Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

2019 Updates to Arizona Bell's Vireo (*Vireo bellii arizonae*) (BEVI) Basic Conceptual Ecological Model for the Lower Colorado River

Photo courtesy of the Bureau of Reclamation

January 2021

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Lower Colorado River Multi-Species Conservation Program

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Acronyms and Abbreviations

BEVI	Arizona Bell's vireo (*Vireo bellii arizonae*)
CAP	critical activity or process
CEM	conceptual ecological model
CF	controlling factor
DDE	1,1-Dichloro-2,2-bis(p-chlorophenyl) ethylene
GBBO	Great Basin Bird Observatory
ha	hectare(s)
HE	habitat element
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
LSO	life-stage outcome
m	meter(s)
N/A	not applicable
ORV	off-road vehicle(s)
Reclamation	Bureau of Reclamation
SWCA	SWCA Environmental Consultants
USFWS	U.S. Fish and Wildlife Service

Symbols

≈	approximately
°C	degrees Celsius
°F	degrees Fahrenheit
>	greater than
%	percent

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 Arizona Bell's Vireo (*Vireo bellii arizonae*) (BEVI)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 Arizona Bell's vireos (*Vireo bellii arizonae*) (BEVI) (Johnson and Unnasch 2015). This update incorporates information reported in publications and presentations at professional meetings since the completion of the original BEVI 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 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 these sections were not updated.

The updates presented in this report change the BEVI conceptual ecological model in several respects. We have added two new components, the controlling factor (Irrigation) and the habitat element (Soil Salinity) to align with other riparian bird models and to better describe critical management actions for BEVI habitats. Other components have been separated or merged for clarity (e.g., Genetic Diversity separated from Infectious Agents; Parental Feeding Behavior merged with Parental Nest Attendance), and additional links have been added or modified for continuity with other models. Other link interaction strengths have been modified, and reasons clarified based on updated information, most importantly, Grazing.

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 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 BEVI. These questions may or may not reflect the current or future goals of 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 paragraph 3 in the initial section of chapter 1 is updated as follows:

The most widely used sources of information for the Arizona Bell's vireo (*Vireo bellii arizonae*) (BEVI) conceptual ecological model (CEM) are the Bureau of Reclamation (Reclamation) (2008, 2016) and Kus et al. (2020). 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) biologists (Great Basin Bird Observatory [GBBO] 2011, 2012b, 2013, 2014, 2015, 2018; SWCA Environmental Consultants [SWCA] 2017, 2019). In addition, sources of information for least Bell's vireos (*Vireo bellii pusillus*) in California, as well as Bell's vireos (*Vireo bellii*) range-wide, were consulted if there was insufficient information available about BEVI along the lower Colorado River (LCR). The purpose of a conceptual model is not to provide an updated literature review but to integrate the available information and knowledge so it can be used for adaptive management.

Update to Arizona Bell's Vireo Reproductive Ecology

BEVI are considered complete migrants, breeding in North America and wintering in central and southern Mexico and Baja California (Kus et al. 2020). Birds typically return to the LCR from their wintering grounds by late March to begin the breeding season. Kus et al. (2020) report that males arrive before females, often a few days to 2 weeks ahead. Scott (1888 *in* Bent 1950) reports that birds arrive already mated and immediately begin nest construction and egg laying.

Along the LCR, BEVI nest in riparian habitat, typically "tall woody and low woody vegetation" (GBBO 2014), consisting of Fremont cottonwood (*Populus fremontii*) and willow (*Salix* sp.) (hereafter cottonwood-willow) with mesquite (*Prosopis* sp.) and/or saltcedar (*Tamarix* sp.) (Anderson and Ohmart 1976; Bart et al. 2010; Reclamation 2016). Male and female BEVI construct a loosely woven hanging nest in a "V" of a tree branch. Three to four eggs are laid, and both parents share incubation, which lasts about 14 days. Young birds fledge from the nest in 10–12 days, but fledglings remain in the vicinity of the nest,

begging for food from their parents for 25–30 days. BEVI primarily feed on insects such as moths and their caterpillars (Lepidoptera), bugs (Hemiptera), and spiders (Aranea) (Bent 1950; Kus 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 THE BEVI

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

Updates to Chapter 2 – BEVI Life-Stage Model

This update standardizes the names of the BEVI 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: (1) Survivors changes to Survival for all three life stages and (2) Offspring and Reproduction change to Fertility. This 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 (at the end of this chapter) are updated accordingly.

Update to Introduction to the BEVI Life Cycle

The introduction is updated as follows:

We have chosen to combine the egg and nestling phases of development into an eggs/nestlings life stage because the eggs and nestlings occupy the same nest; therefore, management focused on the nest will cover both eggs and nestlings. Further, most research conducted on BEVI 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 the incubation and brooding periods.

Update to BEVI Life Stage 1 – Eggs/ Nestlings

This life stage description is updated as follows:

The eggs/nestlings life stage of BEVI begins when the first egg is laid and ends either when the young fledge or the nest fails. Eggs are usually laid in April, and incubation lasts around 14 days (Bent 1950; Terres 1980), with all eggs in a clutch hatching within 2 days of each other. Nestlings are generally present from mid-May into June (Reclamation 2008, 2016), and fledging usually occurs 10–12 days after hatching (Kus et al. 2020; Terres 1980). Least Bell's vireos often raise two broods a season (Franzreb 1989); BEVI likely do the same. The life-stage outcome for the eggs/nestlings life stage is the survival of eggs and

associated nestlings until fledging. It is important to note that the outcome of the eggs/nestlings life stage is inherently tied to the behavior and condition of the parents.

UPDATE TO BEVI LIFE STAGE 2 – JUVENILES

This life stage description is updated as follows:

The juveniles life stage begins at fledging and ends when the bird returns to the breeding grounds the next year. However, for the sake of this report, the influences are only evaluated; the model only addresses the time the juvenile spends on site through the bird's departure from the natal area during fall migration. For a few days after fledging, juveniles will remain close to the nest, within 5–10 meters (m) (Kus et al. 2020). Subsequently, juveniles will remain with their parents for several weeks (25–30 days), and are fed by their parents during this time, although they can, and do, forage on their own (Kus et al. 2020). During fall migration, juveniles generally leave the breeding grounds 1 or 2 weeks after the adults, most leaving in late September or early October (Kus et al. 2020; Reclamation 2008, 2016). The life-stage outcome for the juveniles stage is the survival of the bird from fledging until its return to the breeding grounds the next calendar year. There are no studies available that analyze the juvenile survival rates in this species.

UPDATE TO BEVI LIFE STAGE 3 – BREEDING ADULTS

This life stage description is updated as follows:

The breeding adults life stage begins when the bird returns to the breeding grounds after its first winter and ends when it departs the breeding grounds during fall migration, usually in late September. Generally, adults arrive on the breeding grounds in mid- to late March, with males arriving a few days to 2 weeks before females to set up territories (Kus et al. 2020; NatureServe 2018; Reclamation 2008, 2016). Upon their return, females will choose a territory, and both males and females construct the nest, completing it over a 4- to 5-day period (Kus et al. 2020), although other citations (e.g., Bent 1950) specify that only females construct the nest. There are typically three to five eggs per clutch, and both the male and female incubate the eggs and care for the young (Bent 1950), although

the female may do more than the male (Kus et al. 2020). Bell's vireo pairs will renest after a failed attempt and may continue to renest (typically two to four times) until they are successful or the summer season ends (Kus et al. 2020).

The life-stage outcomes for the breeding adults stage are survival and fertility. The CEM defines the latter as the rate of production of viable eggs by cohorts of breeding adults. Since BEVI eggs are not viable unless fertilized and laid in a nest that is safely constructed, safely located, and well attended, all of these contribute to breeding adult fertility. Fertility is distinguished from fecundity, which is the rate of recruitment of offspring to the next generation (Etterson et al. 2011). In the structure of the present CEM, the fecundity rate would be recognized as a function of both (1) adult survival and fertility in the breeding adults life stage and (2) egg/nestling survival in the eggs/nestlings life stage, the latter of which depends significantly on nest success. Here we have separated the eggs/nestlings life stage from adult fecundity 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.

It is important to note that the post-breeding period—after breeding but before migration—is a significant part of a bird's life cycle. Although males, females, and 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) BEVI life stages and outcomes in the LCR ecosystem

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

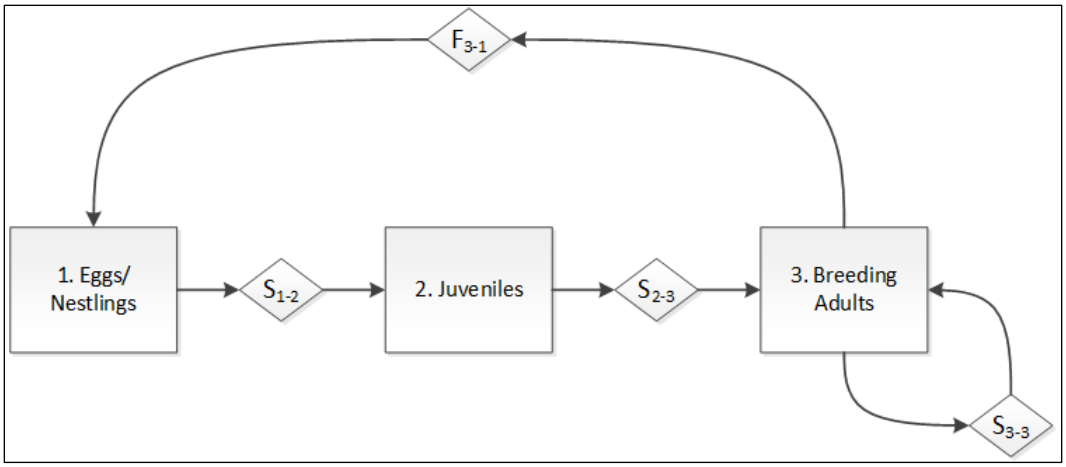

Figure 1.—(Revision of original table 1) Proposed BEVI life history model.
Squares indicate the life stage, and diamonds indicate the life-stage outcomes. S_{1-2} = survival, eggs/nestlings; S_{2-3} = survival, juveniles; S_{3-3} = survival, breeding adults; and F^{3-1} = fertility, breeding adults.

Updates to Chapter 3 – Critical Biological Activities and Processes

This update changes the names of two critical biological activities and processes, Molt and Temperature Regulation, and replaces them with Molting and Thermal Stress for consistency with the other LCR MSCP conceptual ecological model updates. It also adds additional information to all but one critical biological activity – Foraging. Updates to table 2 and details follow:

Table 2.—(Revision of original table 2) Distribution of BEVI 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	**X**		
Foraging		**X**	**X**
Molting (*new*)	**X**	**X**	**X**
Nest attendance			**X**
Nest predation & brood parasitism	**X**		
Nest site selection			**X**
Predation		**X**	**X**
Thermal stress (*renamed*)	**X**	**X**	**X**

DISEASE

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

This process refers to diseases caused by infectious agents, including the effects of ecto- and endoparasites. Disease prevalence and intensity can be influenced by a lack of genetic diversity. Little research has focused on specific diseases inflicting BEVI; however, some mid-western populations of Bell's vireos are

known to be heavily parasitized by mites (e.g., northern fowl mite [*Ornithonyseus sylviarum*)] (Kus et al. 2020), which may weaken nestlings and make them more susceptible to other parasites and diseases.

Although the more common avian diseases and parasites of North American birds are generally known (Morishita et al. 1999), some are often difficult to detect (Jarvi et al. 2002), and they can have differing effects on different species (Palinauskas et al. 2008). BEVI at all life stages are conceivably susceptible to disease. In addition, susceptibility to disease can be enhanced by other factors such as when ongoing stress from parental care weakens parental immune systems (Gill et al. 2019).

EATING

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

This process only applies to the eggs/nestlings life stage because nestlings must eat to stay alive and develop but do not actively forage within their environment in the same way as juveniles and adults. A nestling's ability to eat during the first weeks of life is determined by the foraging and provisioning rate of its parents. (Juveniles are still fed by adults for some time after fledging – see chapter 4, "Parental Care.")

FORAGING

The definition of this critical biological activity or process remains unchanged. No new information was located on BEVI foraging in the Lower Colorado River Valley or elsewhere.

MOLTING

This critical biological process, formerly named Molt, is renamed Molting for consistency with other CEMs. Further, the discussion of this critical biological activity or process is updated 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 BEVI undergo a pre-juvenal molt from natal down into juvenile 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 a partial to complete pre-basic (pre-formative) molt in the summer geographic range from July to September (Pyle et al. 1997). Adults undergo a complete pre-basic molt on the summer grounds from June to August every subsequent year of their lives (Pyle et al. 1997; Reclamation 2008, 2016). Adult BEVI do not undergo a pre-alternate molt (Pyle et al. 1997).

NEST ATTENDANCE

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

Nestlings rely on the parents to provide food, protection from predators, and thermoregulation. In the case of BEVI, both males and females incubate eggs, brood young, and feed nestlings (Kus et al. 2020). Nest attendance is performed by breeding adults (and is dependent in part on their survivorship) and affects the eggs/nestlings life stage (egg hatching and provisioning rate to nestlings).

Nest attendance is affected by food availability. Research shows that nest attentiveness increases with food supplementation (Moreno [1989] and Nilsson and Smith [1988] *in* Theimer et al. 2011) such that an adult bird can spend more time at the nest caring for eggs or young if food is close by.

NEST PREDATION & BROOD PARASITISM

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

Range-wide, nest predation is the primary threat to Bell's vireo nest success (Budnik et al. 2000; Kus et al. 2020). Reported nest predators of least Bell's vireos in California include western scrub jays (*Aphelocoma californica*), Virginia opossum (*Didelphis virginiana*), gophersnakes (*Pituophis melanoleucus*), and Argentine ants (*Linepithema humile*) (Peterson et al. 2004). Other confirmed nest predators include, among others, domestic cats (*Felis catus*) and various snake species (e.g., black rat [*Pantherophis obsoletus*] and California kingsnakes [*Lampropeltis getula californiae*]). Suspected nest predators include birds such as American crows (*Corvus brachyrhynchos*) and greater roadrunners (*Geococcyx californianus*), along with mammals, including raccoons (*Procyon lotor*), coyotes (*Canis latrans*), long-tailed weasels (*Mustela frenata*), and rodent species (Collins et al. 1989 *in* Kus et al. 2020; Franzreb 1989; Nolan 1960). Similar species may prey on young BEVI.

Nest parasitism by cowbirds (*Molothrus ater*) is also a major threat to BEVI (Kus et al. 2020), directly or indirectly affecting nest success. For example, brood parasitism accounted for about one-half of all BEVI nest failures along the Bill Williams River during the 1994 and 1995 nest seasons (Averill-Murray et al. 1999) and for 43 and 28% of nest failures in southeastern Arizona in 2006 and 2007, respectively (S. Steckler and C. Conway, personal communications *in* Kus et al. 2020). Kus and Whitfield (2005) and Laymon (1987) suggest that brood parasitism rates below 20–30% are necessary to maintain stable populations of vireos. Cowbird control is an effective conservation tool. As Parker et al. (2018) reported, Blue Point Conservation Sciences has been trapping cowbirds at locations along the Amargosa River in California since 2007 to improve nest success of least Bell's vireos that nest there. Yearly cowbird trapping has reduced brood parasitism rates from 45% to almost zero. Cowbird removal coupled with habitat restoration has dramatically increased nest success and population numbers of least Bell's vireo in this area (see also McCreedy and Warren [2016] for annual reports of trapping activities and summary of fledging [2009–15]).

Site characteristics and nest placement affect the rate of predation and/or nest parasitism. Budnik et al. (2002) noted in Missouri grassland-shrub habitats that nest height, along with greater nest concealment and shrub cover, reduced rates of cowbird parasitism and predation of Bell's vireos. They recommended that land managers increase the density of large (> 200 square meters) shrub patches in those habitats to reduce predation and parasitism.

Once nest sites are selected, adult vireos have different strategies and rates of success at deterring female cowbirds from depositing eggs in their nests. Initially, birds aggressively chase female cowbirds from the nest; however, if that does not work, and if vireo clutch size declines significantly due to cowbird egg-laying activity, vireos will desert the parasitized nest and renest elsewhere (Kus et al. 2020; Parker 1999). Unfortunately, particularly for least Bell's vireos, the nests of vireos that renest following parasitism also are usually parasitized (Kus 2002b). Burial of cowbird eggs deeper in the nest to prevent their incubation and hatching has also been noted as a strategy in areas outside Arizona (Kus et al. 2020).

These two processes (brood parasitism and nest predation) 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.

NEST SITE SELECTION

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

Both breeding males and females select a nest site and construct the nest (Kus et al. 2020). Nest site selection affects vulnerability to predation and brood parasitism (Budnik et al. 2002), environmental conditions at the nest, and foraging rates and, thus, is important for reproductive success (Saab 1999).

PREDATION

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

Predation is a threat to BEVI in all life stages, and it obviously affects survival. Predation on juveniles and adults is not as easily quantified, but it affects juveniles and adults directly, and it indirectly affects eggs/nestlings survival through abandonment. Predation risk (actual or perceived) can result in many behavioral responses in passerines, including changes in territory location, nest densities, altered clutch size, egg size, etc. (Eggers et al. 2008; Ghalambor and Martin 2002; Lima 2009; Theimer et al. 2011).

For this model, nest predation has been combined with brood parasitism and is treated as a separate critical biological activity and process at the eggs/nestlings life stage (see above). Although there are few, if any, records in the literature of predation on adults, typical predators of adult birds likely include mammals and raptors such as falcons (*Falco* sp.) and accipiters (*Accipiter* sp.) (Kus et al. 2020). Kus et al. (2020) report a suspected incidence of a long-tailed weasel attack on a sleeping adult female least Bell's vireo in the nest.

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 activity is revised as follows:

Avoiding thermal stress is important for any organism inhabiting a region with temperatures as high as that of the LCR. Although overheating is possible during all life stages, most of the concern has been directed at eggs and nestlings (Rosenberg et al. 1991). However, adults can moderate the thermal stress of eggs

and nestlings through their own behavior (incubating, brooding, or shading) and through nest placement. Theimer et al. (2011) found that there was a temperature threshold that triggered changes in BEVI thermoregulatory behavior. Between 29 and 31 degrees Celsius (ºC) (84–88 degrees Fahrenheit [ºF]), parental behavior switched from brooding (to keep eggs warm) to shading eggs (to keep them cool) and from sitting tightly on the nest to standing over the nest and fanning with feathers.

Updates to Chapter 4 – 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 Predator Density becoming Predators; adds one new habitat element (Soil Salinity); splits one habitat element (Genetic Diversity and Infectious Agents) into two separate elements; combines two habitat elements (Parental Feeding Behavior and Parental Nest Attendance) into Parental Care; and updates the discussions of 15 habitat elements. Table 3 is updated to reflect these changes as follows:

Table 3.—(Revision of original table 3) Distribution of BEVI 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	
Brood/litter size (*renamed*)		X	X		X				
Canopy closure						X	X	X	X
Diversity of vegetation			X				X		
Food availability			X		X		X		
Genetic diversity (*replaces genetic diversity and infectious agents*)	X								
Infectious agents	X								
Intermediate structure						X	X	X	X
Local hydrology					X		X		X
Matrix community			X			X	X	X	
Nest predator & cowbird density						X			
Parental care (*replaces parental feeding behavior and parental nest attendance*)		X	X			X		X	X
Patch size						X	X	X	
Predators (*renamed)*					X		X	X	
Previous year's use							X		
Soil salinity (*new*)	N/A*								
Stem density						X	X	X	
Temperature					X		X		X
Vegetation community type (*renamed*)						X	X	X	

*: Soil salinity does not affect any critical biological activity or process directly; it acts through vegetation community type or intermediate structure. No habitat element *directly* affects molting; rather, the effects are *indirect* from infectious agents via disease and food availability via foraging.

ANTHROPOGENIC DISTURBANCE

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

Full name: **Human activity within or surrounding a given habitat patch, including noise, pollution, and other disturbances associated with human activity**. Whether due to recreation, land management, or scientific research activities, the presence of humans can disturb BEVI, causing changes in behavior that might ultimately affect survival (Greaves 1989; Kus et al. 2008), although Brown (1993 *in* Kus et al. 2020) considers Bell's vireos to be relatively tolerant of anthropogenic disturbance. Most problematic would be disturbances during the nesting season that would discourage nesting or cause nest abandonment. Barlow (1962 *in* Kus et al. 2020) reports premature fledging of nestlings in response to anthropogenic disturbance at the nest.

Anthropogenic disturbance can affect both breeding success and the survival of birds (reviewed by Barber et al. 2010; Francis and Barber 2013). Noise might mask conspecific cues such as songs or calls—making it more difficult for BEVI to attract or find mates or defend territories. Noise may also affect foraging, eating, nest attendance, predation rates, etc. (Ware et al. 2015). Anthropogenic disturbance effects have not been thoroughly studied in BEVI or within the LCR, so specific impacts are not quantified. Barrett (1996 *in* TranSafety, Inc. 1997) reports on U.S. Fish and Wildlife Service (USFWS) recommendations to avoid traffic or construction noise levels above 60 decibels near nesting least Bell's vireos, although the biological validity of this number has been questioned.

Anthropogenic disturbance is considered to be a habitat element, as it is an environmental characteristic with which a nesting or foraging vireo must contend.

In 2017, two BEVI territories were found at Yuma East Wetlands. This site is adjacent to Interstate 8, downtown Yuma, and active railroad tracks, and it contains nature trails and a city park that are used regularly. Anthropogenic noise of one kind or another is nearly constant. Although there is no information regarding nest success for these birds that year, it is evident that this type of noise disturbance did not dissuade BEVI from establishing nesting territories if the habitat is otherwise suitable (C. Dodge and B. Raulston 2018, personal communications).

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. Brood/litter size is a life-stage outcome for breeding adults (fertility) that acts as a habitat element for eggs/nestlings and juveniles. Clutch 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 (See Gill et al. 2019 and references therein), as well as other factors such as predator density (see chapter 4, "Nest Predator & Cowbird Density"). The typical brood consists of three to four young (Kus et al. 2020).

CANOPY CLOSURE

The definition and discussion 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); measures of canopy foliage such as canopy closure, cover, leaf area index, and density are interrelated and all assess some aspect of the density of foliage in the overstory (Jennings et al. 1999; Korhonen et al. 2006; Smith et al. 2009). Ohmart (1994) considers the overstory to be the most important layer of vegetation for desert riparian habitats because of its ameliorating effects on temperature.

GBBO found that BEVI territories were placed in sites with tall woody habitat with significantly greater canopy cover than non-use sites. However, they also observed that BEVI "readily nest in riparian shrub habitats" (GBBO 2011).

Canopy cover may affect the availability of food (Smith et al. 2006) in part by modifying moisture levels in the habitat patch; moisture levels have been identified as important to arthropod abundance (Allen 2016). Tree canopies and shade also moderate temperatures in a vegetation patch (Thelander and Crabtree 1994).

DIVERSITY OF VEGETATION

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

Full name: **Either horizontal or vertical diversity of the vegetation structure at the patch or microhabitat scales or diversity of community types or ages at the landscape scale**. The diversity of vegetation affects site use by many animals (Erdelen 1984; MacArthur and MacArthur 1961; Wiens et al. 1993). BEVI prefer nest sites with low, dense shrub cover (predominantly native willows), often near the edge of a thicket or woodland, generally habitats typical of early successional stages (Kus et al. 2020). At the Bill Williams River National Wildlife Refuge, BEVI use mostly edges (mesquite and catclaw [(*Acacia greggii*] habitat) that do not have an overstory component (A. Leist 2015, personal communication).

Horizontal heterogeneity of vegetation within a territory or patch is also important for Bell's vireo site use. Least Bell's vireo nests are often placed in low shrubs near small openings under the canopy (Franzreb 1989) at the edge of a patch of vegetation. Dense areas provide vegetation to conceal nests and provide microclimate needed for egg and nestling development. At the Bill Williams National Wildlife Refuge, BEVI that nest in interior habitats select those whose interiors mostly have open spaces, such as washes or edges (A. Leist 2015, personal communication). Although proximity to open areas may increase vulnerability to nest predators, brood parasites, or predation in general, it may also facilitate foraging. In fact, GBBO biologists have observed BEVI foraging in open areas when provisioning nestlings and fledglings (A. Leist 2015, personal communication).

FOOD AVAILABILITY

The definition of this habitat element remains unchanged. No new information was located about BEVI food availability in the Lower Colorado River Valley or elsewhere.

GENETIC DIVERSITY

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

Full name: **The genetic diversity of BEVI (sub)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 (Allendorf and Leary 1986). Franzreb (1989) reports that habitat fragmentation not only increases cowbird parasitism rates, it separates vireos into distinct subpopulations more susceptible to local extinction (see Kus et al. 2020). GBBO (2012a) also acknowledges the importance of connectivity among subpopulations to stability in vireo populations. Dispersal distances for BEVI are not known; however, least Bell's vireos were reported to have dispersed 350 kilometers into the Central Valley of California in 2005 (Howell et al. 2010).

Klicka et al. (2015) describe the first genetic analysis of the Bell's vireo across its range in North America and recommend that the Bell's vireo should be divided into two species on an east/west divide, with the western species being named the least vireo (*Vireo pusillus*). They also support the idea of two subspecies for the western population, and recommend that additional genetic studies be done to resolve the taxonomic status of the western subspecies (BEVI and least Bell's vireo) and better assess their distributions. Populations identified as least Bell's vireos (versus BEVI) would then be afforded protection by the Endangered Species Act. They did find what is currently known as the least Bell's vireo (federally endangered subspecies) in California very near the border with Nevada and not far from the LCR.

INFECTIOUS AGENTS

The habitat element, Genetic Diversity and 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**. The infectious agent habitat element refers to the spectrum of viruses, bacteria, fungi, and parasites that individual BEVI are likely to encounter during each life stage. The effects of disease and other infectious agents are poorly understood. Although the more common avian diseases and parasites of North American birds are generally known (Morishita et al. 1999), some are often difficult to detect (Jarvi et al. 2002), and they can have differing effects on different species (Palinauskas et al. 2008). BEVI at all life stages are conceivably susceptible to disease.

INTERMEDIATE STRUCTURE

The definition of this habitat element is updated as follows:

Full name: **The concealment provided by the vegetation structure between the canopy and the herbaceous (=ground) layer**. This element refers to the visual density of vegetation (i.e., concealment) below the uppermost canopy layer to the ground. Dense understory vegetation (a shrub layer up to 3 m high) is characteristic of least Bell's vireo nesting habitat (Franzreb 1989; Goldwasser 1981; Kus et al. 2020) and is one of the most often-listed characteristics of BEVI habitat (B. Sabin and A. Leist 2015, personal communications). Studies in the LCR from 2008 through 2010 showed that BEVI selected denser vegetation (based on densitometer readings) for nesting (GBBO 2011; A. Leist 2015, personal communication). A denser understory may support a more diverse and abundant invertebrate food supply as well as provide protection or concealment from nest predators and cowbird parasitism (Budnik et al. 2002; Kus et al. 2020; Sharp and Kus 2006).

LOCAL HYDROLOGY

The definition and discussion 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, 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 of a given patch are an important determinant of BEVI habitat quality in riparian areas because it affects other aspects of habitat such as vegetation structure, cottonwood recruitment, and abundance of the arthropods (Ahlers and Moore 2009; Burke et al. 2009). Wetter conditions might also provide cooler temperatures and higher overall humidity necessary for egg and chick survival, generally, in these desert systems (McLeod and Pellegrini 2013; Rosenberg et al. 1991). BEVI may benefit similarly from higher humidity levels in dense vegetation. Additionally, local hydrology can also affect prey composition and overall food abundance (Ellis et al. 2001).

Vireo nests have been measured at occurring less than 1,000 m from water in California sites with the presence of ponded surface water (either perennial or intermittent water) (Averill-Murray and Corman 2005 *in* Kus et al. 2020) or moist soil considered important features of vireo nesting habitat (Barlow 1962 *in* Kus et al. 2020; Rosenberg et al. 1991). GBBO (2010) also found a strong association

between BEVI territory location and proximity of surface water at selected LCR sites. In particular, they are found along the Virgin River and the edges of Lakes Mead, Mohave, and Havasu.

MATRIX COMMUNITY

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

Full name: **The type of habitat surrounding riparian patches used by vireos**. This element refers to the types of plant communities and land-use activities surrounding the riparian habitat patches used by BEVI. Least Bell's vireo forage in upland vegetation next to riparian corridors (Gray and Greaves 1984; Kus and Miner 1989; Salata 1983 *in* Kus et al. 2020); therefore, the matrix community may affect foraging of BEVI if habitat is suitable. While potentially useful for foraging, however, in California, researchers found that least Bell's vireo territories surrounded by agriculture and urban development produced fewer young than did territories bordering on native vegetation (RECON 1989 *in* Kus 2002a).

Work by Kus et al. (2008), looking at factors affecting nest survival in least Bell's vireo populations in California, found that factors at the landscape scale, not the fine or intermediate scale, were most important determinants of survival. Specifically, the proximity to golf courses increased the odds of predation, while the proximity to natural, wetland habitat decreased the odds of predation, supporting the idea that the matrix community does have an effect on least Bell's vireos and factors affecting their habitat use and nest success.

It is unknown to what extent BEVI use habitats surrounding their riparian nesting areas in the LCR. BEVI tend to have smaller territories and nest close together in areas where the habitat is best (C. Dodge and B. Raulston 2018, personal communications).

NEST PREDATOR & COWBIRD DENSITY

The definition and discussion 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 BEVI 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 BEVI during different life stages, the density and spatial distribution of these fauna in the riparian habitat used by vireos, and the ways in which predator activity may vary in relation to other factors (e.g., time of day, patch size and width, matrix community type, etc.) (Thompson, III 2007). Documented nest predators of least Bell's vireo in California include western scrub jays, Virginia opossum, gophersnakes, and the Argentine ants (Peterson et al. 2004). See "Nest Predation & Brood Parasitism," above, for additional lists of predators.

For open cup nesters like BEVI, nest predation has been identified as a major factor affecting annual productivity (Martin 1988; Ricklefs 1969). Specifically, Budnik et al. (2000) observed that high rates of nest predation and cowbird parasitism were the main contributing factors to the low annual production in Bell's vireos in Missouri grassland-shrub habitats.

Parental Care

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

Full name : **The ability and behavior of parents to provide care to nests, eggs, nestlings, and 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 recently fledged birds. Bell's vireo parents have been reported to provide some food to their young for 25–30 days after fledging (NatureServe 2018), although fledged juveniles also forage on their own (Kus et al. 2020). The care provided by one or both parents can include providing shelter and warmth, providing food, warding off predators, and teaching the young necessary life skills. The better the quality of the parental care, the healthier the condition and, therefore, the higher the rate of survival of the offspring, other things being equal. Parental care is affected by food availability, the presence of predators, and the ability to thermoregulate.

Patch Size

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

PREDATORS

This habitat element replaces the original, Predator Density, for clarity and consistency among models, and it is updated as follows:

Full name: **The abundance and distribution of predators that depredate BEVI during the post-fledging 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 BEVI during the juveniles or breeding adults life stages. The variables of this element include the species and size of the fauna that prey on BEVI during these life stages, the density and spatial distribution of such predators in the riparian habitat used by BEVI, and whether predator activity may vary in relation to other factors (e.g., time of day, patch size and width, matrix community type, etc.) (Thompson 2007). For example, mesopredator release coupled with the introduction of new predators (e.g., domestic and feral cats [*Felis silvestris catus*]) in more urban developments around riparian habitat may be contributing to increases in predator density in least Bell's vireo habitat in California (USFWS 2006). Apart from direct effects on BEVI survival, predator density also can alter parental care behavior, nest site selection, and foraging activity (Chalfoun and Martin 2009; Lima 1998, 2009).

PREVIOUS YEAR'S USE

The definition of this habitat element is updated as follows:

Full name: **The location of the previous year's breeding attempt (and whether or not that attempt was successful)**. Bell's vireos typically return to the same nesting territory year after year (Franzreb 1989; Greaves 1989). Fledglings also return to their natal area to breed (Greaves and Gray 1991). Allen et al. (2017) report on an 8-year-old least Bell's vireo that was banded as a nestling and has occupied the same general area of the middle San Louis Rey River for a number of years. It is not known whether this is due to site fidelity, whether these territories simply have the best microhabitat for nesting, or whether there are other cues that trigger nesting (Kus et al. 2020). GBBO (2014) also report that BEVI shows strong site fidelity; however, although they often return to the same habitat patch, they may not use the same territory, as has been observed with banded birds at the Beal Lake Conservation Area (C. Dodge and B. Raulston 2018, personal communications). Whether this tendency to return to the same habitat to breed contributes to greater BEVI nest success, as has been demonstrated with the southwestern willow flycatcher (*Empidonax traillii extimus*) (McLeod and Pellegrini 2013; Paxton et al. 2007) is not known.

Riparian systems are dynamic, so it is expected that BEVI would move around from time to time in response to habitat changes. In particular, hatch year and second year birds tend to move around more (C. Dodge 2018, personal communication.)

SOIL SALINITY

This habitat element is a new addition to the CEM, and it is defined 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 (77 °F)** (San Joaquin River Restoration Program 2014). Rising soil salinity is a serious environmental issue 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 (e.g., 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).

STEM DENSITY

The definition of this habitat element is updated as follows:

Full name: **The stem density of trees and shrubs greater than 2.5 centimeters in diameter**. This element refers to the number of trees and/or shrubs per acre of that size or larger. The greater the tree and/or shrub density, the greater the likelihood of denser vegetative cover. Stem density can be correlated with tree canopy cover, intermediate structure, and total vegetation density (see "Diversity of Vegetation," above).

TEMPERATURE

The definition of this habitat element has been updated as follows:

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. 1987; Rosenberg et al. 1991).

VEGETATION COMMUNITY TYPE

This habitat element replaces the original, Community Type, with a slightly updated definition and discussion 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 BEVI. In the Southwest, BEVI typically breed in cottonwood-willow riparian forest, with mesquite or seep-willow (*Baccharis salicifolia*) understory shrubs (Grinnell 1914; Kus et al. 2020; GBBO 2011; Leist et al. 2016). BEVI territories along the LCR had significantly less upland vegetation than non-use sites (GBBO 2011; A. Leist 2015, personal communication). Bell's vireos occasionally use saltcedar—in fact, 52% of the nests along the LCR (Averill-Murray et al. 1999) and 64% of the nests in the Grand Canyon were in saltcedar (Brown 1993 *in* Kus et al. 2020). A mixed saltcedar/honey mesquite (*Prosopis glandulosa*) community is found at a number of LCR sites. Phenology of the mesquite and catclaw on LCR sites is also important for migration, arrival on the LCR, and nest initiation of BEVI (A. Leist 2015, personal communication; McGrath et al. 2009).

In addition to nest site selection, vegetation community type also affects invertebrate diversity and nutrient content (Wiesenborn 2014).

Updates to Chapter 5 – Controlling Factors

This update standardizes the name of one controlling factor, Pesticide/Herbicide Application, and replaces it with Pesticide Application; adds one new controlling factor (Irrigation); and updates the discussion of six controlling factors. Table 4 is updated as follows:

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 (*new*)	Mechanical thinning	Natural thinning	Nuisance species introduction &	Pesticide application (*renamed*)	Planting regime	Recreational activities	Water storage-delivery system design & operation
Anthropogenic disturbance				X					X	
Brood/litter size (*renamed)*	N/A*									
Canopy closure	X			X	X	X		X	X	
Diversity of vegetation	X	X							X	
Food availability						X	X			
Genetic diversity (*renamed*)										X
Infectious agents (*renamed*)										X
Intermediate structure	X	X		X		X		X	X	
Local hydrology			X							X
Matrix community	X	X						X		
Nest predator & cowbird density						X			X	
Parental care	N/A*									
Patch size	X	X						X	X	
Predators (*renamed)*						X			X	
Previous year's use	N/A*									
Soil salinity (*new*)			X							X
Stem density	X	X		X	X			X	X	
Temperature	N/A*									
Vegetation Community type *(renamed)*	X	X				X		X	X	

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

FIRE MANAGEMENT

The discussion of this controlling factor is updated as follows:

This factor addresses any fire management (whether prescribed fire or fire suppression) that could affect BEVI or their habitat. Effects may include creation of habitat that supports or excludes BEVI, a reduction in the food supply of invertebrates, or support of species that pose threats to BEVI such as predators, competitors, or carriers of infectious agents. Shrub-dependent Bell's vireos in prairie habitats declined in abundance with increased fire frequency; areas of infrequently burned habitat (at least 4-year interval) are essential for vireos in a prairie matrix (Powell 2008). Although typically not a major threat in most riparian habitats, severe wildfires have affected southwestern willow flycatcher breeding sites in the past decade (Ellis et al. 2008; Graber et al. 2007; USFWS 2002a) and could affect BEVI riparian habitats, similarly. 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 2018, personal communication). A hot, complete burn that destroys all vegetation will obviously prevent BEVI from nesting until vegetation regrows in subsequent years. However, a partial burn may not prevent nesting in suboptimal habitat and, in fact, may act as a population sink.

Climate change is also projected to affect fire frequency along the LCR (USFWS 2013) in part by altering rainfall patterns.

GRAZING

The paragraph about feral swine (*Sus scrofa*) has been moved to the Nuisance Species Introduction & Management controlling factor (see below). The updated discussion of this controlling factor is as follows:

This factor addresses the grazing activity on riparian habitats along the LCR and in surrounding areas that could affect BEVI or their habitat. Overgrazing by cattle (Bovidae), burros (*Equus asinus*), or mule deer (*Odocoileus hemionus*) across the arid Southwestern United States has substantially degraded riparian habitat in many areas (see Appendix G *in* USFWS 2002b). (Note: Reclamation staff and researchers have observed mule deer and burros browsing on LCR sites, which may affect vegetation communities if population numbers increase to the point that overgrazing occurs.) Grazing may thin the understory or prevent the

establishment of cottonwood and willow seedlings (Kauffman et al. 1997). Overmire (1963 *in* Kus et al. 2020) observed that overgrazing reduced shrub growth at an Oklahoma study site, resulting in a 50% reduction in vireo density.

In particular, overgrazing has been identified as a management issue 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 riparian bird density, including that of Bell's vireos, within 4 years. Livestock grazing is also known to occur at the Gila River study area (Graber et al. 2012).

In the case of BEVI, however, grazing by cattle or mule deer does not have much impact in the LCR habitats in which BEVI currently occur (C. Dodge and B. Sabin 2018, personal communications). Additionally, BEVI appear to tolerate some level of burro activity. Burros have been regularly seen on Planet Ranch since 2016 (B. Raulston 2019, personal communication), although there was a proposal to remove burros from adjacent private lands in 2017–18 (Bureau of Land Management 2017). In 2017, BEVI nested at Planet Ranch in areas where burros were common (SWCA 2017). Burros have been observed along the habitat edges where BEVI were detected and areas where BEVs were using the scattered mesquites in the old farm fields (C. Ronning 2019, personal communication).

Grazing activity may also influence other controlling factors, such as Nuisance Species Introduction & Management, by increasing cowbird presence or by spreading non-native grass seeds into riparian habitat (Bartuszevige and Endress 2008; Goguen and Mathews 2001; Tucson Audubon 2012).

IRRIGATION

This is a new controlling factor.

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 BEVI. 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 Reclamation's and other land management agencies' water rights).

The LCR MSCP and USFWS irrigate portions of several conservation areas along the LCR valley to create and manage habitat for general wildlife, LCR MSCP covered species, and associated wetland habitat. BEVI have been found consistently at three restoration sites, including the Beal Lake Conservation Area, Cibola National Wildlife Refuge Unit #1 Conservation Area, and the Laguna Division Conservation Area (GBBO 2014, 2015, 2018; Reclamation 2016).

Mechanical Thinning

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

Natural Thinning

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

Nuisance Species Introduction & Management

The discussion of 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 BEVI survival and reproduction. The nuisance species may infect, prey on, compete with, or present alternative food resources for BEVI during one or more life stages; cause other alterations to the riparian food web that affect BEVI; or affect physical habitat features such as canopy or shrub cover. For example, cowbird control has successfully reduced parasitism rates in many Bell's vireo populations (Averill-Murray et al. 1999; Kus et al. 2020; Kus and Whitfield 2005; and Morrison and Averill-Murray 2002). Removal of an invasive plant species, giant reed grass (*Arundo donax*), has helped re-establish native riparian vegetation at certain California sites, which have subsequently been used by least Bell's vireos.

BEVI will successfully nest in saltcedar. However, research by Brand and Noon (2011) on the San Pedro River found that BEVI nests in saltcedar had low

seasonal fecundity and significantly fewer fledglings per nest as compared with nests in cottonwood. The complicated nature of the relationship between saltcedar and BEVI is further highlighted by another introduced species—the tamarisk beetle (*Diorhabda* spp.). The tamarisk beetle was introduced into the LCR region in order to control invasive saltcedar (Bateman et al. 2013). However, defoliation of saltcedar due to beetle infestation causes decreases in humidity and cover along with increases in temperature (Bateman et al. 2013), thereby degrading areas dominated by saltcedar as habitat for BEVI.

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 cottonwood and willow, as well as mesquite, each important riparian species on which BEVI depends (Boland 2016; Leathers 2015). To date, the beetles have not been found outside of California, and 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 2019). However, Boland (2016) reported that damage to riparian habitat in California occurred rapidly once the beetles arrived, with willows and cottonwoods having the highest infestation rates. The presence of surface water was also a factor contributing to higher infestation rates.

In addition to non-native plants and insect pests, non-native feral swine have been identified as a problem for least Bell's vireos 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). It is unknown what effect they may have on BEVI and nest success (C. Dodge and B. Raulston 2018, personal communications).

PESTICIDE APPLICATION

The discussion of this controlling factor is updated as follows:

This factor addresses pesticide applications that may occur on or adjacent to riparian habitat of the LCR region. Pesticides, including herbicides, may drift into riparian areas, removing plant species important to BEVI habitat structure and composition. Pesticide effects may include lethal or sublethal poisoning of BEVI via ingestion of treated insects, pollution of runoff into wetland habitats

that are toxic to prey of BEVI, and a reduced or modified invertebrate food supply. Least Bell's vireo eggs have been reported to have high residues of DDE, but with no egg shell thinning detected (Brown 1993 *in* Kus et al. 2020).

PLANTING REGIME

The discussion of 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 (Bangert et al. 2013; Wiensenborn 2014).

Although BEVI use a variety of habitats, the Bell's vireo can use similar habitat components as the southwestern willow flycatcher and, therefore, may respond positively to habitat management for the southwestern willow flycatcher in low elevation riparian habitat especially if there is a dense shrub layer (Latta et al. 1999). In addition, habitat restoration for least Bell's vireos in California by planting cuttings of riparian species has been successful at attracting the vireos to nest (Howell and Dettling 2009; Kus 1998). Successful vireo nesting was reported within 3–5 years after restoration in sites with a dense understory within 0.9 m of the ground and proximity to some water (Baird and Reiger 1989; Kus 1998). In the LCR, BEVI have been found in restoration sites older than 2 years (GBBO 2010, 2012b, 2013, 2014, 2015). Of these, BEVI remain most abundant at the Beal Lake Conservation Area restoration area (GBBO 2015; SWCA 2019). There is also a moderate population at the Laguna Division Conservation Area (SWCA 2019). This site was on an old river channel, and the soil is moist or inundated for most of the breeding season with a more heterogeneous planting regime, unlike other sites (B. Sabin 2019, personal communication). Leist et al. (2016) recommended plantings of mesquite to create a dense understory, surrounded by cottonwood and willow, near water.

RECREATIONAL ACTIVITIES

The discussion of this controlling factor is updated as follows:

This factor addresses the disturbance to BEVI from recreational and research 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 recreational activities (e.g., boating, fishing, wildlife viewing, horseback riding, camping, and off-road vehicle [ORV] use) as well as the frequency and intensity of those activities. The impacts may consist of disturbance and habitat alteration. Recreational activities can influence nest predator densities by either increasing nest predator success rates through interfering with or distracting prey or by decreasing nest predator success rates through interfering with or distracting the predator (Mason 2015; Ware et al. 2015).

ORVs have been identified as a threat to least Bell's vireo in the Santa Ana watershed, California, mainly due to effects on riparian nesting habitat. Effects of ORVs and similar recreational activities may include tramping, clearing of vegetation, woodcutting, prevention of seedling germination due to soil compaction, among other effects (USFWS 2002a). Additionally, intensive research and monitoring that regularly disturbs nesting birds may adversely affect nest success. The impacts will depend on the tolerance of the bird species in question, nest predators and brood parasites present in the habitat, the frequency and type of nest disturbance, and other factors. However, precautionary measures should be included in the design of monitoring protocols until more is known about the potential effects of research-related disturbance on nesting BEVI.

WATER STORAGE-DELIVERY SYSTEM DESIGN & OPERATION

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

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

This factor includes river and off-channel water management, including pumping of groundwater and diversion of river water to manage water levels in refuge ponds, as well as dewatering and flushing of marsh habitats. The amount of water, flooding frequency, water depth and stability, etc., each affect the local hydrology and, therefore, the species composition and density of the riparian plant community favored by BEVI for food, shelter, and nesting. Large-scale water releases in spring can flood low-lying BEVI nests in downstream areas (Brown and Johnson 1985 *in* Kus et al. 2020). Dam and reservoir construction projects

also destroy and separate riparian habitat patches, which may affect the genetic makeup of BEVI populations (Franzreb 1989). In contrast, management of water levels at Glen Canyon Dam added riparian habitat in the Grand Canyon for BEVI (Brown and Johnson 1985 *in* Kus et al. 2020). Generally, the dynamic nature of a free-flowing river creates a mosaic of riparian habitats, and thus, a natural flow regime should be beneficial to BEVI.

Updates to Chapter 6 – Conceptual Ecological Model by Life Stage

The following sections identify all changes made to the BEVI 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 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

- Irrigation effect on Local Hydrology (HE): Amount and frequency of irrigation will directly influence local hydrology, including both groundwater, soil moisture, and the presence and length of stay of surface water. However, effects may be short term and/or small scale depending on soil conditions, the irrigation system, climate, and the exact nature of the irrigation regime. The link is hypothesized to be complex and unidirectional, with proposed high intensity, low spatial scale, and low temporal scale; medium predictability; and high understanding. *Applies to all life stages*.

- Irrigation effect on Soil Salinity (HE): Depending upon the source of the water and nature of soils, irrigation can increase or decrease soil salinity. Without careful consideration of irrigation regimes in relation to water origin and soil type, it is well established that soil salinity can increase, although the exact response of salinity depends on the precise details of the irrigation regime. The link is hypothesized to be complex and unidirectional, with proposed high intensity, low spatial scale, and low temporal scale; medium predictability; and medium understanding. *Applies to all life stages*.

- Irrigation effect on Canopy Closure (HE): Irrigation regimes determine the extent of canopy closure. The link is hypothesized to be complex and unidirectional, with proposed high intensity, low spatial scale, and low temporal scale; medium predictability; and medium understanding. *Applies to all life stages.*

- Irrigation effect on Intermediate Structure (HE): Irrigation regimes affect intermediate structure within stands. The link is hypothesized to be complex and unidirectional, with proposed high intensity, low spatial scale, and low temporal scale; medium predictability; and medium understanding. *Applies to all life stages.*

- Water Storage Delivery System Design & Operation effect on Soil Salinity (HE): Main stem flooding generally decreases soil salinity, but it can affect soil salinity positively or negatively, depending on soil type and operations. The link is hypothesized to be complex and unidirectional, with proposed high intensity, high spatial scale, and medium temporal scale; medium predictability; and medium understanding. *Applies to all life stages*.

- Water Storage Delivery System Design & Operation effect on Irrigation (CF): Irrigation is only possible with appropriate water storage delivery and operation. While irrigation is critically dependent on water delivery, the exact irrigation regime that results is difficult to predict well in advance. The link is hypothesized to be complex and unidirectional, with proposed medium intensity, medium spatial scale, and medium temporal scale; medium predictability; and high understanding. *Applies to all life stages*.

- Grazing effect on Nuisance Species Introduction & Management (CF): This is a new link to reflect the ways in which grazing activity can contribute to the spread of non-native species (e.g., non-native grasses; cowbirds). The link is hypothesized to be complex and unidirectional, with low link intensity, low spatial scale, and low temporal scale, as grazing currently is not a concern on LCR sites being used by or managed for BEVI. Link predictability is medium, and link understanding is high. *Applies to all life stages.*

- Recreational Activities effect on Canopy Closure (HE): This link was added for continuity with models of other riparian nesting birds. *Applies to all life stages.*

- Nuisance Species Introduction & Management effect on Canopy Closure (HE): This link has been added for continuity with models of other riparian nesting birds. *Applies to all life stages.*

DELETED LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS

No change.

UPDATED LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS

- Grazing effect on Vegetation Community Type (HE): The original link was considered to be complex and unidirectional, with high link intensity, high spatial scale, and low temporal scale, as grazing can have great effects on community composition and is often implemented over large and long scales. However, grazing impacts currently are not a concern on LCR sites being used by or managed for BEVI. Therefore, the values have been modified in this update. The link remains complex and unidirectional; however, link intensity, spatial scale, and temporal scale are low. Link predictability remains medium, and link understanding remains high. *Applies to all life stages.*

- Grazing effect on Diversity of Vegetation (HE): The original link was considered to be complex and unidirectional, with high link intensity, high spatial scale, and low temporal scale, as grazing can have great effects on community composition and is often implemented over large and long scales. However, grazing impacts currently are not a concern on LCR sites being used by or managed for BEVI. Therefore, the values have been modified in this update. The link remains complex and unidirectional; however, link intensity, spatial scale, and temporal scale are low. Link predictability remains medium, and link understanding remains high. *Applies to all life stages.*

- Grazing effect on Matrix Community (HE): The original link was considered to be complex and unidirectional, with high intensity, high spatial scale, and low temporal scale, as grazing can have great effects on the surrounding community composition and is often implemented over large and long scales. However, grazing impacts are currently not a concern on LCR sites being used by or managed for BEVI. Therefore, the values have been modified in this update. The link remains complex and unidirectional; however, link intensity is low, and spatial scale and temporal are low. Link predictability remains medium, and link understanding remains high. *Applies to all life stages.*

- Grazing effect on Patch Size (HE): The original link was considered to be complex and unidirectional, with high intensity, high spatial scale, and low temporal scale, as grazing can have great effects on community composition and is often implemented over large and long scales. However, grazing impacts are currently not a concern on LCR sites being used by or managed for BEVI. Therefore, the values have been modified in this update. The link remains complex and unidirectional; however, the link intensity is low, and the spatial and temporal scales are low. Link predictability remains medium, and link understanding remains high. *Applies to all life stages.*

- Grazing effect on Intermediate Structure (HE): The original link was considered to be complex and unidirectional, with high intensity, high spatial scale, and low temporal scale, as grazing can have great effects on understory structure by trampling and removal of vegetation and is often implemented over large and long scales. However, grazing impacts are currently not a concern on LCR sites being used by or managed for BEVI. Therefore, the values have been modified in this update. The link remains complex and unidirectional; however, link intensity is low, and the spatial and temporal scales are low. Link predictability remains medium, and link understanding remains high. *Applies to all life stages.*

New Links with Habitat Elements as Causal Agents

- Infectious Agents effect on Disease (CAP): This new link was added due to the separation of the formerly combined Genetic Diversity & Infectious Agents into two new habitat elements. Infectious agents such as pathogens and vectors in an environment affect transmission risk, and fewer infectious agents mean less likelihood of disease transmission. The link is hypothesized to be positive, with no or an unknown threshold, and unidirectional, with proposed low intensity, low spatial scale, and low temporal scale; medium predictability; and low understanding. *Applies to all life stages*.

- Soil Salinity effect on Vegetation Community Type (HE): Some plant species grow better at different salinity levels; generally, desirable vegetation types for BEVI are not found at high salinity levels. The link is hypothesized to be complex and unidirectional, with proposed high intensity, medium spatial scale, and medium temporal scale; medium predictability; and medium understanding. *Applies to all life stages*.

- Genetic Diversity effect on Disease (CAP): Increased genetic diversity can contribute to protection against disease. While the effects of inbreeding can last for generations, there is currently no evidence of inbreeding in BEVI populations along the LCR, indicating that a lack of genetic diversity does not appear to be a problem. The link is hypothesized to be negative, with proposed low intensity, low spatial scale, and low temporal scale; high predictability; and medium understanding. *Applies to all life stages.*

- Soil Salinity effect on Diversity of Vegetation (HE): Soil salinity generally affects plant vigor negatively, but the exact effects vary depending on plant species and salinity levels. The link is hypothesized to be complex, with no or an unknown threshold, and unidirectional, with proposed medium intensity, medium spatial scale, and medium temporal scale; low predictability; and medium understanding. *Applies to all life stages*.

Deleted Links with Habitat Elements as Causal Agents

No change.

Updated Links with Habitat Elements as Causal Agents

- Food Availability effect on Foraging (CAP): The link intensity was changed from high to low. BEVI are generalist insectivores, and food is not likely to be a limiting factor. *Applies to the juveniles and breeding adults life stages.*

- Food Availability effect on Nest Attendance (CAP): The link intensity was changed from high to low. BEVI are generalist insectivores, and food is not likely to be a limiting factor. *Applies to the breeding adults life stages.*

- Local Hydrology effect on Thermal Stress (CAP): The link character reason was revised to reflect a change of the habitat element name from Temperature Regulation to Thermal Stress. *Applies to all life stages.*

- Anthropogenic Disturbance effect on Predators (HE): The link understanding was changed from unknown to low for consistency among models. *Applies to the breeding adults life stage*.

- Anthropogenic Disturbance effect on Nest Site Selection (CAP): The link understanding was changed from unknown to low for consistency among models. All other interactions remain the same. *Applies to the breeding adults life stage.*

- Anthropogenic Disturbance effect on Nest Attendance (CAP): The link understanding was changed from unknown to low for consistency among models. All other interactions remain the same. *Applies to the breeding adults life stage.*

- Anthropogenic Disturbance effect on Foraging (CAP): The link understanding was changed from unknown to low for consistency among models. All other interactions remain the same. *Applies to the breeding adults life stage.*

- Anthropogenic Disturbance effect on Predation (CAP): The link understanding was changed from unknown to low for consistency among models. All other interactions remain the same. *Applies to the breeding adults life stage.*

- Temperature effect on Thermal Stress: The link character type and reason were revised to reflect a change of the critical biological activity and process name from Temperature Regulation to Thermal Stress. *Applies to all life stages.*

- Canopy Closure effect on Thermal Stress: The link character type and reason were revised to reflect a change of the critical biological activity and process name from Temperature Regulation to Thermal Stress. *Applies to all life stages.*

- Parental Care effect on Thermal Stress: The link character type and reason were revised to reflect a change of the critical biological activity and process name from Temperature Regulation to Thermal Stress. *Applies to the eggs/nestlings life stage.*

New Links with Critical Activities/ Processes as Causal Agents

No change.

Deleted Links with Critical Activities/ Processes as Causal Agents

- Nest Site Selection effect on Thermal Stress (CAP): This link has been removed for continuity with other bird models. *Applies to the breeding adults life stage*.

Updated Links with Critical Activities/ Processes as Causal Agents

- Thermal Stress effect on Survival: The link character type and reason were revised to reflect a change in the critical biological activity and process name from Temperature Regulation to Thermal Stress. *Applies to all life stages.*

- Disease effect on Thermal Stress: The link reason, character type, and direction were revised to reflect a change in the critical biological activity and process name from Temperature Regulation to Thermal Stress. *Applies to all life stages.*

New Links with Life-Stage Outcomes as Causal Agents

No change.

SUMMARY OF STANDARDIZATION OF TERMS

(Blue indicates new or revised items; orange indicates replaced items. Italicized entries are explanatory comments)

BEVI conceptual ecological model updated terms, 2019	BEVI conceptual ecological model original terms, 2015–16
Life stages	
Eggs/Nestlings	Nest
Juveniles	Juvenile
Breeding Adults	Breeding Adult
Life-stage outcomes	
Survival	Survivors
Fertility	Offspring
	Reproduction
Critical biological activities and processes	
Disease	Disease
Eating	Eating
Foraging	Foraging
Molting (*renamed*)	Molt
Nest Attendance	Nest Attendance
Nest Predation & Brood Parasitism	Nest Predation and Brood Parasitism
Nest Site Selection	Nest Site Selection
Predation	Predation
Thermal Stress (*renamed*)	Temperature Regulation
Habitat elements	
Anthropogenic Disturbance	Anthropogenic Disturbance
Brood/Litter Size (*renamed*)	Brood Size
Canopy Closure	Canopy Closure
Vegetation Community Type (*renamed*)	Community Type
Diversity of Vegetation	Diversity of Vegetation
Food Availability	Food Availability
Genetic Diversity (*new*)	Genetic Diversity and Infectious Agents
Infectious Agents (*new*)	
Intermediate Structure	Intermediate Structure
Local Hydrology	Local Hydrology
Matrix Community	Matrix Community
Nest Predator & Cowbird Density	Nest Predator and Cowbird Density
Parental Care (*renamed)*	Parental Feeding Behavior
	Parental Nest Attendance
Patch Size	Patch Size
Predators (*renamed)*	Predator Density
Previous Year's Use	Previous Year's Use
Soil Salinity (*new*)	
Stem Density	Stem Density
Temperature	Temperature
Controlling actors	
Fire Management	Fire Management
Grazing	Grazing
Irrigation (*new*)	
Mechanical Thinning	Mechanical Thinning
Natural Thinning	Natural Thinning
Nuisance Species Introduction & Management	Nuisance Species Introduction and 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 and Operation

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ATTACHMENT 1

Arizona Bell's Vireo (*Vireo bellii arizonae*) (BEVI)
Habitat Data

Table 2-1.—Arizona Bell's vireo (BEVI) (*Vireo bellii arizonae*) (BEVI) habitat data
(*Note*: This is an update of Table 2.1 found in Attachment 2 of the original SWFL conceptual ecological model document. * The data presented in this table reflect those available in the literature at the time this model was developed. These data have not been validated.

Habitat element	Value or range	Location	Reference
Anthropogenic disturbance	Anthropogenic disturbance caused premature fledging.	Kansas	Barlow 1962
	Effects of disturbance, including noise, not quantified in lower Colorado River.		
	Little effect of noise on nest site selection in Yuma, Arizona	Lower Colorado River	C. Dodge and B. Raulston 2018
Brood/litter size	Usually three to five eggs laid, commonly four (least Bell's vireo (*Vireo bellii pusillus*), but other subspecies as well)	Range-wide	Kus et al. 2020; NatureServe 2018
Canopy closure	BEVI select sites with more patchy or open canopy than other riparian birds; overstory open or absent.	Various	Kus et al. 2020
	BEVI nest in sites with significantly greater canopy closure than non-use sites.	Lower Colorado River	Great Basin Bird Observatory (GBBO) 2011
	Most least Bell's vireo nests were located under extensive overhead canopy.	Ynez River, California	Olsen and Gray 1989
Diversity of vegetation	BEVI prefer dense cover near openings in which they can forage.	Bill Williams River National Wildlife Refuge, Arizona	GBBO 2011
	Nest near edge of thicket; usually edges without overstory.	Various	Kus et al. 2020

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Habitat element	Value or range	Location	Reference
Food availability	Taxa include: Hemiptera, Coleoptera, Lepidopteran larvae, Orthoptera, Diptera, and Aranea (spiders).	Lower Colorado River	Yard et al. 2004
Genetic diversity	No data available.		
Infectious agents	No data available.		
Intermediate structure	For least Bell's vireo – Dense vegetation within 1–3 meters (m) of ground.	California	Franzreb 1989; Goldwasser 1981
	Nests unparasitized by cowbirds (*Molothrus ater*) were surrounded by more vegetation within 5 m of nest than parasitized nests.	Kansas	Parker 1999
	94% of least Bell's vireo nests located at heights between 0.2–1.0 m and where foliage density and plant species richness were greatest.	Ynez River, California	Olsen and Gray 1989
Local hydrology	For least Bell's vireo – Standing water within 1 kilometer (0.6 mile)	California	Kus et al. 2020
Matrix community	Optimal matrix community is natural habitat (e.g., wetlands, better than golf course); a surrounding matrix of agricultural or urban land reduced nest success.	California	Kus et al. 2008
Nest predator & cowbird density	Cowbird densities < 30% needed to maintain least Bell's vireo populations.	California	Laymon 1987

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(*Note*: This is an update of Table 2.1 found in Attachment 2 of the original SWFL conceptual ecological model document. * The data presented in this table reflect those available in the literature at the time this model was developed. These data have not been validated.

Habitat element	Value or range	Location	Reference
Parental care	No data available.		
Patch size	BEVI more abundant and reproduced more successfully in larger Fremont cottonwood-willow (*Populus fremontii-Salix* sp.), patches >160 hectares (ha) (≈395 acres)	Lower Colorado River	Lynn 1996
	>20 ha (49 acres) recommended patch size for restored vegetation.	Lower Colorado River	Rosenberg et al. 1991
	Average territory size for least Bell's vireos – 0.7 ha (1.8 acres)	California	Kus et al. 2020
	Linear territory 180 m (200 yards) long.	California	Grinnell 1914
Predators	There are no data related to predator density and BEVI survival or breeding success. Only species lists available.		
Previous year's use	Least Bell's vireos return to the same nesting territory year after year.	California	Franzreb 1989; Greaves 1989
	Juveniles return to natal area to breed.	California	Greaves and Gray 1991
Soil salinity	No data available specifically for BEVI habitats.		
Stem density	No data available.		
Temperature	BEVI change temperature regulatory behavior between 29 and 31 degrees Celsius (84–88 degrees Fahrenheit)	Lower Colorado River	Theimer et al. 2011

Table 2-1.—Arizona Bell's vireo (BEVI) (*Vireo bellii arizonae*) (BEVI) habitat data
(*Note*: This is an update of Table 2.1 found in Attachment 2 of the original SWFL conceptual ecological model document. * The data presented in this table reflect those available in the literature at the time this model was developed. These data have not been validated.

Habitat element	Value or range	Location	Reference
Vegetation community type	Mature cottonwood-willow, mesquite (*Prosopis* sp.), seep willow (*Baccharis salicifolia*), saltcedar (*Tamarix* sp.), and arrowweed (*Pluchea sericea*).	Southwestern United States	Bent 1950; Grinnell 1914; Kus et al. 2020
	BEVI territories have significantly less upland habitat than non-use sites.	Lower Colorado River	GBBO 2011
	Will nest in saltcedar.	Lower Colorado River	Averill-Murray et al. 1999

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