Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

2019 Updates to Summer Tanager (*Piranga rubra*) (SUTA) Basic Conceptual Ecological Model for the Lower Colorado River

Photo courtesy of the Bureau of Reclamation

August 2020

Work conducted under LCR MSCP Work Task G6

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Lower Colorado River Multi-Species Conservation Program

2019 Updates to Summer Tanager (*Piranga rubra*) (SUTA) Basic Conceptual Ecological Model for the Lower Colorado River

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August 2020

Mehlman, D.W., and R. Unnasch. 2020. 2019 Updates to Summer Tanager (*Piranga rubra*) (SUTA) Basic Conceptual Ecological Model for the Lower Colorado River. Submitted to the Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Boulder City, Nevada, by Sound Science, LLC, Boise, Idaho, under contract No. R16PC000028.

ACRONYMS AND ABBREVIATIONS

CAP	critical biological activity or process
CEM	conceptual ecological model
CF	controlling factor
cm	centimeter(s)
dbh	diameter at breast height
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)
Reclamation	Bureau of Reclamation
SD	standard deviation
SE	standard error
SUTA	summer tanager (*Piranga rubra*)

Symbols

°C	degrees Celsius (*aka* centigrade)
>	greater than
<	less 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

1 Summer Tanager (*Piranga rubra*) Habitat Data

Foreword

This report provides an update to the original conceptual ecological model (CEM) prepared for the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) for the summer tanager (*Piranga rubra*) (SUTA) (Miller et al. 2015). This update incorporates information reported in publications and presentations at professional meetings since the completion of the original SUTA conceptual ecological model and also incorporates information from the professional experiences of LCR MSCP staff and other experts. An updated version of the CEM workbook incorporates the new information. This report constitutes an appendix to the original CEM. The full CEM report, including its life-stage diagrams, has not been updated.

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

The updates reported in this report change the SUTA conceptual ecological model in several ways. The terminology used has been updated and standardized in many parts to be consistent across species as much as possible. Two critical biological activities and processes were split into separate activities and processes to better reflect their effects on different life stages and for consistency with other CEMs. Many changes were made to habitat elements: (1) addition of one element for consistency, (2) separation of two former combined habitat elements into two separate elements each 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 in order to standardize terminology across all CEMs.

This update both explicitly and implicitly identifies possible new research and monitoring questions concerning gaps in knowledge that may bear on adaptive management of SUTA. 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 the information for the summer tanager (*Piranga rubra*) (SUTA) conceptual ecological model (CEM) are Brand et al. (2010), Powell and Steidl (2000, 2002), Robinson (2020), 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 SUTA in other areas of the Southwest were consulted to supplement research along the lower Colorado River (LCR). The purpose of a CEM is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

UPDATE TO SUMMER TANAGER REPRODUCTIVE ECOLOGY

SUTA are considered complete migrants, breeding in North America and wintering in Central and South America (Robinson 2020). Birds return to the LCR from their wintering grounds in mid-April to begin the breeding season (Great Basin Bird Observatory 2018; Small 1994). Male birds arrive before females, with courtship beginning immediately upon the arrival of the females. Nest building commences 2 to 4 weeks after arrival, with the first egg laid shortly after nest completion (Rosenberg et al. 1991).

The SUTA female builds an open-cup nest of dried, herbaceous vegetation that is generally sturdy and well-constructed, at least within the western population of birds occupying the LCR (Robinson 2020). The typical clutch consists of three to four eggs, with two broods common in the Southwestern United States (Rosenberg et al. 1991). SUTA nests are often depredated and are subject to variable rates of brood parasitism by brown-headed cowbirds (*Molothrus ater*), up to 100% in some fragmented landscapes in the Eastern United States (Brawn and Robinson 1996; Powell and Steidl 2000) but apparently considerably lower in the West (Robinson 2020). In the Western United States, SUTA are known to be aggressive toward cowbirds that approach the nest (Robinson 2020).

Incubation begins after the last egg is laid and lasts approximately 11–12 days (Fitch and Fitch 1955; Robinson 2020). Young birds fledge from the nest in 8–12 days and continue to be fed by adults for at least 3 weeks (Robinson 2020).

SUTA are bee and wasp specialists, capturing prey primarily by hawking (Bent 1958; Rosenberg et al. 1982). However, SUTA may be locally dependent on cicadas (*Diceroprocta apache*), consuming large numbers at about the time of first brood fledging (Rosenberg et al. 1982). SUTA also consume fruit, at least in some parts of their range, during some seasons (Robinson 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 SUTA

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

Updates to Chapter 2 – SUTA Life-Stage Model

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

UPDATE TO INTRODUCTION TO THE SUTA LIFE CYCLE

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

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

We have chosen to combine the separate egg and nestling stages into a single eggs/nestlings stage because both the eggs and nestlings occupy the same nest; therefore, management focused on the nest will cover eggs and nestlings (e.g., fire management, recreation management). Further, most research conducted on SUTA 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.

The migratory nature of SUTA complicates its management. Under the LCR MSCP, management of the breeding grounds is a primary responsibility; we therefore focus on three life stages occurring within LCR MSCP lands—eggs/nestlings, juveniles, and breeding adults. SUTA management during migration and winter are certainly important but outside of the scope of the Bureau of Reclamation's (Reclamation) responsibilities.

UPDATE TO SUTA LIFE STAGE 1 – EGGS/ NESTLINGS

We consider the eggs/nestlings stage to be the first in the life cycle of SUTA. It begins when the egg is laid and ends either when the young fledge or the nest fails. Eggs are usually laid in mid-May to mid-July, and incubation lasts around 11–12 days, with all eggs in a clutch hatching within 2 days of each other (Rosenberg et al. 1991). Young birds fledge from the nest in 8–12 days and continue to be fed by adults for at least 3 weeks (Robinson 2020). Powell and Steidl (2000) found very high rates (approximately 80%) of nest predation of other open-nesting passerine species along the LCR, suggesting that the nest stage is an especially important time in the life cycle. The rate of depredation of SUTA within the LCR is unknown. The life-stage outcome from the eggs/nestlings stage is the survival of eggs and associated nestlings until fledging. It is important to note that the outcome of the eggs/nestlings stage is inherently tied to the behavior and condition of the parents.

UPDATE TO SUTA LIFE STAGE 2 – JUVENILES

The juveniles stage begins at fledging and ends when the bird returns to the breeding grounds the next year. Juveniles will remain in the general vicinity of the nest and of parents for at least 3 weeks and are fed by the parents during this time (Robinson 2020). Migration begins in August and generally occurs at night (Robinson 2020). Migration has not been thoroughly studied in this species, especially with the western populations. The life-stage outcome from the juveniles stage is the survival of the bird from fledging until the return to the breeding grounds 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 the adult annual survival rate that has been reported to be approximately 0.56 (Michel et al. 2006; Ricklefs and Shea 2007).

UPDATE TO SUTA LIFE STAGE 3 – BREEDING ADULTS

As the focus of this CEM is upon the LCR region, the breeding adults stage begins when the bird returns to the LCR breeding grounds after its first winter and ends when it departs the LCR breeding grounds during fall migration. Hence, an individual may re-enter the breeding adults life stage a number of times during its

life. Generally, adults arrive on the breeding grounds between mid-April and early May, with males arriving earlier and setting up territories before females arrive (Small 1994).

The female will choose a nest site and then build a nest 2–4 weeks after arrival (Rosenberg et al. 1991). The female begins incubation the day the last egg is laid and lasts approximately 11–12 days (Fitch and Fitch 1955). Males do not incubate but do provide food for the female on the nest (Potter 1973). The adult female also forages independently (Potter 1973). Young birds fledge from the nest in 8–12 days and continue to be fed by adults for at least 3 weeks (Fitch and Fitch 1955; Robinson 2020). Two broods are common in southwestern populations (Rosenberg et al. 1991).

The life-stage outcomes for breeding adults are survival and fertility—here defined as the production of eggs. As noted earlier, 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 stage from breeding adults fecundity to more clearly display the information regarding nest success so that it can be better assessed by management. Therefore, the fecundity of adults involves the acts of pairing, site selection, nest building, and production of eggs. The longevity record for SUTA, based on band recovery, is currently 9 years and 0 months (Bird Banding Laboratory 2020).

The post-breeding period—after breeding but before migration—is a significant part of a bird's life cycle. During the post-breeding period, adults may prospect for potential future breeding areas or move into habitat types, different from breeding areas, that provide good conditions for migratory staging (Vega Rivera et al. 2003). Vega Rivera et al. (2003) found that half of scarlet tanagers (*Piranga olivacea*) moved into earlier successional forests post-breeding, while half remained within the breeding area. 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 (e.g., foraging and refuge) is similar and, in many cases, identical, and thus, management directed at breeding adults will likely benefit all demographics present on the breeding grounds.

UPDATE TO LIFE-STAGE MODEL SUMMARY

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

Table 1.—(Revision of original table 1) SUTA 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

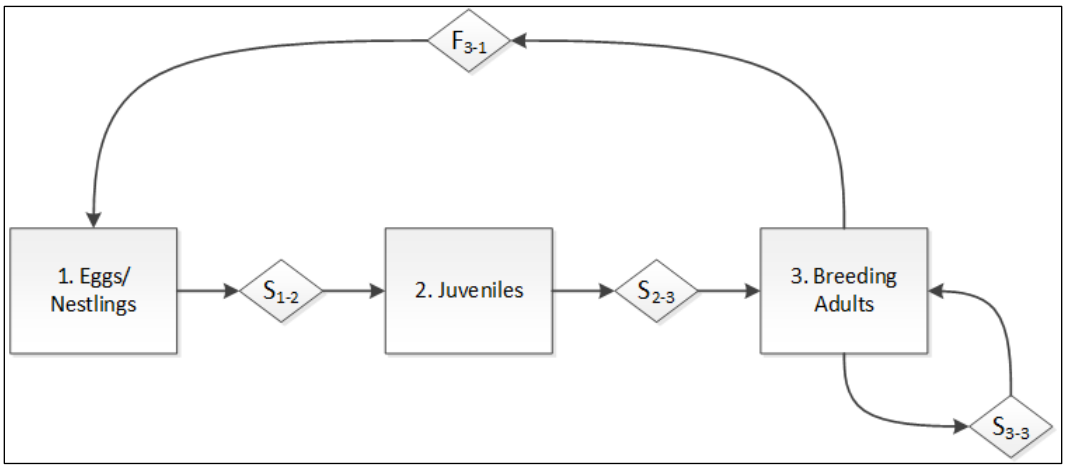

Figure 1.—(Revision of original figure 1) Proposed SUTA life history model. Squares indicate the life stages, and diamonds indicate life-stage outcomes. S_{1-2} = Survival, Eggs/Nestlings; S_{2-3} = Survival, Juveniles; S_{3-3} = Survival, Breeding Adults; and F_{3-1} = Fertility, Breeding Adults.

Updates to Chapter 3 – Critical Biological Activities and Processes

This update identifies nine critical biological activities or processes that affect one or more SUTA life stages. The original SUTA conceptual ecological model (Miller et al. 2015) identified seven. This update changes the names of two critical biological activities and processes, Molt and Temperature Regulation, replacing them with Molting and Thermal Stress, respectively; splits 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 and Brood Parasitism into two separate critical biological activities and processes, Nest Predation & Brood Parasitism and Predation, for consistency with other LCR MSCP conceptual ecological model updates; and updates the discussions of seven critical biological activities and processes. Table 2 lists the nine critical biological activities or processes in this update, and their distribution across life stages, and indicates which are new to this update or renamed from the original SUTA conceptual ecological model.

Table 2.—Distribution of SUTA critical biological activities and processes among life stages

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

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

The most widely used sources of the information used to identify the critical biological activities and processes are Brand et al. (2010), Lima (2009), Powell and Steidl (2002), Robinson (2020), Rosenberg et al. (1991), and Smith and Finch (2013). These publications summarize and cite large bodies of earlier studies; where appropriate and accessible, those earlier studies are directly cited. The identification also integrates information from both older, and more recent works, as well as the expert knowledge of LCR MSCP biologists. The following paragraphs discuss the nine critical biological activities and processes in alphabetical order.

DISEASE

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

EATING

This 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 only applies to the eggs/nestlings and juveniles life stages. Juveniles 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

This 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 adults. Juveniles forage on their own but are still fed by adults shortly after fledging. SUTA are hawking insectivores that forage above the canopy, along edges, and within forest openings (Rosenberg

et al. 1982). Foraging is done by juveniles and adults, but it is important to note that foraging by the parents affects the provisioning rate to nestlings and nest attendance by adults.

MOLTING

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

Molting 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 SUTA undergo a molt from natal down into juvenal plumage while in the nest (Robinson 2020). 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 pre-basic (pre-formative) molt in their summer geographic range from July to September (Pyle 1997). Adults undergo a complete pre-basic molt on the summer grounds from June to September every subsequent year of their lives (Pyle 1997). Adult SUTA undergo a limited, partial, or incomplete pre-alternate molt (depending on whether the bird is in its second calendar year or older) from November to April (mostly in February – March), largely or fully on their wintering grounds (Pyle 1997). Recent analyses show little evidence that SUTA undergo a molt-migration strategy, despite some suggestions to the contrary (Pyle et al. 2009, 2018; Robinson 2020).

NEST ATTENDANCE

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

NEST PREDATION & BROOD PARASITISM

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

process named Predation, and it is renamed Nest Predation & Brood Parasitism for consistency with other CEMs and to clarify its meaning. The discussion is updated as follows:

Nest predation and brood parasitism certainly affect survival and the success of riparian bird species within the LCR, but data specific to SUTA are less available (Brand et al. 2010, Powell and Steidl 2000). Powell and Steidl (2000) found that nest predation was more significant than parasitism, accounting for 81% of nest failures of riparian bird species along a southwestern riparian corridor, although they found no specific instances of either for SUTA at this site. Nest predator and brood parasite abundance is influenced by patch size and the nest's relative proximity to a vegetation edge (Rosenberg et al. 1999; Winfree 2004). These two processes have been combined for the eggs/nestlings life stages because (1) cowbirds are both nest predators and brood parasites (Theimer et al. 2011) and (2) habitat characteristics (e.g., distance to edge, patch width) affect both processes similarly (Rosenberg et al. 1999). Further evidence suggests a host of behavioral characteristics can also influence nest predation rates, including brood size, parental nest attendance, and parental feeding behavior (Martin and Briskie 2009).

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, with males selecting territories and females selecting the actual nest site within that territory (Powell and Steidl 2002; Robinson 2020). 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 (Brand et al. 2010; Lima 2009; Powell and Steidl 2002; Robinson 2020; Smith and Finch 2013).

PREDATION

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

Predation is a threat to SUTA in all life stages, and it obviously affects survival. For this model, nest predation has been combined with brood parasitism and is treated as a separate critical process (see above). Predator abundance is influenced by patch size and the nest's relative proximity to a vegetation edge (Rosenberg et al. 1999; Winfree 2004). Predation on juveniles and adults is not as easily quantified, but it affects juveniles and adults and indirectly affects nest survival through abandonment. Predation risk can result in many behavioral adaptations in passerines, including nest locations, densities, clutch sizes, 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:

Thermal stress is important to any organism inhabiting a region with temperatures as high as that along 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). The optimal temperature for egg development is 37–38 degrees Celsius (°C), with exposure to temperatures greater than 40.5 °C potentially lethal (Gill et al. 2019). Adults can influence the thermal stress on eggs/nestlings through their own behavior (incubation, brooding, or shading) and/or nest placement.

Updates to Chapter 4 – Habitat Elements

This update identifies 18 habitat elements that affect 1 or more critical biological activities or processes across 1 or more SUTA life stages. The original SUTA conceptual ecological model (Miller et al. 2015) identified 17 habitat elements. This update standardizes the names of two habitat elements, with Brood Size becoming Brood/Litter Size and Community Type becoming Vegetation Community Type; adds one habitat element (Temperature) for consistency with other CEMs; separates the former habitat element Predator and Cowbird Density into two distinct habitat elements, Nest Predators & Cowbird Density and Predators; splits one habitat element (Genetic Diversity and Infectious Agents) into two separate elements (Genetic Diversity and Infectious Agents); combines the habitat elements (Parental Feeding Behavior and Parental Nest Attendance) into Parental Care; combines the habitat elements Stand Height and Tree Size into Stand Height; and updates the discussions of 15 habitat elements.

Table 3 lists the 18 habitat elements in this update, indicates the critical biological activities or processes they *directly* affect across all SUTA life stages, and indicates which habitat elements are new to this update or renamed from the original SUTA conceptual ecological model.

Table 3.—(Revision of original table 3) Distribution of SUTA habitat elements and the critical biological activities or 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 predation & brood parasitism**	**Nest site selection**	**Predation**	**Thermal stress**
Anthropogenic disturbance		X	X		X	X	X		
Brood/litter size (*replaces brood size*)		X	X		X				
Canopy closure						X	X		X
Food availability		X	X						
Genetic diversity (*replaces genetic diversity and infectious agents*)	X								
Infectious agents (*new*)	X								
Local hydrology							X		X
Nest predators & cowbird density (*new*)					X	X	X		
Parental care (*replaces parental feeding behavior and parental nest attendance*)		X	X			X			X
Patch size						X	X	X	
Predators (*replaces predator and cowbird density*)					X	X	X	X	
Soil salinity	N/A*								
Soil temperature	N/A*								
Stand height						X	X		
Temperature (*new*)					X		X		X
Tree density						X	X		
Understory density						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 SUTA 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 size is related to maternal health, and the well-being of both parents depends in part on the availability of sufficient food resources in close proximity to the breeding territory as well as other factors such as predator density (see below, "Nest Predators & Cowbird Density"). SUTA typically lay three or four eggs, although two and five have also been observed (Robinson 2020).

CANOPY CLOSURE

The 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). This element refers to the percent canopy closure of canopy vegetation in the vicinity of the nest site. Canopy closure of riparian vegetation, especially higher density in the upper canopy, has been shown to be important to SUTA. Dense vegetation around the nest may provide more optimal microclimate for thermal regulation (Rosenberg et al. 1991) and camouflage from nest predators. Canopy closure may also affect the availability of food (Smith et al. 2006).

Powell and Steidl (2000, 2002) found that SUTA choose patches with relatively high canopy cover in relation to other species in the area (mean 69.5 ± 3.6%

canopy cover); however, the canopy cover of the area closest to the nest was not found to be different from the canopy cover in the remainder of the stand, although nest concealment was high.

FOOD AVAILABILITY

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

Full name: **The abundance of food available for adults and their young.** This element refers to the taxonomic and size composition of the invertebrates that an individual SUTA will encounter during each life stage as well as the density and spatial distribution of the food supply in proximity to the nest. SUTA are primarily insectivorous during the breeding season, relying heavily on cicadas (50%) and bees/wasps (25%) (Rosenberg et al. 1982). The peak timing of cicada emergence appears to coincide with the SUTA fledging date within the preferred habitat of SUTA (Rosenberg et al. 1982). Cicada emergence and abundance is regulated by soil temperatures and is thus influenced by canopy closure and local hydrology (Andersen 1994). Higher soil temperatures lead to earlier emergence and lower abundance of cicadas (Andersen 1994). Furthermore, cicada abundance can influence the soil profile by transferring the equivalent of as much as 12% of the annual rainfall of water from deeper water tables to shallower soils, increasing local soil moisture, which can influence the community type and health of the ecosystem (Andersen 1994). Cicadas do this by ingesting and excreting xylem fluid from roots back into soils and by burrowing, which increases percolation of water from rain and irrigation into soils (Andersen 1994).

However, SUTA have been reported to rely on fruits late in the breeding season and during migration (Robinson 2020). The abundance and condition of the food supply affects adult health, growth and development of nestlings and juveniles, the progress of molt, and the success of later stages in the annual cycle (i.e., migration). Wiesenborn (2012, 2013, 2014) recommends that maintenance of diverse insect populations, particularly in restoration habitats in the LCR, be considered in order to sustain appropriate invertebrate diets for insectivorous species such as SUTA.

GENETIC DIVERSITY

The habitat element of Genetic Diversity and 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 the (sub)population.** 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. Shepherd and Burns (2007) studied the genetic diversity of the LCR populations of SUTA and found the population to possess diverse genetics that are shared across the range of the population.

INFECTIOUS AGENTS

The habitat element of 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.** This element refers to the spectrum of bacteria, fungi, ecto-parasites, endo-parasites, and viruses that individual SUTA are likely to encounter during each life stage. There have been few specific studies of the infectious agents and their effects on SUTA (Robinson 2020). 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 have differing effects on different species (Merino et al. 2000; Palinauskas et al. 2008).

LOCAL HYDROLOGY

The definition of this habitat element has been 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 affect other aspects of habitat such as vegetation structure and abundance of arthropods. Wetter conditions might also provide cooler temperatures and more humid conditions necessary for egg and chick survival in these desert systems (Rosenberg et al. 1991). SUTA were more likely to nest closer to water, with the odds of nesting decreasing 0.128 for every meter (perpendicular distance) from a nearby stream channel (Powell and Steidl 2002).

NEST PREDATORS & COWBIRD DENSITY

The original habitat element, Predators and Cowbird Density, is separated into two habitat elements, Nest Predators & Cowbird Density and Predators, to better define specific habitat elements and to be consistent with other CEMs. The discussion is slightly 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 SUTA 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 SUTA during the eggs/nestlings life stage, the density and spatial distribution of these fauna in the riparian habitat used by tanagers, and whether predator activity may vary in relation to other factors (e.g., time of day, patch size and width, matrix community type). Powell and Steidl (2000) report observing that 81% of southwestern riparian nests they studied were depredated with a large amount of brood parasitism as well. Studies in eastern North America have shown that brood parasitism of SUTA nests can decrease the number of offspring that fledge by 20% (Robinson 2020).

However, Rasmussen and Sealy (2006) suggest that counting the fledging rate underestimates the impact of brood parasitism. Rosenberg et al. (1999) found no effect of the presence of cowbirds on the presence of SUTA within a nest stand. 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). Predation on SUTA has not been thoroughly studied (Robinson 2020). Based upon defensive aggression behavior, it is surmised that SUTA may be depredated by blue jays (*Cyanocitta cristata*), Cooper's hawks (*Accipiter cooperii*), raccoons (*Procyon lotor*), squirrels (*Sciurus* spp.), and black rat snakes (*Elaphe obsoleta*) (Fitch and Fitch 1955; Potter 1973; Robinson 2020).

PARENTAL CARE

This habitat element replaces the former elements of 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 for both parents to share nesting and brood rearing responsibilities until fledging and to provision food for recently fledged birds. It is affected by

the presence of predators and competitors, food availability, and the ability to thermally regulate. Parents provide food for young for approximately 3 weeks after fledging (Robinson 2020). The provisioning rate is dependent upon food availability and the number of young in the brood, and it influences the amount of food and time spent foraging by the juvenile birds. Female SUTA have sole responsibility of brooding young, but the territory is actively defended by males (Potter 1973). When a second brood is initiated, the juveniles are fed by the adult male (Mengel 1965 *in* Robinson 2020).

PATCH SIZE

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

PREDATORS

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

Full name: **The abundance and distribution of species that depredate SUTA during the juveniles and breeding adults life stages**. This element refers to a set of closely related variables that affect the likelihood that different kinds of predators will encounter and successfully prey on SUTA during the juveniles or breeding adults life stages. The variables of this element include the species and size of the fauna that prey on SUTA during different life stages, the density and spatial distribution of these fauna in the riparian habitat used by tanagers, and the ways in which predator activity may vary in relation to other factors (e.g., patch size and stand characteristics) (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).

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 °C** (San Joaquin River Restoration Program 2014). Salinity is one of the major ecosystem problems throughout the entire Colorado River Basin, with concentrations increasing dramatically from the headwaters to the LCR at the international Boundary with Mexico (LaHue 2017; U.S. Geological Survey 2000), and it 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.** This element refers to the temperature of the soils in and around the foraging area of SUTA. Soil temperature has been shown to influence the timing and abundance of cicadas, a primary dietary item for SUTA during the breeding season (Andersen 1994; Rosenberg et al. 1982; Smith et al. 2006). An increase of mean June soil temperatures of 3.5 °C, from 23.4 to 26.9 °C, resulted in earlier emergence of cicadas by more than 2 weeks (Smith et al. 2006).

STAND HEIGHT

This habitat element now includes both the former elements of Stand Height and Tree Size. The definition is updated as follows:

Full name: **The average height of the core stand area being evaluated and tree size, measured by diameter at breast height, averaged across the stand**. Stand height may be important for SUTA occupancy in riparian environments, but little quantifiable data exist. Powell and Steidl (2000) found that SUTA nested in large trees (mean 55.2 ± 7.0 centimeter [cm] diameter at breast height [dbh], 12.3 ± 1.0 meter [m] height) and that nests were placed on larger limbs (mean 5.0 ± 0.7 cm diameter). Powell and Steidl (2002) found that SUTA occupy nesting stands with larger-than-average trees on the landscape.

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).

TREE DENSITY

The definition of this habitat element is updated as follows:

Full name: **The stem density of trees as measured by trees per acre.** The greater the tree and/or shrub density, the greater the likelihood of denser vegetative cover. Tree density can be correlated with canopy cover and total vegetation density. Powell and Steidl (2000) found that SUTA nest sites had a mean tree density of 1.7 ± 0.3% stems (> 8 cm dbh) per 0.008-hectare (ha) circular plot.

UNDERSTORY DENSITY

The definition of this habitat element is updated as follows:

Full name: **The density of the understory layer.** SUTA appear to select for lower understory (0–1.5 m) density (but not mid-story [> 1.5–4 m] density), including lower vegetative coverage, lower volume, and fewer shrubs at the canyon scale, but only fewer shrubs at the nest stand scale (Powell and Steidl 2000, 2002). Powell and Steidl (2000) found that SUTA nest sites had less vegetation in the understory (mean 19.2 ± 1.0% understory volume, 23.2 ± 4.0% understory coverage, 23.3 ± 4.8% shrub [< 8 cm dbh] stems per 0.008 ha).

VEGETATION COMMUNITY TYPE

This habitat element replaces the original, Community Type. The definition 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 SUTA. Research shows that SUTA are adaptable, able to use various types of native and non-native broadleaf deciduous habitats at different elevations (Rosenberg et al. 1991). However, SUTA densities are substantially higher in native habitats such as large cottonwood stands within the LCR region (Brand et al. 2010; Powell and Steidl 2000). Recent surveys along the LCR found SUTA territories in Fremont cottonwood-willow (*Populus fremontii-Salix* spp.) and mixed (mixture of cottonwood-willow and mesquite [*Prosopis* spp.]) habitat plots (2018: 8 territories in cottonwood-willow, 3 in mixed; 2017: 10 territories in cottonwood-willow, 2 in mixed), and no territories in mesquite-only habitat plots (SWCA Environmental Consultants 2018, 2019).

Updates to Chapter 5 – Controlling Factors

This update identifies 10 controlling factors that affect 1 or more habitat elements and/or critical biological activities or processes across the 3 SUTA life stages. The original SUTA conceptual ecological model (Miller et al. 2015) identified 10 controlling factors. This update standardizes the name of one controlling factor, Pesticide/Herbicide Application, replacing it with Pesticide Application, and it updates the discussion of four controlling factors. Table 4 lists the 10 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 SUTA 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**	**Natural thinning**	**Nuisance species introduction & management**	**Pesticide application *(replaces pesticide/herbicide application)***	**Planting regime**	**Recreational activities**	**Water storage-delivery system design & operation**
Anthropogenic disturbance		X		X			X	X	X	
Brood/litter size	N/A*									
Canopy closure	X			X	X	X		X	X	
Food availability	X					X	X	X		
Genetic diversity	N/A*									
Infectious agents	N/A*									
Local hydrology			X							X
Nest predators & cowbird density						X		X	X	
Parental care									X	
Patch size	X	X		X	X	X		X	X	
Soil salinity			X							X
Soil temperature	X		X	X	X			X		X
Stand height	X			X	X	X		X		
Temperature	N/A*									
Tree density	X			X	X	X		X	X	
Understory density	X	X	X	X		X		X	X	X
Vegetation community type	X	X	X			X		X	X	X

* N/A values suggest 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 SUTA or their habitat. Effects may include creation of habitat that supports or excludes SUTA, a reduction in the food supply of invertebrates, or support of a species that pose threats to SUTA, such as predators, competitors, or carriers of infectious agents. Although typically not a major threat in most riparian habitats, severe wildfires have affected southwestern willow flycatcher (*Empidonax traillii extimus*) breeding sites in the past decade (Ellis et al. 2008; Graber et al. 2007; U.S. Fish and Wildlife Service 2002) and could affect SUTA habitats. In fact, small, contained fires have recently occurred in a few LCR restoration sites (Hunters Hole and Yuma East Wetlands), and a severe fire occurred in riparian habitat at the Havasu National Wildlife Refuge (C. Dodge 2018, personal communication).

Climate change is also projected to affect fire frequency in the LCR (USFWS 2013). While fire can decrease understory vegetation to the benefit of SUTA, most of the other impacts are negative, such as decreased canopy closure, decreased patch size, and increased soil temperature, which in turn decreases the food supply.

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 SUTA 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 Appendix G *in* U.S. Fish and Wildlife Service 2002). (Note: Reclamation staff and researchers have observed mule deer browsing on LCR sites, which may become an issue if population numbers increase to the point that overgrazing occurs). Grazing may thin the understory, which could benefit SUTA in the short term, but it can also prevent the establishment of cottonwood and willow seedlings (Kauffman et al. 1997; Powell and Steidl 2002). In particular, overgrazing has been an identified as a management issue in Arizona along the San Pedro River and the Verde River (S. Kokos 2014, personal communication). Krueper (1993) and Krueper et al. (2003) report that fencing cattle out of sensitive riparian habitats in the San Pedro Riparian National Conservation Area led to improved habitat quality and increased SUTA

density within 4 years. However, cattle grazing does not have much impact in the LCR habitats in which SUTA occur (C. Dodge and B. Sabin 2018, personal communications).

IRRIGATION

This controlling factor is updated as follows:

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

The LCR MSCP, U.S. Fish and Wildlife Service, and the Colorado River Indian Tribes irrigate portions of several areas along the Lower Colorado River Valley to create and manage habitat for general wildlife, LCR MSCP covered species, and associated wetland habitat. SUTA have been found consistently at restoration sites, including the Beal Lake Conservation Area, Colorado River Indian Tribes' 'Ahakhav Tribal Preserve Habitat Creation Area 09, and the Cibola Valley Conservation Area, and on at least one year at the Palo Verde Ecological Reserve and Yuma East Wetlands (Great Basin Bird Observatory 2011, 2018).

MECHANICAL THINNING

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

NATURAL THINNING

This controlling factor is updated as follows:

This factor addresses the natural death of trees within a patch of a riparian forest or the surrounding matrix. As overstory trees die, they leave openings in the

canopy, thereby allowing light to reach lower vegetation layers and creating the horizontal and vertical foliage profiles. The increased structural complexity may benefit SUTA. Perry et al. (2011) and Powell and Steidl (2002) each found that occupancy rates of SUTA were influenced by structures surrounding the nest site that were different than that of the nest site. The decreased canopy closure may make the stand less attractive for nesting and increase soil temperatures, which can negatively influence cicada timing and abundance (Andersen 1994; Powell and Steidl 2002).

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 SUTA survival and reproduction. Nuisance species may infect, prey on, compete with, or present alternative food resources for SUTA during one or more life stages; cause other alterations to the riparian food web that affect SUTA; or affect physical habitat features such as canopy or shrub cover. For example, although tanagers 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 SUTA 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), thereby degrading areas dominated by tamarisk as habitat for SUTA.

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 SUTA depends (Boland 2016; Leathers 2015). As of 2018, the beetles have not been found outside of California; they may require cooler temperatures, which would prevent or slow their spread into LCR habitats (B. Raulston 2018, personal communication; University of California Agriculture and Natural Resources 2020). However, Boland (2016) 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. Due to the potential threat to all riparian habitat, LCR sites should be monitored regularly for beetle spread.

In addition to non-native plants and insect pests, non-native feral swine (*Sus scrofa*) have been identified as a problem for other riparian species in California's Santa Ana River watershed habitat. Feral swine also occur on the Havasu National Wildlife Refuge and have been sighted elsewhere in the LCR. Through their rooting and wallowing activities, they disturb soil and increase erosion, destroy vegetation, and negatively affect water quality. Swine also compete with and/or prey on native wildlife species. For these reasons, they are currently being culled from the Havasu National Wildlife Refuge (Neskey 2018; U.S. Department of the Interior 2016). It is unknown what effect they may have on SUTA and nest success.

Pesticide Application

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

Planting Regime

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

Recreational Activities

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

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 SUTA 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 SUTA 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

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

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

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

Deleted Links with Controlling Factors as Causal Agents

- Fire Management to Stand Height (HE): Link deleted due to the combination of former habitat elements, Tree Size and Stand Height, into a single habitat element, Stand Height, making one of the former two links duplicative. *Applies to all life stages*.

- Mechanical Thinning to Stand Height (HE): Link deleted due to the combination of former habitat elements, Tree Size and Stand Height, into a single habitat element, Stand Height, making one of the former two links duplicative. *Applies to all life stages*.

- Natural Thinning to Stand Height (HE): Link deleted due to the combination of former habitat elements, Tree Size and Stand Height, into a single habitat element, Stand Height, making one of the former two links duplicative. *Applies to all life stages*.

- Nuisance Species Introduction and Management to Stand Height (HE): Link deleted due to the combination of former habitat elements, Tree Size and Stand Height, into a single habitat element, Stand Height, making one of the former two links duplicative. *Applies to all life stages*.

- Planting Regime to Stand Height (HE): Link deleted due to the combination of former habitat elements, Tree Size and Stand Height, into a single habitat element, Stand Height, making one of the former two links duplicative. *Applies to all life stages*.

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

UPDATED LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS

- Fire Management to Stand Height (HE): Link updated to reflect the combination of the former separate habitat element, Tree Size, into a single habitat element, Stand Height. *Applies to all life stages*.

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

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

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

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

- Irrigation to Local Hydrology (HE): Link updated to provide standardization across CEMs. *Applies to all life stages*.

- Irrigation to Soil Temperature (HE): Link updated to provide standardization across CEMs. *Applies to all life stages*.

- Irrigation to Vegetation Community Type (HE): Link updated to provide standardization across CEMs. *Applies to all life stages*.

- Mechanical Thinning to Stand Height (HE): Link updated to reflect the combination of former separate habitat element, Tree Size, into a single habitat element, Stand Height. *Applies to all life stages*.

- Natural Thinning to Stand Height (HE): Link updated to reflect the combination of former separate habitat element, Tree Size, into a single habitat element, Stand Height. *Applies to all life stages*.

- Planting Regime to Stand Height (HE): Link updated to reflect the combination of former separate habitat element, Tree Size, into a single habitat element, Stand Height. *Applies to all life stages*.

- Water Storage-System Design & Operation to Local Hydrology (HE): Link updated to provide standardization across CEMs. *Applies to all life stages*.

- Water Storage System Design & Operation to Soil Salinity (HE): Link updated to provide standardization across CEMs. *Applies to all life stages*.

- Water Storage System Design & Operation to Soil Temperature (HE): Link updated to provide standardization across CEMs. *Applies to all life stages*.

New Links with Habitat Elements as Causal Agents

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

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

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

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

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

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

- Water Storage-System Design & Operation to Irrigation (CF): Link added to provide standardization across CEMs. *Applies to all life stages*.

DELETED LINKS WITH HABITAT ELEMENTS AS CAUSAL AGENTS

- Anthropogenic Disturbance to Parental Care (HE): Link deleted due to the combination of former habitat elements, Parental Feeding Behavior and Parental Nest Attendance, into a single habitat element, Parental Care, making one of the former two links duplicative. *Applies to the eggs/nestlings life stage*.

- Brood/Litter Size to Parental Care (HE): Link deleted due to the combination of former habitat elements, Parental Feeding Behavior and Parental Nest Attendance, into a single habitat element, Parental Care, making one of the former two links duplicative. *Applies to the eggs/nestlings life stage*.

- Food Availability to Parental Care (HE): Link deleted due to the combination of former habitat elements, Parental Feeding Behavior and Parental Nest Attendance, into a single habitat element, Parental Care, making one of the former two links duplicative. *Applies to the eggs/nestlings life stage*.

- Parental Care to Eating (CAP): Link deleted due to the combination of former habitat elements, Parental Feeding Behavior and Parental Nest Attendance, into a single habitat element, Parental Care, making one of the former two links duplicative. *Applies to the eggs/nestlings life stage*.

- Parental Care to Eating (CAP): Link deleted because eating was separated from foraging, and the former no longer applies. *Applies to the juveniles life stage*.

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

- Parental Care to Nest Predation & Brood Parasitism (CAP): Link deleted due to the combination of former habitat elements, Parental Feeding Behavior and Parental Nest Attendance, into a single habitat element, Parental Care, making one of the former two links duplicative. *Applies to the eggs/nestlings life stage*.

- Parental Care to Nest Predation & Brood Parasitism (CAP): Link deleted because Predation was separated from Nest Predation & Brood Parasitism, and the latter only applies to the eggs/nestlings life stage. *Applies to the juveniles and breeding adults life stages*.

- Soil Salinity to Stand Height (HE): Link deleted due to the combination of former habitat elements, Tree Size and Stand Height, into a single habitat element, Stand Height, making one of the former two links duplicative. *Applies to all life stages*.

- Stand Height to Nest Predation & Brood Parasitism (CAP): Link deleted due to the combination of former habitat elements, Tree Size and Stand Height, into a single habitat element, Stand Height, making one of the former two links duplicative. *Applies to all life stages*.

- Stand Height to Nest Site Selection (CAP): Link deleted due to the combination of former habitat elements, Tree Size and Stand Height, into a single habitat element, Stand Height, making one of the former two links duplicative. *Applies to the breeding adults life stage*.

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

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

UPDATED LINKS WITH HABITAT ELEMENTS AS CAUSAL AGENTS

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

- Stand Height to Nest Site Selection (CAP): Link updated to reflect the combination of former habitat elements, Tree Size and Stand Height, into a single habitat element. *Applies to the breeding adults life stage*.

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

NEW LINKS WITH CRITICAL ACTIVITIES/ PROCESSES AS CAUSAL AGENTS

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

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

Deleted Links with Critical Activities/ Processes as Causal Agents

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

Updated Links with Critical Activities/ Processes as Causal Agents

No change.

New Links with Life-Stage Outcomes as Causal Agents

No change.

SUMMARY OF STANDARDIZATION OF TERMS

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

SUTA conceptual ecological model updated terms, 2019	SUTA conceptual ecological model original terms, 2015
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 ~~E~~Dating)*
Foraging	Eating/Foraging *(see Foraging)*
Molting *(renamed)*	Molt
Nest Attendance	Nest Attendance
Nest Predation & Brood Parasitism *(new)*	Predation and Brood Parasitism *(see Nest Predation and Brood Parasitism; see Predation)*
Nest Site Selection	Nest Site Selection
Predation *(new)*	
Thermal Stress *(renamed)*	Temperature Regulation
Habitat elements	
Anthropogenic Disturbance	Anthropogenic Disturbance
Brood/Litter Size *(renamed)*	Brood Size
Canopy Closure	Canopy Closure
Food Availability	Food Availability
Genetic Diversity *(new)*	Genetic Diversity and Infectious Agents *(see Genetic Diversity; see Infectious Agents)*
Infectious Agents *(new)*	
Local Hydrology	Local Hydrology
Nest Predators & Cowbird Density *(renamed)*	Predators and Cowbird Density *(see Nest Predators & Cowbird Density; see Predators)*
Parental Care *(renamed)*	Parental Feeding Behavior *(see Parental Care)*
	Parental Nest Attendance *(see Parental Care)*
Patch Size	Patch Size
Predators *(new)*	
Soil Salinity	Soil Salinity
Soil Temperature	Soil Temperature
Stand Height *(revised)*	Stand Height
	Tree Size *(see Stand Height)*
Temperature *(new)*	
Tree Density	Tree Density
Understory Density	Understory Density
Vegetation Community Type *(renamed)*	Community Type *(see Vegetation Community Type)*
Controlling factors	
Fire Management	Fire Management
Grazing	Grazing
Irrigation	Irrigation
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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ACKNOWLEDGMENTS

The authors of the original SUTA conceptual ecological model in 2015 acknowledged Chris Dodge, Barbara Raulston, and Beth Sabin, biologists with the LCR MSCP; Sonja Kokos, Adaptive Management Specialist, LCR MSCP, who provided invaluable technical feedback and guidance during the development of the model process and production of that original report; and John Swett, Program Manager, LCR MSCP, for his leadership and support of the LCR MSCP conceptual ecological modeling effort.

The authors of this updated SUTA conceptual ecological model acknowledge additional invaluable technical feedback from Joe Kahl, Jr., Barbara Raulston, and Carolyn Ronning, biologists, with the LCR MSCP; Becky Blasius, Adaptive Management Specialist, LCR MSCP; and Jimmy Knowles, Adaptive Management Group Manager, LCR MSCP.

ATTACHMENT 1

Summer Tanager (*Piranga rubra*) (SUTA) Habitat Data

Table 2-1.—Summer tanager habitat data
(Note: This is an update of table 2.1 found in attachment 2 of the original SUTA model document.)

Habitat element	Values	Location	Reference
Anthropogenic disturbance	No quantifiable values found in the literature		
Brood/litter size	No quantifiable values found in the literature		
Canopy closure	69.5 ± 3.6 standard error (SE) %	Brown Canyon, Baboquivari Mountains, Arizona	Powell and Steidl 2000
	92.8 ± 10.5 standard deviation (SD) %	South Fork Kern River Valley, California	T. Gallion, personal communication, *in* Robinson 2020
Food availability	No quantifiable values found in the literature		
Genetic diversity	No quantifiable values found in the literature		
Infectious agents	No quantifiable values found in the literature		
Local hydrology	No quantifiable values found in the literature		
Nest predators & cowbird density	No quantifiable values found in the literature		
Parental care	No quantifiable values found in the literature		
Patch size	Width > 60 meters	Ouachita Mountains, Arkansas	Perry et al. 2011
Soil salinity	No quantifiable values found in the literature		
Soil temperature	No quantifiable values found in the literature		
Stand height	55.2 ± 7.0 SE centimeter diameter at breast height	Brown Canyon, Baboquivari Mountains, Arizona	Powell and Steidl 2000
	12.3 ± 1.0 SE m height	Brown Canyon, Baboquivari Mountains, Arizona	Powell and Steidl 2000
Tree density	1.7 ± 0.3 SE trees per 5-meter radius circular plot (0.008 hectare) centered on nest	Brown Canyon, Baboquivari Mountains, Arizona	Powell and Steidl 2000
Understory density	23.2 ± 4.0 SE % coverage	Brown Canyon, Baboquivari Mountains, Arizona	Powell and Steidl 2000
	19.2 ± 1.0 SE % volume	Brown Canyon, Baboquivari Mountains, Arizona	Powell and Steidl 2000
Vegetation community type	Willows (*Salix*) and cottonwoods (*Populus*)	Lower Colorado River	Grinnell 1914; Bent 1958; Rosenberg et al.1991
	Sycamore (*Platanus wrightii*), velvet mesquite (*Prosopis velutina*), *Quercus* spp.	Baboquivari Mountains, Arizona	Powell and Steidl 2002

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

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