Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

2019 Updates to Sonoran Yellow Warbler (*Dendroica* = *Setophaga petechia sonorana*) (YWAR) Basic Conceptual Ecological Model for the Lower Colorado River

Photo courtesy of the Bureau of Reclamation

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2019 Updates to Sonoran Yellow Warbler (*Dendroica* = *Setophaga petechia sonorana*) (YWAR) Basic Conceptual Ecological Model for the Lower Colorado River

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Acronyms and Abbreviations

CAP	critical activity or process
CEM	conceptual ecological model
CF	controlling factor
CI	confidence interval
cm	centimeters(s)
DBH	diameter at breast height
GBBO	Great Basin Bird Observatory
HE	habitat element
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
LSO	life-stage outcome
m	meter(s)
N/A	not applicable
SE	standard error
SWCA	SWCA Environmental Consultants
USFWS	U.S. Fish and Wildlife Service
YWAR	Sonoran yellow warbler (*Dendroica petechia sonorana* = *Setophaga petechia sonorana*)

Symbols

°C	degrees Celsius
>	greater than
<	less than
%	percent

Definitions

For the purposes of this document, vegetation layers are defined as follows:

Canopy – The canopy is the uppermost strata within a plant community. The canopy is exposed to the sun and captures the majority of its radiant energy.

Understory – The understory comprises plant life growing beneath the canopy without penetrating it to any extent. The understory exists in the shade of the canopy and usually has lower light and higher humidity levels. The understory includes subcanopy trees and the shrub and herbaceous layers.

Shrub layer – The shrub layer is comprised of woody plants between 0.5 and 2.0 meters in height.

Herbaceous layer – The herbaceous layer is most commonly defined as the forest stratum composed of all vascular species that are 0.5 meter or less in height.

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Attachment

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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 Sonoran yellow warbler (*Dendroica petechia sonorana* = *Setophaga petechia sonorana*) (YWAR) (McClure and Unnasch 2015). This update incorporates information reported in publications and presentations at professional meetings since the completion of the original YWAR conceptual ecological model and also incorporates information from the professional experiences of LCR MSCP staff and other experts. An updated version of the CEM workbook incorporates the new information. This report constitutes an appendix to the original CEM. The full CEM report, including its life-stage diagrams, has not been updated.

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

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

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

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

Updates to Chapter 1 – Introduction

The information in paragraph 3 in the initial section of chapter 1 is updated as follows:

The most widely used sources of information for the Sonoran yellow warbler (*Dendroica petechia sonorana = Setophaga petechia sonorana*) (YWAR) conceptual ecological model (CEM) are Floyd (2007), Heath (2008), Lower Colorado River Multi-Species Conservation Program (LCR MSCP) (2008, 2016), Lowther et al. (2020), Rosenberg et al. (1991), and Wise-Gervais (2005). These publications summarize and cite large bodies of earlier studies. The CEM also integrates numerous additional sources, particularly reports and articles completed since these publications; information on current research projects; and the expert knowledge of LCR MSCP biologists (Dodge and Kahl 2012; Great Basin Bird Observatory [GBBO] 2016, 2017; SWCA Environmental Consultants [SWCA] 2019; and Wiesenborn 2013, 2014). In addition, sources of information for yellow warblers (*Setophaga petechia = Dendroica petechia*) range-wide were consulted if there was insufficient information available about the YWAR 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 into a CEM so it can be used for adaptive management.

UPDATE TO SONORAN YELLOW WARBLER REPRODUCTIVE ECOLOGY

Yellow warblers are considered complete migrants, breeding in North America and wintering in Central America and northern South America. The breeding adults life stage begins when the bird returns to the breeding grounds (initially after its first winter) and ends when it departs the breeding grounds during fall migration. (*Note*: There have been occasional records of YWAR overwintering in southern California and in the LCR [Small 1994]). YWAR begin arriving to their Southwestern United States breeding areas in mid-March (Wise-Gervais 2005) or April (Rosenberg et al. 1991; Small 1994). In Arizona, breeding activity peaks in June, but occurs from late April to mid-July, and adults have been reported feeding fledglings as late as August 10 (Wise-Gervais 2005). Dodge and Kahl (LCR MSCP 2016) have confirmed resident breeding YWAR as early as April 4 in the LCR (C. Dodge 2018, personal communication), with birds present through late September (Dodge and Kahl 2012).

Males typically arrive on the breeding grounds before females (Lowther et al. 2020). Females build the nest and lay four or five eggs, which they alone incubate, although the males may feed the nesting female during this time

(Lowther et al. 2020). The incubation period generally lasts 11–12 days, with young fledging 8–10 days after hatching (Lowther et al. 2020; Wise-Gervais 2005). GBBO (2016) reported incubation dates for the LCR between April 19 – May 18 (they did not survey past this date). While brooding is performed by the female alone, the male will help feed the nestlings (Lowther et al. 2020). After fledging, the young will remain with adults for an additional 17–21 days (Smith 1943).

YWAR typically nest in riparian Fremont cottonwood-Goodding's willow (*Populus fremontii-Salix gooddingii*) forests and associated understory habitats along the LCR (GBBO 2011, 2012, 2013, 2014, 2016; LCR MSCP 2008, 2016; Rosenberg et al. 1991). They are generalist insectivores that take insect prey in proportion to availability (Lowther et al. 2020).

CONCEPTUAL ECOLOGICAL MODEL PURPOSES

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

CONCEPTUAL ECOLOGICAL MODEL STRUCTURE FOR THE YWAR

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

Updates to Chapter 2 – YWAR Life-Stage Model

This update standardizes the names of the YWAR life stages by switching to the plural noun form for each name for consistency with the other LCR MSCP conceptual ecological model updates. The names of the original life-stage outcomes are standardized as follows: (1) Survivors changes to Survival for all three life stages and (2) Reproduction changes to Fertility. 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 YWAR LIFE CYCLE

The introduction is updated as follows:

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

Our model of the life cycle of a typical migratory bird distinguishes three life stages: eggs/nestlings, juveniles, and breeding adults. These life stages were included because they balance the need to understand the model in the context of past work and the need to present the ecological information necessary to effectively manage for the critical biological activities that drive the growth—or decline—of populations of migratory birds along the LCR.

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 have separated the eggs/nestlings life stage from adult fertility to more clearly display the information regarding nest success so that it can be better assessed by management. In addition, we have chosen to combine the egg and nestling phases of development into the eggs/nestlings life stage because both the eggs and nestlings occupy the same nest. Therefore, management focused on the nest will cover both eggs and nestlings.

The migratory nature of the YWAR complicates its management. The LCR MSCP is mainly responsible for management on the breeding grounds, and we therefore focus on three life stages occurring within LCR MSCP lands—eggs/nestlings, juveniles, and breeding adults. Although the yellow warbler has

been reported to winter along the LCR at low densities (Rosenberg et al. 1991; Small 1994), the model does not address the biology of the YWAR during migration or in its winter range.

UPDATE TO YWAR LIFE STAGE 1 – EGGS/ NESTLINGS

This life stage description is updated as follows:

We consider the eggs/nestlings life stage to be the first in the life cycle of YWAR. It begins when the first egg is laid and ends either when the young fledge or the nest fails. YWAR generally lay eggs in Arizona, beginning in late April, with nests having young around mid-May (LCR MSCP 2008). Active YWAR nests have been recorded between April 28 and July 14 (LCR MSCP 2008) with confirmed resident breeding as early as April 4 (C. Dodge 2018, personal communication). GBBO (2016) reported incubations dates beginning April 19. The nest life stage lasts about 25 days, starting with the first egg and ending when the last fledgling leaves the nest. In general, yellow warbler nestlings fledge 8 to 10 days post-hatching (Lowther et al. 2020).

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

UPDATE TO YWAR LIFE STAGE 2 – JUVENILES

There is no change to this life stage from the original model.

The juveniles life stage begins at fledging and ends when the bird returns to the breeding grounds the next year. Fledglings will remain with adults 17–21 days post-fledging (Smith 1943). The life-stage outcome from the juveniles stage is the survival of the bird from fledging until its return to the breeding grounds the next calendar year. There are no studies available that analyze juvenile survival rates in this species.

UPDATE TO YWAR LIFE STAGE 3 – BREEDING ADULTS

This life stage description is updated as follows:

The breeding adults life stage begins when the bird returns to the breeding grounds after its first winter and ends when it departs the breeding grounds during fall migration. Yellow warblers begin arriving at their Southwestern United States breeding areas in mid-March (Wise-Gervais 2005) or April (Rosenberg et al. 1991; Small 1994). In Arizona, breeding activity peaks in June, but occurs from late April to mid-July, and adults have been reported feeding fledglings as late as August 10 (Wise-Gervais 2005). Dodge and Kahl (2012) reported singing YWAR between May 3 and June 21 at the Cibola National Wildlife Refuge Unit #1 Conservation Area Nature Trail. They also confirmed resident breeding YWAR as early as April 4 in the LCR (C. Dodge 2018, personal communication), with birds present through late September (Dodge and Kahl 2012).

Across the breeding range of yellow warblers, males tend to arrive on the breeding grounds before females (Lowther et al. 2020). The nest is built by the female who usually lays four or five eggs and conducts all of the incubation, during which she might be fed by the male (Lowther et al. 2020). The incubation period generally lasts 11–12 days, with young fledging 8–12 days after hatching (Lowther et al. 2020; Wise-Gervais 2005). While brooding is performed by the female alone, the male will help feed the nestlings (Lowther et al. 2020).

LIFE-STAGE MODEL SUMMARY

Table 1.—YWAR life stages and outcomes in the LCR ecosystem

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

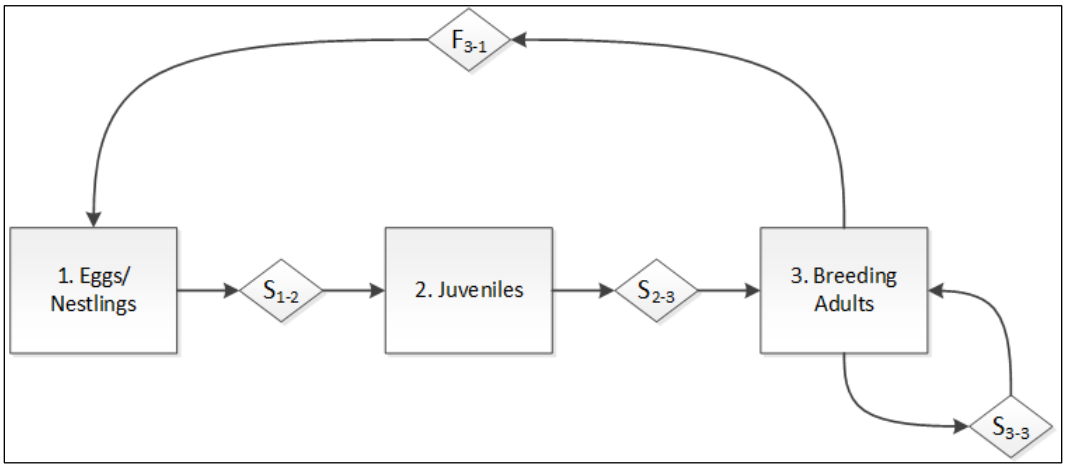

Figure 1.—(Revision of original table 1) Proposed YWAR life history model.
Squares indicate the life-stage, and diamonds indicate the life-stage outcomes. S_{1-2} = survival, eggs/nestlings, S_{2-3} = survival, juveniles, S_{3-3} = survival, breeding adults, and F_{3-1} = fertility, breeding adults.

Updates to Chapter 3 – Critical Biological Activities and Processes

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

Table 2.—(Revision of original table 2) Distribution of YWAR critical biological activities and processes among life stages (Xs indicate that the critical biological activity or process is applicable to that life stage.)

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

DISEASE

The discussion of this critical biological activity or process remains unchanged; however, a reference has been updated. No new information was located on YWAR diseases in the Lower Colorado River Valley or elsewhere.

This process refers to diseases caused by infectious agents, including the effects of ecto- and endoparasites. Disease prevalence and intensity can be influenced by the lack of genetic diversity. Little is known about the effects of disease on the yellow warbler across its range (Lowther et al. 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) that can be difficult to detect (Jarvi et al. 2002) and that have differing effects on different species (Merino et al. 2000; Palinauskas et al. 2008). YWAR in all life stages are conceivably susceptible to disease.

EATING

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

This process only applies to the eggs/nestlings life stage because nestlings must eat to stay alive and develop but do not actively forage within their environment in the same way as juveniles and adults. A nestling's ability to eat is determined by the provisioning rate of its parents. Note that although the parents will feed the juveniles (see chapter 4, "Parental Care"), this is assumed to affect foraging and, for simplicity, we do not include eating as a critical biological activity for juveniles; rather, food acquisition by juveniles and adults is classified as foraging.

FORAGING

The discussion of this critical biological activity or process remains unchanged; however, references have been updated. No new information was located on YWAR foraging in the Lower Colorado River Valley or elsewhere.

Yellow warblers are generalist insectivores that forage by sallying, gleaning, and hovering (Eckhardt 1979; Frydendall 1967; Hutto 1981; Lowther et al. 2020; Yard et al. 2004). In Utah (Frydendall 1967) and Colorado (Eckhardt 1979), gleaning is by far the most often used strategy. Frydendall (1967) notes that individuals of the yellow warbler subspecies (*S. p. morcomi*) show no innate restriction to particular foraging heights and added that the height of their foraging is only limited by the height of the vegetation itself. Frydendall (1967) further classifies *S. p. morcomi* as a mid- to high-level forager. In Colorado, foraging was concentrated mostly in willows (Eckhardt 1979), whereas in Utah, foraging was mostly in box elder (*Acer negundo*), followed by willow (Frydendall 1967). Both juveniles and adults forage, 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 this critical biological activity or process 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 (Howell 2010). Nestling YWAR undergo a molt from natal down into juvenal plumage while in the nest. The success of this molt is dependent upon the adult provisioning rate (Howell 2010). Molting is an energetically costly process that may make nestlings more susceptible to death when resources are scarce (Gill et al. 2019; Howell 2010). 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).

Juveniles then undergo a partial pre-basic (pre-formative) molt, which usually starts before fledging, in the summer geographic range from May to September (Lowther et al. 2020; Pyle et al. 1997). Adults undergo a complete pre-basic molt largely on the summer grounds from June to September every subsequent year of their lives (Pyle et al. 1997). Therefore, both juvenile and breeding adults likely undergo at least some molt on the breeding grounds. Adult birds molt on the breeding grounds after the breeding season, and before autumn migration, and face the same challenges as nestlings (Howell 2010; Rimmer 1988).

Adult YWAR then undergo a partial to incomplete pre-alternate molt (depending on whether the bird is in its second calendar year or older) from December to April, largely or fully on the wintering grounds (Pyle et al. 1997).

NEST ATTENDANCE

The discussion of this critical biological activity or process remains unchanged; however references have been updated. No new information was located on YWAR nest attendance in the Lower Colorado River Valley or elsewhere.

The female does all of the incubating and brooding, but the male helps with feeding the young (Lowther et al. 2020). Along the LCR, female YWAR will incubate, or shade their eggs, depending on the temperature (Theimer et al. 2010). Although little information on responses to predators is available, yellow warblers will mob potential predators, and females will give distraction displays when confronted by potential nest predators (Lowther et al. 2020). Tewksbury et al.

(2002) document a complicated interplay between the need for parents to guard against egg removal by cowbirds (*Molothrus ater*) while also foraging and avoiding nest predation. Nest attendance by breeding adults therefore affects the survival of nestlings (Tewksbury et al. 2002).

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

NEST PREDATION & BROOD PARASITISM

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

Yellow warblers are frequent victims of brood parasitism (Hansen and Rotella 2002; Heath 2008; Lowther et al. 2020; Morgan et al. 2006; Wise-Gervais 2005), which certainly affects the number of yellow warbler offspring fledged from parasitized nests (Lowther et al. 2020; Ortega and Ortega 2000; Rock et al. 2013; Tewksbury et al. 2002; Timmer et al. 2011). However, the yellow warbler has evolved anti-parasitism strategies that include nest abandonment and/or the construction of new nests on top of parasitized clutches (Lowther et al. 2020), which allows them to fledge young from parasitized nests (Clark and Robertson 1981; Heath et al. 2010; Lichtenstein and Sealy 1998; Lowther et al. 2020; Sealy 1992; Tewksbury et al. 2002).

Although the rates and effects of brood parasitism for YWAR are poorly understood, Heath (2008) and the LCR MSCP (2008, 2016) state that cowbird parasitism poses a "limited to moderate threat" to YWAR along the LCR, and Rosenberg et al. (1991) express doubt that brood parasitism is the principal cause of decline of YWAR. The latter note that the subspecies was abundant during the early 20th century despite high rates of parasitism.

There is also heterogeneity in parasitism rates across regions (Lowther et al. 2020). Perhaps the only study of brood parasitism of YWAR is by Theimer et al. (2011), which reports 1 of 7 (14%) monitored nests parasitized at the Pahranagat National Wildlife Refuge and 6 of 22 (27%) nests parasitized at Mesquite, Nevada.

Nest predation is likely the most common cause of nest failure for yellow warblers, in general (Cain et al. 2003; Heath et al. 2010; Quinlan and Green 2012; Rogers 1994), and specifically for YWAR (Heath 2008), although studies on the effects of nest predation on YWAR productivity are lacking (LCR MSCP 2008,

2016). Theimer et al. (2011) report that none of the 7 nests at the Pahranagat National Wildlife Refuge were depredated, whereas 13 of 22 (59%) nests at Mesquite, Nevada, were depredated. Common known or potential nest predators of YWAR range-wide include American crows (*Corvus brachyrhynchos*) and jays (*Corvus* sp.); mammals such as red foxes (*Vulpes vulpes*), weasels (*Mustela* sp.), striped skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*); black racer snakes (*Coluber constrictor*), and gartersnakes (*Thamnophis sirtalis*) (Batts 1958 *in* Lowther et al. 2020; Bigglestone 1913; Briskie 1995; Goossen and Sealy 1982 *in* Lowther et al. 2020; Latif et al. 2012).

Nest predation and brood parasitism have been combined for the eggs/nestlings life stage because (1) cowbirds are both nest predators and brood parasites (Latif et al. 2011; Tewksbury et al. 2002; Theimer et al. 2011) and (2) habitat characteristics (vegetation density, patch size, etc.) likely affect both processes similarly. Further, Tewksbury et al. (2002) demonstrate that, in Montana, females in parasitized nests increased their nest attendance, thus increasing the need for the males to feed the females and increasing the activity at a nest. The increase in activity at nests increased the likelihood of nest predation—providing a link whereby brood parasitism leads to an increase in predation (Tewksbury et al. 2002).

Nest Site Selection

The discussion of this critical biological activity or process remains unchanged. No new information was located on YWAR nest site selection in the Lower Colorado River Valley or elsewhere.

Predation

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

Predation is a threat to YWAR in all life stages, and it obviously affects survival. The predators of and rates of depredation upon eggs and nestlings are much better understood than the depredation of adults (see above, "Nest Predation & Brood Parasitism"). Predators of adults are likely to be similar to those of other birds sharing habitat with yellow warblers (Bent 1953; Lowther et al. 2020) and include mammals such as long-tailed weasels (*Mustela frenata*) (Batts 1958 *in* Lowther et al. 2020), and possibly small raptors such as American kestrels (*Falco sparverius*) and accipiters (California Wildlife Habitat Relationships 2005), as well as some common nest predators listed previously.

THERMAL STRESS

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

Avoiding thermal stress is important for any organism inhabiting a region with temperatures as high as those of the LCR. 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 moderate the thermal stress of eggs and nestlings through their incubating, brooding, and shading behaviors (Theimer et al. 2011) as well as through nest placement. At the northern edge of the yellow warbler's range, nests are better insulated and larger than elsewhere, presumably as an adaptation to colder temperatures (Briskie 1995; Rohwer and Law 2010). Similar modifications in nest construction may also occur in warmer regions in response to the need to regulate egg and nestling temperatures.

Updates to Chapter 4 – Habitat Elements

This update standardizes the names of three habitat elements, with Brood Size becoming Brood/Litter Size, Community Type becoming Vegetation Community Type, and Predator Density becoming Predators; adds one new habitat element (Soil Salinity); splits one habitat element (Genetic Diversity & Infectious Agents) into two separate elements; combines two habitat elements (Parental Feeding Behavior and Parental Nest Attendance) into Parental Care; and updates the discussions of eight habitat elements. Table 3 is updated to reflect these changes as follows:

Table 3.—(Revision of original table 3) Distribution of YWAR habitat elements and the critical biological activities and processes that they directly affect across all life stages

(Xs indicate that the habitat element is applicable to that critical biological activity or process.)

Critical biological activity or process ➔ / **Habitat element 🡻**	Disease	Eating	Foraging	Molting	Nest attendance	Nest predation & brood parasitism	Nest site selection	Predation	Thermal stress
Anthropogenic disturbance			X		X	X	X	X	
Brood/litter size (*renamed*)		X	X		X				
Canopy closure			X			X	X	X	X
Food availability			X		X		X		
Genetic diversity (*replaces genetic diversity & infectious agents*)	X								
Infectious agents	X								
Humidity					X		X		X
Intermediate structure			X			X	X	X	X
Local hydrology	N/A*								
Matrix community			X				X		
Nest predator & cowbird density						X			
Parental care (*renamed*)		X	X			X		X	X
Patch size						X		X	
Predators					X		X	X	
Soil salinity (*new*)	N/A*								
Temperature					X				X
Tree density						X	X	X	
Vegetation community type (*renamed*)			X			X	X	X	

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

ANTHROPOGENIC DISTURBANCE

The definition of this habitat element is updated as follows:

Full name: **Human activity within or surrounding a given habitat patch, including noise, pollution, and other disturbances associated with human activity**. Whether due to recreational, land management, or scientific research activities, anthropogenic disturbance can affect both breeding success and the survival of birds (reviewed by Barber et al. 2010; Francis and Barber 2013). Noise might mask conspecific cues such as songs or calls—making it more difficult for YWAR to attract or find mates or defend territories. McClure et al. (2013) found that road noise severely affects yellow warbler site use during migration (attachment 1), although the effect during the breeding season is unstudied. In the LCR, YWAR successfully nest at Yuma East Wetlands, which is adjacent to Interstate 8, downtown Yuma, and active railroad tracks, and contains nature trails and a city park that are used regularly. Anthropogenic noise is nearly constant. However, most YWAR in the LCR have been documented to nest in habitats that have less human activity (C. Dodge 2018, personal communication). Anthropogenic disturbance is considered to be a habitat element, as it is an environmental characteristic with which a nesting or foraging warbler must contend.

BROOD/LITTER SIZE

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

Full name: **The number of young in the nest**. This element refers to the number of young that the parents must rear per nest. Brood/litter size is a life-stage outcome for breeding adults (fertility) that acts as a habitat element for eggs/nestlings and juveniles. The well-being of both parents depends, in part, on the availability of sufficient food resources in close proximity to the breeding territory (See Gill et al. [2019] and references therein) as well as other factors such as predator density (see chapter 4, "Nest Predator & Cowbird Density"). Yellow warblers usually lay four to five eggs (Lowther et al. 2020) and rarely attempt a second brood in a season after successfully fledging young (Goossen and Sealy 1982 *in* Lowther et al. 2020).

CANOPY CLOSURE

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

Full name: **The percentage of ground area shaded by overhead foliage in the vicinity of the nest** (Daubenmire 1959). It can be measured as angular canopy closure with a field-of-view instrument, such as a camera or spherical densiometer, or as vertical canopy closure by using lidar. Both measures are related (Korhonen et al. 2011). Measures of canopy foliage, such as canopy closure, cover, leaf area index, and density, are interrelated and all assess some aspect of the density of foliage in the overstory (Jennings et al. 1999; Korhonen et al. 2006; Smith et al. 2009). Ohmart (1994) considers the overstory to be the most important layer of vegetation for desert riparian habitats because of its ameliorating effects on temperature.

Various measures of canopy closure have been examined regarding yellow warblers. Whitmore (1975, 1977) reports that the yellow warbler was positively associated with canopy cover—the percent of the forest floor covered by the vertical projection of tree crowns (Jennings et al. 1999)—along the Virgin River in Utah. The GBBO (2011) measured canopy closure—the proportion of sky hemisphere obscured by vegetation (Jennings et al. 1999)—and found that sites used by YWAR had a higher average canopy closure than non-used sites along the LCR (attachment 1). Conversely, Quinlan and Green (2012) report that British Columbia yellow warbler territories had lower canopy closure (*sensu* Jennings et al. 1999) than did random sites (attachment 1). Canopy cover is often related to tree stem density (James 1971; Rudnicki et al. 2004).

FOOD AVAILABILITY

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

Full name: **The abundance of food available for adults and their young**. This element refers to the taxonomic and size composition of the invertebrates that an individual YWAR will encounter during each life stage as well as the density and spatial distribution of the food supply in proximity to the nest. Yellow warblers are generalist insectivores that take insect prey in proportion to availability (Lowther et al. 2020) (see chapter 3, "Foraging" for more information on foraging strategies). In addition, Petit et al. (1990) found that YWAR had high plasticity in their foraging behavior, which may support their generalist diet. The abundance and condition of the food supply affects adult health as well as the growth and development of the young during the nest and juvenile stages.

There do not appear to be any studies conducted that looked specifically at the diet of YWAR (Heath 2008; LCR MSCP 2008, 2016). However, Frydendall (1967) studied the diet of *S. p. morcomi* in Utah, and this perhaps sheds some light on the diet of YWAR. In Utah, yellow warblers feed exclusively on arthropods, with no individuals seen eating fruits or berries available to them (Frydendall 1967). Hymenoptera were the most numerous insects in the diet, followed by Diptera, Hemiptera, and Coleoptera (Frydendall 1967). In the Grand Canyon, aquatic midges made up 45% of the yellow warbler's diet (Yard et al. 2004).

Even though aquatic midges constituted 45% of yellow warbler diets in the Grand Canyon (Yard et al. 2004), the generalist nature of yellow warbler feeding (LCR MSCP 2008; Petit et al. 1990) suggests that aquatic insects are not a necessity for the birds. Frydendall (1967) specifically notes that the proximity to water is a main feature of yellow warbler habitat, not necessarily because of aquatic insects, but because moist soils allow for the growth of lush vegetation, which in turn produces abundant insect prey. The diversity of insects therefore seems to be less important than the abundance of insects. In Riverside County, California, yellow warblers are associated with increased numbers of native arthropods (Allen et al. 2005).

Ohmart (1994) notes that because foliage volume is related to insect abundance, the greater the density of vegetation, the greater the density of most bird species in western riparian habitats. As noted above, the general consensus in the literature is that lush vegetation provides the conditions necessary to produce an abundant prey base for yellow warblers, although specific details are never presented.

Wiesenborn (2013, 2014) notes that a diversity of native vegetation plantings provides an abundant, nutrient-rich food source of insects and spiders for riparian birds. He similarly notes that aquatic habitats may be an important component of restoration, as they are a good source of high-nitrogen-content dragonflies and other aquatic insects.

GENETIC DIVERSITY

The habitat element, 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 YWAR (sub)populations**. This element refers to the genetic homogeneity versus heterogeneity of a (sub)population. The greater the heterogeneity, the greater the possibility that individuals of a given life

stage will have genetically encoded abilities to survive their encounters with the diverse stresses presented by their environment and/or take advantage of the opportunities presented (Allendorf and Leary 1986). To date, no genetic studies have been performed on YWAR along the LCR.

Infectious Agents

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

Full name: **The types, abundance, and distribution of infectious agents and their vectors**. The infectious agent habitat element refers to the spectrum of viruses, bacteria, fungi, and parasites that individual YWAR are likely to encounter during each life stage. The effects of disease, parasites, and other infectious agents are poorly understood (Lowther et al. 2020). 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) that can be difficult to detect (Jarvi et al. 2002), and that have differing effects on different species (Merino et al. 2000; Palinauskas et al. 2008).

Humidity

This habitat element remains unchanged. No new information was located about humidity requirements of YWAR in the Lower Colorado River Valley or elsewhere.

Intermediate Structure

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

Full name: **The concealment provided by the vegetation structure between the canopy and the herbaceous (= ground) layer**. A more dense intermediate structure may support a more diverse and abundant invertebrate food supply (Ohmart 1994) as well as provide protection or concealment from predators (Latif et al. 2012). In general, intermediate structure, especially of shrubs, is associated with YWAR breeding habitat (Rosenberg et al. 1991; Wise-Gervais 2005). For example, shrub cover was positively associated with yellow warbler habitat in California (Allen et al. 2005; Humple and Burnett 2010; Latif et al. 2012; see

attachment 1), Canada (Quinlan and Green 2012), and Arizona (Brown and Trosset 1989). In Colorado, Knopf and Sedgwick (1992) (attachment 1) note that the most powerful descriptors of yellow warbler breeding habitat were those describing the density and arrangement of shrubs. Brown and Trosset (1989) also describe the volume of intermediate foliage (2–3 meters in height) to be a powerful descriptor of breeding habitat of YWAR.

Conversely, along the LCR, measures of understory and mid-story density were not significantly different between YWAR nest sites and non-use sites (GBBO 2011). In Utah, yellow warblers were associated with campgrounds with a higher density of shrub stems but the same amount of foliage density as non-campground sites (Blakesley and Reese 1988). Ruth and Stanley (2002) found that yellow warblers in Wyoming and Colorado selected larger, more open shrubs for nesting. Further, in riparian sites along the Virgin River, Utah, yellow warblers were associated with areas with lower shrub density (Whitmore 1977).

LOCAL HYDROLOGY

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

Full name: **Aspects such as the distance to standing water or the presence of adjacent water bodies, timing and volume of floods, depth to the water table, and soil moisture levels**. This element refers to anything that affects soil moisture, such as the proximity of water to the nesting habitat, elevation, irrigation practices, and soil texture. In the Huachuca Mountains of Arizona, Strong and Bock (1990) note that yellow warblers are typically found in large cottonwood cienegas, which have "abundant water." Along the LCR, surface water is positively related to bird species richness (Hinojosa-Huerta et al. 2008). Wet sites seem to be important to yellow warblers, at least in part because the depth to the water table is important for the riparian vegetation upon which yellow warblers depend (Ohmart 1994), as well as to their insect prey (Frydendall 1967). Flooding might also affect the activity of yellow warbler nest predators (Cain et al. 2003).

There is broad agreement in the literature that yellow warblers prefer "wet" sites, but the measures and indices of "wetness" differ among studies. For example, along the Las Vegas Wash, YWAR were more abundant in areas with native vegetation, which had higher proportions of the landscape covered by water and greater soil moisture, than in areas with exotic vegetation (attachment 1; Shanahan et al. 2011). Initial work by the GBBO (2011) along the LCR suggested that YWAR prefer wet sites, as warbler territories had less upland habitat and were less often near dry washes than were non-use sites. Over the 5 years of this study, GBBO (2016) most often found YWAR at sites with high

habitat complexity near natural wetlands or riparian areas. Conversely, Brand et al. (2010) suggest that yellow warbler density is unrelated to hydrologic regime (whether a site experienced ephemeral, intermittent, or perennial flow) along the San Pedro River in Arizona.

MATRIX COMMUNITY

This habitat element remains unchanged. No new information was located about the YWAR matrix community in the Lower Colorado River Valley or elsewhere.

NEST PREDATORS & COWBIRD DENSITY

The definition of this habitat element is updated as follows:

Full name: **The abundance and distribution of nest predators and brood parasites**. This element refers to a set of closely related variables that affect the likelihood that different kinds of predators will encounter and successfully prey on YWAR during the eggs/nestlings life stage or that cowbirds or other nest parasites will lay eggs in the nest. Theimer et al. (2011) did not identify any predators specifically preying upon YWAR nests along the LCR but did note several species that might prey upon YWAR nests, including sharp-shinned hawks (*Accipiter striatus*), red-shouldered hawks (*Buteo lineatus*), western screech owls (*Megascops kennicottii*), American crows, Bewick's wrens (*Thryomanes bewickii*), gray catbirds (*Dumetella carolinensis*), yellow-breasted chats (*Icteria virens*), Bullock's crioles (*Icterus bullockii*), and brown-headed cowbirds (*Molothrus ater*). Non-avian predators observed by Theimer et al. (2011) include short-tailed weasels (*Mustela frenata*), deer mice (*Peromyscus* spp.), woodrats (*Neotoma* spp.), and the common kingsnake (*Lampropeltis getula*). Cowbird parasitism remains a low to moderate threat to YWAR in the LCR (C. Dodge 2018, personal communication; LCR MSCP 2016).

PARENTAL CARE

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

Full name: **The ability and behavior of parents to provide care to nests, eggs, nestlings, and juveniles after they fledge from the nest**. This element refers to the capacity of both parents to share nesting and brood-rearing responsibilities until fledging and to provision food for recently fledged birds. The care provided by one or both parents can include providing shelter and warmth, providing food, warding off predators, and teaching the young necessary life skills. The better the quality of the parental care, the healthier the condition and, therefore, the higher the rate of survival of the offspring, other things being equal. Parental care is affected by food availability, the presence of predators and competitors, and the ability to thermoregulate.

In YWAR, brooding is performed by the female, who is fed by the male. During brooding, the female will adjust her behavior to regulate the temperature of the eggs by shading (Lowther et al. 2020; Theimer et al. 2010) or even fanning the eggs with her wings (Lowther et al. 2020). Both parents feed the nestlings (Lowther et al. 2020). The attentiveness of a brooding female is influenced by both the likelihood of cowbird parasitism and nest predation (Tewksbury et al. 2002). Lowther et al. (2020) report that fledgling yellow warblers will remain with their parents for up to 21 days post-fledging.

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. Although patch size is not usually listed as a factor in yellow warbler habitat selection, it is generally considered important for riparian birds in the Southwestern United States (Ohmart 1994). Patch size can also affect habitat selection by predators as well as the rates of predation (see Theimer et al. 2011 and references therein). Patch size is related to the amount of edge in a given patch, which has been shown to affect predation of yellow warbler nests (Cain et al. 2003). Saab (1999) refers to yellow warblers as small patch and edge specialists. In the LCR, patch quality affects territory size. With optimal habitat conditions, YWAR will nest closer together, fitting as many territories as possible into the patch (Leist et al. 2016; C. Dodge and B. Sabin 2018, personal communications).

PREDATORS

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

Full name: **The abundance and distribution of predators that affect YWAR during the post-fledging 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 YWAR during the juveniles or breeding adults life stages. The variables of this element include the species and size of the fauna that prey on YWAR during different life stages, the density and spatial distribution of these fauna in the riparian habitat used by YWAR, and whether predator activity may vary in relation to other factors (time of day, patch size and width, matrix community type, etc.). The only predator of adult yellow warblers listed by Lowther et al. (2020) is the long-tailed weasel reported in Batts (1958), although it is reasonable to assume that many nest predators (see section above) would also kill an adult, especially an incubating female.

SOIL SALINITY

This is a new habitat element.

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). Rising soil salinity is a serious environmental issue throughout the entire Colorado River Basin, with concentrations increasing dramatically from the headwaters to the LCR at the international Boundary with Mexico (LaHue 2017; U.S. Geological Survey 2000) and is a deterrent to successful habitat restoration (Raulston 2003). Contributors to salinity include natural sources (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).

TEMPERATURE

The definition of this habitat element is updated as follows:

Full name: **The maximum temperature in a habitat patch or nest site**. This element refers to the maximum temperature in the nesting habitat around the

nest site (or during the nesting season). High temperatures typical of the LCR region in summer can kill eggs and stress young in the nest (Rosenberg et al. 1991). The optimal temperature for egg development generally is 37–38 °C, with exposure to temperatures greater than 40.5 °C potentially lethal (Gill et al. 2019). Temperature can also affect the attendance behavior of adults (Lowther et al. 2020; Theimer et al. 2011).

TREE DENSITY

This habitat element remains unchanged. No new information was located about tree density and YWAR in the Lower Colorado River Valley or elsewhere.

VEGETATION COMMUNITY TYPE

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

Full name: **The species composition of the riparian forest patch**. This element refers to the species composition of riparian habitat used for breeding by YWAR. In general, yellow warblers are associated with deciduous trees and riparian forests (Lowther et al. 2020). Along the LCR, YWAR nest in cottonwood-willow forests (GBBO 2016; LCR MSCP 2008, 2016; Rosenberg et al. 1991). Although quantitative information on the percentages of cottonwoods and willows preferred by YWAR is scant, the GBBO (2011, 2016) found that YWAR are positively associated with the presence of cottonwoods and willows and negatively associated with mesquite (*Prosopis* sp.) (attachment 1). Allen et al. (2005) found that the presence of yellow warbler was negatively associated with the *Baccharis* species. YWAR will also use communities that include invasive species such as tamarisk (*Tamarix* spp.) (Heath 2008; LCR MSCP 2008, 2016; Rosenberg et al. 1991; Wise-Gervais 2005). GBBO (2016) notes that YWAR will use tamarisk when large willows or inundated or moist soil are also present. The relationship between YWAR and invasive community types is further discussed in chapter 5, “Nuisance Species Introduction & Management.”

Updates to Chapter 5 – Controlling Factors

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

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

Controlling factor ➔ / **Habitat element ⬇**	Fire management	Grazing	Irrigation (*new*)	Mechanical thinning	Natural thinning	Nuisance species introduction & management	Pesticide application (*renamed*)	Planting regime	Recreational activities	Water storage-delivery system design & operation
Anthropogenic disturbance				X					X	
Brood/litter size (*renamed*)	N/A*									
Canopy closure	X			X	X	X		X	X	
Food availability						X	X			
Genetic diversity (*renamed from genetic diversity & infectious agents*)	N/A*									
Humidity	N/A*									
Infectious agents	N/A*									
Intermediate structure	X	X		X	X	X		X	X	
Local hydrology			X							X
Matrix community	X	X						X		
Nest predator & cowbird density									X	
Parental care (*renamed)*	**N/A***									
Patch size	X	X						X	X	
Predators (*renamed*)									X	
Soil salinity (*new*)			X							
Temperature	N/A*									
Tree density	X			X	X	X		X	X	
Vegetation community type (*renamed*)	X	X				X		X	X	X

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

FIRE MANAGEMENT

The discussion of this controlling factor is updated as follows:

This factor addresses any fire management (whether prescribed fire or fire suppression) that could affect YWAR or their habitat. Management of fire directly affects several aspects of vegetation. Effects may include creation of habitat that supports or excludes YWAR, a reduction in the food supply of invertebrates, or support of species that pose threats to YWAR such as predators, competitors, or carriers of infectious agents. Positive or negative effects of fire on habitat and the species being managed for depend in part on the intensity and extent of the burn. Although typically not a major threat in most riparian habitats, severe wildfires have affected southwestern willow flycatcher breeding sites in the past decade (Ellis et al. 2008; Graber et al. 2007; U.S. Fish and Wildlife Service [USFWS] 2002a) and, similarly, could affect YWAR riparian habitats. Hinojosa-Huerta et al. (2008) recommend that fires be avoided in riparian areas because of potential effects on establishment of cottonwoods and willows. In fact, small 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). YWAR have responded positively to some fires. After a burn at the Cibola Valley Conservation Area, YWAR nested and bred onsite for several years afterward (GBBO 2017; C. Dodge 2018, personal communication).

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

GRAZING

The discussion of 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 YWAR or their habitat. Overgrazing by cattle (Bovidae), burros (*Equus asinus*), or mule deer (*Odocoileus hemionus*) across the arid Southwestern United States has substantially degraded riparian habitat in many areas (see Appendix G *in* USFWS 2002b). (*Note*: Bureau of Reclamation staff and researchers have observed mule deer and burros browsing on LCR sites, which may affect vegetation communities if population numbers increase to the point that overgrazing occurs.) Grazing may thin the understory or even prevent the establishment of cottonwood and willow seedlings (Kauffman et al. 1997). In particular, overgrazing has been an identified as a management

issue along the San Pedro River and the Verde River (S. Kokos 2014, personal communication). Krueper (1993) and Krueper et al. (2003) report that fencing cattle out of sensitive riparian habitats in the San Pedro Riparian National Conservation Area led to improved habitat quality and increased riparian bird density within 4 years. Similarly, fencing of cattle from areas of the Malheur National Wildlife Refuge in Oregon resulted in higher numbers of yellow warblers (Taylor and Littlefield 1986). Livestock grazing is also known to occur at the Gila River study area (Graber et al. 2012). In the case of YWAR, however, grazing by cattle, burros, or mule deer currently does not have much impact in the LCR habitats in which YWAR occur (C. Dodge and B. Sabin 2018, personal communications).

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

IRRIGATION

This is a new controlling factor.

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

The LCR MSCP and USFWS irrigate portions of several conservation areas along the LCR to create and manage habitat for general wildlife, LCR MSCP covered species, and associated wetland habitat. YWAR have been found at a number of these restoration sites including the Beal Lake Conservation Area, Cibola Valley Conservation Area, Palo Verde Ecological Preserve, Cibola National Wildlife Refuge, and Yuma Wetlands East (GBBO 2016, 2017), and recently at the Laguna Division Conservation Area (SWCA Environmental Consultants 2019).

MECHANICAL THINNING

The discussion of this habitat element remains unchanged. No new information was located about mechanical thinning and YWAR in the Lower Colorado River Valley or elsewhere.

NATURAL THINNING

The discussion of this habitat element remains unchanged. No new information was located about tree density and YWAR in the Lower Colorado River Valley or elsewhere.

NUISANCE SPECIES INTRODUCTION & MANAGEMENT

The discussion of this controlling factor is updated as follows:

This factor addresses the intentional or unintentional introduction of nuisance species (animals and plants) and their control that affects YWAR survival and reproduction. Nuisance species may infect, prey upon, compete with, or present alternative food resources for YWAR during one or more life stages; cause other alterations to the riparian food web that affect YWAR; or affect physical habitat features such as canopy closure or intermediate structure.

The most often mentioned nuisance species in the context of YWAR habitat is tamarisk. Some studies report yellow warblers to be negatively associated with tamarisk (Rosenberg et al. 1991; Shanahan et al. 2011; Wise-Gervais 2005) blame the decline of YWAR along the LCR partly on nest failure in tamarisk habitat. However, YWAR will use tamarisk for nesting, and some authors suggest that any habitat contributing to nesting success is equivalent to natural habitat (Heath 2008). Van Riper, III et al. (2008) suggest that tamarisk in wetter habitats and/or with some mixed native vegetation can provide better habitat for YWAR than homogeneous stands of tamarisk in drier locations. McKernan and Braden (2002) *in* Heath (2008) and GBBO (2016) also found that YWAR will use tamarisk, especially when inundated or if moist soil is present. Along the San Pedro River in Arizona, tamarisk habitat is second only to cottonwood-willow habitat in yellow warbler density and far above densities in mesquite habitat (Brand et al. 2010). The GBBO (2011) found no correlations between tamarisk and YWAR nest sites along the LCR. In contrast, Shanahan et al. (2011) report that YWAR

benefited from restoration actions that replaced tamarisk with native vegetation. Finally, yellow warblers can certainly exploit food resources in tamarisk habitats in the Grand Canyon, as documented by Yard et al. (2004). There, the most common yellow warbler prey items were aquatic midges, which were most abundant in tamarisk at those study sites. The complicated nature of the relationship between tamarisk and YWAR 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 YWAR.

Shot hole borer beetles (*Euwallacea* spp.) are a new 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 YWAR depend (Boland 2016; Leathers 2015). To date, the beetles have not been found outside of California, as they may require cooler temperatures, which would prevent or slow their spread into LCR habitats (B. Raulston 2018, personal communication; University of California, Agriculture and Natural Resources 2019). However, Boland (2016) reported that damage to riparian habitat in California occurred rapidly once the beetles arrived, with willows and cottonwoods having the highest infestation rates. The presence of surface water was also a factor contributing to higher infestation rates.

In addition to non-native plants and insect pests, non-native feral swine (*Sus scrofa*) have been identified as a problem for riparian nesting birds in other areas (e.g., least Bell's vireos [*Vireo bellii pusillus*] in the Santa Ana River watershed, California). Feral swine 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 Havasu National Wildlife Refuge (Neskey 2018; U.S. Department of the Interior 2016). It is unknown what effect they may have on YWAR and nest success.

PESTICIDE APPLICATION

The discussion of this controlling factor is updated as follows:

This factor addresses biocide applications that may occur on or adjacent to riparian habitat of the LCR region. Pesticides, including herbicides, may drift into riparian areas, removing plant species important to YWAR habitat structure

and composition. The effects of pesticides may include lethal or sublethal poisoning of YWAR via ingestion of treated insects, pollution of runoff into wetland habitats that are toxic to the prey of YWAR, and a reduced or modified invertebrate food supply.

PLANTING REGIME

The discussion of this controlling factor is updated as follows:

This factor addresses the active program to restore cottonwood-willow riparian habitat along the LCR and includes both the community planted as well as the manner in which it is planted within restoration areas (e.g., density, age, patch size). The composition of the species planted can affect not only the vertical and horizontal structure of the vegetation but also the insect community within a given patch (Bangert et al. 2013; Wiesenborn 2014). In the LCR, YWAR consistently have been found in restoration sites older than 2 years (GBBO 2016).

RECREATIONAL ACTIVITIES

The discussion of this controlling factor is updated as follows:

This factor addresses the disturbance to YWAR from recreational activities along the LCR. 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 activities (e.g., boating, fishing, horseback riding, wildlife viewing, camping, off-road vehicle use) as well as the frequency and intensity of those activities. The impacts may consist of disturbance and habitat alteration; the USFWS (2002a) states that recreational activities can affect the species composition of riparian forests. Recreational activities have a myriad of impacts on vegetation (see table 11.1 in Cole and Landres 1995). For instance, in Utah, riparian width and tree and shrub densities were significantly different between campgrounds and non-campground sites—factors believed to affect the density of yellow warblers (Blakesley and Reese 1988). Recreational activities can influence nest predator densities by either increasing predator success rates through interfering with or distracting prey or by decreasing predator success rates through interfering with or distracting the predator (Mason 2015; Ware et al. 2015). In addition, management of recreational activities can affect noise levels, which can affect YWAR.

WATER STORAGE-DELIVERY SYSTEM DESIGN & OPERATION

The discussion of irrigation has been removed and is now addressed as a separate controlling factor. The discussion of this controlling factor is updated as follows:

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

This factor includes river and off-channel water management, including pumping of groundwater and diversion of river water to manage water levels in refuge ponds, as well as dewatering and flushing of marsh habitats. The amount of water, flooding frequency, water depth and stability, etc., each affect the local hydrology and, therefore, the species composition and density of the riparian plant community favored by YWAR for food, shelter, and nesting. This factor also accounts for large-scale flooding regimes. Natural flooding regimes are generally considered to be beneficial to yellow warblers (Strusis-Timmer 2009), riparian forests, and the associated bird community in general (Hinojosa-Huerta et al. 2008; Ohmart 1994). However, in the short term, scouring floods can destroy yellow warbler habitat (Turley and Holthuijzen 2005).

Updates to Chapter 6 – Conceptual Ecological Model by Life Stage

The following sections identify all changes made to the YWAR 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

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

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

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

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

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

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

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

DELETED LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS

No change.

UPDATED LINKS WITH CONTROLLING FACTORS AS CAUSAL AGENTS

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

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

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

- Grazing effect on Intermediate Structure (HE): The original link was considered to be complex and unidirectional, with high intensity, high spatial scale, and low temporal scale, as grazing can have great effects on understory structure by trampling and removal of vegetation and is often implemented over large areas and long time scales. However, grazing (by cattle, burros or mule deer) is not a concern on LCR sites being used or managed for YWAR at this time. Therefore, the values have been

modified in this update. The link remains complex and unidirectional; however, link intensity is low, spatial scale is low, and temporal scale is low. Link predictability remains medium, and link understanding remains high. *Applies to all life stages.*

NEW LINKS WITH HABITAT ELEMENTS AS CAUSAL AGENTS

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

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

- Genetic Diversity effect on Disease (CAP): Increased genetic diversity can contribute to protection against disease. While the effects of inbreeding can last for generations, there is no evidence of inbreeding in YWAR populations along the LCR. The link is hypothesized to be negative, with proposed low intensity, low spatial scale, and low temporal scale; high predictability; and medium understanding. *Applies to all life stages.*

- Humidity effect on Nest Site Selection CAP): Humidity is important for birds in the LCR, and nests with higher humidity are more likely to be selected as nest sites. The link is hypothesized to be positive, with proposed high intensity, low spatial scale, and low temporal scale; high predictability; and high understanding. *Applies to breeding adults life stage.*

Deleted Links with Habitat Elements as Causal Agents

No change.

Updated Links with Habitat Elements as Causal Agents

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

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

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

New Links with Critical Activities/ Processes as Causal Agents

No change.

Deleted Links with Critical Activities/ Processes as Causal Agents

No change.

UPDATED LINKS WITH CRITICAL ACTIVITIES/ PROCESSES AS CAUSAL AGENTS

- Thermal Stress effect on Survival (LSO): The link character type and reason were revised to reflect the change of critical biological activity and process, Temperature Regulation, to Thermal Stress. *Applies to all life stages.*

- 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 YWAR conceptual ecological model component names
(Blue indicates new or revised items; orange indicates replaced items; italicized entries are explanatory comments.)

YWAR conceptual ecological model, updated terms, 2019	YWAR conceptual ecological model, original terms 2015–16
Life stages	
Eggs/Nestlings	Nest
Juveniles	Juvenile
Breeding Adults	Breeding Adult
Life-stage outcomes	
Survival	Survivors
Fertility	Reproduction
Critical biological activities and processes	
Disease	Disease
Eating	Eating
Foraging	Foraging
Molting *(renamed)*	Molt
Nest Attendance	Nest Attendance
Nest Predation & Brood Parasitism	Nest Predation and Brood Parasitism
Nest Site Selection	Nest Site Selection
Predation	Predation
Thermal Stress *(renamed)*	Temperature Regulation
Habitat elements	
Anthropogenic Disturbance	Anthropogenic Disturbance
Brood/Litter Size *(renamed)*	Brood Size
Canopy Closure	Canopy Closure
Vegetation Community Type *(renamed)*	Community Type
Food Availability	Food Availability
Humidity	Humidity
Genetic Diversity *(new)*	Genetic Diversity and Infectious Agents *(see Genetic Diversity; see Infectious Agents)*
Infectious Agents *(new)*	
Intermediate Structure	Intermediate Structure
Local Hydrology	Local Hydrology
Matrix Community	Matrix Community
Nest Predator & Cowbird Density	Nest Predator and Cowbird Density
Parental Care *(renamed)*	Parental Feeding Behavior *(see Parental Care)*
	Parental Nest Attendance *(see Parental Care)*
Patch Size	Patch Size
Predators	Predator Density
Soil Salinity *(new)*	
Tree Density	Tree Density
Temperature	Temperature
Controlling factors	
Fire Management	Fire Management
Grazing	Grazing
Irrigation *(new)*	
Mechanical Thinning	Mechanical Thinning
Natural Thinning	Natural Thinning
Nuisance Species Introduction & Management	Nuisance Species Introduction and Management
Pesticide Application *(renamed)*	Pesticide/Herbicide Application
Planting Regime	Planting Regime
Recreational Activities	Recreational Activities
Water Storage-Delivery System Design & Operation	Water Storage-Delivery System Design and Operation

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ATTACHMENT 1

Sonoran Yellow Warbler (*Dendroica petechia sonorana* = *Setophaga petechia sonorana*) (YWAR) Habitat Data

Table 1-1.—Sonoran yellow warbler (*Dendroica petechia sonorana* = *Setophaga petechia sonorana*) (YWAR) habitat data
(Note: This is an update of table 2.1 found in attachment 2 of the original YWAR model document.)

Habitat element	Value or range	Location	Reference
Anthropogenic disturbance	< 55 a-weighted decibels * During migration	Idaho	McClure et al. 2013
Brood/litter size	Usually lay four to five eggs	Range-wide	Lowther et al. 2020
Canopy closure	Territories = 19.6%, confidence interval (CI) = 14.4–24.8%; random = 25.5%, CI = 17.8–33.2% * Canopy closure	British Columbia	Quinlan and Green 2012
	Use = 12.3, range = 0.9–72; non-use = 4.3, range = 0–16 * Canopy closure	Lower Colorado River	Great Basin Bird Observatory (GBBO) 2011
Food availability	45% diet comprised of aquatic midges	Grand Canyon, Arizona	Yard et al. 2004
Genetic diversity	No quantifiable values found in the literature		
Infectious agents	No quantifiable values found in the literature		

Table 1-1.—Sonoran yellow warbler (*Dendroica petechia sonorana* = *Setophaga petechia sonorana*) (YWAR) habitat data
(Note: This is an update of table 2.1 found in attachment 2 of the original YWAR model document.)

Habitat element	Value or range	Location	Reference
Intermediate structure	Use = 46.3, CI = 34.6–58.0; non-use = 36.8, CI = 25.6–48.0 * Cover < 5 meters (m) measured using a densiometer	British Columbia	Quinlan and Green 2012
	Use = 249, CI = 214–284; non-use = 120, CI = 95–145 * Number of deciduous stems < 8 centimeters (cm) diameter at breast height (DBH)	British Columbia	Quinlan and Green 2012
	30–80% * Natural concealment range, predation worse when < 30%	California	Latif et al. 2012
	Use = 1.6, random = 15.2 * Distance to closest bush in any quadrant	Colorado	Knopf and Sedgwick 1992
	Use = 34.4, random = 52.5 * Calculated value radius for the five bushes	Colorado	Knopf and Sedgwick 1992
	Use = 15.8, random = 81.8 * Distance to nearest bush in each quadrant	Colorado	Knopf and Sedgwick 1992
	Present = 40%, standard error (SE) = 2.3; absent = 22%, SE = 0.6 * Shrub cover	California	Humple and Burnett 2010
	Suppressed = 9.61, SE = 3.15; released = 21.42, SE = 3.29; previously tall = 60.39, SE = 3.15 * Horizontal cover; YWAR absent from suppressed areas	Yellowstone National Park	Baril et al. 2011
	Campground = 52.5; non-campground = 109.6 * Shrub/sapling stems, YWAR most abundant in campgrounds	Utah	Blakesley and Reese 1988

Table 1-1.—Sonoran yellow warbler (*Dendroica petechia sonorana = Setophaga petechia sonorana*) (YWAR) habitat data
(Note: This is an update of table 2.1 found in attachment 2 of the original YWAR model document.)

Habitat element	Value or range	Location	Reference
Local hydrology	Native = 0.10, SE = 0.04; non-native = 0.04, SE = 0.02 * Proportion of site covered with water; YWAR most abundant at native sites	Lower Colorado River	Shanahan et al. 2011
	Native = 42.4, SE = 8.9; exotic = 14.5, SE = 4.1 * Soil moisture; YWAR most abundant at native sites	Lower Colorado River	Shanahan et al. 2011
Matrix community	No quantifiable values found in the literature		
Nest predator & cowbird density	Species lists available, no information on density at YWAR breeding locations.		
Parental care	No quantifiable values found in the literature		
Patch size	No data on patch size for YWAR; however, patch quality affects territory size. With optimal habitat conditions, YWAR will nest closer together, fitting as many territories as possible into the patch.	Lower Colorado River	C. Dodge and B. Sabin 2018, personal communications
Predators	Species lists available, no other information.		
Soil salinity	No specific data available on soil salinity levels and effect on YWAR habitat.		
Temperature	No thermal tolerance values for YWAR found in literature.		

Table 1-1.—Sonoran yellow warbler (*Dendroica petechia sonorana* = *Setophaga petechia sonorana*) (YWAR) habitat data
(Note: This is an update of table 2.1 found in attachment 2 of the original YWAR model document.)

Habitat element	Value or range	Location	Reference
Tree density	Use = 12.5, range = 0–108; non-use = 0.4, range = 0–5 * High canopy trees (> 10 m)	Lower Colorado River	GBBO 2011
	Use = 16.3, range = 0–53; non-use = 5.1, range = 0–105 * Large trees (> 20 cm DBH and > 4 m in height)	Lower Colorado River	GBBO 2011
	Campground= 19.9; non-campground = 28.3 * Total number of trees; YWAR most abundant in campgrounds	Utah	Blakesley and Reese 1988
Vegetation Community type	Percent of use sites = 11; percent of non-use sites = 19 * Mesquite (*Prosopis* sp.) present in territory	Lower Colorado River	GBBO 2011
	Use = 7.7, range = 0–32; non-use = 0.3, range = 0–4 * Number of large Goodding's willow (*Salix gooddingii*) (> 20 cm diameter at breast height (DBH) and > 4 m tall)	Lower Colorado River	GBBO 2011
	Use = 2.3, range = 0–39; non-use = 0.4, range = 0–5 * Number of large tamarisk (*Tamarix ramosissima*) (> 20 cm DBH and > 4 m tall)	Lower Colorado River	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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