Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

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

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U.S. Department of the Interior
Bureau of Reclamation

October 2015

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Lower Colorado River Multi-Species Conservation Program

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

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Acronyms and Abbreviations

CEM	conceptual ecological model
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
Reclamation	Bureau of Reclamation
SUTA	summer tanager

Symbols

°C	degrees Celsius
>	greater than
<	less than
±	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 Species Conceptual Ecological Model Methodology for the Lower Colorado River Multi-Species Conservation Program

2 Summer Tanager Habitat Data

Foreword

The Lower Colorado River Multi-Species Conservation Program (LCR MSCP) Habitat Conservation Plan requires the creation, and long-term stewardship, of habitat for 20 covered species. This is both an exciting and daunting challenge – exciting, in that success would mean a major conservation achievement in the lower Colorado River landscape, and daunting, in that we need to simultaneously manage our lands for the benefit of 20 species in a mosaic of land cover types. To do so, we need to develop a common understanding of the habitat requirements of each species and the stewardship required to meet those needs.

To provide a framework to capture and share the information that forms the foundation of this understanding, conceptual ecological models (CEMs) for each covered species have been created under the LCR MSCP's Adaptive Management Program. The LCR MSCP's conceptual ecological models are descriptions of the functional relationships among essential components of a species' life history, including its habitat, threats, and drivers. They tell the story of "what's important to the animal" and how our stewardship and restoration actions can change those processes or attributes for the betterment of their habitat. As such, CEMs can provide:

- A synthesis of the current understanding of how a species' habitat works. This synthesis can be based on the published literature, technical reports, or professional experience.
- Help in understanding and diagnosing underlying issues and identifying land management opportunities.
- A basis for isolating cause and effect and simplifying complex systems. These models also document the interaction among system drivers.
- A common (shared) framework or "mental picture" from which to develop management alternatives.
- A tool for making qualitative predictions of ecosystem responses to stewardship actions.
- A way to flag potential thresholds from which system responses may accelerate or follow potentially unexpected or divergent paths.
- A means by which to outline further restoration, research, and development and to assess different restoration scenarios.

- A means of identifying appropriate monitoring indicators and metrics.
- A basis for implementing adaptive management strategies.

Most natural resource managers rely heavily upon CEMs to guide their work, but few explicitly formulate and express the models so they can be shared, assessed, and improved. When this is done, these models provide broad utility for ecosystem restoration and adaptive management.

Model building consists of determining system parts, identifying the relationships that link these parts, specifying the mechanisms by which the parts interact, identifying missing information, and exploring the model's behavior (Heemskerk et al. 2003[1]). The model building process can be as informative as the model itself, as it reveals what is known and what is unknown about the connections and causalities in the systems under management.

It is important to note that CEMs are not meant to be used as prescriptive management tools but rather to give managers the information needed to help inform decisions. These models are conceptual and qualitative. They are not intended to provide precise, quantitative predictions. Rather, they allow us to virtually "tweak the system" free of the constraints of time and cost to develop a prediction of how a system might respond over time to a variety of management options; for a single species, a documented model is a valuable tool, but for 20 species, they are imperative. The successful management of multiple species in a world of competing interests (species versus species), potentially conflicting needs, goals, and objectives, long response times, and limited resources, these models can help land managers experiment from the safety of the desktop. Because quantitative data can be informative, habitat parameters that have been quantified in the literature are presented (in attachment 2) in this document for reference purposes.

These models are intended to be "living" documents that should be updated and improved over time. The model presented here should not be viewed as a definitive monograph of a species' life history but rather as a framework for capturing the knowledge and experience of the LCR MSCP's scientists and land stewards. While ideally the most helpful land management tool would be a definitive list of do's and don'ts, with exact specifications regarding habitat requirements that would allow us to engineer exactly what the species we care about need to survive and thrive, this is clearly not possible. The fact is, that despite years of active management, observation, and academic research on many of the LCR MSCP species of concern, there may not be enough data to support developing such detailed, prescriptive land management.

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[1] Heemskerk, M., K. Wilson, and M. Pavao-Zuckerman. 2003. Conceptual models as tools for communication across disciplines. Conservation Ecology 7(3):8: http://www.consecol.org/vol7/iss3/art8/

The CEMs for species covered under the LCR MSCP are based on, and expand upon, methods developed by the Sacramento-San Joaquin Delta Ecosystem Restoration Program (ERP): https://www.dfg.ca.gov/ERP/conceptual_models.asp. The ERP is jointly implemented by the California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. The Bureau of Reclamation (Reclamation) participates in this program. (See attachment 1 for an introduction to the CEM process.)

Many of the LCR MSCP covered species are migratory. These models only address the species' life history as it relates to the lower Colorado River and specifically those areas that are potentially influenced by LCR MSCP land management. The models DO NOT take into account ecological factors that influence the species at their other migratory locations.

Finally, in determining the spatial extent of the literature used in these models, the goals and objectives of the LCR MSCP were taken into consideration. For species whose range is limited to the Southwest, the models are based on literature from throughout the species' range. In contrast, for those species whose breeding range is continental (e.g., yellow-billed cuckoo) or west-wide, the models primarily utilize studies from the Southwest.

How to Use the Models

There are three important elements to each CEM:

(1) The narrative description of the species' various life stages, critical biological activities and processes, and associated habitat elements.

(2) The figures that provide a visual snapshot of all the critical factors and causal links for a given life stage.

(3) The associated workbooks. Each CEM has a workbook that includes a worksheet for each life stage.

This narrative document is a basic guide, meant to summarize information on the species' most basic habitat needs, the figures are a graphic representation of how these needs are connected, and the accompanying workbook is a tool for land managers to see how on-the-ground changes might potentially change outcomes for the species in question. Reading, evaluating, and using these CEMs requires that the reader understand all three elements; no single component provides all the pertinent information in the model. While it seems convenient to simply read the narrative, we strongly recommend the reader have the figures and workbook open and refer to them while reviewing this document.

It is also tempting to see these products, once delivered, as "final." However, it is more accurate to view them as "living" documents, serving as the foundation for future work. Reclamation will update these products as new information is available, helping to inform land managers as they address the on-the-ground challenges inherent in natural resource management.

The knowledge gaps identified by these models are meant to serve only as an example of the work that could be done to further complete our understanding of the life history of the LCR MSCP covered species. However, this list can in no way be considered an exhaustive list of research needs. Additionally, while identifying knowledge gaps was an objective of this effort, evaluating the feasibility of addressing those gaps was not. Finally, while these models were developed for the LCR MSCP, the identified research needs and knowledge gaps reflect a current lack of understanding within the wider scientific community. As such, they may not reflect the current or future goals of the LCR MSCP. They are for the purpose of informing LCR MSCP decisionmaking but are in no way meant as a call for Reclamation to undertake research to fill the identified knowledge gaps.

John Swett, Program Manager, LCR MSCP
Bureau of Reclamation
September 2015

Executive Summary

This document presents a conceptual ecological model (CEM) for the summer tanager (*Piranga rubra*) (SUTA). The purpose of this model is to help the Bureau of Reclamation (Reclamation), Lower Colorado River Multi-Species Conservation Program (LCR MSCP), identify areas of scientific uncertainty concerning SUTA ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure SUTA habitat and population conditions. (Note: Attachment 1 provides a good introduction to the CEM process. We recommend that those unfamiliar with this process read the attachment before continuing with this document.)

The identified research questions and gaps in scientific knowledge that are the result of this modeling effort serve as examples of topics the larger scientific community could explore to improve the overall understanding of the ecology of this species. These questions may or may not be relevant to the goals of the LCR MSCP. As such, they are not to be considered guidance for Reclamation or the LCR MSCP, nor are these knowledge gaps expected to be addressed under the program.

CONCEPTUAL ECOLOGICAL MODELS

CEMs integrate and organize existing knowledge concerning: (1) what is known about an ecological resource, with what certainty, and the sources of this information, (2) critical areas of uncertain or conflicting science that demand resolution to better guide management planning and action, (3) crucial attributes to use while monitoring system conditions and predicting the effects of experiments, management actions, and other potential agents of change, and (4) how we expect the characteristics of the resource to change as a result of altering its shaping/controlling factors, including those resulting from management actions.

The CEM applied to the SUTA expands on the methodology developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012). The model distinguishes the major life stages or events through which the individuals of a species must pass to complete a full life cycle. It then identifies the factors that shape the likelihood that individuals in each life stage will survive to the next stage in the study area and thereby shapes the abundance, distribution, and persistence of the species in that area.

Specifically, the SUTA conceptual ecological model has five core components:

- **Life stages** – These consist of the major growth stages and critical events through which the individual of a species must pass in order to complete a full reproductive cycle.

- **Life-stage outcomes** – These consist of the biologically crucial outcomes of each life stage, including the number of individuals recruited to the next life stage or age class within a single life stage (recruitment rate), or the number of offspring produced (fertility rate).

- **Critical biological activities and processes** – These consist of activities in which the species engages and biological processes that take place during each life stage that significantly beneficially or detrimentally shape the life-stage outcome rates for that life stage. Critical biological activities and processes typically are "rate" variables.

- **Habitat elements** – These consist of the specific habitat conditions, the abundance, spatial and temporal distributions, and other qualities of which significantly beneficially or detrimentally affect the rates of the critical biological activities and processes for each life stage.

- **Controlling factors** – These consist of environmental conditions and dynamics – including human actions – that determine the abundance, spatial and temporal distributions, and other qualities of the habitat elements for each life stage. Controlling factors are also called "drivers."

The CEM identifies the causal relationships among these components for each life stage. A causal relationship exists when a change in one condition or property of a system results in a change in some other condition or property. A change in the first condition is said to cause a change in the second condition. The CEM method applied here assesses four variables for each causal relationship: (1) the character and direction of the effect, (2) the magnitude of the effect, (3) the predictability (consistency) of the effect, and (4) the certainty of a present scientific understanding of the effect. CEM diagrams and a linked spreadsheet tool document all information on the model components and their causal relationships.

CONCEPTUAL ECOLOGICAL MODEL STRUCTURE

The SUTA conceptual ecological model addresses the SUTA throughout its breeding range. The model thus addresses the landscape as a whole rather than any single reach or managed area. The model does not address the biology of the SUTA during migration or in its winter range.

The most widely used sources of the information for the SUTA conceptual ecological model are Rosenberg et al. (1982, 1991), Powell and Steidl (2000, 2002), Myers (2003), Brand et al. (2010), and Robinson (2012). These publications summarize and cite large bodies of earlier studies. Where appropriate and accessible, those earlier studies are directly cited. The model also integrates numerous additional sources, particularly reports and articles completed since the aforementioned publications; information on current research projects; and the expert knowledge of LCR MSCP biologists. Our purpose is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

The SUTA conceptual ecological model distinguishes and assesses three life stages and their associated outcomes as follows (table ES-1):

Table ES-1.—Outcomes of each of the three life stages of SUTA

Life stage	Life-stage outcome(s)
1. Nest	• Survival
2. Juvenile	• Survival
3. Breeding adult	• Survival • Reproduction

The model distinguishes 7 critical biological activities or processes relevant to 1 or more of these 3 life stages and their outcomes, 17 habitat elements relevant to 1 or more of these 7 critical biological activities or processes for 1 or more life stages, and 10 controlling factors that affect 1 or more of these 17 habitat elements. Because the lower Colorado River (LCR) and its protected areas comprise a highly regulated system, the controlling factors exclusively concern human activities.

The seven critical biological activities and processes identified across all life stages are: disease, eating/foraging, molt, nest attendance, nest site selection, predation and brood parasitism, and temperature regulation. The 17 habitat elements identified across all life stages are: anthropogenic disturbance, brood size, canopy closure, community type, food availability, genetic diversity and infectious agents, local hydrology, parental feeding behavior, parental nest attendance, patch size, predator and cowbird density, soil salinity, soil temperature, stand height, tree density, tree size, and understory density. The 10 controlling factors identified across all habitat elements are: fire management, grazing, irrigation, mechanical thinning, natural thinning, nuisance species introduction and management, pesticide/herbicide application, planting regime, recreational activities, and water storage-delivery system design and operation.

RESULTS

The analysis of the causal relationships show which critical biological activities and processes most strongly support or limit each life-stage outcome in the present system, which habitat elements most strongly affect the rates of these critical biological activities and processes, and which controlling factors most strongly affect the abundance, distribution, or condition of these habitat elements.

The analysis identifies several critical biological activities and processes that significantly affect survivorship across multiple life stages. Highlights of the results include the following:

- Predation and eating/foraging are the most important critical biological activities processes affecting survival of SUTA at all life stages. Depredation of nests can be high and has been shown to be the primary cause of nest failure (exceeding 80 percent) (Powell and Steidl 2000). The effects likely act at the landscape scale. Other processes, such as disease, molt, and temperature regulation are important, but the effects are more indirect and less certain.

- Only two processes directly affect reproduction—nest attendance and nest site selection. These two critical biological activities and processes are especially important because they also affect nestling survival.

Finally, the analysis highlights several potentially important causal relationships about which scientific understanding remains low. These may warrant attention to determine if improved understanding might provide additional management options for improving SUTA survivorship and recruitment along the LCR. Specifically, the findings suggest a need to improve the understanding of the following:

- Nest site selection is by far affected by the most habitat variables and is likely one of the most well-understood processes. SUTA nest in areas with high canopy closure (approximately 70 percent), primarily in willows and cottonwood communities, in wide patches (> 60 meters), with low tree density (1.7 trees per 5-meter radius plot), and with low understory density (approximately 23 percent). However, the sensitivity of the species to subtle changes in the nest stands and their adaptation to invasive tamarisk are not thoroughly understood.

- The effect of predation on juveniles and adults is poorly understood, whereas nest predation is better studied. This likely reflects the relative ease of studying depredation of nests versus free-flying birds. If the persistence or population growth of SUTA populations is considered sensitive to the survival of adults and juveniles, then research regarding predation should be considered.

- The indirect influences on food availability have a large impact on eating/foraging, which is then directly linked with survival of SUTA at all life stages. Further investigation into these indirect effects is warranted.

- The effects of disease, ecto-parsites, and endo-parasites have not been studied in SUTA or among passerine species inhabiting the LCR. Diseases have the potential to have dramatic impacts on populations (Friend et al. 2001; Bunbury et al. 2008; Robinson et al. 2010).

The research questions and gaps in scientific knowledge identified in this modeling effort serve as examples of topics the larger scientific community could explore to improve the overall understanding of the ecology of SUTA. These questions may or may not be relevant to the goals of the LCR MSCP. As such, they are not to be considered guidance for Reclamation or the LCR MSCP, nor are these knowledge gaps expected to be addressed under the program.

Chapter 1 – Introduction

This document presents a conceptual ecological model (CEM) for the summer tanager (*Piranga rubra*) (SUTA). The purpose of this model is to help the Bureau of Reclamation (Reclamation), Lower Colorado River Multi-Species Conservation Program (LCR MSCP), identify areas of scientific uncertainty concerning SUTA ecology, the effects of specific stressors, the effects of specific management actions aimed at habitat and species restoration, and the methods used to measure SUTA habitat and population conditions. The CEM methodology follows that developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012), with modifications. (Note: Attachment 1 provides an introduction to the CEM process. We recommend that those unfamiliar with this process read the attachment before continuing with this document.)

The CEM addresses the SUTA population along the river and the lakes of the lower Colorado River (LCR) and other protected areas along the LCR managed as SUTA habitat. The model thus addresses the landscape as a whole rather than any single reach or managed area.

The most widely used sources of the information for the SUTA conceptual ecological model are Rosenberg et al. (1982, 1991), Powell and Steidl (2000, 2002), Myers (2003), Brand et al. (2010), and Robinson (2012). 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 LCR MSCP biologists.
The purpose of the 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.

This document is organized as follows: The remainder of chapter 1 provides a general description of the reproductive ecology of SUTA, the purpose of the model, and introduces the underlying concepts and structure of the CEM. Succeeding chapters present and explain the model for SUTA along the LCR and evaluate the implications of this information for management, monitoring, and research needs.

SUMMER TANAGER REPRODUCTIVE ECOLOGY

The SUTA is considered a complete migrant, breeding in North America and wintering in Central and South America (Robinson 2012). Birds return to the

LCR from their wintering grounds in mid-April to begin the breeding season (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 2012). 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 predated upon and are subject to high rates of brood parasitism by cowbirds, up to 100 percent in some fragmented landscapes in the Eastern United States (Brawn and Robinson 1996; Powell and Steidl 2000). However, rates within the LCR may be considerably lower (e.g., only 1 in 16 nests parasitized in 1 study) (Robinson 2012).

Incubation begins after the last egg is laid and lasts approximately 11–12 days (Fitch and Fitch 1955). Young birds fledge from the nest in 8–12 days and continue to be fed by adults for at least 3 weeks (Robinson 2012).

The SUTA is a bee and wasp specialist, capturing prey primarily by hawking (Bent 1958; Rosenberg et al. 1982). However, SUTA may be locally dependent on cicadas, consuming large numbers at about the time of first brood fledging (Rosenberg et al. 1982).

CONCEPTUAL ECOLOGICAL MODEL PURPOSES

Adaptive management of natural resources requires a framework to help managers understand the state of knowledge about how a resource "works," what elements of the resource they can affect through management, and how the resource will likely respond to management actions. The "resource" may be a population, species, habitat, or ecological complex. The best such frameworks incorporate the combined knowledge of many professionals accumulated over years of investigations and management actions. CEMs capture and synthesize this knowledge (Fischenich 2008; DiGennaro et al. 2012).

CEMs explicitly identify: (1) the variables or attributes that best characterize resource conditions, (2) the factors that most strongly shape or control these variables under both natural and altered (including managed) conditions, (3) the character, strength, and predictability of the ways in which these factors do this shaping/controlling, and (4) how the characteristics of the resource vary as a result of the interplay of its shaping/controlling factors.

By integrating and explicitly organizing existing knowledge in this way, a CEM summarizes and documents: (1) what is known, with what certainty, and the sources of this information, (2) critical areas of uncertain or conflicting science that demand resolution to better guide management planning and action, (3) crucial attributes to use while monitoring system conditions and predicting the effects of experiments, management actions, and other potential agents of change, and (4) how the characteristics of the resource would likely change as a result of altering its shaping/controlling factors, including those resulting from management actions.

A CEM thus translates existing knowledge into a set of explicit hypotheses. The scientific community may consider some of these hypotheses well tested, but others less so. Through the model, scientists and managers can identify which hypotheses, and the assumptions they express, most strongly influence management actions. The CEM thus helps guide management actions based on the results of monitoring and experimentation. These results indicate whether expectations about the results of management actions – as clearly stated in the CEM – have been met or not. Both expected and unexpected results allow managers to update the model, improving certainty about some aspects of the model while requiring changes to other aspects, to guide the next cycle of management actions and research. The CEM, through its successive iterations, becomes the record of improving knowledge and the ability to manage the system.

CONCEPTUAL ECOLOGICAL MODEL STRUCTURE FOR SUTA

The CEM methodology used here expands on that developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012). The expansion incorporates recommendations of Wildhaber et al. (2007, 2011), Kondolf et al. (2008), and Burke et al. (2009) to provide greater detail on causal linkages and outcomes and explicit demographic notation in the characterization of life-stage outcomes (McDonald and Caswell 1993). Attachment 1 provides a detailed description of the methodology.

The CEM methodology applied here produces a “life history” model, as is common for CEMs focused on individual species (Wildhaber et al. 2007, 2011). That is, the methodology distinguishes the major life stages or events through which the individuals of a species must pass to complete a full life cycle, including reproducing, and the biologically crucial outcomes of each life stage. These biologically crucial outcomes typically include the number of individuals recruited to the next life stage (e.g., juvenile to adult) or next age class within a single life stage (recruitment rate), or the number of viable offspring produced (fertility rate). It then identifies the factors that shape the rates of these outcomes in the study area and thereby shapes the abundance, distribution, and persistence of the species in that area.

The SUTA conceptual ecological model has five core components as explained further in attachment 1:

- **Life stages** – These consist of the major growth stages and critical events through which the individuals of a species must pass in order to complete a full life cycle.

- **Life-stage outcomes** – These consist of the biologically crucial outcomes of each life stage, including the number of individuals recruited to the next life stage (e.g., juvenile to adult) or the number of offspring produced (fertility rate). The rates of the outcomes for an individual life stage depend on the rates of the critical biological activities and processes for that life stage.

- **Critical biological activities and processes** – These consist of the activities in which the species engages and the biological processes that take place during each life stage that significantly affect its life-stage outcomes rates. Examples of activities and processes for a bird species may include nest site selection, foraging, molt, and temperature regulation. Critical biological activities and processes typically are “rate” variables.

- **Habitat elements** – These consist of the specific habitat conditions, the quality, abundance, and spatial and temporal distributions of which significantly affect the rates of the critical biological activities and processes for each life stage. Taken together, the suite of natural habitat elements for a life stage is called the “habitat template” for that life stage. Defining the natural habitat template may involve estimating specific thresholds or ranges of suitable values for particular habitat elements, outside of which one or more critical life activities or processes no longer fully support desired life-stage outcome rates – if the state of the science supports such estimates.

- **Controlling factors** – These consist of environmental conditions and dynamics – including human actions – that determine the quality, abundance, and spatial and temporal distributions of important habitat elements. Controlling factors are also called “drivers.” There may be a hierarchy of such factors affecting the system at different scales of time and space (Burke et al. 2009). For example, the availability of suitable nest sites for a riparian nesting bird may depend on factors such as canopy closure, humidity, intermediate structure, and community type, which in turn may depend on factors such as water storage-delivery system design and operation (dam design, reservoir morphology, and dam operations), which in turn is shaped by watershed geology, vegetation, climate, land use, and water demand.

The CEM identifies these five components and the causal relationships among them that affect life-stage outcome rates. Further, the CEM assesses each causal linkage based on four variables to the extent possible with the available information: (1) the character and direction of the effect, (2) the magnitude of the effect, (3) the predictability (consistency) of the effect, and (4) the status (certainty) of a present scientific understanding of the effect.

The CEM for each life stage thus identifies the causal relationships that most strongly support or limit the rates of its life-stage outcomes, support or limit the rate of each critical biological activity or process, and support or limit the quality, abundance, and distribution of each habitat element (as these affect other habitat elements or affect critical biological activities or processes). In addition, the model for each life stage highlights areas of scientific uncertainty concerning these causal relationships, the effects of specific management actions aimed at these relationships, and the suitability of the methods used to measure habitat and population conditions. Attachment 1 provides further details on the assessment of causal relationships, including the use of diagrams and a spreadsheet tool to record the details of the CEM and summarize the findings.

Chapter 2 – SUTA Life Stage Model

A life stage consists of a biologically distinct portion of the life cycle of a species during which individuals undergo distinct developments in body form and function, engage in distinct behaviors, use distinct sets of habitats, and/or interact with their larger ecosystems in ways that differ from those associated with other life stages. This chapter proposes a life stage model for SUTA along the LCR on which to build the CEM.

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 the 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 nest stage as separate from adult reproduction due to the specific factors influencing the nest, the common creation of multiple broods by this species, and the fit with the life-stage outcome modelling structure used in this CEM process.

We have chosen to combine the egg and nestling stages into a nest 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, etc.). 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 the 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—nest, juvenile, and breeding adult. SUTA management during migration and winter are certainly important but outside of the scope of Reclamation's responsibilities.

SUTA LIFE STAGE 1 – NEST

We consider the nest 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 2012). Powell and Steidl (2000) found very high rates (approximately 80 percent) 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 predation of SUTA within the LCR is unknown. The life-stage outcome from the nest stage is the survival of eggs and associated nestlings until fledging. It is important to note that the outcome of the nest stage is inherently tied to the behavior and condition of the parents.

SUTA LIFE STAGE 2 – JUVENILE

The juvenile 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 2012). Migration begins in August and generally occurs at night (Robinson 2012). Migration has not been thoroughly studied in this species, especially with the western populations. The life-stage outcome from the juvenile 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 the juvenile survival rates in this species; however, it may be assumed to be lower than the adult annual survival rate that has been shown to be approximately 0.56 (Michel et al. 2006; Ricklefs and Shea 2007).

SUTA LIFE STAGE 3 – BREEDING ADULT

As the focus of this CEM is upon the LCR region, the adult 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 adult 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 between 2 and 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 2012). Two broods are common in southwestern populations (Rosenberg et al. 1991).

The life-stage outcomes for breeding adults are survival and fecundity—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 nest stage from adult 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 the production of eggs.

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 that differ from breeding areas and provide good conditions for migratory staging (Vega Rivera et al. 2003). Vega Rivera et al. (2003) found that half of the 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 adult 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.

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 the nest.

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

Life stage	Life-stage outcome(s)
1. Nest	• Survival
2. Juvenile	• Survival
3. Breeding adult	• Survival • Reproduction

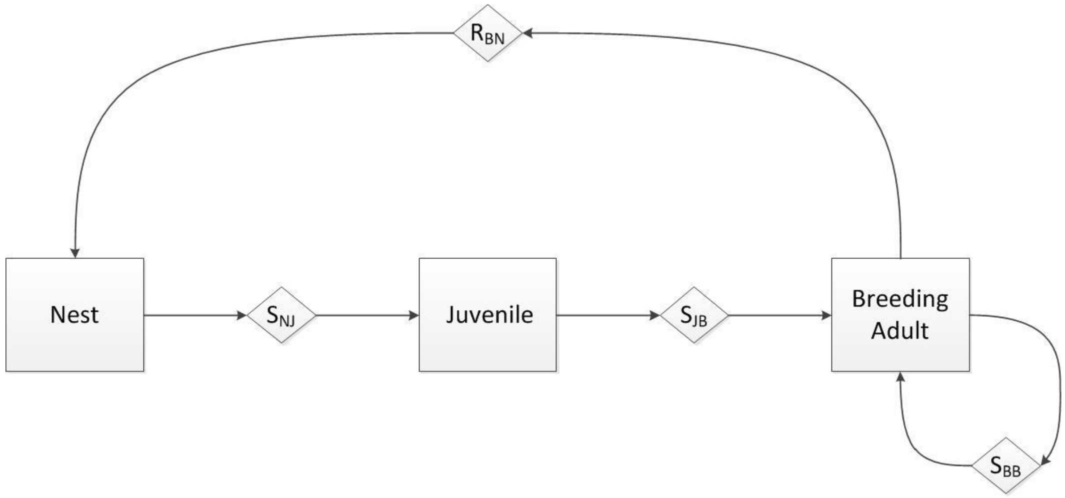

Figure 1.—Proposed SUTA life history model.
Squares indicate the life stages, and diamonds indicate life-stage outcomes.
S_{NJ} = survivorship rate, nest; S_{JB} = survivorship rate, juveniles; S_{BB} = survivorship rate, breeding adults; and R_{BN} = reproduction rate, breeding adults.

Chapter 3 – Critical Biological Activities and Processes

Critical biological activities and processes consist of activities in which the species engages and biological processes that take place during each life stage that significantly shape the rate(s) of the outcome(s) for that life stage. Critical biological activities and processes are "rate" variables (i.e., the rate [intensity] of these activities and processes, taken together, determine the rate of recruitment of individuals from one life stage to the next).

The CEM identifies seven critical biological activities and processes that affect one or more SUTA life stages. Some of these activities or processes differ in their details among life stages. However, grouping activities or processes across all life stages into broad types makes it easier to compare the individual life stages to each other across the entire life cycle. Table 2 lists the seven critical biological activities and processes and their distribution across life stages.

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 ➔**	**Nest**	**Juvenile**	**Breeding adult**
Disease	X	X	X
Eating/foraging	X	X	X
Molt	X	X	X
Nest attendance			X
Nest site selection			X
Predation and brood parasitism	X	X	X
Temperature regulation	X	X	X

The most widely used sources of the information used to identify the critical biological activities and processes are Rosenberg et al. (1991), Powell and Steidl (2002), Lima (2009), Brand et al. (2010), Robinson (2012), 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 seven critical biological activities and processes in alphabetical order.

DISEASE

This process refers to diseases caused by infectious agents, including the effects of ecto- and endo-parasites. Disease prevalence and intensity can be influenced by lack of genetic diversity. Little research has focused on specific diseases inflicting SUTA. 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 have differing effects on different species (Merino et al. 2000; Palinauskas et al. 2008). All life stages are conceivably susceptible to disease.

EATING/FORAGING

Eating and foraging are grouped together to simplify the presentation of similar influences. Eating only applies to the nest and juvenile stages, and foraging is performed by juveniles and adults. Juveniles forage on their own, but are still fed by adults shortly after fledging, and this feeding may be critical to their survival. The ability of nestlings and juveniles to eat is determined by the provisioning rate of its parents. 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.

MOLT

SUTA use a complex alternate molt strategy (Howell 2010). Nestling SUTA must molt from natal down into juvenal plumage while in the nest. The success of this molt is dependent upon the adult provisioning rate. Molting is an energetically costly process that may make nestlings more susceptible to death when resources are scarce. 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). Similarly, adult birds molt on the breeding grounds after the breeding season, and before autumn migration, and face the same challenges as nestlings (Howell 2010).

NEST ATTENDANCE

Female SUTA do all of the incubating and brooding, but the males help with feeding of the young (Potter 1973). Breeding adults attend the nest, and this affects nestling survival.

NEST SITE SELECTION

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 2012). 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 (Powell and Steidl 2002; Lima 2009; Brand et al. 2010; Robinson 2012; Smith and Finch 2013).

PREDATION AND BROOD PARASITISM

Predation and brood parasitism certainly affects survival and the success of SUTA nests within the LCR (Powell and Steidl 2000; Brand et al. 2010). Powell and Steidl (2000) found that nest predation was more significant than parasitism, accounting for 81 percent of nest failures of some species along a southwestern riparian corridor. 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 nestling and egg stages because (1) cowbirds are both nest predators and brood parasites (Theimer et al. 2011) and (2) habitat characteristics (distance to edge, patch width, etc.) affect both processes similarly (Rosenberg et al. 1999). Further evidence suggests a host of behavioral characteristics can also influence predation rates, including brood size, parental nest attendance, and parental feeding behavior (Martin and Briskie 2009). Predation on juveniles and adults is not as easily quantified but 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, egg sizes, etc. (Lima 2009).

TEMPERATURE REGULATION

Temperature regulation is important for 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). Adults can affect the temperature regulation of eggs and nestlings through their own behavior (incubation, brooding, or shading) and through nest placement.

Chapter 4 – Habitat Elements

Habitat elements consist of specific habitat conditions that ensure, allow, or interfere with critical biological activities and processes.

This chapter identifies 17 habitat elements that affect 1 or more critical biological activities or processes across the 3 SUTA life stages. Some of these habitat elements differ in their details among life stages. For example, SUTA at different life stages experience different predation risks depending on the SUTA life stage. However, using the same labels for the same *kinds* of habitat elements across all life stages makes comparison and integration of the CEMs for the individual life stages across the entire life cycle less difficult. Table 3 lists the 17 habitat elements and the critical biological activities and processes that they *directly* affect across all SUTA life stages.

The diagrams and other references to habitat elements elsewhere in this document identify the habitat elements by a one-to-three-word short name. However, each short name in fact refers to a longer, complete name. For example, "predator and cowbird density" is the short name for "The abundance and distribution of predators and brood parasites." The following paragraphs provide the full name for each habitat element and a detailed definition, addressing the elements in alphabetical order.

The most widely used sources of the information used to identify the habitat elements are Rosenberg et al. (1982, 1991), Powell and Steidl (2000, 2002), Brand et al. (2010), Perry et al. 2011, and Robinson (2012). 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 publications.

SUTA in the Southwest United States tend to nest at higher densities in native cottonwood than other plants (Brand et al. 2010). They tend to prefer large riparian patches, often exceeding 60 meters (m) in patch width (Perry et al. 2011). Patches with higher canopy closure and lower understory density are often chosen (Rosenberg et al. 1999; Powell and Steidl 2002). While SUTA are sensitive to patch fragmentation, they still tend to nest in the proximity of the edge (Parker et al. 2005).

SUTA rely heavily on cicadas as a food source during the breeding season (Rosenberg et al. 1982). Cicadas can be sensitive to soil temperatures and local hydrology, and may also directly affect the available water in the upper layers of the soil through urine output, influencing plant communities (Andersen 1994). In

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

Critical biological activity or process ➔ / **Habitat element ➔**	**Disease**	**Eating/foraging**	**Molt**	**Nest attendance**	**Nest site selection**	**Predation and brood parasitism**	**Temperature regulation**
Anthropogenic disturbance		X		X	X	X	
Brood size		X		X			
Canopy closure					X	X	X
Community type		X			X	X	
Food availability		X					
Genetic diversity and infectious agents	X						
Local hydrology					X		X
Parental feeding behavior		X					
Parental nest attendance		X				X	X
Patch size					X	X	
Predator and cowbird density				X	X	X	
Soil salinity	N/A*						
Soil temperature	N/A						
Stand height					X	X	
Tree density					X	X	
Tree size					X	X	
Understory density					X	X	X

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

addition to cicadas, SUTA consume bees and wasps, often switching to fruit late in the breeding season and during migration (Rosenberg et al. 1982; Isler and Isler 1987 as cited in Robinson 2012).

As with all tabulations of habitat associations, inferences that particular habitat characteristics are critical to a species or life stage require evidence and CEMs for why each association matters to species' viability (Rosenfeld 2003; Rosenfeld and Hatfield 2006.)

ANTHROPOGENIC DISTURBANCE

Full name: **Human activity within or surrounding a given habitat patch, including noise, pollution, and other disturbances associated with human activity.** Anthropogenic disturbance can affect both breeding success and 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 SUTA to attract or find mates or defend territories. Noise can cause behavioral changes, physiological changes, and species diversity changes within an area. Anthropogenic disturbance can be generated by industrial applications, transportation, agriculture, recreation, scientific studies, and countless other influences. Anthropogenic disturbance effects on SUTA or within the LCR have not been thoroughly studied, so specific impacts are not quantified.

BROOD SIZE

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 "Predator and Cowbird Density"). SUTA typically lay three or four eggs, although two and five have also been observed (Robinson 2012).

CANOPY CLOSURE

Full name: **The proportion of the sky hemisphere obscured by vegetation when viewed from a single point as measured with a spherical densitometer (Jennings et al. 1999).** This element refers to the percent canopy closure of canopy vegetation in the vicinity of the SUTA 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 relative high canopy cover in relation to other species in the area; 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.

COMMUNITY TYPE

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 tanagers 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).

FOOD AVAILABILITY

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 percent) and bees/wasps (25 percent) (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 add the equivalent of as much as 12 percent of the annual rainfall of water to the local water table, which can influence the community type and health of the ecosystem (Andersen 1994). However, they have been known to rely on fruits late in the breeding season and during migration (Robinson 2012). 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).

GENETIC DIVERSITY AND INFECTIOUS AGENTS

Full name: **The genetic diversity of individuals and the types, abundance, and distribution of infectious agents and their vectors.** The genetic diversity component of 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. Sheperd 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.

The infectious agent component of 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 2012). 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 have differing effects on different species (Merino et al. 2000; Palinauskas et al. 2008)

LOCAL HYDROLOGY

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 have shown a preference for nesting closer to water (Powell and Steidl 2002).

PARENTAL FEEDING BEHAVIOR

Full name: **The ability and behavior of parents to feed and care for juveniles after they fledge from the nest.** This element refers to the capacity of both parents to provision food for recently fledged birds. Parents provide food for young for approximately 3 weeks after fledging (Robinson 2012). This rate is dependent upon food availability and the number of young in the brood and influences the amount of food and time spent foraging by the juvenile birds. When a second brood is initiated, the juveniles are fed by the adult male (Mengel 1965 as cited in Robinson 2012).

PARENTAL NEST ATTENDANCE

Full name: **The ability of both parents to care for young during the egg/incubation and nestling stages.** This element refers to the capacity for both parents to share nesting and brood rearing responsibilities until fledging. It is affected by the presence of predators and competitors, food availability, and the ability to thermal regulate. Female SUTA have sole responsibility of brooding young, but the territory is actively defended by males (Potter 1973).

PATCH SIZE

Full name: **The size of riparian habitat patches.** This element refers to the areal extent of a given patch of riparian vegetation. Patch size affects the number of breeding pairs that an area can support as well as the density of predators, competitors, and brood parasites. SUTA are sensitive to forest fragmentation and maintain higher densities in larger forest patches (Rosenberg et al. 1999). However, they have an affinity for nesting in the proximity of the edge (Parker et al. 2005; Robinson 2012). Perry et al. (2011) illustrates the preference of SUTA for nest patches with wide riparian buffer zones, with predicted occupancy rates rising to a distance of 60 m.

PREDATOR AND COWBIRD DENSITY

Full name: **The abundance and distribution of 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 egg, nestling, or adult life stages 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 different life stages, 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, etc.). Powell and Steidl (2000) report observing that 81 percent of southwestern riparian nests they studied were predated 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 percent (Robinson 2012).

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 (Lima 1998, 2009; Chalfoun and Martin 2009). Predation of SUTA has not been thoroughly studied (Robinson 2012). Based upon defensive aggression behavior, it is surmised that SUTA may be predated upon 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 2012).

SOIL SALINITY

Full name: **The salt content within the root zone of the soil (0–30 inches) as measured by electrical conductivity of the saturation extract value in decisiemens per meter at 25 degrees Celsius (°C)** (San Joaquin River Restoration Program 2014). Soil salinity can impact the vigor of various plant species to different degrees and can ultimately influence the plant community type and structure (San Joaquin River Restoration Program 2014).

SOIL TEMPERATURE

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 (Rosenberg et al. 1982; Andersen 1994; 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

Full name: **The average height of the core stand area being evaluated**. Stand height may be important for SUTA occupancy in riparian environments, but quantifiable studies have not been performed.

TREE DENSITY

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. It is unknown what tree density is preferred by SUTA for nesting within the LCR.

TREE SIZE

Full name: **The diameter of a tree at breast height, averaged across the stand.** Powell and Steidl (2002) found that SUTA occupy nesting stands with larger than average trees on the landscape.

UNDERSTORY DENSITY

Full name: **The density of the understory layer).** SUTA appear to select for lower understory density (but not mid-story density [i.e., 1.5–4 m]), 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 2002).

Chapter 5 – Controlling Factors

Controlling factors consist of environmental conditions and dynamics, both natural and anthropogenic, which significantly affect the abundance, spatial and temporal distribution, and quality of critical habitat elements. These may also directly affect some critical biological activities and processes. A hierarchy of such factors exists, with long-term dynamics of climate and geology at the top. However, this CEM focuses on 10 controlling factors that are within the scope of potential human manipulation. The 10 controlling factors identified in this CEM do not constitute individual variables; rather, each identifies a category of variables (including human activities) that share specific features which make it useful to treat them together. Table 4 lists the 10 controlling factors and the habitat elements they directly affect. Table 4 shows two habitat elements that are not directly affected by any controlling factor. These latter habitat elements are directly shaped by the condition of one or more other habitat elements rather than by any of the controlling factors.

Table 4.—Habitat elements directly affected by controlling factors

Controlling factor ➔ / **Habitat element 🡣**	**Fire management**	**Grazing**	**Irrigation**	**Mechanical thinning**	**Natural thinning**	**Nuisance species introduction and management**	**Pesticide/herbicide application**	**Planting regime**	**Recreational activities**	**Water storage-delivery system design and operation**
Anthropogenic disturbance		X		X			X	X	X	
Brood size	N/A*									
Canopy closure	X			X	X	X		X	X	
Community type	X	X	X			X		X	X	X
Food availability	X					X	X	X		
Genetic diversity and infectious agents	N/A									
Local hydrology			X							X
Parental feeding behavior									X	
Parental nest attendance									X	
Patch size	X	X		X	X	X		X	X	
Predator and cowbird density						X		X	X	
Soil salinity			X							X
Soil temperature	X		X	X	X			X		X
Stand height	X			X	X	X		X		
Tree density	X			X	X	X		X	X	
Tree size	X			X	X	X		X		
Understory density	X	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 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 as predators, competitors, or carriers of infectious agents. Climate change is also projected to affect fire frequency in the LCR (U.S. Fish and Wildlife Service 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 factor addresses the grazing activity on riparian habitats along the LCR that could affect SUTA or their habitat. Grazing by cattle, burros, or mule deer across the arid Southwestern United States has substantially degraded riparian habitat (see references 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 populations are not managed). Grazing may thin the understory, which could benefit SUTA in the short term, but can also prevent the establishment of cottonwood and willow seedlings (Kauffman et al. 1997; Powell and Steidl 2002). Krueper et al. (2003) documented a significant population increase of SUTA in the years following the removal of cattle from a riparian system.

IRRIGATION

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.

MECHANICAL THINNING

This factor addresses the active removal of vegetation from areas within the LCR region. Effects may include creation of habitat that supports or excludes SUTA or supports or excludes species that pose threats to SUTA such as predators, competitors, or carriers of infectious agents. Thinning can be implemented on a small, local scale, resembling natural thinning, or can be implemented on a broad scale, with larger and more complete transition. Mechanical thinning always increases the level of anthropogenic disturbance within the habitat. This factor includes the thinning of vegetation within both riparian and matrix communities.

NATURAL THINNING

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. Powell and Steidl (2002) and Perry et al. (2011) 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 AND MANAGEMENT

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) (Di Tomaso 1998; Brand et al. 2010).

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.

PESTICIDE/HERBICIDE APPLICATION

This factor addresses pesticide or herbicide applications that may occur on or adjacent to riparian habitat of the LCR region. Herbicide may drift into riparian areas, killing important SUTA habitat. Pesticide effects may include lethal or sublethal poisoning of SUTA via ingestion of treated insects, pollution, or runoff into wetland habitats that are toxic to prey of SUTA, and a reduced invertebrate food supply.

PLANTING REGIME

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 was planted within restoration areas (e.g., density, age, and patch size). The composition of the species planted can affect not only the vertical and horizontal structure of the vegetation but also the insect community within a given patch. SUTA have shown to be sensitive to which species are planted during restoration activities in other parts of its range (Gabbe et al. 2002). In addition, SUTA do use invasive tamarisk for nesting, so restoration activities should be evaluated to ensure no loss of habitat availability during the restoration process (Sogge et al. 2008).

RECREATIONAL ACTIVITIES

This factor addresses the disturbance to SUTA from recreational activity. Even non-consumptive human activity can have negative effects on wildlife (reviewed by Boyle and Samson 1985). This is a broad category that encompasses the types of activity (e.g., boating, fishing, horseback riding, and camping) as well as the frequency and intensity of those activities. The impacts may consist of noise or physical presence disturbance and habitat alteration.

WATER STORAGE-DELIVERY SYSTEM DESIGN AND OPERATION

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

The dynamic nature of a free-flowing river creates a mosaic of riparian habitats, and thus, a natural flow regime might be beneficial to SUTA. Natural floods can decrease understory vegetation, improving SUTA habitat and decreasing soil temperatures, enabling cicada emergence to coincide with the greater food demands of a brood (Andersen 1994; Smith et al. 2006).

Chapter 6 – Conceptual Ecological Model by Life Stage

This chapter contains three sections, each presenting the CEM for a single SUTA life stage. The text and diagrams identify the critical biological activities and processes for each life stage, the habitat elements that support or limit the success of these critical biological activities and processes, the controlling factors that determine the abundance and quality of these habitat elements, and the causal links among them. The CEM sections specifically refer to the river and the lakes of the LCR and other protected areas managed as SUTA habitat and thus address the landscape as a whole rather than any single reach or managed area.

The CEM for each life stage assesses the character and direction, magnitude, predictability, and scientific understanding of each causal link based on the following definitions (see attachment 1 for further details):

- **Character and direction** categorizes a causal relationship as positive, negative, or complex. "Positive" means that an increase in the causal node results in an increase in the affected node, while a decrease in the causal node results in a decrease in the affected node. "Negative" means that an increase in the causal node results in a decrease in the affected element, while a decrease in the causal node results in an increase in the affected node. Thus, "positive" or "negative" here do ***not*** mean that a relationship is beneficial or detrimental. The terms instead provide information analogous to the sign of a correlation coefficient. "Complex" means that there is more going on than a simple positive or negative relationship. Positive and negative relationships are further categorized based on whether they involve any response threshold in which the causal agent must cross some value before producing an effect. In addition, the "character and direction" attribute categorizes a causal relationship as uni- or bi-directional. Bi-directional relationships involve a reciprocal relationship in which each node affects the other.

- **Magnitude** refers to "…the degree to which a linkage controls the outcome *relative to other drivers*" (DiGennaro et al. 2012). Magnitude takes into account the spatial and temporal scale of the causal relationship as well as the strength (intensity) of the relationship at any single place and time. The present methodology separately rates the intensity, spatial scale, and temporal scale of each link on a three-part scale from "Low" to "High" and assesses overall link magnitude by averaging the ratings for these three. If it is not possible to estimate the intensity, spatial scale, or temporal scale of a link, the subattribute is rated as "Unknown" and ignored in the averaging. If all three subattributes are "Unknown," however, the overall link magnitude is rated as "Unknown." Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link magnitude provide information analogous to the size of a correlation coefficient.

- **Predictability** refers to "…the degree to which current understanding of the system can be used to predict the role of the driver in influencing the outcome. Predictability … captures variability… [and recognizes that] effects may vary so much that properly measuring and statistically characterizing inputs to the model are difficult" (DiGennaro et al. 2012). A causal relationship may be unpredictable because of natural variability in the system or because its effects depend on the interaction of other factors with independent sources for their own variability. Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link predictability provide information analogous to the size of the range of error for a correlation coefficient. The present methodology rates the predictability of each link on a three-part scale from "Low" to "High." If it is not possible to rate predictability due to a lack of information, then the link is given a rating of "Unknown" for predictability.

- **Scientific understanding** refers to the degree of agreement represented in the scientific literature and among experts in understanding how each causal relationship works—its character, magnitude, and predictability. Link predictability and understanding are independent attributes. A link may be highly predictable but poorly understood or poorly predictable but well understood. The present methodology rates the state of scientific understanding of each link on a three-part scale from "Low" to "High."

The CEM for each life stage thus identifies the causal relationships that most strongly support or limit life-stage outcomes, support or limit the rate of each critical biological activity or process, and support or limit the quality of each habitat element, as that element affects other habitat elements or affects critical biological activities and processes.

A separate spreadsheet is used to record the assessment of the character and direction, magnitude, predictability, and scientific understanding for each causal link, along with the underlying rationale and citations, for each life stage. The CEM for each life stage, as cataloged in its spreadsheet, is illustrated with diagrams showing the controlling factors, habitat elements, critical biological activities and processes, and causal links identified for that life stage. A diagram may also visually display information on the character and direction, magnitude, predictability, and/or scientific understanding of every link. The diagrams use a common set of conventions for identifying the controlling factors, habitat elements, critical biological activities and processes, and life-stage outcomes as well as for displaying information about the causal links. Figure 2 illustrates these conventions.

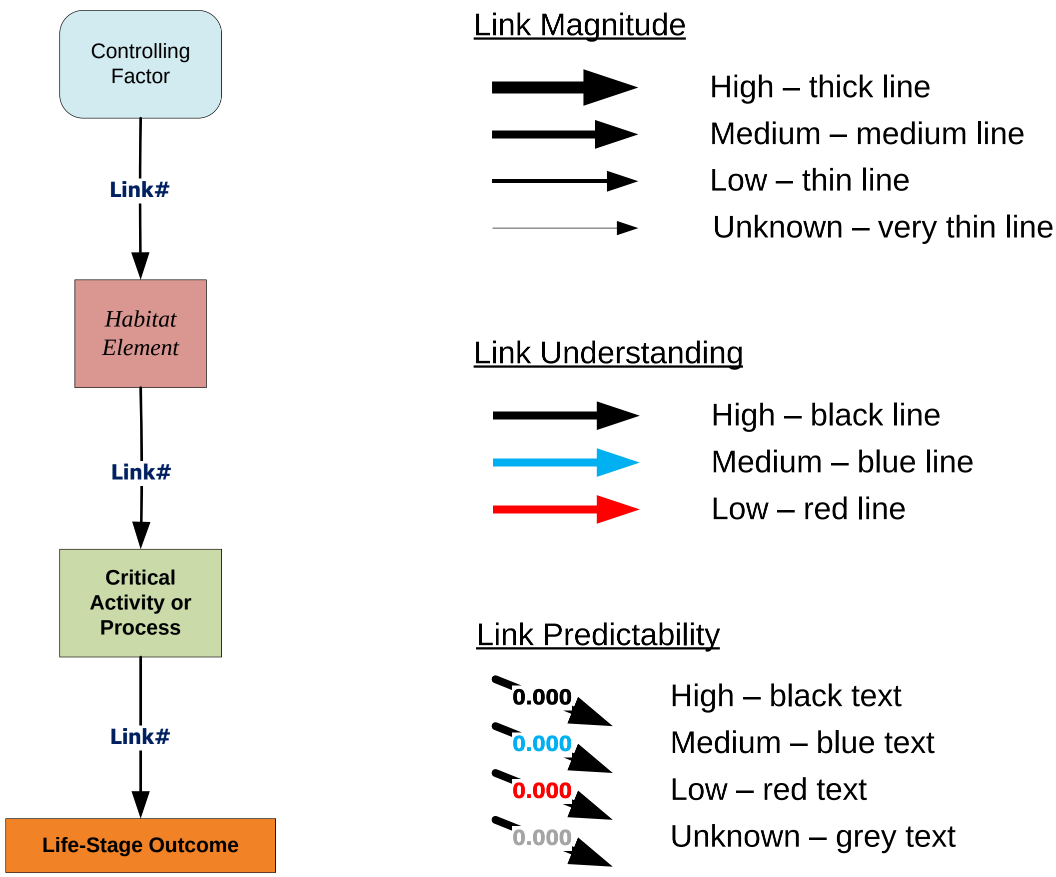

Figure 2.—Diagram conventions for LCR MSCP conceptual ecological models.

The discussion of each life stage includes an analysis of the information contained in the spreadsheet. The analyses highlight causal chains that strongly affect survivorship, identify important causal relationships with different levels of predictability, and identify important causal relationships with high scientific uncertainty. The latter constitutes topics of potential importance for adaptive management investigation.

The causal relationships between controlling factors and habitat elements are essentially identical across all three life stages. For this reason, the discussion of controlling factor-habitat element linkages across all three life stages appears in a subsequent chapter.

SUTA LIFE STAGE 1 – NEST

The nest stage lasts from when the egg is laid until either the young fledge or the nest fails. Success during this life stage – successful transition to the juvenile stage – involves organism survival, maturation, molt, and fledging. The organisms actively interact with their environment.

The CEM (figures 3 and 4) recognizes five (of seven) critical biological activities and processes for this life stage, and they are presented here as they appear on the following figures:

1. **Disease** – Although the literature does not emphasize disease as affecting population levels of SUTA, we still feel that disease bears mentioning. Diseases and parasites are prevalent in avian populations, so it is safe to assume they have an impact on SUTA (Morishita et al. 1999; Lachish et al. 2011). Disease and parasite impacts along the LCR is an area recommended for further research.

   The CEM recognizes genetic diversity and infectious agents as habitat elements directly affecting disease.

2. **Eating** – Foraging is not associated with this life stage; therefore, it is not included with eating. The nestling must eat to maintain metabolic processes.

   The CEM recognizes anthropogenic disturbance, brood size, parental feeding behavior, and parental nest attendance as habitat elements affecting eating.

3. **Molt** – The nestling must molt into juvenal plumage.

   The CEM does not recognize any habitat elements as directly affecting molt.

   Other critical activities influencing molt include those affecting energy resources such as disease and eating.

4. **Predation and Brood Parasitism** – Both nest predation and brood parasitism affect the survival of a nest and are affected by similar habitat elements. Brood parasitism has been identified as a threat to SUTA. High rates of predation and brood parasitism have been observed for SUTA, accounting for over 80 percent of nest failures (Powell and Steidl 2000). Rasmussen and Sealy (2006) further speculate that the impact of brood parasitism post-fledging may be much higher than assumed.

The CEM recognizes anthropogenic disturbance, canopy closure, community type, parental nest attendance, patch size, predator and cowbird density, stand height, tree density, tree size, and understory density as habitat elements affecting predation and brood parasitism. Many of these effects are not well understood.

5. **Temperature Regulation** – The eggs and nestlings must maintain an optimum temperature to develop and survive.

   The CEM recognizes canopy closure, local hydrology, and parental nest attendance as the primary habitat elements directly affecting temperature regulation. Another habitat element having a lesser impact on temperature regulation is understory density.

   Eating and disease are two critical biological activities that can influence temperature regulation.

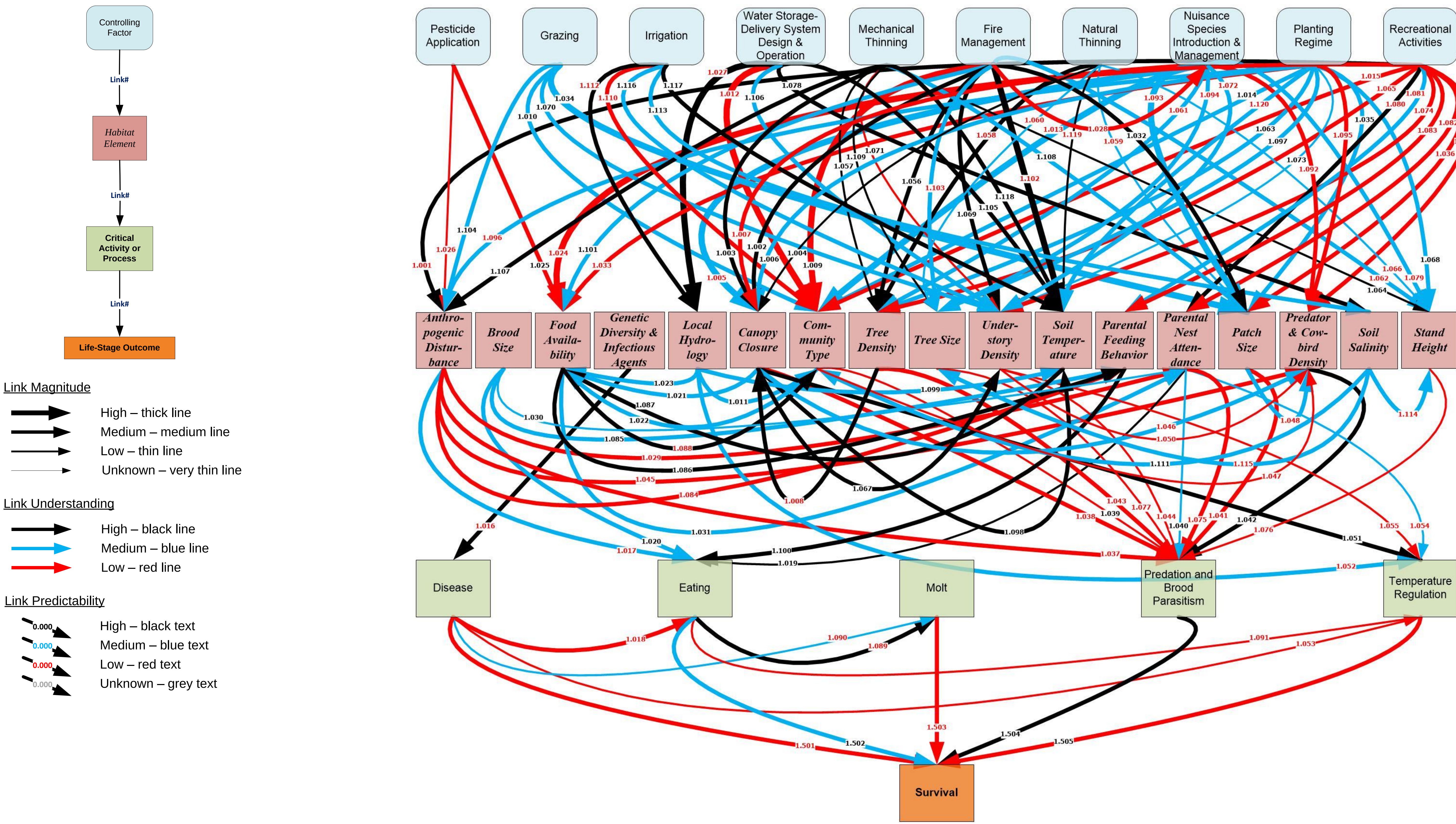

Figure 3.—SUTA Life Stage 1 – Nest, basic CEM diagram. Only elements with connections within this life stage are presented.

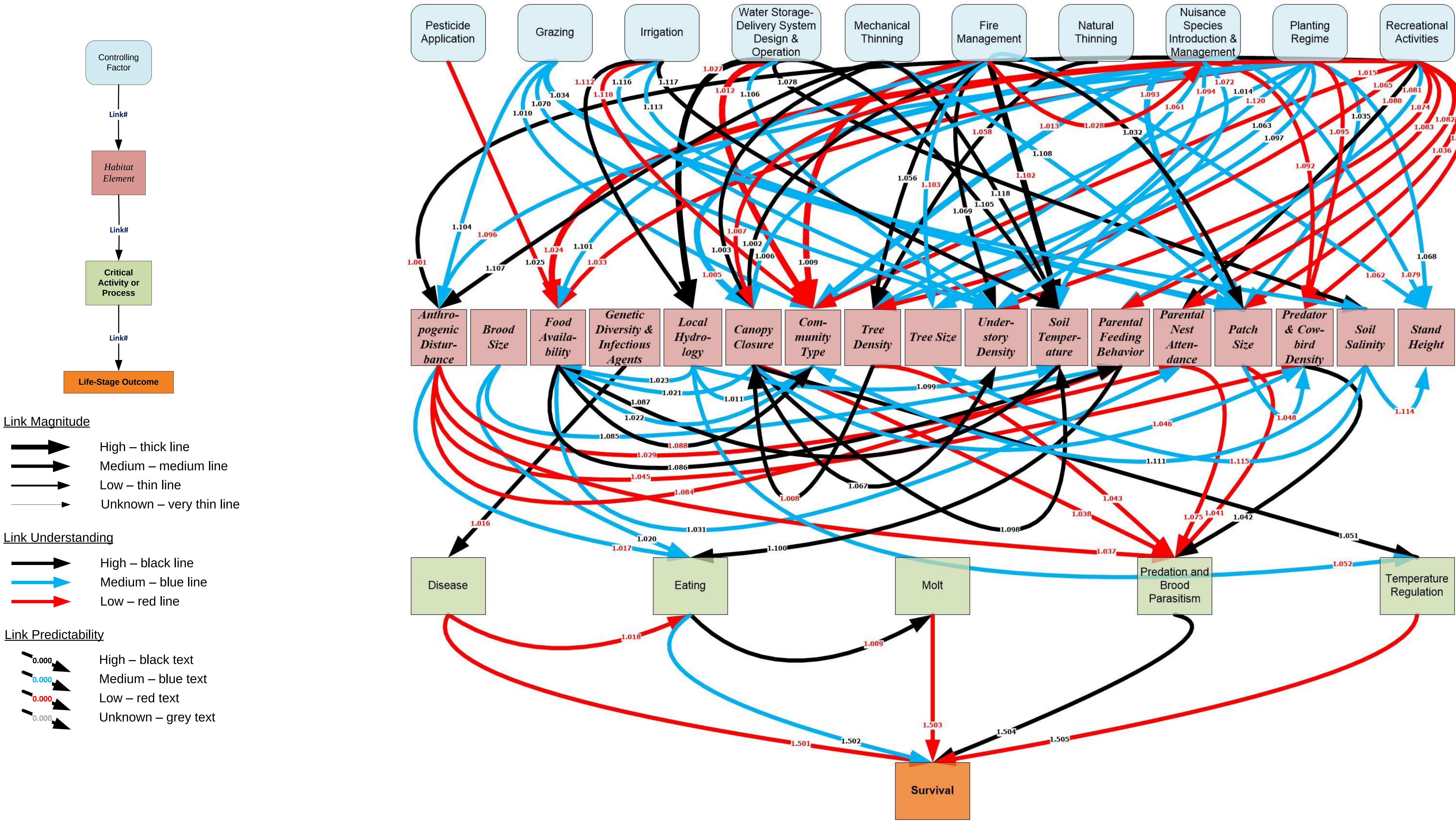

Figure 4.—SUTA Life Stage 1 – Nest, high- and medium-magnitude relationships. Only elements with high- or medium-magnitude connections within this life stage are presented.

SUTA LIFE STAGE 2 – JUVENILE

The juvenile stage begins at fledging and ends when the bird returns to the breeding grounds the next year. However, for the sake of this analysis, we will only emphasize the period between fledging and departure during autumn migration.

Success during this life stage – successful transition to the next stage – involves organism survival and maturation. The organisms actively interact with their environment.

The CEM (figures 5 and 6) recognizes five (of seven) critical biological activities and processes for this life stage, and they are presented here as they appear on the following figures:

1. **Disease** – Although the literature does not emphasize disease as affecting population levels of SUTA, we still feel that disease bears mentioning. Diseases and parasites are prevalent in avian populations, so it is safe to assume they have an impact on SUTA (Morishita et al. 1999; Lachish et al. 2011). Disease and parasite impacts along the LCR is an area recommended for further research.

   The CEM recognizes genetic diversity and infectious agents as a habitat element affecting disease.

2. **Eating/Foraging** – The juvenile must eat to maintain metabolic processes. While they will increasingly forage on their own, they are dependent upon food from their parents for approximately 3 weeks. The degree to which it is dependent upon foraging relates to the feeding rate of the parents and all of the factors affecting parent survival.

   The CEM recognizes anthropogenic disturbance, brood size, canopy closure, community type, food availability and parental feeding behavior as habitat elements affecting eating/foraging.

3. **Molt** – The juvenile must molt into adult plumage.

   The CEM does not recognize any habitat elements as directly affecting molt.

   Other critical activities influencing molt include those affecting energy resources such as disease and eating/foraging.

4. **Predation** – Brood parasitism is no longer a threat to the survival of the bird; therefore, it is no longer included with predation.

   The CEM recognizes anthropogenic disturbance, canopy closure, community type, parental feeding behavior, patch size, predator and cowbird density, stand height, tree density, tree size, and understory density as habitat elements affecting predation. The size of the effect of many of these elements is not well known.

5. **Temperature Regulation** – The juvenile must maintain an optimum temperature to survive.

   The CEM recognizes canopy closure, local hydrology, and understory density as habitat elements directly affecting temperature regulation. Disease and eating/foraging are critical processes that can also influence temperature regulation.

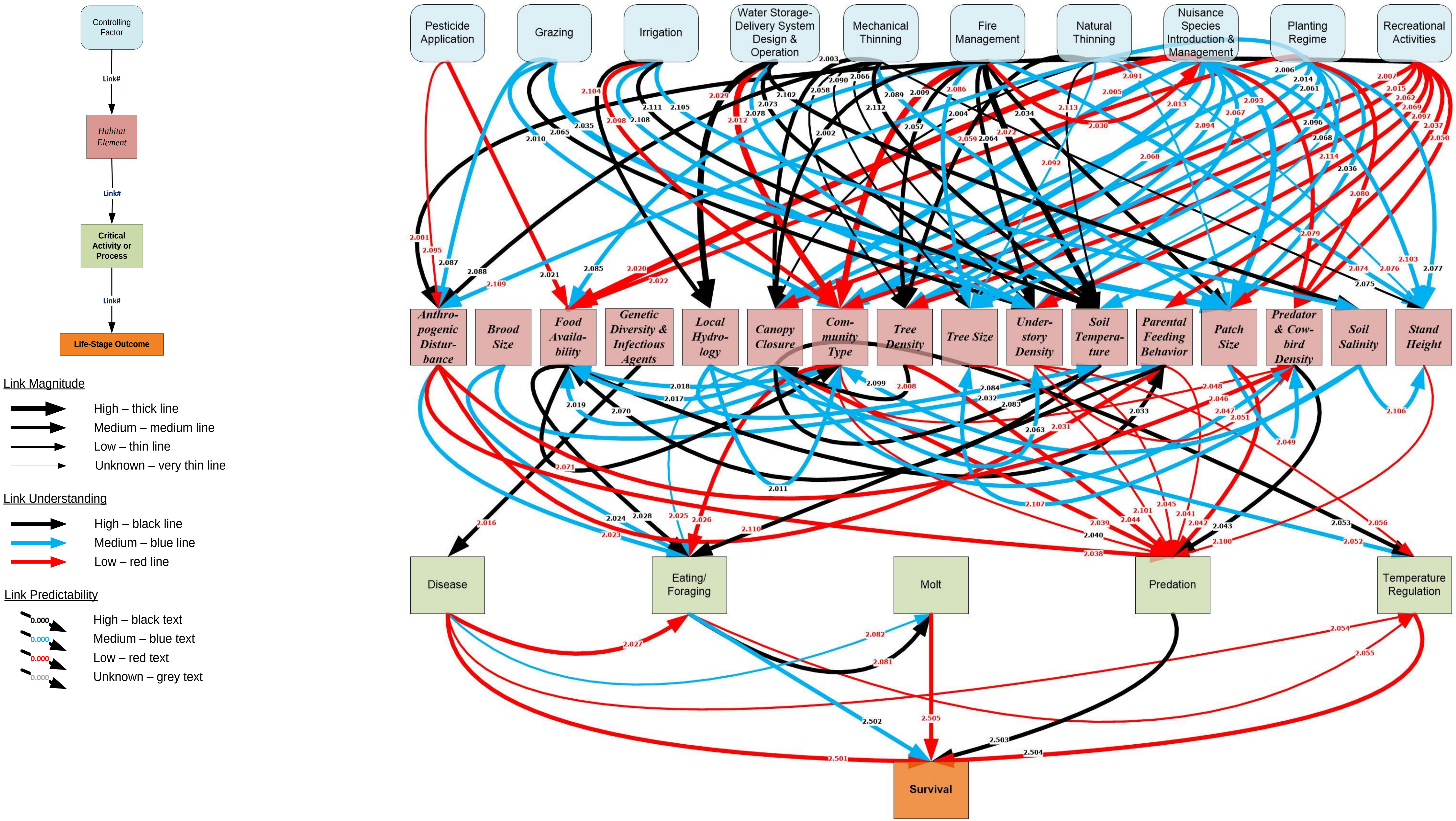

Figure 5.—SUTA Life Stage 2 – Juvenile, basic CEM diagram. Only elements with connections within this life stage are presented.

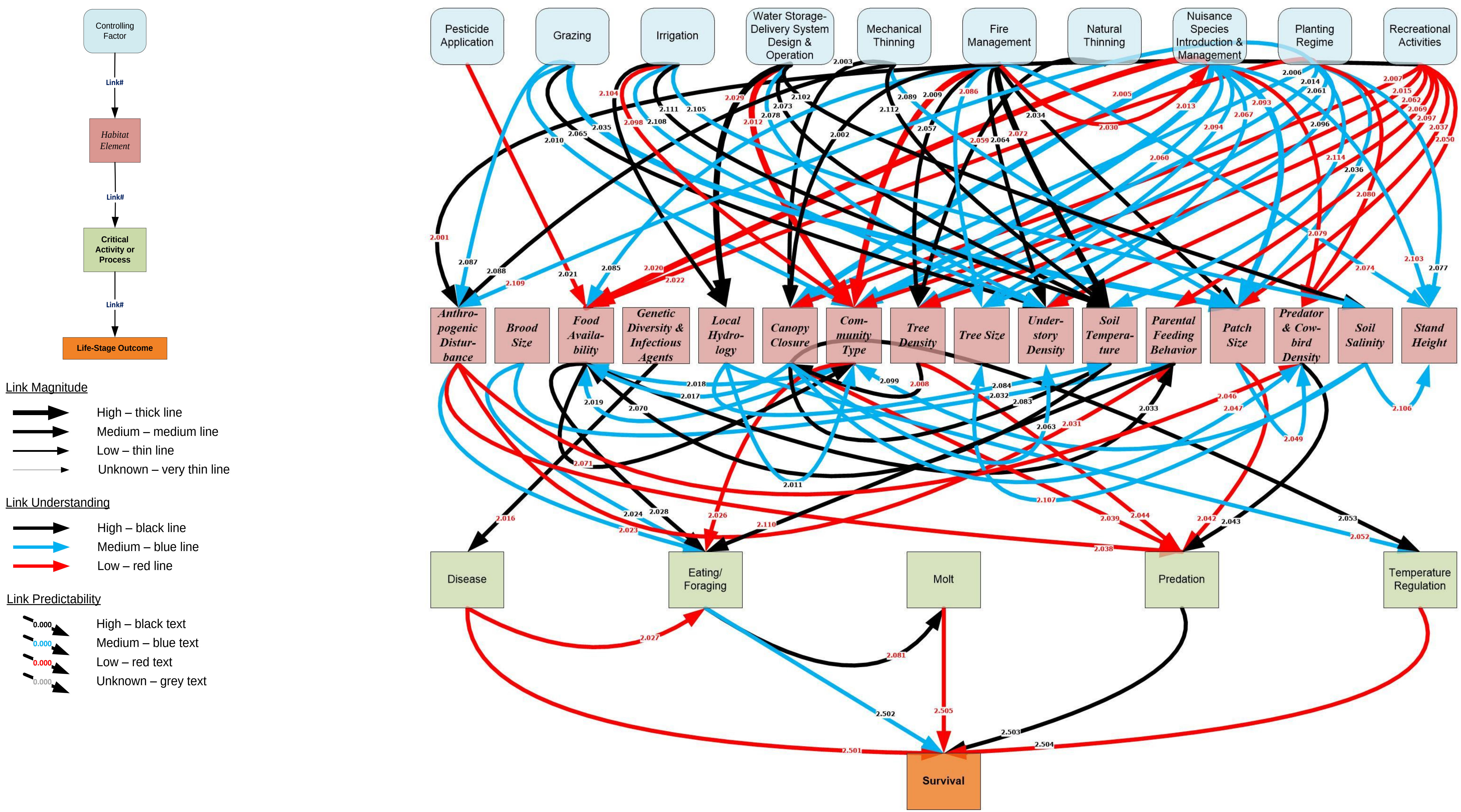

Figure 6.—SUTA Life Stage 2 – Juvenile, high-and medium-magnitude relationships. Only elements with high- or medium-magnitude connections within this life stage are presented.

SUTA LIFE STAGE 3 – BREEDING ADULT

The breeding adult stage begins when the bird returns to the breeding grounds after its first or subsequent winter and ends when it departs the breeding grounds during fall migration. Success during this life stage – successful transition to the next stage – involves organism survival and breeding. Individuals that do not successfully find a territory, floaters, are also included in this category even though they do not breed. The organisms actively interact with their environment.

The CEM (figures 7 and 8) recognizes seven (of seven) critical biological activities and processes for this life stage, and they are presented here as they appear on the following figures:

1. **Disease** – Although the literature does not emphasize disease as affecting population levels of SUTA, we still feel that disease bears mentioning. Diseases and parasites are prevalent in avian populations, so it is safe to assume they have an impact on SUTA (Morishita et al. 1999; Lachish et al. 2011). Disease and parasite impacts along the LCR is an area recommended for further research

   The CEM recognizes genetic diversity and infectious agents as a habitat element influencing the prevalence of disease.

2. **Eating/Foraging** – The breeding adult must forage to feed itself and its young. Both their survival and their young are dependent upon the foraging rate, which can be influenced by a number of factors.

   The CEM recognizes anthropogenic disturbance, brood size, canopy closure, community type, food availability, and parental feeding behavior as primary habitat elements affecting eating/foraging.

3. **Molt** – The adult must molt annually to maintain flight capabilities.

   The CEM does not recognize any habitat elements as directly affecting molt.

   Other critical activities influencing molt include those affecting energy resources such as disease and eating/foraging.

4. **Nest Attendance** – The breeding adult must attend to the nest to incubate eggs, brood young, defend young, and feed young. This primary responsibility falls upon the female, but the male does provide food and nest defense.

   The CEM recognizes anthropogenic disturbance, brood size, and predator and cowbird density as the major factors affecting nest attendance. Disease may have an effect, but it remains unknown.

5. **Nest Site Selection** – This process includes both territory establishment and the placement of nests. Territory establishment is especially important because, if a bird fails to establish a territory (or find a male with a territory in the case of females), the bird will be a floater and is unlikely to breed during that season. The breeding adult must choose where to place territories and nests, thereby affecting breeding success.

   The CEM recognizes anthropogenic disturbance, canopy closure, community type, local hydrology, patch size, predator and cowbird density, stand height, tree density, tree size, and understory density as primary habitat elements affecting nest site selection.

6. **Predation** – Brood parasitism is no longer a threat to the survival of the bird; therefore, it is no longer included with predation. Adults must avoid predation to survive.

   The CEM recognizes anthropogenic disturbance, canopy closure, community type, parental nest attendance, patch size, predator and cowbird density, stand height, tree density, tree size, and understory density as possibly influencing predation rates.

7. **Temperature Regulation** – The adult must maintain an optimum temperature to survive.

   The CEM recognizes canopy closure, local hydrology, and understory density as habitat elements directly affecting temperature regulation. Disease and eating/foraging are critical processes that can also influence temperature regulation.

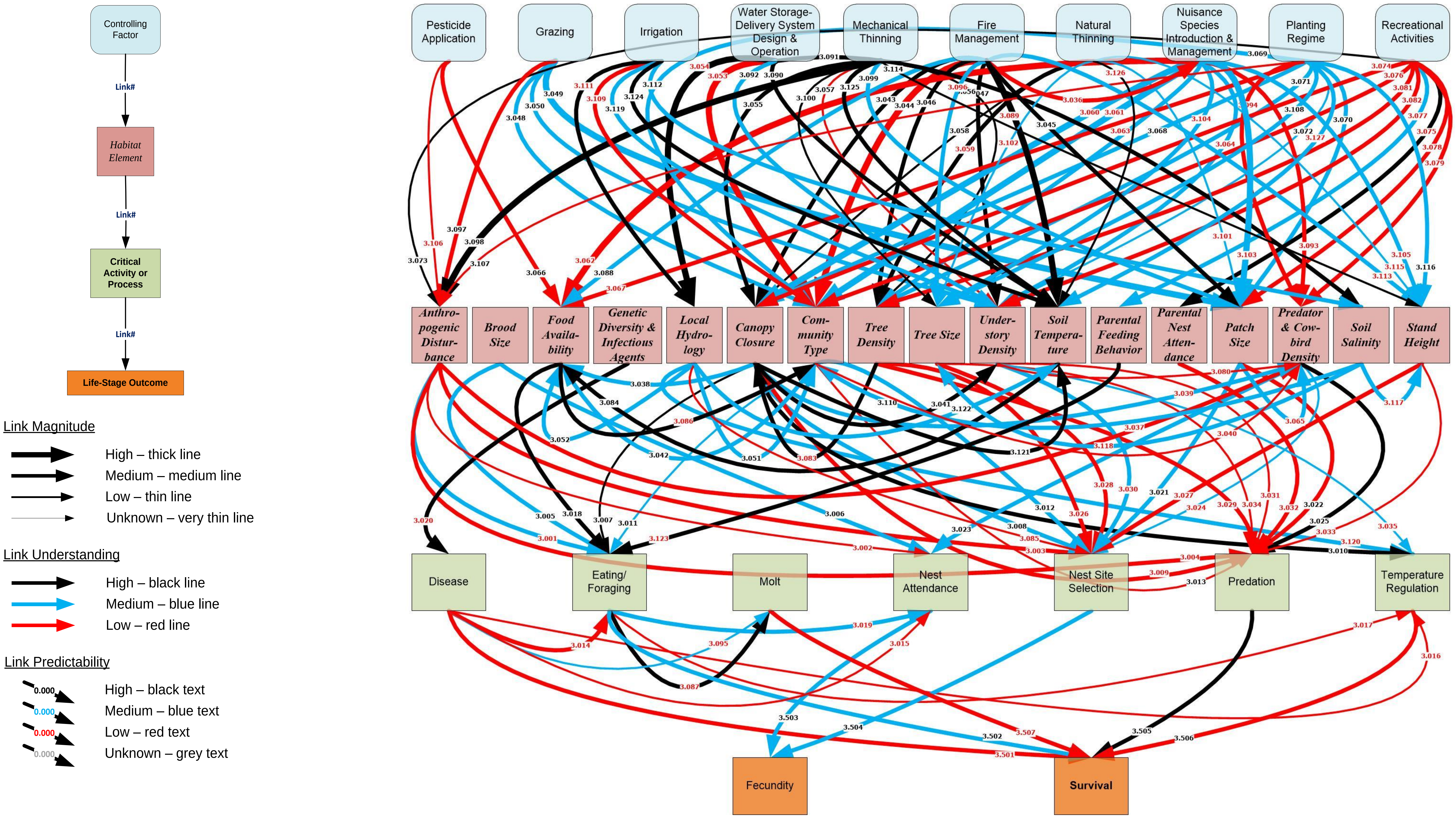

Figure 7.—SUTA Life Stage 3 – Breeding Adult, basic CEM diagram. Only elements with connections within this life stage are presented.

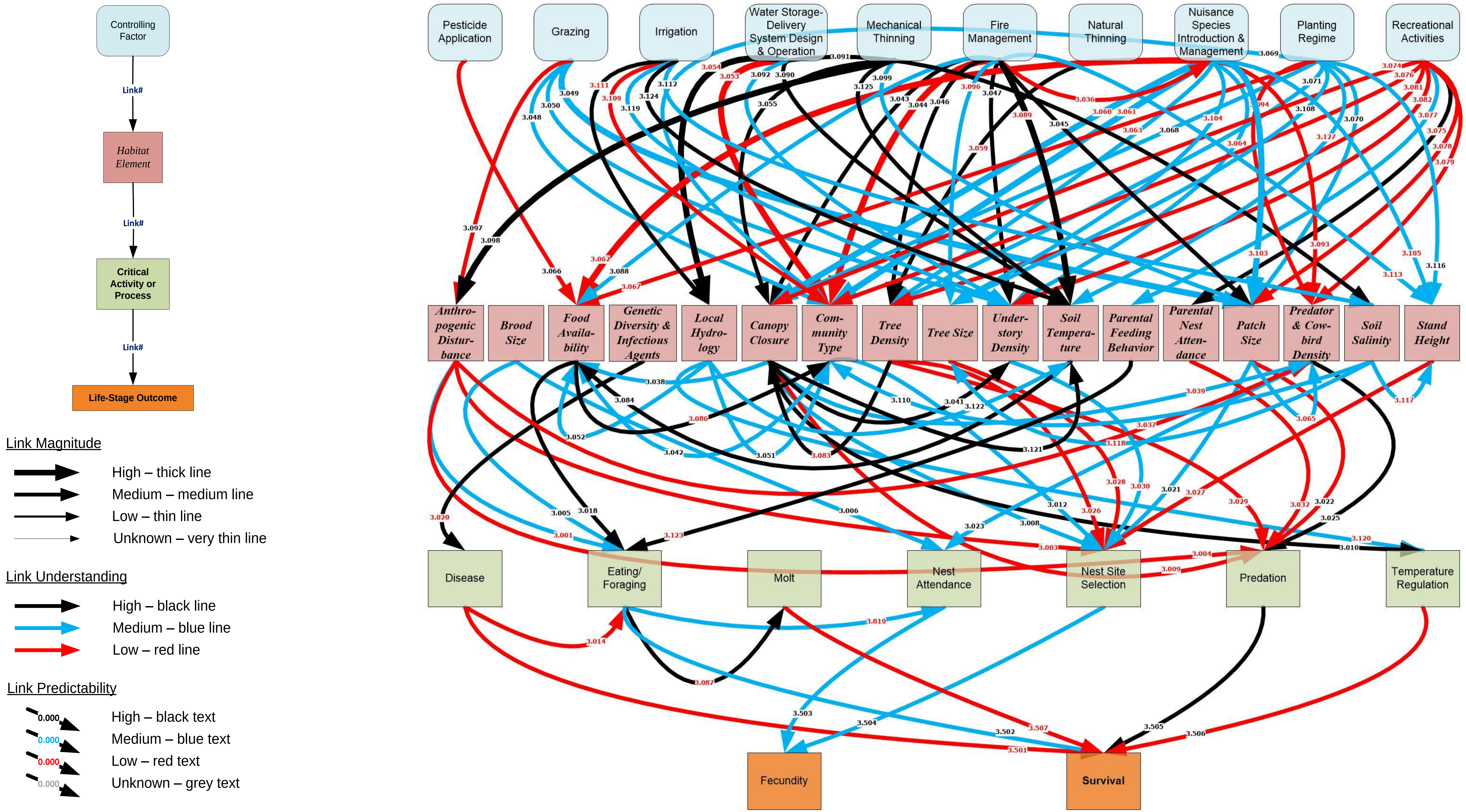

Figure 8.—SUTA Life Stage 3 – Breeding Adult, high- and medium-magnitude relationships. Only elements with high- or medium-magnitude connections within this life stage are presented.

Chapter 7 – Causal Relationships Across All Life Stages

The 10 controlling factors discussed in chapter 5 have the same influence on the same habitat elements for all life stages for which those habitat elements matter. Table 5 shows the magnitudes of *direct* influence of the 10 controlling factors on the 17 habitat elements. The structure of table 5 is the same as for table 4, but table 5 shows the magnitudes of the relationships instead of just their presence/absence. The paragraphs following the table discuss the relative effects of the different controlling factors on each habitat element. The magnitudes of direct influences of controlling factors on habitat elements is color coded in the table as follows:

High = H, Medium = M, Low = L

Table 5.—Magnitude of influence of controlling factors on habitat elements

Controlling factor ➔ / **Habitat element affected ➔**	**Fire management**	**Grazing**	**Irrigation**	**Mechanical thinning**	**Natural thinning**	**Nuisance species introduction and management**	**Pesticide/herbicide application**	**Planting regime**	**Recreational activities**	**Water storage-delivery system design and operation**
Anthropogenic disturbance		**M**		**H**			**L**	**L**	**L**	
Brood size										
Canopy closure	**M**			**M**	**L**	**H**		**M**	**M**	
Community type	**H**	**M**	**M**			**H**		**M**	**M**	**H**
Food availability	**M**					**H**	**M**	**M**		
Genetic diversity and infectious agents										
Local hydrology			**M**							**H**
Parental feeding behavior									**M**	
Parental nest attendance									**M**	
Patch size	**M**	**H**		**M**	**L**	**H**		**M**	**M**	
Predator and cowbird density						**M**		**M**	**M**	
Soil salinity			**M**							**M**
Soil temperature	**H**		**M**	**M**	**L**			**M**		**M**
Stand height	**M**			**L**	**L**	**M**		**M**		
Tree density	**M**			**L**	**M**	**M**		**M**	**M**	
Tree size	**M**			**L**	**L**	**M**		**M**		
Understory density	**M**	**M**	**M**	**L**		**M**		**L**	**M**	**M**

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

ANTHROPOGENIC DISTURBANCE

All activities involving humans increase anthropogenic disturbance. The scale and scope of the influences depend upon the scale and scope of the activity. In general, most activities are of narrow scope and short duration; however, systematic influences can cause repeated noise (e.g., campsites, off-highway vehicle trails, or nearby roads).

CANOPY CLOSURE

The controlling factors that directly affect canopy closure include fire management, mechanical thinning, natural thinning, nuisance species introduction and management, planting regime, and recreational activities. Recreational activities, fire, and mechanical/natural thinning will generally reduce canopy closure, whereas the effects of planting regime and nuisance species introduction and management depend on the management actions and species involved.

Fire affects many aspects of vegetation structure and composition and can destroy SUTA habitat (Engstrom et al. 1984). Fire management can have great effects on vegetation structure and is usually implemented over large areas. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely last less than a decade. Engstrom et al. (1984) found that SUTA were one of the first species to recolonize after a low-intensity fire.

Mechanical thinning is generally done at the patch level, with effects lasting until vegetation grows back, and can be scaled appropriately. Although natural thinning affects canopy closure, it works on small scales, creating forest gaps. The effect only lasts until the vegetation grows back.

Nuisance species can change the structure of entire communities, with lasting effects. Although effects are experienced at a patch level, invasive species can spread across entire regions, and their effects can last for decades unless a complete transformation of the community type occurs.

Planting regimes have the ability to greatly affect vegetation. However, planting decisions are made at the scale of an individual restoration site. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term.

Finally, the potential impact of recreational activities on SUTA habitat is great, although it depends on the activity. Decisions regarding management of recreational activities can affect large areas, but the dynamic nature of both human activity and riparian communities means that effects of recreational activities will likely last less than a decade after the activity is halted.

COMMUNITY TYPE

The controlling factors that directly affect community type are fire management, grazing, irrigation, nuisance species introduction and management, planting regime, recreational activities, and water storage-delivery system design and operation. It is not possible to state whether the effects of controlling factors are positive or negative, as community type is not a numeric variable.

Fire affects many aspects of vegetation structure and composition and can destroy SUTA habitat (Engstrom et al. 1984). Fire management can have great effects on vegetation structure and, thus, community type, and it is usually implemented over either small or large areas. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely last less than a decade. Engstrom et al. (1984) found that SUTA were one of the first species to recolonize after a low-intensity fire.

Grazing affects many aspects of riparian vegetation structure and composition (Kauffman et al. 1997). Grazing activity can have great effects on community composition and is often implemented over large and long scales (Kauffman et al. 1997). However, the dynamic nature of riparian communities means that effects of grazing will likely last less than a decade unless a complete transformation of the community type occurs.

Irrigation and water storage and flow regimes can change the structure of entire plant communities, with lasting effects (Nilsson and Svedmark 2002).

Nuisance species can change the structure of entire communities, with lasting effects. However, although the effects are experienced at a patch level, invasive species can spread across entire regions, and their effects can last decades.

Planting regimes have the ability to greatly affect vegetation. However, planting decisions are made at the scale of individual restoration sites. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term.

Recreational activities can influence the species composition of riparian forests, although it depends on the activity.

FOOD AVAILABILITY

The controlling factors that directly affect the food available to SUTA include fire management, nuisance species introduction and management, pesticide/herbicide application, and planting regime.

Nuisance species can change the arthropod community. Effects of invasive species can spread across entire regions and last for decades.

The magnitude of the effect of pesticides/herbicides depends on many factors, but the potential magnitude is very high. However, the most likely scenario involves pesticide/herbicide applications at individual agricultural fields affecting nearby patches and the effects dissipating less than a decade after application. SUTA rely heavily upon cicadas, bees, and wasps. Beyond these top prey, SUTA appear to be generalists, and thus, a change in the arthropod community might not signify a change in the availability of prey (Rosenberg et al. 1982; Robinson 2012).

Cicada emergence timing and cicada abundance are both controlled by soil temperatures (Smith et al. 2006). Cicadas emerge in the greatest numbers and with timing coinciding with the greatest need by breeding SUTA when the soils are well shaded and cooler (Smith et al. 2006). Controlling factors such as fire management, mechanical thinning, natural thinning, and planting regime that affect canopy cover will, in turn, affect cicada abundance due to the effect on soil temperatures.

LOCAL HYDROLOGY

The only controlling factors affecting local hydrology are irrigation and water storage-delivery system design and operation—it is not possible to put a direction on the effect. The amount of water released or stored affects water levels and therefore distance to water, soil moisture, and other hydrological conditions. Water storage and flow regimes can affect vegetation communities, food abundance and specifically cicada abundance (Nilsson and Svedmark 2002; Smith et al. 2006). The effects of water storage spreads over large scales, but the effects of changes in flow regimes likely last less than a decade unless a complete transformation of the habitat occurs.

PARENTAL FEEDING BEHAVIOR

Parental feeding behavior is influenced by any factors involving humans entering nesting areas during the nesting phase. We have emphasized recreational activities as the most likely sustained disturbance that could be managed. Invasive species could play a role in disturbance if they included novel predators or parasites, but we chose not to include them, as none have been identified.

PARENTAL NEST ATTENDANCE

Parental nest attendance is influenced by any factors involving humans entering nesting areas during the nesting phase. We have emphasized recreational activities as the most likely sustained disturbance that could be managed. Invasive species could play a role in disturbance if they included novel predators or parasites, but we chose not to include them, as none have been identified.

PATCH SIZE

The controlling factors that directly affect patch size include fire management, grazing, mechanical thinning, natural thinning, nuisance species introduction and management, planting regime, and recreational activities. Recreational activities, fire, grazing, and thinning will generally reduce the size of a given patch, whereas the effects of planting regime and nuisance species depend on the management actions and species involved.

Fire affects many aspects of vegetation structure and composition and can destroy SUTA habitat (Engstrom et al. 1984). Fire management can have great effects on vegetation structure and, thus, patch size, and it is usually implemented over large areas. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely be short term. Engstrom et al. (1984) found that SUTA were one of the first species to recolonize after a low-intensity fire.

Grazing affects many aspects of riparian vegetation structure and composition (Kauffman et al. 1997). Grazing activity can have great effects on community composition and patch size and is often implemented over large and long scales (Kauffman et al. 1997). However, the dynamic nature of riparian communities means that the effects of grazing will likely be short term in nature.

Planting regimes have the ability to greatly affect vegetation. However, planting decisions are made at the scale of individual restoration sites. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term, and patch size can be integrated into restoration planning.

Recreational activities can influence the composition of the species' riparian forests, although it depends on the activity.

PREDATOR AND COWBIRD DENSITY

The controlling factors directly affecting predator and cowbird density include nuisance species introduction and management, planting regime, and recreational activities. The direction and size of these effects are difficult to quantify. Some studies have shown predator presence differs among community types, native and non-native habitats (Schmidt et al. 2005). Any change in the composition of the predator community can have a large and lasting impact on the SUTA population (Lima et al. 2009).

SOIL SALINITY

The controlling factors directly affecting soil salinity include irrigation and water storage-delivery system design and operation. Soil salinity is affected by the amount of water reaching the soil and the salinity of the water (San Joaquin River Restoration Program 2014). Main stem water generally has lower salinity levels than groundwater and, thus, can have a large impact on lowering soil salinity (San Joaquin River Restoration Program 2014).

SOIL TEMPERATURE

The controlling factors influencing soil temperature generally include all of the factors affecting canopy closure (fire management, mechanical thinning, natural thinning, and planting regime), with the addition of irrigation and water storage-delivery system design and operation. Fire and thinning will generally reduce canopy closure, increasing soil temperatures, whereas the effects of irrigation will be to decrease soil temperatures. Water storage-delivery system design and operation and planting regime depend on the management actions and the species involved.

STAND HEIGHT

The controlling factors directly affecting stand height include fire management, mechanical thinning, natural thinning, and planting regime. Stand height can also be influenced by nuisance species introduction and management depending upon the species and the management practices implemented.

Fire affects many aspects of vegetation structure and composition and can destroy SUTA habitat (Engstrom et al. 1984). Fire management can have great effects on vegetation structure and can be implemented over small or large areas.

Mechanical thinning is generally performed at the patch level, with effects lasting until vegetation grows back, and can be as intense as managers wish. Although natural thinning affects stand height, it works on small scales, creating forest gaps. The effect only lasts until the vegetation grows back.

Planting regimes have the ability to greatly affect vegetation. The timing and type of trees planted can impact stand height in the long run. However, planting decisions are made at the scale of an individual restoration site. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term.

TREE DENSITY

The controlling factors that directly affect tree density include fire management, mechanical thinning, natural thinning, nuisance species introduction and management, planting regime, and recreational activities. Recreational activities, fire, and mechanical/natural thinning will generally reduce tree density, whereas the effects of planting regime and nuisance species introduction and management depend on the management actions and species involved.

Fire affects many aspects of vegetation structure and composition and can destroy SUTA habitat (Engstrom et al. 1984). Fire management can have great effects on vegetation structure and is usually implemented over large areas. However, the dynamic nature of both fire and riparian communities means that the effects of fire management will likely last less than a decade. Engstrom et al. (1984) found that SUTA were one of the first species to recolonize after a low-intensity fire.

Mechanical thinning would be done at the patch level, with effects lasting until vegetation grows back, and can be as intense as managers choose. Although natural thinning affects tree density, it works on small scales, creating forest gaps. The effect only lasts until the vegetation grows back.

Nuisance species can change the structure of entire communities, with lasting effects. Although effects are experienced at a patch level, invasive species can spread across entire regions, and their effects can last for decades unless a complete transformation of the community type occurs.

Planting regimes have the ability to greatly affect vegetation. However, planting decisions are made at the scale of an individual restoration site. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term.

Finally, the potential impact of recreational activities on SUTA habitat is great, although it depends on the activity. Decisions regarding management of recreational activities can affect large areas, but the dynamic nature of both human activity and riparian communities means that effects of recreational activities will likely last less than a decade after the activity is halted.

TREE SIZE

The controlling factors directly affecting tree size include fire management, mechanical thinning, natural thinning, nuisance species introduction and management, and planting regime.

Fire and thinning will generally reduce tree size, whereas the effects of planting regime and nuisance species introduction and management depend on the management actions and species involved. Fire affects many aspects of vegetation structure and composition and can destroy SUTA habitat (Engstrom et al. 1984). Fire management can have great effects on vegetation structure and can be implemented over small or large areas.

Mechanical thinning is generally performed at the patch level, with effects lasting until vegetation grows back, and can be as intense as managers wish. Although natural thinning affects tree size, it works on small scales, creating forest gaps. The effect only lasts until other trees grow larger.

Planting regimes have the ability to greatly affect vegetation. The timing and type of trees planted can impact tree cover in the long run. However, planting decisions are made at the scale of an individual restoration site. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term.

UNDERSTORY DENSITY

The controlling factors that directly affect understory density include fire management, grazing, irrigation, mechanical thinning, nuisance species introduction and management, planting regime, recreational activities, and water storage-delivery system design and operation. Recreational activities, fire, and thinning will generally reduce understory density, whereas the effects of nuisance species introduction and management, planting regime, and water storage-delivery system design and operation depend on the management actions and species involved. The effect of irrigation depends upon the quantity and source of the water, especially as it relates to soil salinity (San Joaquin River Restoration Program 2014).

Fire affects many aspects of vegetation structure and composition and can destroy SUTA habitat (Engstrom et al. 1984). Fire management can have great effects on vegetation structure and is usually implemented over large areas. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely last less than a decade. Engstrom et al. (1984) found that SUTA were one of the first species to recolonize after a low-intensity fire.

Grazing affects many aspects of riparian vegetation structure and composition (Kauffman et al. 1997). Grazing activity can have great effects on community composition and is often implemented over large and long scales (Kauffman et al. 1997). However, the dynamic nature of riparian communities means that the effects of grazing will likely last less than a decade.

Irrigation has two effects on the understory. By increasing irrigation, soil moisture increases, and the understory cover may increase. However, irrigation also influences soil salinity, and this depends upon the source of the water.

Mechanical thinning would be done at the patch level, with effects lasting until vegetation grows back, and can be as intense as managers choose. The effect only lasts until the vegetation grows back.

Nuisance species can change the structure of entire communities, with lasting effects. Although effects are experienced at a patch level, invasive species can spread across entire regions, and their effects can last for decades unless a complete transformation of the community type occurs.

Planting regimes have the ability to greatly affect vegetation. However, planting decisions are made at the scale of individual restoration sites. Although riparian communities tend to be ephemeral, restoration sites are heavily managed, so the effects are likely medium or even long term.

The potential impact of recreational activities on SUTA habitat is great, although it depends on the activity. Decisions regarding management of recreational activities can affect large areas, but the dynamic nature of both human activity and riparian communities means that effects of recreational activities will likely last less than a decade after the activity is halted. Many recreational activities are increasing within the area, so these effects could be long term in nature, and some may cause a permanent transition within the ecosystem.

Finally, the amount of water released or stored affects water levels and therefore distance to water, soil moisture, and other hydrological conditions. Water storage and flow regimes, specifically floods, can affect understory density (Hunter 1987a; Lite et al. 2005). The effects of flood spreads over large scales, but the effects of changes in flow regimes likely last less than a decade unless a complete transformation of the habitat occurs.

Chapter 8 – Discussion and Conclusions

This chapter summarizes the findings of this assessment in three ways by posing three questions: (1) which critical biological activities and processes most strongly affect the individual life stages across all life stages (2) which habitat elements, in terms of their abundance, distribution, and quality, most strongly affect the most influential activities and processes, and (3) which of these causal relationships appear to be the least understood in ways that could affect their management?

MOST INFLUENTIAL ACTIVITIES AND PROCESSES ACROSS ALL LIFE STAGES

Figure 9 identifies the critical biological activities and processes that this assessment found most strongly directly or indirectly affect the success of each life stage (high or medium magnitude). The findings presented in this diagram may be summarized as follows:

- Predation and eating/foraging are the most important critical biological activities and processes affecting survival of SUTA at all life stages. Depredation of nests can be high and has been shown to be the primary cause of nest failure (exceeding 80 percent) (Powell and Steidl 2000). The effects act at the landscape level. Other processes such as disease, molt, and temperature regulation are important, but the effects are less certain.

- Only two processes directly affect reproduction—nest attendance and nest site selection. These two critical biological activities and processes are especially important because they also affect nestling survival.

POTENTIALLY PIVOTAL ALTERATIONS TO HABITAT ELEMENTS

Figure 10 identifies the habitat elements that this assessment indicates most strongly directly or indirectly affect the critical biological activities and processes identified on figure 9 across all life stages (high or medium magnitude). The findings presented in this diagram may be summarized as follows:

- Nest site selection is by far affected by the most habitat variables. It has been the most studied among the factors influencing this species. It is probably the top determinant as to whether individual birds choose to nest in the area.

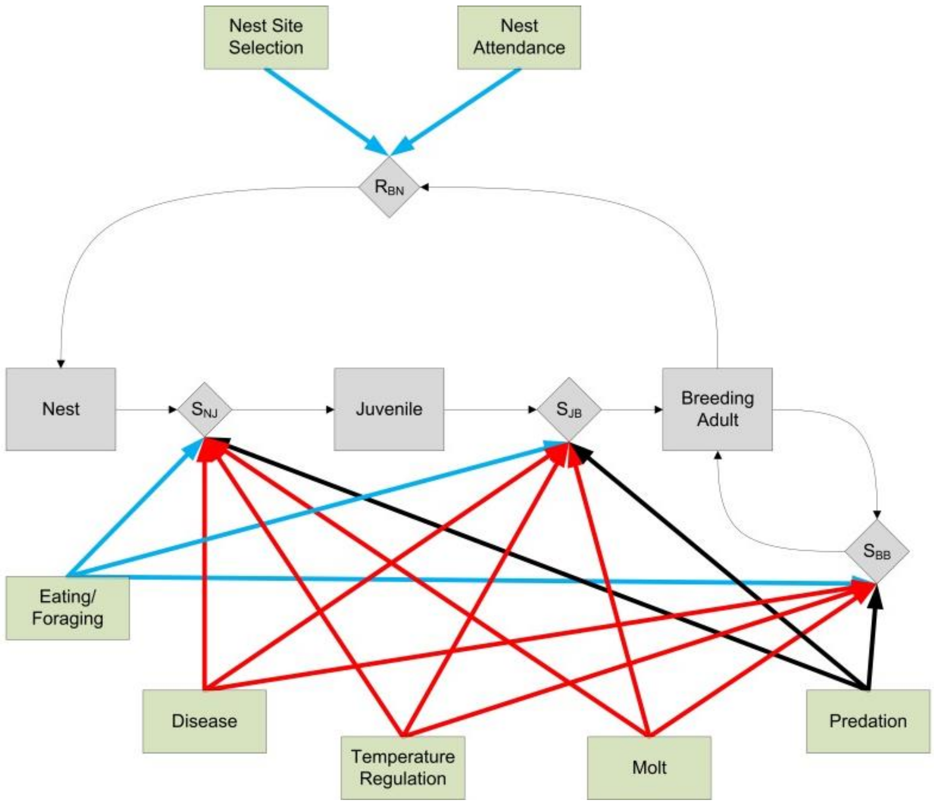

Figure 9.—Most influential biological activities and processes affecting each life stage of SUTA.
Only elements with high- or medium-magnitude connections are presented. The legend is provided on figure 2.

- Predation and brood parasitism may be influenced by many of the same habitat variables as nest site selection; however, less is known in this area. Patch size can affect predation rates because of its effects on the proportion of habitat near the edge of the patch, an area that has been shown to have higher predation rates (Chalfoun and Martin 2009; Theimer et al. 2011). Predator density affects predation rates (Lima 2009).

- Nest attendance is only strongly affected by brood size and predator and cowbird density. Brood size can influence the adult's commitment to the nest and affect the amount of time adult SUTA must spend foraging versus attending the nest. Predator density can influence nest defense behavior and thus nest attendance. Food availability impacts nest attendance indirectly by influencing foraging time.

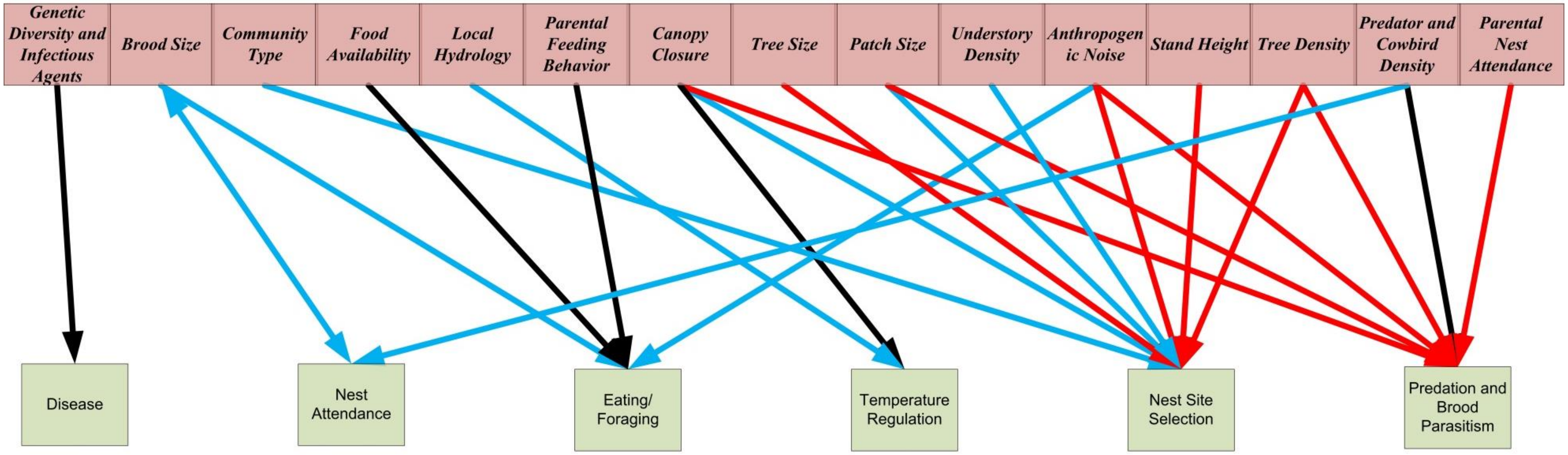

Figure 10.—Habitat elements that directly or indirectly affect the most influential biological activities and processes across all life stages of SUTA.
Only elements with high- or medium-magnitude connections within this life stage are presented. The legend is provided on figure 2.

- Anthropogenic disturbance, brood size, and food availability (specifically cicada availability) all drive the ability of SUTA at each life stage to acquire needed energy and nutrients. Furthermore, the parent's feeding behavior can influence the eating rate of juveniles and nestlings.

- Disease and temperature regulation are important physiological concerns that can be impacted strongly by habitat elements such as local hydrology and canopy closure as well as the presence of genetic diversity and infectious agents.

GAPS IN UNDERSTANDING

Figures 9 and 10 use the conventional color coding of individual causal relationships to identify relationships that the CEM identifies as having high, intermediate, or low levels of scientific confirmation. As noted in attachment 1, "Low" scientific understanding of a relationship means that it is "… subject to wide disagreement or uncertainty in peer-reviewed studies from within the ecosystem of concern and in scientific reasoning among experts familiar with the ecosystem." In many cases, the scientific principles are well understood, but the factual details are insufficiently understood within the LCR. The two figures show large numbers of red arrows, indicating relationships that the assessment identifies as having a low level of scientific understanding. Each of these red arrows identifies a causal relationship that may warrant further field, laboratory, or literature investigation. The following paragraphs highlight some potentially important areas of low understanding.

- Nest site selection is by far affected by the most habitat variables and is one of the most well-understood processes. However, many gaps in knowledge exist, and the sensitivity of the species to subtle changes in the nest stands and their adaptation to invasive tamarisk are not thoroughly understood.

- The effects of predation on juveniles and adults is poorly understood, whereas nest predation is better studied. This likely reflects the relative ease of studying depredation of nests versus free-flying birds. If the persistence or population growth of SUTA populations is considered sensitive to the survival of adults and juveniles, then research regarding predation should be considered.

- The indirect influences on food availability has a large impact on eating/foraging, which is then directly linked with survival of SUTA at all life stages. Further investigation into these indirect effects is warranted.

- The effects of disease, ecto-parasites, and endo-parasites have not been studied in SUTA or among passerine species inhabiting the LCR. Diseases have the potential to have dramatic impacts on populations (Robinson et al. 2010).

This list of uncertainties is not meant to be exhaustive but only to highlight topics the literature identifies as potentially pivotal to SUTA recruitment along the LCR and to identify important knowledge gaps in these publications. They are not in any way to be considered guidance for Reclamation or LCR MSCP, nor are these knowledge gaps expected to be addressed under the program.

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ATTACHMENT 1

Species Conceptual Ecological Model Methodology for the Lower Colorado River Multi-Species Conservation Program

OVERVIEW OF METHODOLOGY

The conceptual ecological models (CEMs) for species covered by the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) Habitat Conservation Plan expand on a methodology developed by the Sacramento-San Joaquin Delta Ecosystem Restoration Program (ERP): https://www.dfg.ca.gov/ERP/conceptual_models.asp. The ERP is jointly implemented by the California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. The Bureau of Reclamation participates in this program.

The ERP methodology incorporates common best practices for constructing CEMs for individual species (Wildhaber et al. 2007; Fischenich 2008; DiGennaro et al. 2012). It has the following key features:

- It focuses on the *major life stages or events* through which each species passes and the *output(s)* of each life stage or event. Outputs typically consist of survivorship or the production of offspring.

- It identifies the *major drivers* that affect the likelihood (rate) of each output. Drivers are physical, chemical, or biological factors – both natural and anthropogenic – that affect output rates and therefore control the viability of the species in a given ecosystem.

- It characterizes these interrelationships using a "*driver-linkage-outcomes*" approach. Outcomes are the output rates. Linkages are cause-effect relationships between drivers and outcomes.

- It *characterizes each causal linkage* along four dimensions: (1) the character and direction of the effect, (2) the magnitude of the effect, (3) the predictability (consistency) of the effect, and (4) the certainty of present scientific understanding of the effect (DiGennaro et al. 2012).

The CEM methodology used for species covered by the LCR MSCP Habitat Conservation Plan species expands this ERP methodology. Specifically, the present methodology incorporates the recommendations and examples of Wildhaber et al. (2007, 2011), Kondolf et al. (2008), and Burke et al. (2009) for a more hierarchical approach and adds explicit demographic notation for the characterization of life-stage outcomes (McDonald and Caswell 1993). This expanded approach provides greater detail on causal linkages and outcomes. The expansion specifically calls for identifying **four** types of model components for each life stage, and the causal linkages among them, as follows:

- **Life-stage outcomes** are outcomes of an individual life stage, including the recruitment of individuals to the next succeeding life stage (e.g., juvenile to adult). For some life stages, the outcomes, alternatively or additionally, may include the survival of individuals to an older age class within the same life stage or the production of offspring. The rates of life-stage outcomes depend on the rates of the critical biological activities and processes for that life stage.

- **Critical biological activities and processes** are activities in which a species engages and the biological processes that must take place during each life stage that significantly affect life-stage outcomes. They include activities and processes that may benefit or degrade life-stage outcomes. Examples of critical activities and processes include mating, foraging, avoiding predators, avoiding other specific hazards, gamete production, egg maturation, leaf production, and seed germination. Critical activities and processes are "rate" variables. Taken together, the rate (intensity) of these activities and processes determine the rates of different life-stage outcomes.

- **Habitat elements** are specific habitat conditions that significantly ensure, allow, or interfere with critical biological activities and processes. The full suite of natural habitat elements constitutes the natural habitat template for a given life stage. Human activities may introduce habitat elements not present in the natural habitat template. Defining a habitat element may involve estimating the specific ranges of quantifiable properties of that element *whenever the state of knowledge supports such estimates*. These properties concern the abundance, spatial and temporal distributions, and other qualities of the habitat element that significantly affect the ways in which it ensures, allows, or interferes with critical biological activities and processes.

- **Controlling factors** are environmental conditions and dynamics – both natural and anthropogenic – that determine the quality, abundance, and spatial and temporal distributions of one or more habitat elements. In some instances, a controlling factor alternatively or additionally may directly affect a critical biological activity or process. Controlling factors are also called "drivers." A hierarchy of controlling factors will exist, affecting the system at different temporal and spatial scales. Long-term dynamics of climate and geology define the domain of this hierarchy (Burke et al. 2009). For example, the availability of suitable nest sites for a riparian nesting bird may depend on factors such as canopy cover, community type, humidity, and intermediate structure which, in turn, may depend on factors such as water storage-delivery system design and operation (dam design, reservoir morphology, and dam operations) which, in turn, is shaped by watershed geology, vegetation, climate, land use, and water demand. *The LCR MSCP conceptual ecological models focus* *on controlling factors that are within the scope of potential human manipulation, including management actions directed toward the species of interest.*

The present CEM methodology also explicitly defines a "life stage" as a biologically distinct portion of the life cycle of a species. The individuals in each life stage undergo distinct developments in body form and function; engage in distinct types behaviors, including reproduction; use different sets of habitats or the same habitats in different ways; interact differently with their larger ecosystems; and/or experience different types and sources of stress. A single life stage may include multiple age classes. A CEM focused on life stages is not a demographic model per se (McDonald and Caswell 1993). Instead, it is a complementary model focused on the ecological factors (drivers) that shape population dynamics.

This expanded approach permits the consideration of **six** possible types of causal relationships, on which management actions may focus, for each life stage of a species:

(1) The effect of one controlling factor on another

(2) The effect of a controlling factor on the abundance, spatial and temporal distributions, and other qualities of a habitat element

(3) The effect of the abundance, spatial and temporal distributions, and other qualities of one habitat element on those of another

(4) The effect of the abundance, spatial and temporal distributions, and other qualities of a habitat element on a critical biological activity or process

(5) The effect of one critical biological activity or process on another

(6) The effect of a critical biological activity or process on a specific life-stage outcome

Each controlling factor may affect the abundance, spatial and temporal distributions, and other qualities of more than one habitat element and several controlling factors may affect the abundance, spatial or temporal distributions, or other qualities of each habitat element. Similarly, the abundance, spatial and temporal distributions, and other qualities of each habitat element may affect more than one biological activity or process, and the abundances, spatial or temporal distributions, or other qualities of several habitat elements may affect each biological activity or process. Finally, the rate of each critical biological activity or process may contribute to the rates of more than one life-stage outcome.

Integrating this information across all life stages for a species provides a detailed picture of: (1) what is known, with what certainty, and the sources of this information; (2) critical areas of uncertain or conflicting science that demand resolution to better guide LCR MSCP management planning and action; (3) crucial attributes to use to monitor system conditions and predict the effects of experiments, management actions, and other potential agents of change; and (4) how managers may expect the characteristics of a resource to change as a result of changes to controlling factors, including changes in management actions.

Conceptual Ecological Models as Hypotheses

The CEM for each species produced with this methodology constitutes a collection of hypotheses for that species. These hypotheses concern: (1) the species' life history; (2) the species' habitat requirements and constraints; (3) the factors that control the quality, abundance, and spatial and temporal distributions of these habitat conditions; and (4) the causal relationships among these. Knowledge about these model components and relationships may vary, ranging from well settled to very tentative. Such variation in the certainty of current knowledge always arises as a consequence of variation in the types and amount of evidence available and in the ecological assumptions applied by different experts.

Wherever possible, the information assembled for the LCR MSCP species CEMs documents the degree of certainty of current knowledge concerning each component and linkage in the model. This certainty is indicated by the quality, abundance, and consistency of the available evidence and by the degree of agreement/disagreement among the experts. Differences in the interpretations or arguments offered by different experts may be represented as alternative hypotheses. Categorizing the degree of agreement/disagreement concerning the components and linkages in a CEM makes it easier to identify topics of greater uncertainty or controversy.

Characterizing Causal Relationships

A causal relationship exists when a change in one condition or property of a system results in a change in some other condition or property. A change in the first condition is said to cause a change in the second condition. The present CEM methodology includes methods for assessing causal relationships (links) along four dimensions (attributes) adapted from the ERP methodology (DiGennaro et al. 2012):

(1) The character and direction of the effect

(2) The magnitude of the effect

(3) The predictability (consistency) of the effect

(4) The certainty of present scientific understanding of the effect

The present and ERP methodologies for assessing causal linkages differ in three ways. First, the ERP methodology assesses these four attributes for the *cumulative* effect of the entire causal chain leading up to each outcome. However, the LCR MSCP methodology recognizes six different types of causal linkages as described above. This added level of detail and complexity makes it difficult in a single step to assess the cumulative effects of all causal relationships that lead up to any one individual causal link. For example, in the present methodology, the effect of a given critical biological activity or process on a particular life-stage outcome may depend on the effects of several habitat elements on that critical biological activity or process which, in turn, may depend on the effects of several controlling factors. For this reason, the present methodology assesses the four attributes separately for each causal link *by itself* rather than attempting to assess cumulative effects of all causal linkages leading to the linkage of interest. The present methodology assesses cumulative effects instead through analyses of the data assembled on all individual linkages. The analyses are made possible by assembling the data on all individual linkages in a spreadsheet as described below.

Second, the present CEM methodology explicitly divides link magnitude into three separate subattributes and provides a specific methodology for integrating their rankings into an overall ranking for link magnitude: (1) link intensity, (2) link spatial scale, and (3) link temporal scale. In contrast, the ERP methodology treats spatial and temporal scale together and does not separately evaluate link intensity. The present methodology defines link intensity as the relative strength of the effect of the causal node on the affected node *at the places and times where the effect occurs*. Link spatial scale is the relative spatial extent of the effect of the causal node on the affected node. Link temporal scale is the relative temporal extent of the effect of the causal node on the affected node. The present methodology defines link magnitude as the average of the separate rankings of link intensity, spatial scale, and temporal scale as described below.

Third, the ERP methodology addresses a single, large landscape, while the present methodology needed the flexibility to generate models applicable to a variety of spatial scopes. For example, the present methodology needed to support modeling of a single restoration site, the LCR main stem and flood plain, or the entire Lower Colorado River Basin. Consequently, the present methodology assesses the spatial scale of cause-effect relationships only relative to the spatial scope of the model.

The LCR MSCP conceptual ecological model methodology thus defines the four attributes for a causal link as follows:

- **Link character** – This attribute categorizes a causal relationship as positive, negative, involving a threshold response, or "complex." "Positive" means that an increase in the causal node results in an increase in the affected node, while a decrease in the causal node results in a decrease in the affected node. "Negative" means that an increase in the causal node results in a decrease in the affected element, while a decrease in the causal node results in an increase in the affected node. Thus, "positive" or "negative" here do ***not*** mean that a relationship is beneficial or detrimental. The terms instead provide information analogous to the sign of a correlation coefficient. "Threshold" means that a change in the causal agent must cross some value before producing an effect. "Complex" means that there is more going on than a simple positive, negative, or threshold effect. In addition, this attribute categorizes a causal relationship as uni- or bi-directional. Bi-directional relationships involve a reciprocal relationship in which each node affects the other.

- **Link magnitude** – This attribute refers to "… the degree to which a linkage controls the outcome *relative to other drivers*" (DiGennaro et al. 2012). Magnitude takes into account the spatial and temporal scale of the causal relationship as well as the strength (intensity) of the relationship in individual locations. The present methodology provides separate ratings for the intensity, spatial scale, and temporal scale of each link, as defined above, and assesses overall link magnitude by averaging these three elements. Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link magnitude provide information analogous to the size of a correlation coefficient. Tables 1-1 through 1-4 present the rating framework for link magnitude.

- **Link predictability** – This attribute refers to "… the degree to which the current understanding of the system can be used to predict the role of the driver in influencing the outcome. Predictability … captures variability … [and recognizes that] effects may vary so much that properly measuring and statistically characterizing inputs to the model are difficult" (DiGennaro et al. 2012). A causal relationship may be unpredictable because of natural variability in the system or because its effects depend on the interaction of other factors with independent sources for their own variability. Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link predictability provide information analogous to the size of the range of error for a correlation coefficient. Table 1-5 presents the scoring framework for link predictability.

- **Link understanding** refers to the degree of agreement represented in the scientific literature and among experts in understanding how each driver is linked to each outcome. Table 1-6 presents the scoring framework for understanding. Link predictability and understanding are independent attributes. A link may be considered highly predictable but poorly understood or poorly predictable but well understood.

Conceptual Ecological Model Documentation

The documentation for each CEM provides information in three forms: (1) a narrative report, (2) causal diagrams showing the model components and their causal linkages for each life stage, and (3) a spreadsheet that is used to record the detailed information (e.g., linkage attribute ratings) for each causal linkage. The spreadsheet and diagrams, built using Microsoft Excel™ and Microsoft Visio™, respectively, are linked so that the diagrams provide a fully synchronized summary of the information in the spreadsheet.

The narrative report for each species presents the definitions and rationales for the life stages/events and their outcomes identified for the species' life history; the critical biological activities and processes identified for each life stage; the habitat elements identified as supporting or impeding each critical biological activity or process for each life stage; the controlling factors identified as affecting the abundance, spatial and temporal distributions, and other qualities of the habitat elements for each life stage; and the causal linkages among these model components.

The narrative report includes causal diagrams (*aka* "influence diagrams") for each life stage. These diagrams show the individual components or nodes of the model for that stage (life-stage outcomes, critical biological activities and processes, habitat elements, and controlling factors) and their causal relationships. The causal relationships (causal links) are represented by arrows indicating which nodes are linked and the directions of the causal relationships. The attributes of each causal link are represented by varying line thickness, line color, and other visual properties as shown on figure 1-1. The diagram conventions mostly follow those in the ERP methodology (DiGennaro et al. 2012).

The spreadsheet for each CEM contains a separate worksheet for each life stage. Each row in the worksheet for a life stage represents a single causal link. Table 1-7 lists the fields (columns) recorded for each causal link.

Link Attribute Ratings, Spreadsheet Fields, and Diagram Conventions

Table 1-1.—Criteria for rating the relative intensity of a causal relationship – one of three variables in the rating of link magnitude (after DiGennaro et al. 2012, Table 2)

Link intensity – the relative strength of the effect of the causal node on the affected node *at the places and times where the effect occurs*.	
High	Even a relatively small change in the causal node will result in a relatively large change in the affected node *at the places and times where the effect occurs*.
Medium	A relatively large change in the causal node will result in a relatively large change in the affected node; a relatively moderate change in the causal node will result in no more than a relatively moderate change in the affected node; and a relatively small change in the causal node will result in no more than a relatively small change in the affected node *at the places and times where the effect occurs*.
Low	Even a relatively large change in the causal node will result in only a relatively small change in the affected node *at the places and times where the effect occurs*.
Unknown	Insufficient information exists to rate link intensity.

Table 1-2.—Criteria for rating the relative spatial scale of a cause-effect relationship – one of three variables in the rating of link magnitude (after DiGennaro et al. 2012, Table 1)

Link spatial scale – the relative spatial extent of the effect of the causal node on the affected node. The rating takes into account the spatial scale of the cause and its effect.	
Large	Even a relatively small change in the causal node will result in a change in the affected node across a large fraction of the spatial scope of the model.
Medium	A relatively large change in the causal node will result in a change in the affected node across a large fraction of the spatial scope of the model; a relatively moderate change in the causal node will result in a change in the affected node across no more than a moderate fraction of the spatial scope of the model; and a relatively small change in the causal node will result in a change in the affected node across no more than a small fraction of the spatial scope of the model.
Small	Even a relatively large change in the causal node will result in a change in the affected node across only a small fraction of the spatial scope of the model.
Unknown	Insufficient information exists to rate link spatial scale.

Table 1-3.—Criteria for rating the relative temporal scale of a cause-effect relationship – one of three variables in the rating of link magnitude (after DiGennaro et al. 2012, Table 1)

Link temporal scale – the relative temporal extent of the effect of the causal node on the affected node. The rating takes into account the temporal scale of the cause and its effect.	
Large	Even a relatively small change in the causal node will result in a change in the affected node that persists or recurs over a relatively large span of time – decades or longer – even without specific intervention to sustain the effect.
Medium	A relatively large change in the causal node will result in a change in the affected node that persists or recurs over a relatively large span of time – decades or longer – even without specific intervention to sustain the effect; a relatively moderate change in the causal node will result in a change in the affected node that persists or recurs over only a relatively moderate span of time – one or two decades – without specific intervention to sustain the effect; a relatively small change in the causal node will result in a change in the affected node that persists or recurs over only a relatively short span of time – less than a decade – without specific intervention to sustain the effect.
Small	Even a relatively large change in the causal node will result in a change in the affected node that persists or recurs over only a relatively short span of time – less than a decade – without specific intervention to sustain the effect.
Unknown	Insufficient information exists to rate link temporal scale.

Table 1-4.—Criteria for rating the overall relative link magnitude of a cause-effect relationship based on link intensity, spatial scale, and temporal scale

Link magnitude – the overall relative magnitude of the effect of the causal node on the affected node based on the numerical average for link intensity, spatial scale, and temporal scale. (Calculated by assigning a numerical value of 3 to “High” or “Large,” 2 to “Medium,” 1 to “Low” or “Small,” and not counting missing or “Unknown” ratings.)	
High	Numerical average ≥ 2.67
Medium	Numerical average ≥ 1.67 but < 2.67
Low	Numerical average < 1.67
Unknown	No subattribute is rated High/Large, Medium, or Low/Small, but at least one subattribute is rated Unknown.

Table 1-5.—Criteria for rating the relative predictability of a cause-effect relationship (after DiGennaro et al. 2012, Table 3)

Link predictability – the statistical likelihood that a given causal agent will produce the effect of interest.	
High	Magnitude of effect is largely unaffected by random variation or by variability in other ecosystem dynamics or external factors.
Medium	Magnitude of effect is moderately affected by random variation or by variability in other ecosystem processes or external factors.
Low	Magnitude of effect is strongly affected by random variation or by variability in other ecosystem processes or external factors.
Unknown	Insufficient information exists to rate link predictability.

Table 1-6.—Criteria for rating the relative understanding of a cause-effect relationship (after DiGennaro et al. 2012, Table 3)

Understanding – the degree of agreement in the literature and among experts on the magnitude and predictability of the cause-effect relationship of interest.	
High	Understanding of the relationship is subject to little or no disagreement or uncertainty in peer-reviewed studies from within the ecosystem of concern or in scientific reasoning among experts familiar with the ecosystem. Understanding may also rest on well-accepted scientific principles and/or studies in highly analogous systems.
Medium	Understanding of the relationship is subject to moderate disagreement or uncertainty in peer-reviewed studies from within the ecosystem of concern and in scientific reasoning among experts familiar with the ecosystem.
Low	Understanding of the relationship is subject to wide disagreement, uncertainty, or lack of evidence in peer-reviewed studies from within the ecosystem of concern and in scientific reasoning among experts familiar with the ecosystem.
Unknown	(*The "Low" rank includes this condition*).

Table 1-7.—Organization of the worksheet for each life stage

Col.	Label	Content
A	Species	Identifies the species being modeled by four-letter code.
B	Link#	Contains a unique identification number for each causal link.
C	Life Stage	Identifies the life stage affected by the link.
D	Causal Node Type	Identifies whether the causal node for the link is a controlling factor, habitat element, critical biological activity or process, or life-stage outcome.
E	Causal Node	Identifies the causal node in the link.
F	Effect Node Type	Identifies whether the effect node for the link is a controlling factor, habitat element, critical biological activity or process, or life-stage outcome.
G	Effect Node	Identifies the effect node in the link.
H	Link Reason	States the rationale for including the link in the conceptual ecological model, including citations as appropriate.
I	Link Character Type	Identifies the character of the link based on standard definitions.
J	Link Character Direction	Identifies whether the link is uni- or bi-directional.
K	Link Character Reason	States the rationale for the entries for Link Character Type and Link Character Direction, including citations as appropriate.
L	Link Intensity	Shows the rating of link intensity based on the definitions in table 1-1.
M	Link Spatial Scale	Shows the rating of link spatial scale based on the definitions in table 1-2.
N	Link Temporal Scale	Shows the rating of link temporal scale based on the definitions in table 1-3.
O	Link Average Magnitude	Shows the numerical average rating of link intensity, spatial scale, and temporal scale based on the definitions in table 1-4.
P	Link Magnitude Rank	Shows the overall rating of link magnitude based on the Link Average Magnitude, grouped following the criteria in table 1-4.
Q	Link Magnitude Reason	States the rationale for the ratings for link intensity, spatial scale, and temporal scale, with citations as appropriate.
R	Link Predictability Rank	Shows the rating of link predictability based on the definitions in table 1-5.
S	Link Predictability Reason	States the rationale for the rating of link predictability, with citations as appropriate.
T	Link Understanding Rank	Shows the rating of link understanding based on the definitions in table 1-6.
U	Link Understanding Reason	States the rationale for the rating of link predictability, including comments on alternative interpretations and publications/experts associated with different interpretations when feasible, with citations as appropriate.
V	Management Questions	Briefly notes questions that appear to arise from the preceding entries for the link, focused on critical gaps or uncertainties in knowledge concerning *management actions and options*, with reasoning, including the estimate of relative importance when possible.
W	Research Questions	Brief notes that appear to arise from the preceding entries for the link, focused on critical gaps or uncertainties in *basic scientific knowledge*, with reasoning, including the estimate of relative importance when possible.
X	Other Comments	Provides additional notes on investigator concerns, uncertainties, and questions.
Y	Update Status	Provides information on the history of editing the information on this link for updates carried out after completion of an initial version.

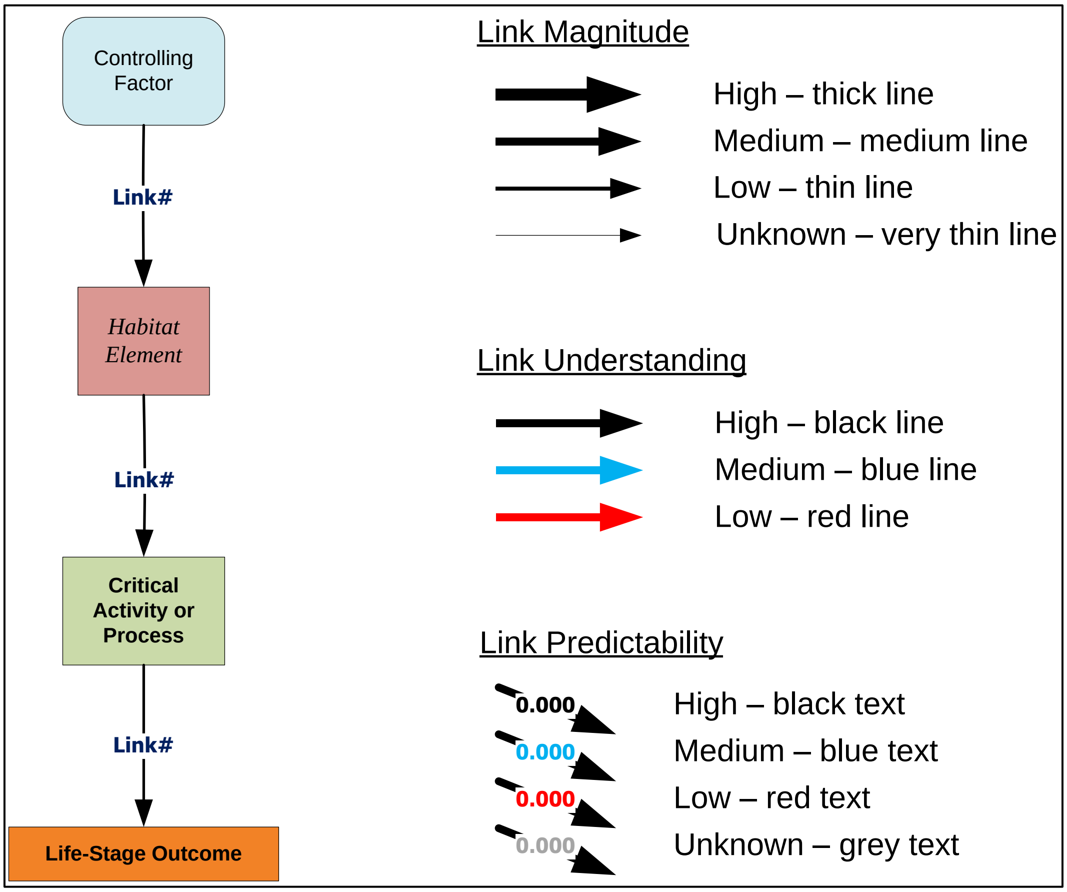

Figure 1-1.—Conventions for displaying cause and effect nodes, linkages, link magnitude, link understanding, and link predictability.

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ATTACHMENT 2

Summer Tanager Habitat Data

Table 1.—Summer tanager habitat data

Habitat element	Values	Location	Reference
Canopy closure	69.5 ± 3.6 SE[1] percent	Brown Canyon, Baboquivari Mountains, Arizona	Powell and Steidl 2000, 2002
	92.8 ± 10.5 SD[2] percent	South Fork Kern River Valley, California	T. Gallion, personal communication, as cited in Robinson 2012
Community type	Willows (Salix) and cottonwoods (Populus)	Lower Colorado River	Grinnell 1914; Bent 1958; Rosenberg et al.1991
	Sycamore, velvet mesquite, *Quercus* spp.	Baboquivari Mountains, Arizona	Powell and Steidl 2002
Patch size	Width > 60 meters	Ouachita Mountains, Arkansas	Perry et al. 2011
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, 2002
Understory density	23.2 ± 4.0 SE percent	Brown Canyon, Baboquivari Mountains, Arizona	Powell and Steidl 2000, 2002

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.

[1] SE standard error.

[2] SD = standard deviation.

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