Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

2019 Updates to Gila Woodpecker (*Melanerpes uropygialis*) (GIWO) Basic Conceptual Ecological Model for the Lower Colorado River

Photo courtesy of the Bureau of Reclamation

March 2021

Work conducted under LCR MSCP Work Task G6

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Lower Colorado River Multi-Species Conservation Program

2019 Updates to Gila Woodpecker (*Melanerpes uropygialis*) (GIWO) 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
cm	centimeter(s)
DBH	diameter at breast height
GBBO	Great Basin Bird Observatory
GIWO	Gila woodpecker (*Melanerpes uropygialis*)
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
n =	sample size
Reclamation	Bureau of Reclamation

Symbols

>	greater than
%	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

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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 Gila woodpecker (*Melanerpes uropygialis*) (GIWO) (Miller and Unnasch 2016). This update incorporates information reported in publications and presentations at professional meetings since the completion of the original GIWO 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 reported in this report change the GIWO 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 two elements for consistency, (2) separation of one former combined habitat element into two separate elements to better reflect different components of habitat, and (3) 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 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 GIWO. 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 of this chapter is updated as follows:

The most widely used sources of information for the Gila Woodpecker (*Melanerpes uropygialis*) (GIWO) conceptual ecological model (CEM) include Bent (1939), Bradley (2005), Edwards and Schnell (2020), Kaufman (1996), and Rosenberg et al. (1982, 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) biologists. In addition, sources of information for GIWO in other areas of the Southwest were consulted to supplement research along the lower Colorado River (LCR). The purpose of a conceptual ecological model is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

UPDATE TO GILA WOODPECKER REPRODUCTIVE ECOLOGY

The GIWO is considered a sedentary species, occupying the LCR year round, although some individuals may move to higher elevations in winter (Brush et al. 1983; Edwards and Schnell 2020; Kaufman 1996). Within the LCR, GIWO have the narrowest habitat breadth during the breeding season, expanding the breadth in mid-summer and fall (Hunter 1984). GIWO occur most often in tall stands of Fremont cottonwoods (*Populus fremontii*) and willows (*Salix* sp.) with high foliage density and diversity (Hunter 1984). Breeding season may begin in March or April and may extend through August, with one to three broods (Bradley 2005; Inouye et al. 1981; Phillips et al. 1964). The species is known to reuse nest cavities for many years in succession, but new nests are usually excavated after the breeding season by both sexes (Kaufman 1996). Second broods are usually initiated in a different cavity than the first brood (Dawson 1923). GIWO compete with European starlings (*Sturnus vulgaris*) and flickers (*Colaptes* spp.) for nest cavities, and both defend territories and nest cavities against them, and may be evicted by them (Brenowitz 1978; Kerpez and Smith 1990a), although starlings are not regularly found in the LCR (B. Raulston, 2020 personal communication). As GIWO are only believed to excavate cavities in winter, the result of eviction could affect reproduction (Kerpez and Smith 1990a).

GIWO most commonly use saguaros (*Carnegia gigantea*) or tall native trees within cottonwood-willow woodlands for nesting (Rosenberg et al. 1991); use of cottonwoods is prevalent outside the range of the saguaro (Brenowitz 1978). However, the species has also been observed using honey mesquite (*Prosopis glandulosa)* or screwbean mesquite (*P. pubescens*) and cultivated trees such as eucalyptus (*Eucalyptus* sp.), athel tamarisk (*Tamarix aphylla*), palm (*Arecaceae* sp.), and orchard trees (Rosenberg et al. 1991; L. Sabin, personal observation). Brush et al. (1983) rarely found GIWO in honey or screwbean mesquite and hypothesize that this may be the result of the hardness of mesquite.

The typical clutch consists of two to seven eggs, with three to four most common and with fewer eggs in later broods (Edwards and Schnell 2020). Brood parasitism has not been noted in the literature for this species. Incubation lasts approximately 13 days and is performed by both sexes (Baicich and Harrison 1997; Hensley 1959). Young birds fledge from the nest in about 4 weeks and continue to be fed by adults for some time (Kaufman 1996).

GIWO eat many varieties of insects and fruits (Edwards and Schnell 2020). The diet during the breeding season can be dominated by cicadas (Cicadidae) (50–75%) (Anderson et al. 1982; Rosenberg et al. 1982), although quantitative studies are limited. Other food items include ants, beetles, grasshoppers, termites, moths, butterflies, saguaro fruit, and miscellaneous berries (Anderson et al. 1982; Edwards and Schnell 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 GIWO

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

Updates to Chapter 2 – GIWO Life-Stage Model

This update standardizes the names of the GIWO 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 by changing Reproduction to Fertility for breeding adults. 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 (at the end of this chapter) are updated accordingly.

UPDATE TO INTRODUCTION TO THE GIWO LIFE CYCLE

In the development of the CEM for GIWO, we could not find a complete demographic study of the species. We therefore chose to represent GIWO 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). However, we treat the eggs/nestlings life 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 GIWO 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 GIWO is mostly a resident species within LCR MSCP lands, although some individuals move outside the area in late summer (50%) (Anderson et al. 1982; Brush et al. 1983; Edwards and Schnell 2020). The LCR MSCP is mainly responsible for management within LCR MSCP lands, so we therefore focus on three life stages occurring fully within those LCR MSCP lands—eggs/nestlings, juveniles, and breeding adults. GIWO management outside of the LCR area is certainly important, but it is outside of the scope of the LCR MSCP's responsibilities and, thus, omitted from this model.

UPDATE TO GIWO LIFE STAGE 1 – EGGS/ NESTLINGS

We consider the eggs/nestlings life stage to be the first in the life cycle of the GIWO. It begins when the egg is laid and ends either when the young fledge or the nest fails. Eggs are usually laid in March or April, and as late as mid-July, and incubation lasts approximately 13 days (Bradley 2005; Hensley 1959; Inouye et al. 1981; Phillips et al. 1964). GIWO in the LCR initiated incubation from March 27 to May 4 (Great Basin Bird Observatory [GBBO] 2018). Young birds fledge from the nest in about 4 weeks and continue to be fed by adults (Kaufman 1996). Brood parasitism has not been observed in this species, and nest predation has not been thoroughly studied. GIWO compete with European starlings and are often evicted by them (Kerpez and Smith 1990a). The life-stage outcome from 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 and the quality of the nest site as selected by the parents.

UPDATE TO GIWO LIFE STAGE 2 – JUVENILES

The juveniles life stage begins at fledging and ends with the beginning of the breeding season the following year. Juveniles will remain in the general vicinity of the nest and are fed by the parents for some time after fledging (Kaufman 1996). The life-stage outcome from the juveniles life stage is the survival of the bird from fledging until the beginning of the breeding season the next calendar year. There are no studies available that analyze juvenile survival rates in this species; however, it may be assumed to be lower than adult survival rates that have been shown to be approximately 0.69 ± 0.14 (based on very small sample size [n = 30]) (DeSante and Kaschube 2009).

UPDATE TO GIWO LIFE STAGE 3 – BREEDING ADULTS

The breeding adults life stage begins at the beginning of the breeding season after the GIWO's first winter. The life-stage outcomes for breeding adults life stage are survival and fertility, here defined as the production of eggs. Most studies of bird demography define fecundity—or the reproductive rates of adults—as the number of offspring fledged (Etterson et al. 2011). 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, within this model, the reproduction of adults involves the acts of pairing, site selection, nest building, and the production of eggs.

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, even excavating new nests (Kaufman 1996), or move into habitat types that differ from breeding areas. Hunter (1984) reports a widening of habitat breadth after the breeding season. 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; 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) GIWO 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 • Breeding adults fertility

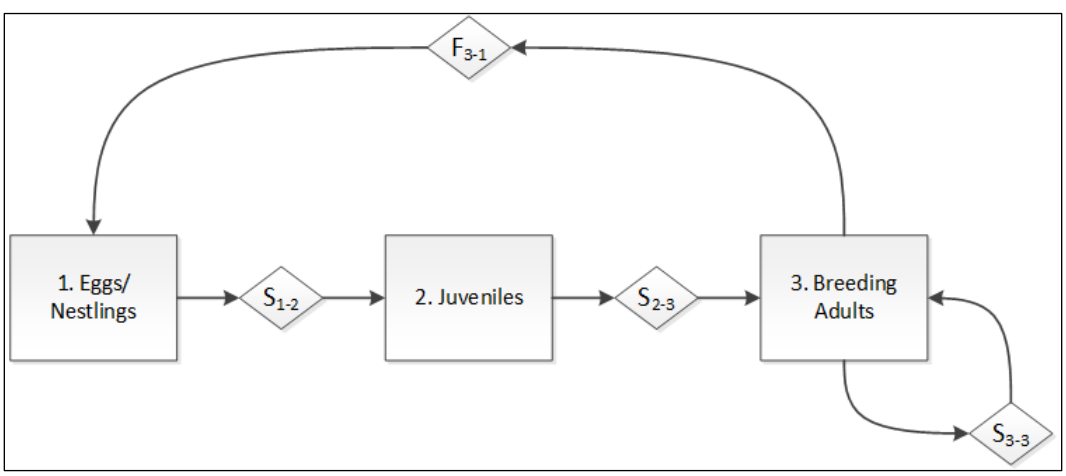

Figure 1.—(Revision of original figure 1) Proposed GIWO life history model. Squares indicate the life stage, and diamonds indicate the life-stage outcomes. S_{1-2} = survival, eggs/nestlings; S_{2-3} = survival, juveniles; S_{3-3} = survival, breeding adults; and F_{3-1} = fertility, breeding adults.

Updates to Chapter 3 – Critical Biological Activities and Processes

This update identifies 10 critical biological activities or processes that affect 1 or more GIWO life stages. The original GIWO conceptual ecological model (Miller and Unnasch 2016) identified eight. The update changes the names of two critical biological activities and processes, Molt and Temperature Regulation, replacing them with Molting and Thermal Stress, respectively; splits the critical biological activity and process, Eating/Foraging, into two separate critical biological activities and processes, Eating and Foraging, for consistency with the other LCR MSCP conceptual ecological model updates; splits the critical biological activity and process, Predation, into two separate critical biological activities and processes, Nest Predation and Predation, for consistency with other LCR MSCP conceptual ecological model updates; and updates the discussions of five critical biological activities and processes. Table 2 lists the 10 critical biological activities or processes in this update and their distribution across life stages, and it also indicates which are new to this update or renamed from the original GIWO conceptual ecological model.

Table 2.—(Revision of original table 2) Distribution of GIWO 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 cavity competition	**X**		**X**
Nest predation (*new*)	**X**		
Nest site selection			**X**
Predation		**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 Bent (1939), Bradley (2005), Edwards and Schnell (2020), Kaufman (1996), and Rosenberg et al. (1982, 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 10 critical biological activities and processes in alphabetical order.

DISEASE

This critical biological activity or process has been updated as follows:

This process refers to diseases caused either by lack of genetic diversity or by infectious agents, including the effects of ecto- and endoparasites. Little research has focused on specific diseases affecting GIWO. 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); we assume that such diseases could have similar effects on near-passerines such as GIWO. Short and Banks (1965) mention at least one GIWO was infected with a tapeworm in northwest Baja California. GIWO at all life stages are conceivably susceptible to disease.

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 updated as follows:

Eating applies to the eggs/nestlings and juveniles life stages. Nestlings are fed by adults and do not forage. Juveniles forage on their own, but are still fed by 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 their parents.

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 updated as follows:

Foraging is performed by juveniles and breeding adults. Juveniles forage on their own, but they are still fed by adults shortly after fledging. Adults forage for themselves and their offspring. GIWO primarily forage on tree bark using pecking, probing, and gleaning foraging methods, most often in dead substrates, and most often in cottonwood habitat (Brush et al. 1983; Rosenberg et al. 1982). GIWO demonstrate a wide variety of opportunistic foraging behaviors ranging from harvesting larvae from galls (Speich and Radke 1975) to foraging at feeding stations (Gilman 1915). 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. Further, the discussion of Molting 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). Molting is an energetically costly process that may make nestlings more susceptible to death when resources are scarce (Gill et al. 2019; Howell 2010). The GIWO uses a molt strategy common to most North American woodpeckers (Pyle 1997; Pyle and Howell 1995). They begin molting their primaries from juvenal to basic plumage while still in the nest, and this continues for 3 to 4 months after fledging (Pyle 1997; Pyle and Howell 1995). The success of this molt is dependent upon the adult provisioning rate (Howell 2010). Juveniles then undergo an incomplete pre-basic (pre-formative) molt from August to October (Pyle 1997). Adults subsequently undergo an annual pre-basic molt from July to October (Pyle 1997). Adult GIWO do not undergo a pre-alternate molt (Pyle 1997). Feather quality may be negatively affected by poor diet, and the nestlings may compensate by shifting resources from other critical functions, such as the immune system, putting them at further risk (Birkhead et al. 1999).

NEST ATTENDANCE

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

NEST CAVITY COMPETITION

This critical biological activity or process is updated as follows:

Brenowitz (1978) and Kerpez and Smith (1990a) report that European starlings and flickers compete with GIWO for nest cavities and that GIWO can be evicted from cavities by both species. GBBO (2019) reports an altercation between ladder-backed woodpeckers (*Dryobates scalaris*) and GIWO at a nest cavity. Kerpez and Smith (1990a) also found that GIWO nest in lower densities when starlings are present than when absent. As GIWO usually excavate cavities during the previous summer or over winter (Edwards and Schnell 2020; Kerpez and Smith 1990a), this competition could have a direct effect on adult reproduction. If eviction occurs after eggs are laid, the result is death of the nest and its contents. However, starlings are not regularly found in the LCR (B. Raulston 2020, personal communication).

NEST PREDATION

This habitat element is added to separate nest predation from predation on breeding adults and juveniles and for consistency with other CEMs. The discussion of Nest Predation is updated as follows.

Nest predation is a threat to GIWO in the eggs/nestlings life stage. and it obviously affects survival. Depredation of the nest has not been studied in this species (Edwards and Schnell 2020); however, many cavity-nesting species do suffer high rates of nest predation (Christman and Dhondt 1997). GIWO adult males increase nest attendance when greater densities of predators are present (Martindale 1982). Brood parasitism has not been documented in this species (Edwards and Schnell 2020).

NEST SITE SELECTION

This critical biological activity or process has been updated as follows:

GIWO are known to reuse nest cavities for many years in succession, but new nests are usually excavated after the breeding season by both sexes (Kaufman 1996). Second broods are usually initiated in a different cavity than the first brood (Dawson 1923). Both breeding males and females excavate nesting cavities. GIWO most commonly use saguaros or tall native trees within cottonwood-willow woodlands for nesting (Rosenberg et al. 1991). However, the species has also been observed using honey or screwbean mesquite and cultivated trees such as eucalyptus and athel tamarisk (Rosenberg et al. 1991). 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, or unique events such as flooding (Lima 2009; Powell and Steidl 2000, 2002; Smith and Finch 2013).

PREDATION

This critical biological activity or process has been updated as follows:

Predation is a threat to GIWO in the juveniles and breeding adults life stages, and it obviously affects survival. Predation of free-flying individuals has not been studied in this species (Edwards and Schnell 2020). GIWO have been known to be evicted from nest cavities by starlings (Kerpez and Smith 1990a); however, it is not known if this occurred after the clutch was established (i.e., predation) or before (i.e., competition).

Predation of juveniles and breeding adults is not easily quantified, but it affects juvenile and breeding adult survival, and it can indirectly affect nest survival through nest abandonment after predation of the breeding adult birds. 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. The discussion of Thermal Stress is updated as follows:

Temperature regulation is important for any organism inhabiting a region with temperatures as high as that of the LCR. Although overheating is possible in all life stages, most of the concern has been toward eggs and nestlings (Hunter et al. 1987a, 1987b; Rosenberg et al. 1991). Adults can affect the temperature regulation of eggs and nestlings through their own behavior (incubation, brooding, or shading) and through nest placement. In some studies, GIWO have been shown to use non-random orientation of cavity entrances placed toward magnetic north, believed to benefit temperature regulation (Inouye et al. 1981; Korol and Hutto 1984). However, Kerpez and Smith (1990b) found no evidence that nest cavity orientation was different than random. Further, GIWO adults appear to invest more resources to maintain lower body temperatures than other woodpecker species in the area (Braun 1969) and alter their foraging habitats toward more shaded areas during the hottest part of the day (Edwards and Schnell 2020).

Updates to Chapter 4 – Habitat Elements

This update identifies 19 habitat elements that affect 1 or more critical biological activities or processes across one or more GIWO life stages. The original GIWO conceptual ecological model (Miller and Unnasch 2016) identified 17 habitat elements. This update standardizes the names of five habitat elements, with Brood Size becoming Brood/Litter Size, Community Type becoming Vegetation Community Type, Nest Cavity Competitor Density becoming Nest Cavity Competitors, Predator Density becoming Predators, and Tree Size becoming Stand Height; adds two new habitat elements (Nest Predators and Temperature); splits one habitat element (Genetic Diversity & Infectious Agents) into two separate elements; combines two habitat elements (Parental Feeding Behavior and Parental Nest Attendance) into one habitat element (Parental Care); and updates the discussion of 15 habitat elements. Table 3 lists the 19 habitat elements in this update, indicates the critical biological activities or processes they *directly* affect across all GIWO life stages, and indicates which habitat elements are new to this update or renamed from the original GIWO conceptual ecological model.

Table 3.—(Revision of original table 3) Distribution of GIWO 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 activity or process.)

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

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

* N/A values suggest 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 GIWO 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. It differs from clutch size, which refers to the number of eggs laid. Brood/litter size is related to parental 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 density. Larger broods can result in lower nestling survival and smaller fledglings, and it can negatively affect parental body condition (Dijkstra et al. 1990). The typical GIWO clutch consists of two to seven eggs, with three to four most common, and with fewer eggs in later broods (Edwards and Schnell 2020). Two broods per year are common in this species (Inouye et al. 1981; 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 a GIWO nest site. The range of canopy closure selected by GIWO has not been quantified, but canopy closure influences temperature regulation and can influence other habitat elements important to the species, such as soil temperature, which in turn influences food abundance and timing. GIWO selected territories in the LCR with a denser canopy than in areas not used (GBBO 2011). Dense vegetation around the nest may provide more optimal microclimate for thermal regulation (Rosenberg et al. 1991) and camouflage from nest predators. GIWO are more sensitive to

temperature than other woodpeckers in the area (Braun 1969), and they alter their foraging habitats toward more shaded areas during the hottest part of the day (Edwards and Schnell 2020). Cottonwood canopy closure may also affect the availability of cicadas (Smith et al. 2006).

FOLIAGE DENSITY & DIVERSITY

The definition of this habitat element is updated as follows:

Full name: **The vertical distribution, density, and diversity of foliage**. This element refers to the height, abundance, and vertical species composition of riparian habitat used for breeding by GIWO (Hunter 1984). Higher values typically represent taller stands with multiple layers of diverse foliage. Hunter (1984) reports a disproportionate use of habitats by GIWO with three or four layers of vegetation and the majority of foliage above 6 meters (m) in height.

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 and fruits that an individual GIWO will encounter during each life stage as well as the density and spatial distribution of the food supply in proximity to the nest. GIWO eat many varieties of insects (beetles, moths, ants, butterflies, and cicadas) and fruits (Edwards and Schnell 2020; Rosenberg et al. 1982). GIWO are known to eat the fruit of saguaros and other cacti (Davie 1900). The diet during the breeding season can be dominated by cicadas (50–75%) (Rosenberg et al. 1982), but quantitative studies are limited. The abundance and condition of the food supply affects adult health, growth and development of nestlings and juveniles, molting, and the success of later stages in the annual cycle (i.e., migration) (Alonso-Alvarez and Tella 2001; Lindström 1999).

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 of GIWO (sub)populations**. This 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 (summarized by Booy et al. 2000). The genetic diversity of GIWO within the LCR has not been studied.

INFECTIOUS AGENTS

The definition of this habitat element is updated as follows:

Full name: **The types, abundance, and distribution of infectious agents and their vectors**. This refers to the spectrum of viruses, bacteria, fungi, ecto-parasites, and endoparasites that individual GIWO are likely to encounter during each life stage. There have been no specific studies of the infectious agents and their effects on GIWO within the LCR. However, there is a wealth of knowledge regarding avian diseases and parasites that affect 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

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, abundance of arthropods, and soil salinity. Wetter conditions might also provide cooler temperatures and more humid conditions necessary for egg and chick survival in desert systems (Rosenberg et al. 1991). GBBO (2011) found GIWO territories to be positively associated with the presence of a water source within 1,000 m.

NEST CAVITY COMPETITORS

This habitat element has been renamed from Nest Cavity Competitor Density for consistency with other CEMs. The definition and discussion of Nest Cavity Competitors is updated as follows:

Full name: **The presence and density of nest cavity competitors that may block or displace nesting GIWO**. Kerpez and Smith (1990a) report that European starlings compete with GIWO for nest cavities and that GIWO can be evicted from cavities by starlings. Kerpez and Smith (1990a) also found that GIWO nest in lower densities when starlings are present than when absent. However, starlings are not regularly found in the LCR (B. Raulston 2020, personal communication).

GBBO (2019) reports an altercation between a ladder-backed woodpecker and GIWO at a nest cavity. Although both GIWO and gilded flickers (*Colaptes chrysoides*) use saguaros for nesting, they excavate their cavities in different parts of the cactus, with the larger flicker excavating in the top 3 m of a stem, where the skeletal tissue is softer (MacAuliffe and Hendricks 1988). For this reason, competition with other woodpeckers is probably not a strong factor in nest site location. As GIWO usually excavate cavities during the previous summer or over winter (Edwards and Schnell 2020; Kerpez and Smith 1990a), any competition could have a direct effect on adult fecundity. If eviction occurs after eggs are laid, the result is death of the nest's contents. Conflict is expected to increase as the density of competitors increases.

Numerous species are known to use GIWO cavities as nest sites (see list in Edwards and Schnell 2020), but these secondary cavity users are not true competitors of GIWO.

NEST PREDATORS

This habitat element is added for consistency with other CEMs and to distinguish egg/nestling predators from breeding adult and juvenile predators.

Full name: **The abundance and distribution of nest predators**. 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 GIWO during the eggs/nestlings life stage, although there is no information on nest predators in this species (Edwards and Schnell 2020). The variables of this element include the species and size of the fauna that prey on GIWO during the eggs/nestlings life stages, the density and spatial distribution of these fauna in the habitat used by

GIWO, and the ways in which nest predator activity may vary in relation to other factors (e.g., intermediate structure, matrix community type, patch size and width, time of day, vegetation diversity) (Thompson, III 2007). The effect of predator density can have impacts more subtle than survival by altering breeding behavior, foraging behavior, nest site selection, and prey behavior (Lima 1998, 2009).

PARENTAL CARE

This habitat element combines the former, separate elements, Parental Feeding Behavior and Parental Nest Attendance, into Parental Care. The definition of Parental Care is updated 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 their capacity to provision food for nestlings and recently fledged juveniles. The provisioning rate is dependent upon food availability and the number of young in the brood. It is affected by the presence of predators and competitors, food availability, and the ability to thermally regulate. Both sexes share the responsibility of brooding young and defending the territory, although the roles of the sexes differ (Edwards and Schnell 2020; Martindale 1982). Fledged young are fed by parents for an extended period of time and this rate influences the amount of food consumed and time spent foraging by juvenile birds. Parents appear to balance foraging and nest defense and adapt to the presence of predators, competitors, and the behavior of their mate (Martindale 1982, 1983).

PATCH SIZE

The definition of this habitat element is updated as follows:

Full name: **The size of riparian habitat patches**. This element refers to the areal extent of a given patch of riparian vegetation. Patch size affects the number of breeding pairs that an area can support as well as the density of predators and competitors. GIWO may be sensitive to forest fragmentation. Rosenberg et al. (1991) state that they are essentially absent from fragments smaller than 20 hectares (ha). However, GBBO has found them in areas where fragments larger than 20 ha do not exist (L. Sabin 2015, personal communication).

PREDATORS

This habitat element replaces the original, Predator Density, for clarity and consistency among models. The definition of Predators is updated as follows:

Full name: **The abundance and distribution of predators that affect GIWO during the post-fledgling and adult stages**. This element refers to a set of closely related variables that affect the likelihood that different kinds of predators will encounter and successfully prey on GIWO during the juveniles or breeding adults life stages. The variables of this element include the species and size of the fauna that prey on GIWO during juveniles and breeding adults life stages, the density and spatial distribution of these fauna in the riparian habitat used by GIWO, and whether predator activity may vary in relation to other factors (e.g., time of day, patch size and width, matrix community type). The effect of predator density can have impacts more subtle than survival by altering prey behavior, nest site selection, breeding behavior, and foraging behavior (Chalfoun and Martin 2009; Lima 1998, 2009). Although a historical record exists of whiskered screech-owl (*Megascops trichopsis*) predation on GIWO (Gilman 1909), recent summaries suggest no information is available on predation of GIWO (Edwards and Schnell 2020).

SNAG DENSITY

The definition of this habitat element is updated as follows:

Full name: **The density of standing dead trees**. This element refers to the number of standing dead trees or large dead branches of live trees per hectare within the breeding patch. GIWO are positively associated with the density of snags > 12-centimeter (cm) diameter at breast height (DBH) in their territories, and the density of snags > 12 cm DBH within 100 m and within 1,000 m, presumably because this increases the number of available nest cavity locations for breeding (GBBO 2011).

SOIL SALINITY

The definition 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 degrees Celsius (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).

SOIL TEMPERATURE

The definition of this habitat element is updated as follows:

Full name: **The temperature of the soil within the foraging area of GIWO**. This element refers to the temperature of the soils in and around the foraging area of this species. Soil temperature has been shown to influence the timing and abundance of cicadas, a dietary item of GIWO during the breeding season (Anderson 1994; Rosenberg et al. 1982; Smith et al. 2006).

STAND HEIGHT

This habitat element replaces the original, Tree Size, for compatibility with other CEMs. The definition of Stand Height is updated as follows:

Full name: **The average height of the core stand area being evaluated and tree size, measured by DBH, averaged across the stand**. This element refers to the average size of trees within the nest stand, typically measured in DBH or height. GIWO have been shown to prefer nesting stands with larger trees (> 12 cm DBH and > 10 m tall) (GBBO 2011; McCreedy 2008).

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).

VEGETATION COMMUNITY TYPE

This habitat element replaces the original, Community Type. The definition of Vegetation Community Type is updated 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 GIWO. GIWO most commonly use saguaros or tall native trees within cottonwood-willow woodlands for nesting (GBBO 2011, 2018; Johnson et al. 2018; Rosenberg et al. 1991). However, the species has also been observed using honey or screwbean mesquite and cultivated trees such as eucalyptus and athel tamarisk, palm, orchard trees, and telephone poles (GBBO 2018; Johnson et al. 2018; Rosenberg et al. 1991; L. Sabin, personal observation). Brush et al. (1983) rarely found GIWO in honey or screwbean mesquite and hypothesize that this may be the result of the hardness of mesquite. In the LCR, Gooding's willow and Fremont cottonwood were significantly positively correlated with GIWO breeding territories (GBBO 2011). Higher densities of GIWO territories are consistently found in cottonwood-willow as opposed to mesquite and mixed habitat types (SWCA Environmental Consultants 2019).

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 GIWO life stages. The original GIWO conceptual ecological model (Miller and Unnasch 2016) also identified nine controlling factors. This update standardizes the name of one controlling factor (Pesticide/Herbicide Application) and replaces it with Pesticide Application; it also updates the discussion of four 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 GIWO 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		
Foliage density and diversity	X	X	X	X	X	X	X	X	
Food availability	X				X	X			
Genetic diversity					X				
Infectious agents					X	X			
Local hydrology			X		X				X
Nest cavity competitors	X				X				
Nest predators	X				X		X	X	
Parental care								X	
Patch size	X	X		X			X	X	
Predators	X				X		X	X	
Snag density	X			X					
Soil salinity			X						X
Soil temperature	X		X	X	X		X	X	X
Stand height	X			X	X	X	X		
Temperature	N/A*								
Vegetation community type	X	X	X		X	X	X	X	

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

FIRE MANAGEMENT

This controlling factor is updated as follows:

This factor addresses any fire management (whether prescribed fire or fire suppression) that could affect GIWO or their habitat. Effects may include creation of habitat that supports or excludes GIWO, a reduction in the food supply of invertebrates, or support of species that pose threats to GIWO such as predators, competitors, or carriers of infectious agents. Most aspects of fire have a negative effect on the presence of GIWO, such as decreasing snags, decreasing cover, or decreasing vertical density and diversity, all of which can increase soil temperatures and decrease food abundance. However, fire may be used as a tool to alter the community type back to a more native structure for the long-term benefit of GIWO. For example, fire may create snags useable by GIWO (Smith and Finch 2017). Climate change is also projected to affect fire frequency along the LCR (U.S. Fish and Wildlife Service 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 GIWO 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; Cannon and Knopf 1984; Clary and Webster 1989; General Accounting Office 1988; Klebenow and Oakleaf 1984; Rickard and Cushing 1982; Schultz and Leininger 1990; and U.S. Forest Service 1979). (*Note:* Mule deer have been observed by Bureau of Reclamation (Reclamation) staff and researchers on some LCR sites, and their browsing may affect vegetation communities if deer populations numbers increase to the point that overgrazing occurs.). Grazing may thin the understory, preventing the establishment of cottonwood and willow seedlings or other middle story components (Kauffman et al. 1997; Powell and Steidl 2002). Krueper et al. (2003) document a significant population increase of some avian species in the years following the removal of cattle from a riparian system, although the results for GIWO were inconclusive.

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, irrigation 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 GIWO. 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 or other agencies' water rights).

MECHANICAL THINNING

The definition of this controlling factor remains unchanged. No new information was located on mechanical thinning among GIWO 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 GIWO survival and reproduction. Nuisance species may infect, prey on, compete with, or present alternative food resources for GIWO during one or more life stages; cause other alterations to the riparian food web that affect GIWO; or affect physical habitat features such as canopy or shrub cover. For example, although GIWO 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).

The complicated nature of the relationship between tamarisk and GIWO is highlighted by another introduced species—the tamarisk beetle (*Diorhabda carinulata*). The 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), potentially degrading areas dominated by tamarisk as habitat for GIWO.

Although the European starling is a documented competitor for nest cavities of GIWO and can evict GIWO from cavities (Kerpez and Smith 1990a), there are few, if any, effective control or management techniques that can be applied (Cabe 2020). However, there is not a significant population of starlings using LCR MSCP conservation areas presently (B. Raulston 2020, personal communication).

Pesticide Application

This controlling factor is renamed from the original, Pesticide/Herbicide Application, for consistency with other CEMs. The controlling factor of Pesticide Application is updated as follows:

This factor addresses biocide applications that may occur on or adjacent to riparian habitat of the LCR region. Pesticides may drift into riparian areas, killing important GIWO habitat. Pesticide effects may include lethal or sublethal poisoning of GIWO via ingestion of treated insects, pollution from runoff into wetland habitats that are toxic to prey of GIWO, and a reduction in the invertebrate food supply. Herbicides could modify vegetation community type, structure, density, and diversity.

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, 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. GBBO (2014) reports that conservation and habitat creation areas surveyed and several prior years had no confirmed GIWO breeding pairs presumably because these areas had neither big trees, snags, nor many saguaros. However, GBBO (2015, 2017, 2019) documents GIWO usage of conservation areas in later years, although actual nests were apparently outside the areas and the birds' territory included the conservation area; this suggested that restoration could provide nesting habitat given sufficient time. An examination of avian

diversity approximately 10 years after restoration at the 142-ha Yuma East Wetlands site showed GIWO only present in restored plots (versus unrestored controls) during the breeding season, though it is not indicated whether or not they were actually nesting in the plots (Trathnigg and Phillips 2015).

RECREATIONAL ACTIVITIES

This controlling factor is updated as follows:

This factor addresses the disturbance to GIWO 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.

WATER STORAGE-DELIVERY SYSTEM DESIGN & OPERATION

The definition of this controlling factor remains unchanged. No new information was located on water storage-delivery system design and operation among GIWO in the Lower Colorado River Valley or elsewhere.

Updates to Chapter 6 – Conceptual Ecological Model by Life Stage

The following sections identify all changes made to the GIWO conceptual ecological model workbook other than changes that involve only updates to names. These latter changes are listed separately in table 5 (see below, "Summary of Standardization of Terms"). 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

- Fire Management to Nest Cavity Competitors (HE): This link was added based on the availability of new information and analysis. *Applies to the eggs/nestlings and breeding adults life stages*.

- Fire Management to Nest Predators (HE): This link was added based on the availability of new information and analysis. *Applies to the eggs/nestlings life stage*.

- Fire Management to Predators (HE): This link was based on the availability of new information and analysis. *Applies to the juveniles and breeding adults life stages*.

- Grazing to Nuisance Species Introduction & Management (CF): This link was based on the availability of new information and analysis. *Applies to all life stages*.

- Irrigation to Foliage Density & Diversity (HE): This link was based on the availability of new information and analysis. *Applies to all life stages*.

- Irrigation to Vegetation Community Type (HE): This link was based on the availability of new information and analysis. *Applies to all life stages*.

- Mechanical Thinning to Stand Height (HE): This link was based on the availability of new information and analysis. *Applies to the juveniles life stage*.

- Nuisance Species Introduction & Management to Nest Cavity Competitors (HE): This link was based on the availability of new information and analysis. *Applies to the eggs/nestlings and breeding adults life stages*.

- Nuisance Species Introduction & Management to Local Hydrology (HE): This link was based on the availability of new information and analysis. *Applies to the juveniles and breeding adults life stages*.

- Pesticide Application to Fertility (LSO): This link was based on the availability of new information and analysis. *Applies to the breeding adults life stage*.

- Pesticide Application to Survival (LSO): This link was based on the availability of new information and analysis. *Applies to all life stages*.

- Pesticide Application to Stand Height (HE): This link was based on the availability of new information and analysis. *Applies to all life stages*.

- Pesticide Application to Vegetation Community Type (HE): This link was based on the availability of new information and analysis. *Applies to all life stages*.

- Recreational Activities to Soil Temperature (HE): This link was based on the availability of new information and analysis. *Applies to all life stages*.

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

- Water Storage-Delivery System Design & Operation to Local Hydrology (HE): This link was based on the availability of new information and analysis. *Applies to the eggs/nestlings life stage*.

DELETED LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS

- Planting Regime to Stand Height (HE): This link was deleted because it became a duplicate link. *Applies to all life stages*.

- Recreational Activities to Parental Feeding Behavior (HE): This link was deleted because the combination of Parental Feeding Behavior with Parental Nest Care created a duplicate link. *Applies to the breeding adults life stage*.

UPDATED LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS

- Food Availability to Eating (CAP): This link was updated based on the separation of Eating/Foraging into two processes. *Applies to the juveniles life stage*.

- Grazing to Anthropogenic Disturbance (HE): This link was updated based on the availability of new information and analysis. *Applies to all life stages*.

- Grazing to Foliage Density & Diversity (HE): This link was updated based on the availability of new information and analysis. *Applies to all life stages*.

- Grazing to Patch Size (HE): This link was updated based on the availability of new information and analysis. *Applies to all life stages*.

- Grazing to Vegetation Community Type (HE): This link was updated based on the availability of new information and analysis. *Applies to all life stages*.

- Irrigation to Local Hydrology (HE): This link was updated for compatibility with other CEMs. *Applies to all life stages*.

- Irrigation to Soil Salinity (HE): This link was updated for compatibility with other CEMs. *Applies to all life stages*.

- Irrigation to Soil Temperature (HE): This link was updated for compatibility with other CEMs. *Applies to all life stages*.

- Mechanical Thinning to Snag Density (HE): This link was updated based on the availability of new information and analysis. *Applies to all life stages*.

- Mechanical Thinning to Stand Height (HE): This link was updated based on the availability of new information and analysis. *Applies to the breeding adults life stage*.

- Nuisance Species Introduction & Management to Canopy Closure (HE): This link was updated based on the availability of new information and analysis. *Applies to all life stages*.

- Nuisance Species Introduction & Management to Infectious Agents (HE): This link was updated based on the availability of new information and analysis. *Applies to the juveniles and breeding adults life stages*.

- Nuisance Species Introduction & Management to Local Hydrology (HE): This link was updated based on the availability of new information and analysis. *Applies to the eggs/nestlings life stage*.

- Planting Regime to Foliage Density and Diversity (HE): This link was updated based on the availability of new information and analysis. *Applies to the eggs/nestlings and juveniles life stages*.

- Recreational Activities to Parental Care (HE): This link was updated based on the availability of new information and analysis. *Applies to the breeding adults life stage*.

- Water Storage-Delivery System Design & Operation to Local Hydrology (HE): This link was updated based on the availability of new information and analysis. *Applies to the juveniles and breeding adults life stages*.

- Water Storage-Delivery System Design & Operation to Soil Salinity (HE): This link was updated based on the availability of new information and analysis. *Applies to all life stages*.

- Water Storage-Delivery System Design & Operation to Soil Temperature (HE): This link was updated based on the availability of new information and analysis. *Applies to all life stages*.

NEW LINKS WITH HABITAT ELEMENTS AS CAUSAL AGENTS

- Anthropogenic Disturbance to Foraging (CAP): This link was added based on separation of former critical biological activity or process, Eating/ Foraging, into separate critical biological activities or processes. *Applies to the juveniles life stage*.

- Food Availability to Foraging (CAP): This link was added due to separation of former critical biological activity or process, Eating/ Foraging, into separate critical biological activities or processes. *Applies to the juveniles life stage*.

- Infectious Agents to Disease (CAP): This link was added due to separation of former habitat element, Genetic Diversity & Infectious Agents, into separate habitat elements. *Applies to all life stages*.

- Infectious Agents to Survival (LSO): This link was added based on availability of new information and analysis. *Applies to all life stages*.

- Nest Predators to Eating (CAP): This link was added due to the separation of Nest Predators as a habitat element from Predators. *Applies to the eggs/nestlings life stage*.

- Nest Predators to Nest Site Selection (CAP): This link was added due to the separation of Nest Predators as a habitat element from Predators. *Applies to the breeding adults life stage*.

- Predators to Foraging (CAP): This link was added based on the availability of new information and analysis. *Applies to the juveniles and breeding adults life stages*.

- Temperature to Nest Attendance (CAP): This link was added based on the availability of new information and analysis. *Applies to the breeding adults life stage*.

- Temperature to Nest Site Selection (CAP): This link was added based on the availability of new information and analysis. *Applies to the breeding adults life stage*.

- Temperature to Parental Care (CAP): This link was added based on the availability of new information and analysis. *Applies to the eggs/nestlings life stage*.

- Temperature to Thermal Stress (CAP): This link was added based on the availability of new information and analysis. *Applies to all life stages*.

- Vegetation Community Type to Eating (CAP): This link was added based on the availability of new information and analysis. *Applies to the eggs/nestlings life stage*.

- Vegetation Community Type to Foraging (CAP): This link was added based on the availability of new information and analysis. *Applies to the juveniles and breeding adults life stages*.

DELETED LINKS WITH HABITAT ELEMENTS AS CAUSAL AGENTS

- Food Availability to Brood/Litter Size (HE): This link was deleted because this link only applies to the breeding adults life stage. *Applies to the eggs/nestlings and juveniles life stages*.

- Food Availability to Parental Nest Attendance (HE): This link was deleted because the combination of Parental Feeding Behavior with Parental Nest Care created a duplicate link. *Applies to the eggs/nestlings life stage*.

- Genetic Diversity & Infectious Agents to Brood/Litter Size (HE): This link was deleted due to lack of supporting information or data. *Applies to all life stages*.

- Genetic Diversity & Infectious Agents to Thermal Stress (CAP): This link was deleted due to lack of supporting information or data. *Applies to all life stages*.

- Parental Feeding Behavior to Eating/Foraging (CAP): This link was deleted because the combination of Parental Feeding Behavior with Parental Nest Care created a duplicate link. *Applies to the eggs/nestlings life stage*.

- Parental Care to Nest Attendance (HE): This link was deleted because Parental Care only applies to the eggs/nestlings and juveniles life stages. *Applies to the breeding adults life stage*.

- Predators to Nest Attendance (HE): This link was deleted because the combination of Parental Feeding Behavior with Parental Nest Care created a duplicate link. *Applies to the eggs/nestlings life stage*.

- Vegetation Community Type to Infectious Agents (HE): This link was deleted due to lack of supporting information or data. *Applies to all life stages*.

UPDATED LINKS WITH HABITAT ELEMENTS AS CAUSAL AGENTS

- Food Availability to Eating (CAP): This link was updated due to separation of former critical biological activity or process, Eating/Foraging, into separate critical biological activities or processes. *Applies to the juveniles life stage*.

- Genetic Diversity to Disease (CAP): This link was updated due to the separation of Genetic Diversity & Infectious Agents into two processes. *Applies to all life stages*.

- Infectious Agents to Nest Site Selection (CAP): This link was updated due to the lack of information or literature pertaining to this species. *Applies to the breeding adults life stage*.

- Nest Predators to Nest Predation (CAP): This link was updated based on the availability of new information and analysis. *Applies to the eggs/nestlings life stage*.

- Nest Predators to Parental Care (HE): This link was updated based on the availability of new information and analysis. *Applies to the eggs/nestlings life stage*.

- Vegetation Community Type to Nest Predation (CAP): This link was updated based on the availability of new information and analysis. *Applies to the eggs/nestlings life stage*.

New Links with Critical Activities/ Processes as Causal Agents

- Foraging to Molting (CAP): This link was added due to separation of former critical biological activity or process, Eating/Foraging, into separate critical biological activities or processes. *Applies to the juveniles life stage*.

- Foraging to Nest Attendance (CAP): This link was added for compatibility with other CEMs. *Applies to the breeding adults life stage*.

- Foraging to Thermal Stress (CAP): This link was added due to separation of former critical biological activity or process, Eating/Foraging, into separate critical biological activities or processes. *Applies to the juveniles life stage*.

- Foraging to Survival (LSO): This link was added due to separation of former critical biological activity or process, Eating/Foraging, into separate critical biological activities or processes. *Applies to the juveniles life stage*.

- Thermal Stress to Nest Site Selection (CAP): This link was added based on the availability of new information and analysis. *Applies to the breeding adults life stage*.

Deleted Links with Critical Activities/ Processes as Causal Agents

No change.

UPDATED LINKS WITH CRITICAL ACTIVITIES/ PROCESSES AS CAUSAL AGENTS

- Disease effect on Thermal Stress (CAP): Temperature Regulation was changed to Thermal Stress; therefore, the character type has been changed to positive, and the direction is now bi-directional. The reason has been revised. Disease may increase physiological vulnerability to thermal stress and vice versa. All other link values and reasons remain the same. Applies to all life stages.

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.)

GIWO conceptual ecological model, updated terms, 2019	GIWO 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 *(new)*	Predation
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
Foliage Density and Diversity	Foliage Density and Diversity
Food Availability	Food Availability
Genetic Diversity *(new)*	Genetic Diversity and Infectious Agents *(see Genetic Diversity; see Infectious Agents)*
Infectious Agents *(new)*	
Local Hydrology	Local Hydrology
Nest Cavity Competitors *(renamed)*	Nest Cavity Competitor Density
Nest Predators *(new)*	Predator Density *(see Nest Predators)*
Parental Care *(renamed)*	Parental Feeding Behavior *(see Parental Care)*
	Parental Nest Attendance *(see Parental Care)*
Patch Size	Patch Size
Predators *(renamed)*	Predator Density
Snag Density	Snag Density
Soil Salinity	Soil Salinity
Soil Temperature	Soil Temperature
Stand Height *(renamed)*	Tree Size *(see Stand Height)*
Temperature *(new)*	
Vegetation Community Type *(renamed)*	Community Type *(see Vegetation Community Type)*
Controlling factors	
Fire Management	Fire Management
Grazing	Grazing
Irrigation	Irrigation
Mechanical Thinning	Mechanical 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

Gila Woodpecker (*Melanerpes uropygialis*) (GIWO) Habitat Data

Table 1-1.—Gila woodpecker (*Melanerpes uropygialis*) (GIWO) habitat data
(*Note*: This is an update of table 2.1 found in attachment 2 of the original GIWO 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	Selected territories with a denser canopy than in areas not used	Lower Colorado River (LCR)	Great Basin Bird Observatory (GBBO) 2011
Foliage density and diversity	More often in tall Fremont cottonwoods (*Populus fremontii*) and willows (*Salix* sp.) with three or four layers of vegetation and the majority of foliage above 6 meters (m) in height	LCR	Hunter 1984
Food availability	Diet includes many insects (beetles, moths, ants, butterflies, and cicadas) and fruits (saguaros [*Carnegia gigantea*] other cacti)	LCR	Rosenberg et al. 1982; Edwards and Schnell 2020
	Diet during breeding season can be dominated by cicadas (50–75%)	LCR	Rosenberg et al. 1982
Genetic diversity	No quantifiable values found in the literature		
Infectious agents	No quantifiable values found in the literature		
Local hydrology	Positively associated with water source within 1,000 m	LCR	GBBO 2011
Nest cavity competitors	European starlings (*Sturnus vulgaris*) compete with GIWO for nest cavities; GIWO can be evicted from cavities by starlings and nest in lower densities when starlings are present than when absent	Pinal and Pima Counties, Arizona	Kerpez and Smith 1990
	Northern flickers (*Colaptes auratus*) compete with GIWO for nest cavities	Gila River, New Mexico	Brenowitz 1978
Nest predators	No quantifiable values found in the literature		
Parental care	No quantifiable values found in the literature		
Patch size	> 20 hectares	LCR	Rosenberg et al. 1991
	Found in areas where fragments larger than 20 hectares do not exist	LCR	L. Sabin 2015, personal communication
Predators	No quantifiable values found in the literature		
Snag density	Greater numbers of snags in territory, within 100 m and within 1,000 m	LCR	GBBO 2011

Table 1-1.—Gila woodpecker (*Melanerpes uropygialis*) (GIWO) habitat data
(*Note*: This is an update of table 2.1 found in attachment 2 of the original GIWO model document.)

Habitat element	Value or range	Location	Reference
Soil salinity	No quantifiable values found in the literature		
Soil temperature	No quantifiable values found in the literature		
Stand height	Blue palo verde (*Parkinsonia florida*) – average plant height = 7.3 m, average nest height = 4.2 m, average diameter at breast height (DBH) = 39 centimeters (cm), and average DBH = 46 cm. Smallest – 25 cm DBH and 7.3 m in height.	Southeast California	McCreedy 2008
	Positively associated with trees > 12 cm DBH and > 10 m in height	LCR	GBBO 2011
Vegetation community type	Saguaros, cottonwoods, willows, Arizona sycamore (*Platanus wrightii*), and mesquite (*Prosopis* sp.)	Southern Arizona	Bent 1939
	Cottonwood-willow, eucalyptus (*Eucalyptus* sp.), athel tamarisk (*Tamarix aphylla*), honey mesquite (*Prosopis glandulosa*), and screwbean mesquite (*Prosopis pubescens)*. Of 29 nests in the Bill Williams River Delta in 1977–78, 18 were in willows, 6 were in saguaros, and 5 were in Fremont cottonwoods.	LCR	Rosenberg et al. 1991
	Fremont cottonwoods, Goodding's willows, and mesquite. Also nest in exotics.	Arizona	Bradley 2005
	Desert riparian: Fremont cottonwoods, Goodding's willows, and Arizona sycamore Mesquite bosque: Blue palo verde, honey mesquite, and screwbean mesquite Urban: Athel tamarisk eucalyptus, and blue fan palm (*Brahea armata*)	Southeast California	McCreedy 2008
	Presence of mistletoe (*Viscum album*), willows, and Fremont cottonwood positively correlated with presence of GIWO	LCR	GBBO 2011

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

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