents *(new)*	
Local Hydrology	Local Hydrology
Nest Predators & Cowbird Density *(renamed)*	Predator & Cowbird Density
Parental Care *(renamed)*	Parental Feeding Behavior *(see Parental Care)*
	Parental Nest Attendance *(see Parental Care)*
Patch Size	Patch Size
Predators *(new)*	Predator & Cowbird Density *(see Nest Predators & Cowbird Density; see Predators)*
Soil Salinity	Soil Salinity
Stand Height *(revised)*	Tree Size *(see Stand Height)*
Temperature *(new)*	
Understory Density	Understory Density
Vegetation Community Type *(renamed)*	Community Type *(see Vegetation Community Type)*
	Water Availability *(see Local Hydrology)*
Controlling factors	
Fire Management	Fire Management
Grazing	Grazing
Irrigation	Irrigation
Mechanical Thinning	Mechanical Thinning
Nuisance Species Introduction & Management	Nuisance Species Introduction & Management
Pesticide Application *(renamed)*	Pesticide/Herbicide Application
Planting Regime	Planting Regime
Recreational Activities	Recreational Activities
Water Storage-Delivery System Design & Operation	Water Storage-Delivery System Design & Operation

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ATTACHMENT 1

Vermilion Flycatcher (*Pyrocephalus rubinus*) Habitat Data

Table 1-1.—Vermilion flycatcher habitat data
(*Note*: This is an update of Table 2.1 found in Attachment 2 of the original VEFL model document.)

Habitat element	Value or range	Location	Reference
Anthropogenic disturbance	No quantifiable values found in the literature		
Brood/litter size	No quantifiable values found in the literature		
Canopy closure	Not found in areas with dense Fremont cottonwood (*Populus fremontii*) canopy	Arizona	Ellison et al. (2020)
Food availability	No quantifiable values found in the literature		
Genetic diversity	No quantifiable values found in the literature		
Infectious agents	No quantifiable values found in the literature		
Local hydrology	No quantifiable values found in the literature		
Nest predators & cowbird density	No quantifiable values found in the literature		
Parental care	No quantifiable values found in the literature		
Patch size	No quantifiable values found in the literature		
Soil salinity	No quantifiable values found in the literature		
Tree size	No quantifiable values found in the literature		
Understory density	Not found in areas with thick honey mesquite (*Prosopis glandulosa*) understory	Arizona	Ellison et al. (2020)
Vegetation community type	Nest trees used: Goodding's willow (*Salix gooddingi*, 38 %), Fremont cottonwood (24 %), honey mesquite (21 %), and Arizona sycamore (*Platanus wrightii*, 16 %)	Lower Colorado River	Ellison et al. (2020)

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

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