Lower Colorado River
Multi-Species Conservation Program

Balancing Resource Use and Conservation

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

Photo courtesy of the Bureau of Reclamation

U.S. Department of the Interior
Bureau of Reclamation

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Lower Colorado River Multi-Species Conservation Program

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

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ACRONYMS AND ABBREVIATIONS

CEM	conceptual ecological model
cm	centimeter(s)
DBH	diameter at breast height
GIWO	gila woodpecker
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
Reclamation	Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service

Symbols

>	greater than
≥	greater than or equal to
±	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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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 element 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 gila woodpecker (*Melanerpes uropygialis*) (GIWO). 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 GIWO ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure GIWO habitat and population conditions. (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 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 GIWO 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 GIWO conceptual ecological model has five core components:

- **Life stages** – These consist of the major growth stages and critical events through which an individual GIWO 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 the biological processes that take place during each life stage that significantly beneficially or detrimentally shape the life-stage outcome rates for that life stage.

- **Habitat elements** – These consist of the specific habitat conditions, the abundance, spatial and temporal distributions, and other qualities that 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 GIWO conceptual ecological model addresses the GIWO throughout its breeding range. 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 GIWO conceptual ecological model are Bent (1939), Rosenberg et al. (1982), Rosenberg et al. (1991), Kaufman (1996), Edwards and Schnell (2000), and Bradley (2005). 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 these 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 GIWO 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 GIWO

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

The model distinguishes 8 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 8 critical biological activities or processes for 1 or more life stages, and 9 controlling factors that affect 1 or more of these 17 habitat elements. Because the lower Colorado River (LCR) comprises a highly regulated system, the controlling factors exclusively concern human activities.

The eight critical biological activities and processes identified across all life stages are: disease, eating/foraging, molt, nest attendance, nest cavity competition, nest site selection, predation, and temperature regulation. The 17 habitat elements identified across all life stages are: anthropogenic disturbance, brood size, canopy closure, community type, foliage density and diversity, food availability, genetic diversity and infectious agents, local hydrology, nest cavity competitor density, parental feeding behavior, parental nest attendance, patch size, predator density, snag density, soil salinity, soil temperature, and tree size. The nine controlling factors identified across all habitat elements are: fire management, grazing, irrigation, mechanical 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 shows 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:

- Disease, eating/foraging, and predation are the most important critical biological activities processes affecting survival of GIWO at all life stages. The effects of eating/foraging are direct and well understood. Depredation of nests can be high within the LCR but has not been studied in GIWO specifically (exceeding 80 percent for other species) (Powell and Steidl 2000). Disease has effects on nearly all avian populations and is thus assumed to be a factor within the LCR, although it has not been studied in the area or in the GIWO.

- Nest cavity competition, particularly by European starlings (*Sturnus vulgaris*), depending upon the timing and form it takes, may prevent GIWO from breeding in a given season (affecting reproduction) or may be a type of predation if displacement occurs after eggs are laid (affecting nest survival). The extent of displacement by nest competitors has been noted, but its impact on the GIWO population has not been studied.

- Three processes directly affect reproduction as we have defined it (i.e., just through egg laying)—nest attendance, nest cavity competition, and nest site selection. These 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 GIWO survivorship and recruitment within the LCR. Specifically, the findings suggest a need to improve the understanding of:

- Nest site selection is by far affected by the most habitat variables. This is not a surprise, as adult birds are expected to choose nest site locations that optimize all of the factors affecting survival for themselves and their young. However, significant uncertainty still exists with regard to the specific ranges of habitat and the sensitivity to subtle changes within the breeding environment.

- Predation is the next most affected process. Predators use many of the habitat variables chosen by their prey to identify suitable habitat. Patch size affects predation rates because of its effects on the proportion of stand area near the edge of a patch, a factor which has been shown to influence predation (Chalfoun and Martin 2009; Theimer et al. 2011). Predator density affects predation rates (Lima 2009). Nest cavity competition may resemble predation if nest displacement occurs after the eggs are laid; otherwise, it may directly affect reproduction.

- Nest attendance is affected by food availability and predator density. Predator density can influence nest defense behavior and thus nest attendance.

- Food availability drives the ability of GIWO at each life stage to acquire needed energy and nutrients, but foraging may be disrupted by anthropogenic disturbance.

- Disease is an important physiological concern that can be impacted strongly by habitat elements such as a lack of genetic diversity and the presence of vectors and infectious agents and by stress caused by disturbance. Similarly, temperature regulation can be affected by both biotic and abiotic factors.

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 the GIWO. 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 Gila woodpecker (*Melanerpes uropygialis*) (GIWO). 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 GIWO ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure GIWO 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 GIWO population along the river and lakes of the lower Colorado River (LCR) and other protected areas along the LCR managed as GIWO habitat. The model thus addresses the landscape as a whole rather than any single reach or managed area.

The most widely used sources of information for the GIWO conceptual ecological model include Bent (1939), Rosenberg et al. (1982), Rosenberg et al. (1991), Kaufman (1996), Edwards and Schnell (2000), and Bradley (2005). 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 conceptual ecological model is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

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

GILA WOODPECKER REPRODUCTIVE ECOLOGY

The GIWO is considered a sedentary species, occupying the LCR year round, although some individuals may move to higher elevations in winter (Brush et al.

1983; Kaufman 1996; Edwards and Schnell 2000). Within the LCR, GIWO has the narrowest habitat breadth during the breeding season, expanding the breadth in mid-summer and fall (Hunter 1984). GIWO occur most often in tall stands of cottonwoods (*Populus fremontii*) and willows (*Salix* sp.) with high foliage density and diversity (Hunter 1984). Breeding season may begin in March or April and may extend through August, with one to three broods (Phillips et al. 1964; Inouye et al. 1981; Bradley 2005). The species is known to reuse nest cavities for many years in succession, but new nests are usually excavated after the breeding season by both sexes (Kaufman 1996). Second broods are usually initiated in a different cavity than the first brood (Dawson 1923 *in* Edwards and Schnell 2000). GIWO compete with European starlings (*Sturnus vulgaris*) for nest cavities and are often evicted by them (Kerpez and Smith 1990a). As GIWO are only believed to excavate cavities in winter, the result of eviction could affect reproduction (Kerpez and Smith 1990a).

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

The typical clutch consists of two to seven eggs, with three to four most common and with fewer eggs in later broods (Edwards and Schnell 2000). Brood parasitism has not been noted in the literature for this species. Incubation lasts approximately 13 days and is performed by both sexes (Hensley 1959; Baicich and Harrison 1997). Young birds fledge from the nest in about 4 weeks and continue to be fed by adults for some time (Kaufman 1996).

The GIWO eats many varieties of insects and fruits (Edwards and Schnell 2000). The diet during the breeding season can be dominated by cicadas (Cicadidae) (50–75 percent) (Anderson et al. 1982; Rosenberg et al. 1982), although quantitative studies are limited. Other food items include ants, beetles, grasshoppers, termites, moths, butterflies, saguaro fruit, and miscellaneous berries (Anderson et al. 1982; Edwards and Schnell 2000).

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 THE GIWO

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), Kondolf et al. (2008), Burke et al. (2009), and Wildhaber

(2011) 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 resulting model is a "life history" model, as is common for CEMs focused on individual species (Wildhaber et al. 2007; Wildhaber 2011). That is, it 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 GIWO 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 viable eggs 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 foraging, molt, nest site selection, and temperature regulation. Critical biological activities and processes typically are "rate" variables; the rate (intensity) of the activities and processes, taken together, determine the rate of recruitment of individuals to the next life stage.

- **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. These effects on critical biological activities and processes may be either beneficial or detrimental. 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 biological 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 – GIWO 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 GIWO within the LCR on which to build the CEM.

INTRODUCTION TO THE GIWO LIFE CYCLE

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

In many studies of avian demography, nest survival is considered integral in the reproduction of adults because adults are heavily invested in the care of eggs and nestlings (Etterson et al. 2011). However, we treat the 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 phases of development 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. Further, most research conducted on GIWO breeding has focused on the number of young fledged and not on the number of eggs hatched—meaning that most of the available information is on the habitat characteristics and management actions associated with success of the nest through both incubation and brooding periods.

The GIWO is mostly a resident species within LCR MSCP lands, although some individuals move outside the area in late summer (50 percent) (Anderson et al. 1982; Brush et al. 1983; Edwards and Schnell 2000). The LCR MSCP is mainly responsible for management within LCR MSCP lands, and we therefore focus on three life stages occurring fully within LCR MSCP lands—nest, juvenile, and breeding adult. GIWO management outside of the LCR area is certainly important, but it is outside of the scope of Reclamation's responsibilities and thus omitted from this model.

GIWO LIFE STAGE 1 – NEST

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

GIWO LIFE STAGE 2 – JUVENILE

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

GIWO LIFE STAGE 3 – BREEDING ADULT

The adult stage begins at the beginning of the breeding season after its first winter. The life-stage outcomes for breeding adults are survival and reproduction, here defined as the production of eggs. Most studies of bird demography define fecundity—or the reproductive rates of adults—as the number of offspring fledged (Etterson et al. 2011). We have separated the nest stage from adult fecundity to more clearly display the information regarding nest success so that it can be better assessed by management. Therefore, within this model, the reproduction of adults involves the acts of pairing, site selection, nest building, and the production of eggs.

It is important to note that the post-breeding period is a significant part of a bird's life cycle. During the post-breeding period, adults may prospect for potential future breeding areas, even excavating new nests (Kaufman 1996), or move into habitat types that differ from breeding areas. Hunter (1984) reports a widening of habitat breadth after the breeding season. Although males, females, and post-breeding individuals have different goals and responsibilities on the breeding grounds, we have included them all within the breeding adult life stage because their habitat use is similar, and thus, management directed at breeding adults will likely benefit all demographics present on the breeding grounds.

LIFE STAGE MODEL SUMMARY

Based on this information, the GIWO 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.—GIWO 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

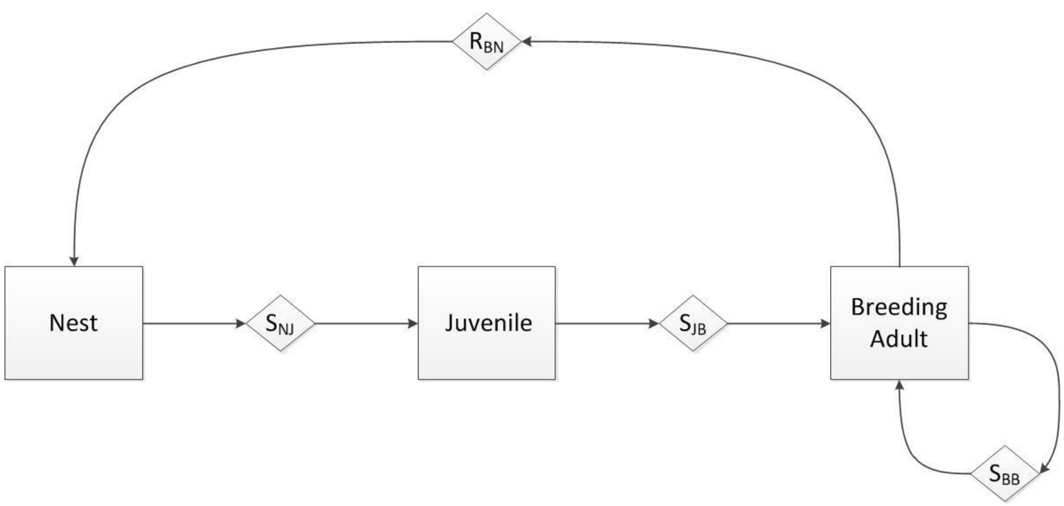

Figure 1.—Proposed GIWO life history model.
Squares indicate the life stage, and diamonds indicate the life-stage outcomes. S_{NJ} = survivorship rate, nest; S_{JB} = survivorship rate, juveniles; S_{BB} = survivorship rate, breeding adults; and R_{BN} = reproduction rate, breeding adults.

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 eight critical biological activities and processes that affect one or more GIWO 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 eight critical biological activities and processes and their distribution across life stages.

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

Life stage ➔ / **Critical biological activity or process ➔**	**Nest**	**Juvenile**	**Breeding adult**
Disease	X	X	X
Eating/foraging	X	X	X
Molt	X	X	X
Nest attendance			X
Nest cavity competition	X		X
Nest site selection			X
Predation	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 Bent (1939), Rosenberg et al. (1982), Rosenberg et al. (1991), Kaufman (1996), Edwards and Schnell (2000), and Bradley (2005). 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 eight critical biological activities and processes in alphabetical order.

DISEASE

This process refers to diseases caused either by lack of genetic diversity or by infectious agents, including the effects of ecto- and endo-parasites. Little research has focused on specific diseases inflicting the GIWO. However, there is a wealth of knowledge regarding avian diseases and parasites that affect passerine birds within North America, which indicates a large number of diseases (Morishita et al. 1999) can be difficult to detect (Jarvi et al. 2002) and can have differing effects on different species (Merino et al. 2000; Palinauskas et al. 2008). Short and Banks (1965) mention at least one GIWO was infected with a tapeworm in northwest Baja California. GIWO at all life stages are conceivably susceptible to disease.

EATING/FORAGING

Nestlings are fed by adults and do not forage. Juveniles forage on their own, but are still fed by adults shortly after fledging, and this feeding may be critical to their survival. The ability of nestlings and juveniles to eat is determined by the provisioning rate of its parents. Adults forage for themselves and their offspring. GIWO primarily forage on tree bark using pecking, probing, and gleaning foraging methods, most often in dead substrates, and most often in cottonwood habitat (Rosenberg et al. 1982; Brush et al. 1983). GIWO demonstrate a wide variety of opportunistic foraging behaviors ranging from harvesting larvae from galls (Speich and Radke 1975) to foraging at feeding stations (Gilman 1915 *in* Edwards and Schnell 2000). 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

The GIWO uses a molt strategy common to most North American woodpeckers (Pyle and Howell 1995). Nestling GIWO must molt from natal down into juvenal plumage while in the nest. Additionally, they begin molting their primaries from juvenal to definitive while still in the nest, and this continues for 3 to 4 months (Pyle and Howell 1995). 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 face the same challenges as nestlings (Pyle and Howell 1995).

NEST ATTENDANCE

Both sexes of GIWO incubate, attend the nest, and feed the young, continuing after fledging (Edwards and Schnell 2000). Parents appear to balance foraging and nest defense and adapt to the presence of predators and the behavior of their mate (Martindale 1982, 1983). Breeding adults attend the nest, and this affects the survival of the nest.

NEST CAVITY COMPETITION

Kerpez and Smith (1990a) report that European starlings compete with GIWO for nest cavities. Furthermore, they report GIWO being evicted from cavities by starlings. Lastly, Kerpez and Smith (1990a) found that GIWO nest in lower densities when starlings are present than when absent. As GIWO usually excavate cavities during the previous summer or over winter (Kerpez and Smith 1990a; Edwards and Schnell 2000), this competition could have a direct effect on adult reproduction. If eviction occurs after eggs are laid, the result is death of the nest and its contents.

NEST SITE SELECTION

The species is known to reuse nest cavities for many years in succession, but new nests are usually excavated after the breeding season by both sexes (Kaufman 1996). Second broods are usually initiated in a different cavity than the first brood (Dawson 1923 *in* Edwards and Schnell 2000). GIWO compete with European starlings for nest cavities, are often evicted by them, and occur in lower densities when they are present (Kerpez and Smith 1990a). Both breeding males and females excavate nesting cavities. The GIWO most commonly uses saguaros or tall native trees within cottonwood-willow woodlands for nesting (Rosenberg et al. 1991). However, the species has also been observed using honey or screwbean mesquite and cultivated trees such as eucalyptus and athel tamarisk (Rosenberg et al. 1991). Nest site selection is important for reproductive success because nest success varies spatially as a result of vegetation characteristics, food availability, predator types and densities, hydrology, or unique events such as flooding (Powell and Steidl 2000, 2002; Lima 2009; Smith and Finch 2013).

PREDATION

Predation is a threat to GIWO at all life stages, and it obviously affects survival. Neither predation of the nest or of free-flying individuals has been studied in this species (Edwards and Schnell 2000); however, many cavity-nesting species do suffer high rates of nest predation (Christman and Dhondt 1997). GIWO adult males increase nest attendance when greater densities of predators are present (Martindale 1982). Brood parasitism has not been documented in this species (Edwards and Schnell 2000). GIWO have been known to be evicted from nest cavities by starlings (Kerpez and Smith 1990a); however, it is not known if this occurred after the clutch was established (i.e., predation) or before (i.e., competition).

Predation of juveniles and adults is not easily quantified but affects juvenile and adult survival and can indirectly affect nest survival through nest abandonment after predation of the breeding adult birds. Predation risk can result in many behavioral adaptations in passerines, including nest locations, densities, clutch size, egg size, etc. (Lima 2009).

TEMPERATURE REGULATION

Temperature regulation is important for any organism inhabiting a region with temperatures as high as that of the LCR. Although overheating is possible in all life stages, most of the concern has been toward eggs and nestlings (Hunter et al. 1987a, 1987b; Rosenberg et al. 1991). Adults can affect the temperature regulation of eggs and nestlings through their own behavior (incubation, brooding, or shading) and through nest placement. In some studies, GIWO have been shown to use non-random orientation of cavity entrances, believed to benefit temperature regulation (Inouye et al. 1981; Korol and Hutto 1984). However, Kerpez and Smith (1990b) found no evidence that nest cavity orientation was different than random. Further, GIWO adults appear to invest more resources to maintain lower body temperatures than other woodpecker species in the area (Braun 1969) and alter their foraging habitats toward more shaded areas during the hottest part of the day (Edwards and Schnell 2000).

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 GIWO life stages. Habitat elements are included when specific studies have shown them to be relevant to GIWO, relevant to other bird species within the LCR, or relevant to bird species in general such that we can assume it likely affects GIWO. Some of these habitat elements differ in their details among life stages. For example, different GIWO life stages experience different predation risks depending on the GIWO 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 GIWO 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 density" is the short name for "The abundance and distribution of predators that affect GIWO during the post-fledgling and adult stages." The following paragraphs provide the full name for each habitat element and a detailed definition, addressing the elements in alphabetical order.

The most commonly used sources of the information used to identify the habitat elements include Bent (1939), Rosenberg et al. (1982), Rosenberg et al. (1991), Kaufman (1996), Edwards and Schnell (2000), and Bradley (2005). The identification also integrates information from both older and more recent works as well as the expert knowledge of LCR MSCP biologists.

GIWO in the Southwest United States most commonly use saguaros or tall native trees within cottonwood-willow woodlands for nesting (Rosenberg et al. 1991). However, the species has also been observed using honey or screwbean mesquite and cultivated trees such as eucalyptus, athel tamarisk, palm, and orchard trees (Rosenberg et al. 1991; L. Sabin 2015, personal communication). Brush et al. (1983) rarely found GIWO in honey or screwbean mesquite and hypothesize that this may be the result of the hardness of mesquite.

GIWO eat many varieties of insects and fruits (Edwards and Schnell 2000). The diet during the breeding season can be dominated by cicadas (50–75 percent) (Anderson et al. 1982; Rosenberg et al. 1982), although quantitative studies are limited. Other food items include ants, beetles, grasshoppers, termites, moths,

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

Critical biological activity or process → / **Habitat element ↓**	**Disease**	**Eating/foraging**	**Molt**	**Nest attendance**	**Nest cavity competitor density**	**Nest site selection**	**Predation**	**Temperature regulation**
Anthropogenic disturbance	X	X		X		X	X	X
Brood size	X	X		X			X	
Canopy closure							X	X
Community type						X	X	
Foliage density and diversity						X		
Food availability		X		X		X		
Genetic diversity and infectious agents	X					X		X
Local hydrology						X		X
Nest cavity competitor density					X			
Parental feeding behavior		X		X				
Parental nest attendance		X					X	X
Patch size						X	X	
Predator density		X		X		X	X	
Snag density						X		
Soil salinity	N/A*							
Soil temperature	N/A							
Tree size						X		

*N/A values suggest that none of the identified habitat elements *directly* affect the activity or process.

butterflies, saguaro fruit, and miscellaneous berries (Anderson et al. 1982; Edwards and Schnell 2000). Cicadas and other insects can be sensitive to soil temperatures and local hydrology yet also directly affect the local water table influencing plant communities (Anderson 1994).

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 GIWO to attract or find mates or defend territories. Noise can shift the foraging/vigilence tradeoff – either putting an individual at higher risk due to starvation or to predation (Ware et al. 2015). Noise can cause behavioral changes, physiological changes, and species diversity changes within an area (reviewed by Barber et al. 2010). Each of these impacts may impact the survival and reproduction of a species.

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. Larger broods can result in lower nestling survival and smaller fledglings, and it can negatively affect parental body condition (Dijkstra et al. 1990). The typical GIWO clutch consists of two to seven eggs, with three to four most common with fewer eggs in later broods (Edwards and Schnell 2000). Two broods per year are common in this species (Inouye et al. 1981; Rosenberg et al. 1991).

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 GIWO nest site. The range of canopy closure selected by the GIWO has not been quantified, but canopy closure influences temperature regulation and can influence other habitat elements important to the species, such as soil temperature, which in turn influences food abundance and timing. Dense vegetation around the nest may provide more optimal microclimate for thermal regulation (Rosenberg et al. 1991) and camouflage from nest predators. GIWO are more sensitive to temperature than other woodpeckers in the area (Braun 1969), and they alter their foraging habitats toward more shaded areas during the hottest part of the day (Edwards and Schnell 2000). Cottonwood canopy closure may also affect the availability of cicadas (Smith et al. 2006).

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 GIWO. GIWO most commonly use saguaros or tall native trees within cottonwood-willow woodlands for nesting (Rosenberg et al. 1991; Great Basin Bird Observatory 2010). However, the species has also been observed using honey or screwbean mesquite and cultivated trees such as eucalyptus and athel tamarisk, palm, and orchard trees (Rosenberg et al. 1991; L. Sabin, personal observation). Brush et al. (1983) rarely found GIWO in honey or screwbean mesquite and hypothesize that this may be the result of the hardness of mesquite.

FOLIAGE DENSITY AND DIVERSITY

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

FOOD AVAILABILITY

Full name: **The abundance of food available for adults and their young**. This element refers to the taxonomic and size composition of the invertebrates and fruits that an individual GIWO will encounter during each life stage as well as the density and spatial distribution of the food supply in proximity to the nest. GIWO eat many varieties of insects (beetles, moths, ants, butterflies, and cicadas) and fruits (Rosenberg et al. 1982; Edwards and Schnell 2000). GIWO are known to eat the fruit of saguaro and other cacti (Davie 1900 *in* Edwards and Schnell 2000). The diet during the breeding season can be dominated by cicadas (50–75 percent) (Rosenberg et al. 1982), but quantitative studies are limited. The abundance and condition of the food supply affects adult health, growth and development of nestlings and juveniles, the progress of molt, and the success of later stages in the annual cycle (i.e., migration) (Lindström 1999; Alonso-Alvarez and Tella 2001).

GENETIC DIVERSITY AND INFECTIOUS AGENTS

Full name: **The genetic diversity of GIWO 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 (summarized by Booy et al. 2000). The genetic diversity of GIWO within the LCR has not been studied.

The infectious agent component of this element refers to the spectrum of viruses, bacteria, fungi, ecto-parasites, and endo-parasites that individual GIWO are likely to encounter during each life stage. There have been no specific studies of the infectious agents and their effects on the GIWO within the LCR. However, there is a wealth of knowledge regarding avian diseases and parasites that affect birds within North America, which indicates a large number of diseases (Morishita et al. 1999) can be difficult to detect (Jarvi et al. 2002) and can have differing effects on different species (Merino et al. 2000; Palinauskas et al. 2008).

LOCAL HYDROLOGY

Full name: **Aspects such as the distance to standing water or the presence of adjacent water bodies, the timing and volume of floods, depth to the water table, and soil moisture levels**. This element refers to anything that affects soil moisture such as the proximity of water to the nesting habitat, elevation, irrigation practices, and soil texture. The local hydrological conditions affect other aspects of habitat such as vegetation structure, abundance of arthropods, and soil salinity. Wetter conditions might also provide cooler temperatures and more humid conditions necessary for egg and chick survival in desert systems (Rosenberg et al. 1991).

NEST CAVITY COMPETITOR DENSITY

Full name: **The presence and density of nest cavity competitors that may block or displace nesting GIWO**. Kerpez and Smith (1990a) report that European starlings compete with GIWO for nest cavities. Furthermore, they report GIWO being evicted from cavities by starlings. Lastly, Kerpez and Smith (1990a) found that GIWO nest in lower densities when starlings are present than when absent. As GIWO usually excavate cavities during the previous summer or over winter (Kerpez and Smith 1990a; Edwards and Schnell 2000), this competition could have a direct effect on adult fecundity. If eviction occurs after eggs are laid, the result is death of the nest and its contents. Conflict is expected to increase as the density of competitors increase.

PARENTAL FEEDING BEHAVIOR

Full name: **The ability and behavior of parents to feed and care for nestlings and juveniles after they fledge from the nest**. This element refers to the capacity of both parents to provision food for nestlings and recently fledged birds. This rate is dependent upon food availability and the number of young in the brood. Young are fed by parents for an extended period of time. This rate influences the amount of food consumed and time spent foraging by juvenile birds. Parents appear to balance foraging and nest defense and adapt to the presence of predators and the behavior of their mate (Martindale 1982, 1983).

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 of 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. Both sexes share the responsibility of brooding young and defending the territory, although the roles of the sexes differ (Martindale 1982; Edwards and Schnell 2000). Martindale (1982) demonstrates that predator density and competition influence foraging rate in males in predictable ways.

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 and competitors. GIWO may be sensitive to forest fragmentation. Rosenberg et al. (1991) state that they are essentially absent from fragments smaller than 20 hectares. However, the Great Basin Bird Observatory has found them in areas where fragments larger than 20 hectares do not exist (L. Sabin 2015, personal communication).

PREDATOR DENSITY

Full name: **The abundance and distribution of predators that affect GIWO during the post-fledgling and adult stages**. This element refers to a set of closely related variables that affect the likelihood that different kinds of predators will encounter and successfully prey on GIWO during the nest, juvenile, or adult life stages. The variables of this element include the species and size of the fauna that prey on GIWO during different life stages, the density and spatial distribution of these fauna in the riparian habitat used by GIWO, and whether predator activity may vary in relation to other factors (e.g., time of day, patch size and width, matrix community type, etc.). 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). Powell and Steidl (2000) report observing that 81 percent of southwestern riparian nests they studied were predated; however, these were not cavity nests and GIWO was not part of this study.

SNAG DENSITY

Full name: **The density of standing dead trees**. This element refers to the number of standing dead trees or large dead branches of live trees per hectare within the breeding patch. The greater the snag density, the greater the number of available nest cavity locations for GIWO breeding (Great Basin Bird Observatory 2010).

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 (San Joaquin River Restoration Program 2014).** Soil salinity can impact the vigor of various plant species to different degrees and can ultimately influence plant community type and structure (San Joaquin River Restoration Program 2014).

SOIL TEMPERATURE

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

TREE SIZE

Full name: **The diameter of a tree at breast height, averaged across the stand**. This element refers to the average size of trees within the nest stand, typically measured in diameter at breast height (DBH) or height. GIWO have been shown to prefer nesting stands with larger trees (> 12 centimeters DBH and > 10 m) (McCreedy 2008; Great Basin Bird Observatory 2010).

Chapter 5 – Controlling Factors

Controlling factors consist of environmental conditions and dynamics, both natural and anthropogenic, which significantly affect the abundance, spatial and temporal distributions, and quality of critical habitat elements. These may also significantly directly affect some critical biological activities or processes. A hierarchy of such factors exists, with long-term dynamics of climate and geology at the top. However, this CEM focuses on nine immediate controlling factors that are within the scope of potential human manipulation. The nine 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 that make it useful to treat them together. Table 4 lists the nine controlling factors and the habitat elements they directly affect. Table 4 shows two habitat elements that are not directly affected by any controlling factor (brood size and nest cavity competitor density). The 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**	**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		
Community type	X	X			X		X	X	
Foliage density and diversity	X	X		X	X	X	X	X	
Food availability	X				X	X			
Genetic diversity and infectious agents					X	X			
Local hydrology			X						X
Nest cavity competitor density	N/A*								
Parental feeding behavior								X	
Parental nest attendance								X	
Patch size	X	X		X			X	X	
Predator density					X		X	X	
Snag density	X			X					
Soil salinity			X						X
Soil temperature	X		X	X	X			X	
Tree size	X				X	X		X	

* N/A value suggests 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 GIWO or their habitat. Effects may include creation of habitat that supports or excludes GIWO, a reduction in the food supply of invertebrates, or support of species that pose threats to GIWO as predators, competitors, or carriers of infectious agents. Most aspects of fire have a negative effect on the presence of GIWO, such as decreasing snags, decreasing cover, or decreasing vertical density and diversity, all of which can increase soil temperatures, decreasing food abundance. However, fire may be used as a tool to alter the community type back to a more native structure to the long-term benefit of GIWO. Climate change is also projected to affect fire frequency along the LCR (U.S. Fish and Wildlife Service [USFWS] 2013).

GRAZING

This factor addresses the grazing activity on riparian habitats along the LCR and in surrounding areas that could affect GIWO or their habitat. Grazing by cattle, burros, or mule deer across the arid Southwestern United States has substantially degraded riparian habitat (see USDA Forest Service 1979; Rickard and Cushing 1982; Cannon and Knopf 1984; Klebenow and Oakleaf 1984; General Accounting Office 1988; Clary and Webster 1989; Schultz and Leininger 1990; and Belsky et al. 1999 *in* USFWS 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, preventing the establishment of cottonwood and willow seedlings or other middle story components (Kauffman et al. 1997; Powell and Steidl 2002). Krueper et al. (2003) document a significant population increase of some avian species in the years following the removal of cattle from a riparian system, although the results for GIWO were inconclusive.

IRRIGATION

This factor addresses the human activities of artificially introducing water to the landscape to influence habitat. In many cases, irrigation may be implemented to simulate more natural riparian processes or to manage soil salinity levels.

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 GIWO or supports or excludes species that pose threats to GIWO such as predators, competitors, or carriers of infectious agents. Thinning can be implemented on a small local scale, resembling natural thinning, or it 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.

NUISANCE SPECIES INTRODUCTION AND MANAGEMENT

This factor addresses the intentional or unintentional introduction of nuisance species (animals and plants) and their control that affects GIWO survival and reproduction. Nuisance species may infect, prey on, compete with, or present alternative food resources for GIWO during one or more life stages; cause other alterations to the riparian food web that affect GIWO; or affect physical habitat features such as canopy or shrub cover. For example, although GIWO successfully nest in sites dominated by invasive tamarisk (*Tamarix* spp.), they do so in lower densities, and tamarisk may negatively affect habitat in other ways (e.g., by lowering the water table) (Di Tomaso 1998; Brand et al. 2010).

The complicated nature of the relationship between tamarisk and GIWO is highlighted by another introduced species—the tamarisk beetle (*Diorhabda carinulata*). The beetle was introduced to the LCR region in order to control invasive tamarisk (Bateman et al. 2013). However, defoliation of tamarisk due to beetle infestation causes decreases in humidity and cover along with increases in temperature (Bateman et al. 2013), potentially degrading areas dominated by tamarisk as habitat for GIWO.

PESTICIDE/HERBICIDE APPLICATION

This factor addresses biocide applications that may occur on or adjacent to riparian habitat of the LCR region. Herbicides may drift into riparian areas, killing important GIWO habitat. Pesticide effects may include lethal or sublethal poisoning of GIWO via ingestion of treated insects, pollution of runoff into wetland habitats that are toxic to prey of GIWO, 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 is planted within restoration areas (e.g., density, age, and patch size). The composition of the species planted can affect not only the vertical and horizontal structure of the vegetation but also the insect community within a given patch.

RECREATIONAL ACTIVITIES

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

WATER STORAGE-DELIVERY SYSTEM DESIGN AND OPERATION

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

The dynamic nature of a free-flowing river creates a mosaic of riparian habitats, and thus, a natural flow regime might be beneficial to GIWO. Natural floods can decrease understory vegetation and decrease soil temperatures, enabling insect and 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 GIWO 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 protected areas managed as GIWO habitat and thus address this 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 or 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.

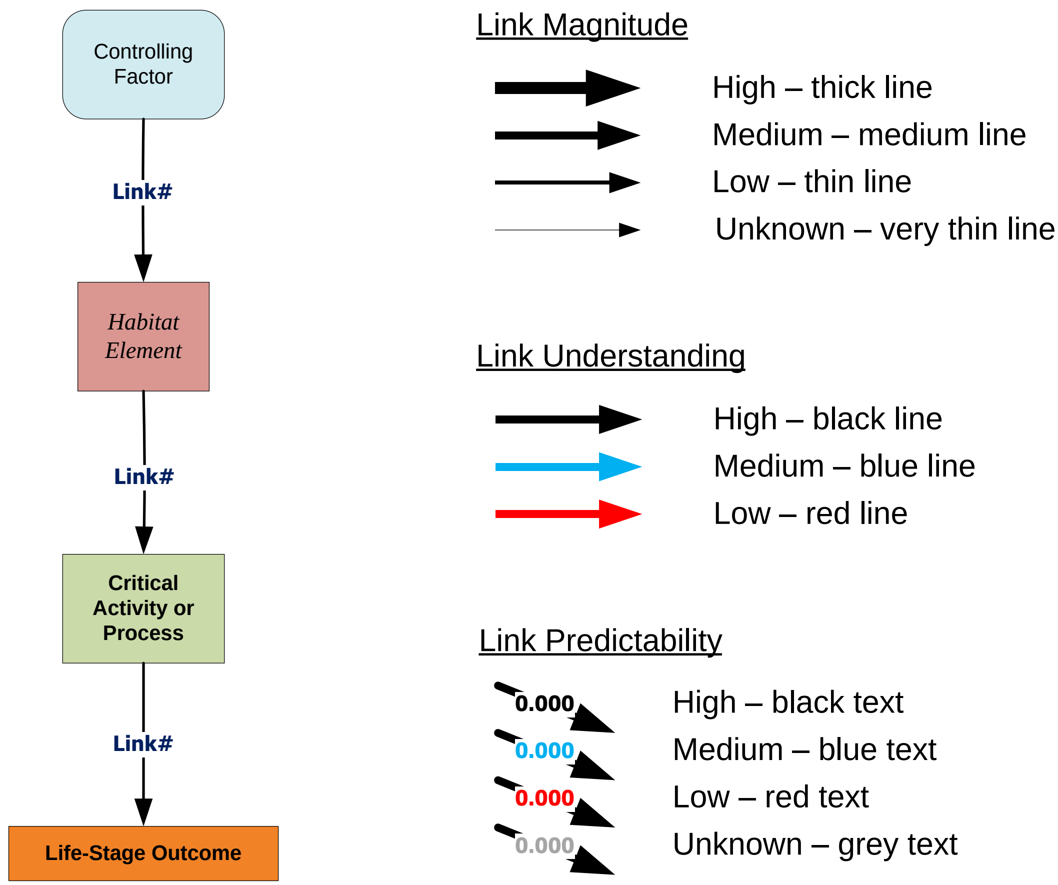

Figure 2.—Diagram conventions for LCR MSCP conceptual ecological models.

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.

GIWO 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 six (of eight) critical biological activities and processes for this life stage, ordered as they appear on the following figures:

1. **Disease** – Although the literature does not emphasize disease as affecting population levels of GIWO, 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 GIWO (Morishita et al. 1999; Lachish et al. 2011). Short and Banks (1965) mention at least one GIWO was infected with a tapeworm in northwest Baja California. Disease and parasite impacts along the LCR are areas recommended for further research.

   The CEM recognizes genetic diversity and infectious agents as a habitat element directly influencing the prevalence of disease. Additionally, anthropogenic disturbance can increase stress, which impacts immune function, and increased brood size can be correlated to increased prevalence of disease.

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

   The CEM recognizes anthropogenic disturbance, canopy closure, genetic diversity and infectious agents, local hydrology, and parental nest attendance as the primary habitat elements directly affecting temperature regulation. Eating and disease are two critical biological activities that can influence temperature regulation.

3. **Predation** – Predation affects the survival of a nest. High rates of predation have been observed for GIWO and for other species within the LCR, accounting for over 80 percent of nest failures in some species (Powell and Steidl 2000).

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

4. **Eating/Foraging** – The nestling must eat to maintain metabolic processes.

   The CEM recognizes anthropogenic disturbance, brood size, food availability, parental feeding behavior, parental nest attendance, and predator density as habitat elements affecting eating/foraging.

5. **Molt** – The nestling must molt into juvenile plumage before leaving the nest.

   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.

6. **Nest Cavity Competition** – The eggs and nestlings must survive eviction by cavity competitors.

   The CEM recognizes nest cavity competitor density as the primary factor affecting nest cavity competition. Kerpez and Smith (1990a) note that starlings, known cavity competitors, are only present on plots within 4 kilometers of agricultural areas.

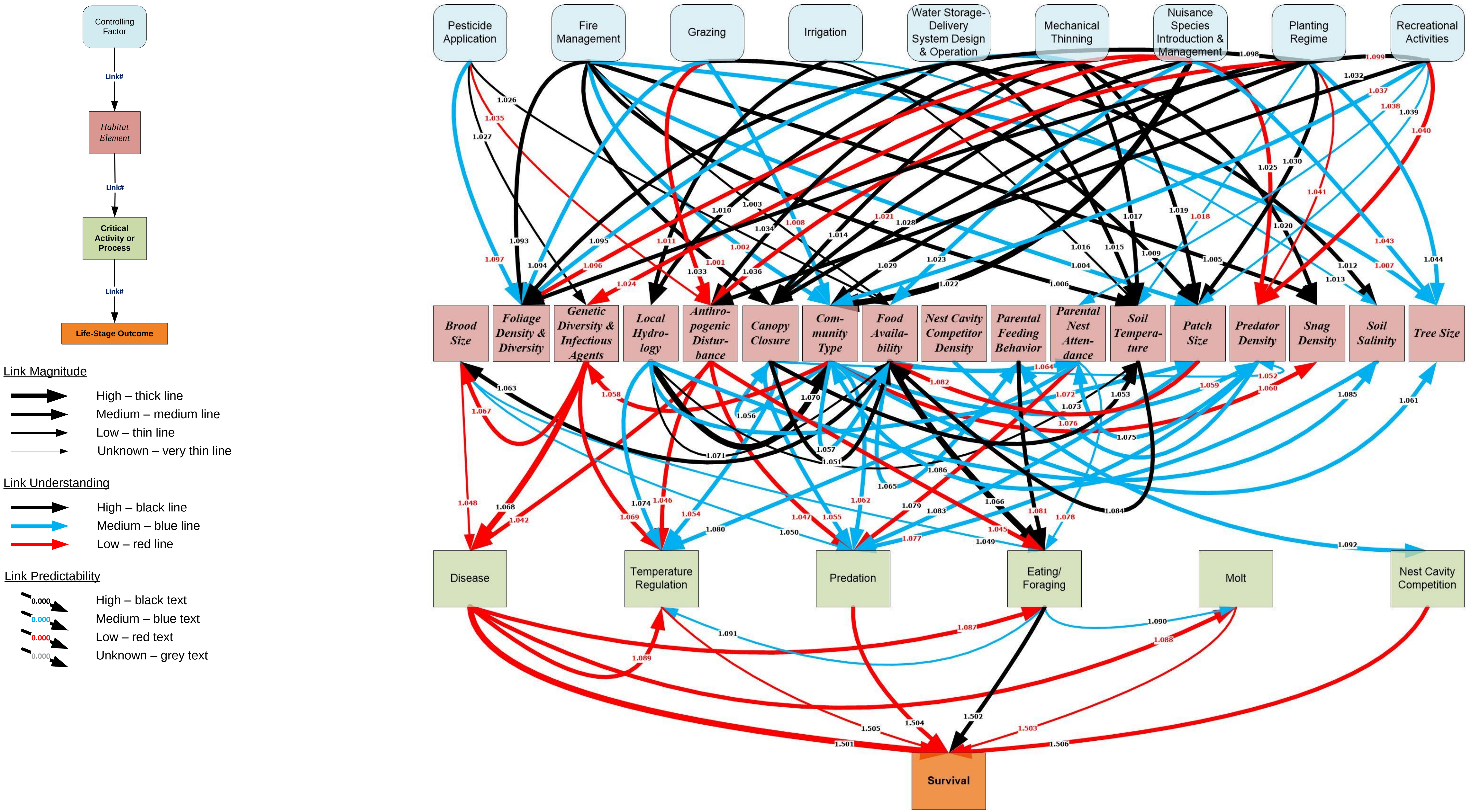

Figure 3.—GIWO life stage 1 – nest, basic CEM diagram. Only elements with connections within this life stage are presented.

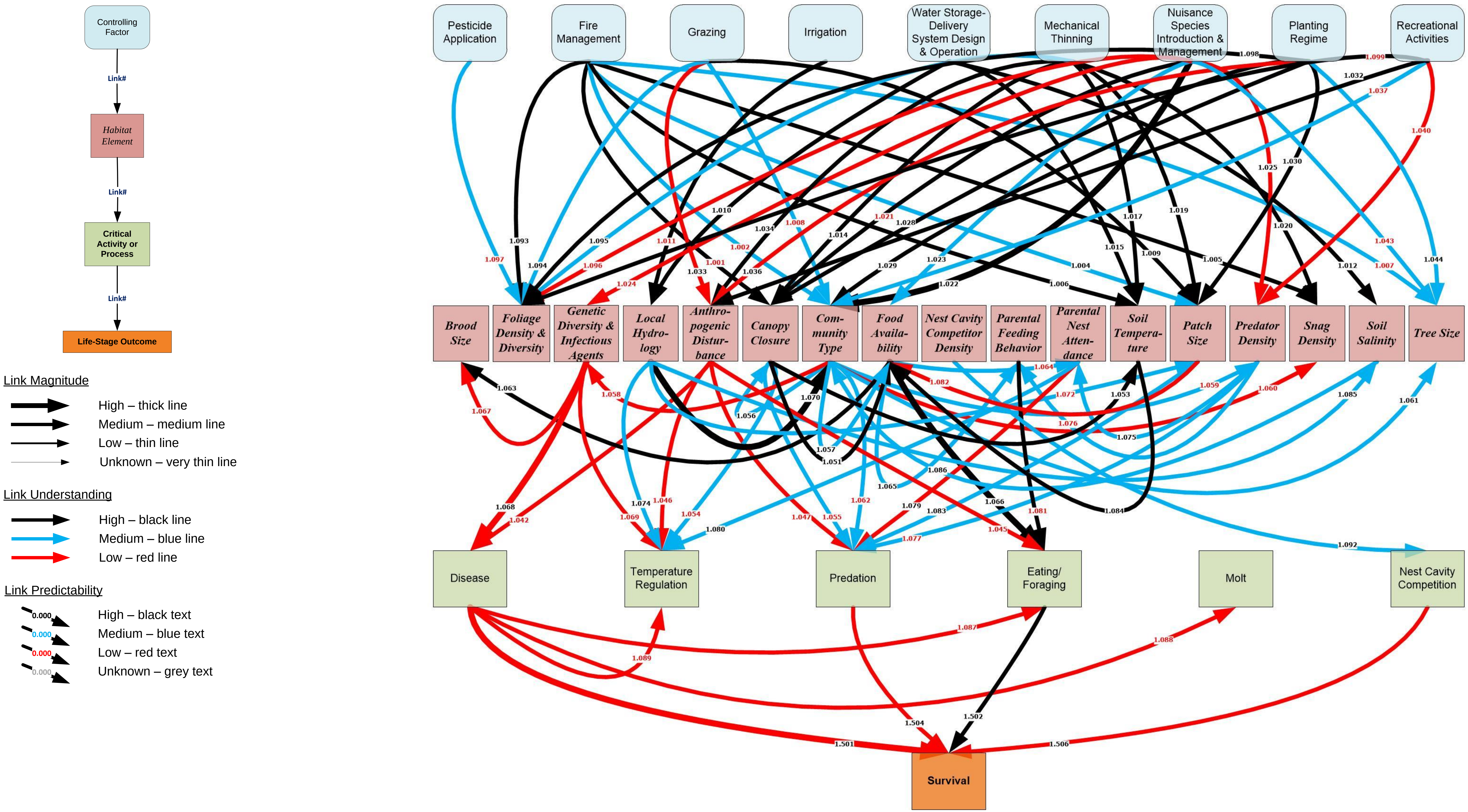

Figure 4.—GIWO life stage 1 – nest, high- and medium-magnitude relationships. Only elements with high- or medium-magnitude connections within this life stage are presented.

GIWO LIFE STAGE 2 – JUVENILE

The juvenile stage begins at fledging and ends at the beginning of the breeding season the following year. Success during this life stage – successful transition to the next stage – involves organism survival and maturation.

The CEM (figures 5 and 6) recognizes five (of eight) 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 GIWO, we still feel that disease bears mentioning. Diseases and parasites are prevalent in avian populations, so it is safe to assume they may have an impact on GIWO (Morishita et al. 1999; Lachish et al. 2011). Short and Banks (1965) mention at least one GIWO was infected with a tapeworm in northwest Baja California. Disease and parasite impacts along the LCR are areas recommended for further research.

   The CEM recognizes genetic diversity and infectious agents as a habitat element influencing the prevalence of disease. Additionally, anthropogenic disturbance can increase stress, which impacts immune function, and can thus increase the prevalence of disease.

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

   The CEM recognizes anthropogenic disturbance, canopy closure, genetic diversity and infectious agents, and local hydrology as the primary habitat elements directly affecting temperature regulation. Eating and disease are two critical biological activities that can influence temperature regulation.

3. **Predation** – Predation affects the survival of a nest. High rates of predation have been observed for GIWO and for other species within the LCR, accounting for over 80 percent of nest failures of some species (Powell and Steidl 2000).

   The CEM recognizes anthropogenic disturbance, canopy closure, community type, patch size, and predator density as habitat elements affecting predation.

4. **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 an unknown period of time. The degree to which they are 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, food availability, and parental feeding behavior as habitat elements affecting foraging. In addition, disease can affect the foraging efficiency of a juvenile.

5. **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.

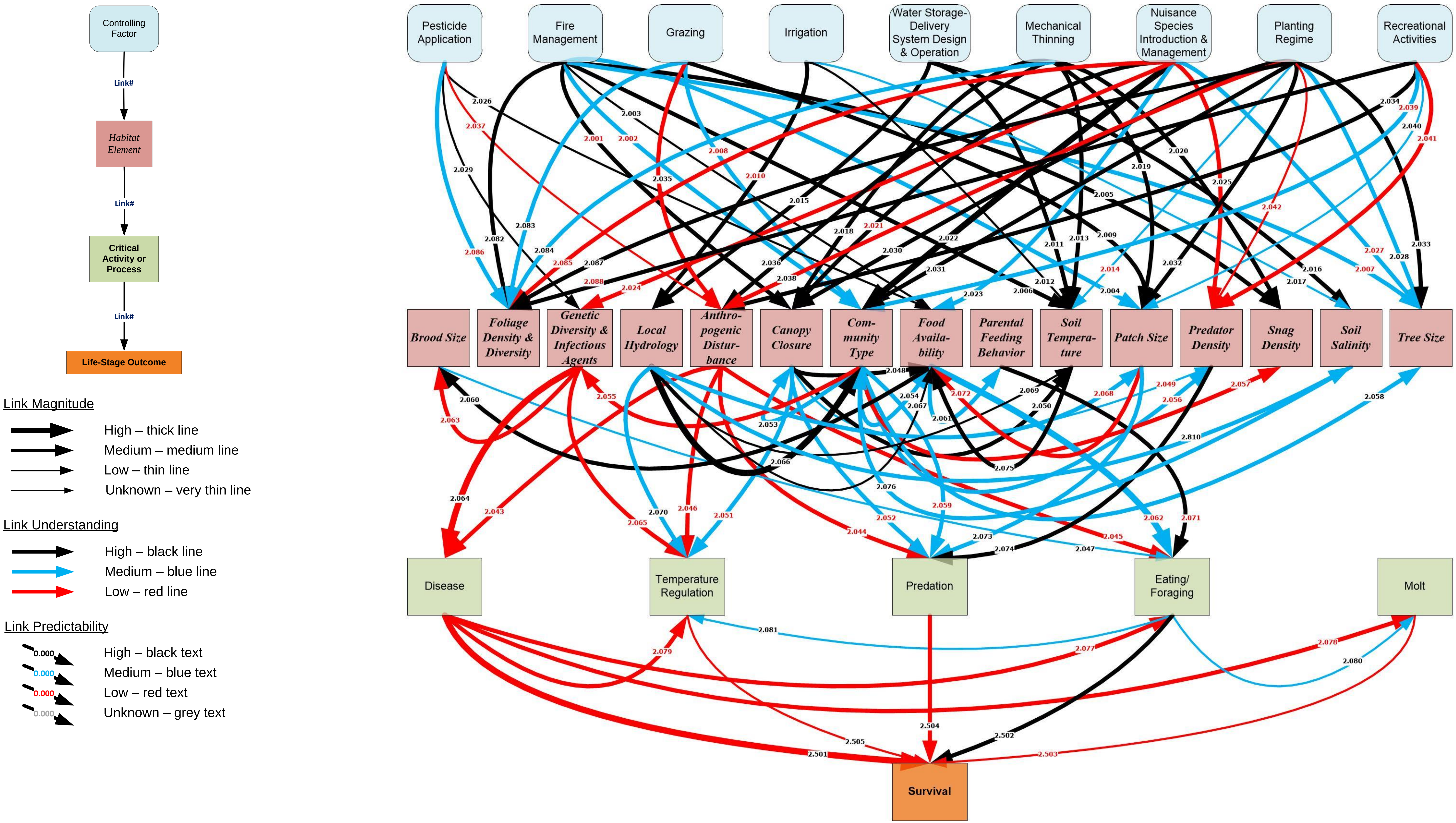

Figure 5.—GIWO life stage 2 – juvenile, basic CEM diagram. Only elements with connections within this life stage are presented.

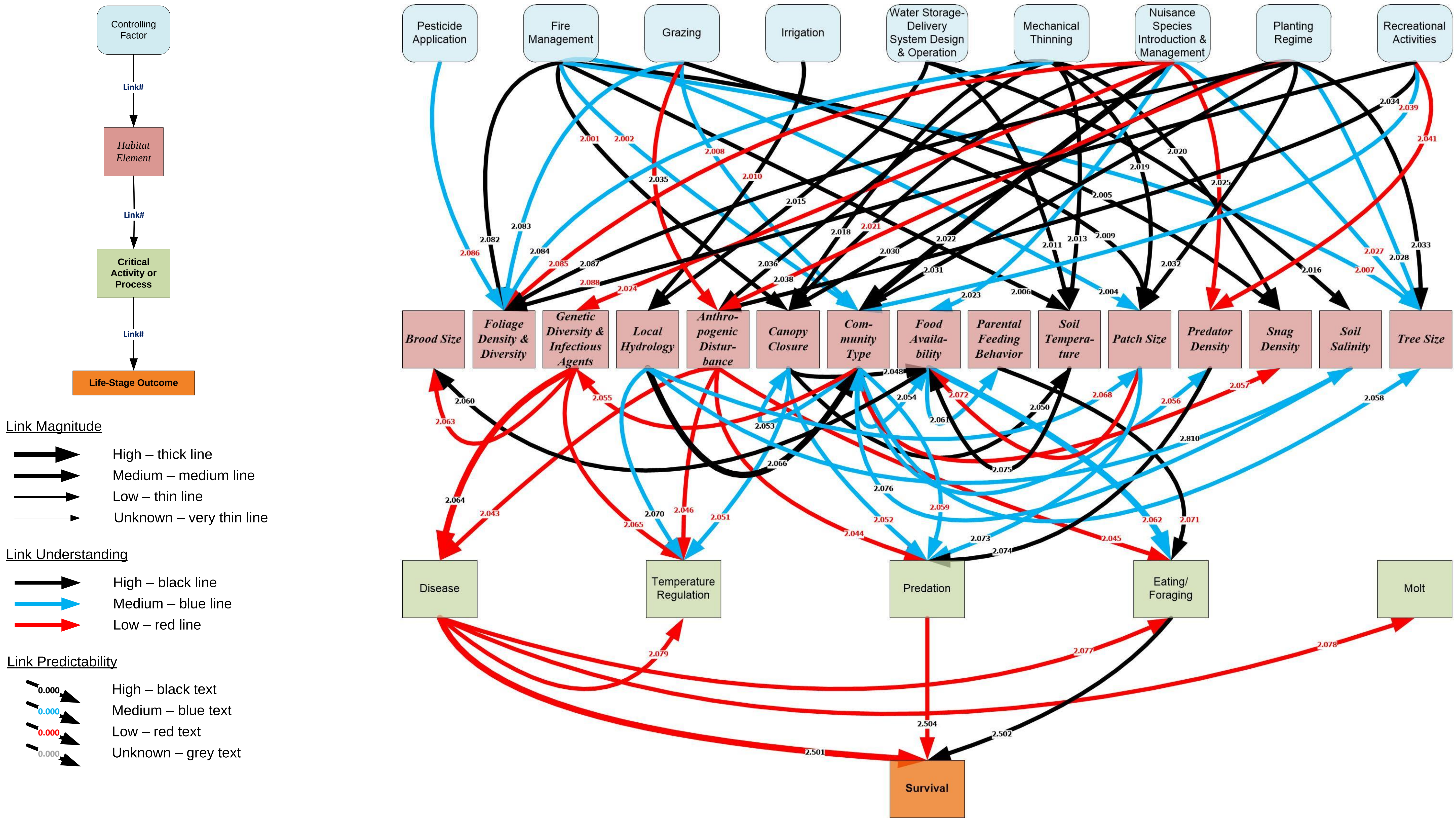

Figure 6.—GIWO life stage 2 – juvenile, high- and medium-magnitude relationships. Only elements with high- or medium-magnitude connections within this life stage are presented.

GIWO LIFE STAGE 3 – BREEDING ADULT

The breeding adult stage begins at the beginning of the breeding season after the bird's first winter. For the sake of this model, success during this life stage involves breeding and organism survival from one year to the next. Individuals that do not successfully find a territory, floaters, are also included in this category even though they do not breed.

The CEM (figures 7 and 8) recognizes eight (of eight) 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 GIWO, we still feel that disease bears mentioning. Diseases and parasites are prevalent in avian populations, so it is safe to assume they may have an impact on GIWO (Morishita et al. 1999; Lachish et al. 2011). Short and Banks (1965) mention at least one GIWO was infected with a tapeworm in northwest Baja California. Disease and parasite impacts along the LCR are areas recommended for further research.

   The CEM recognizes genetic diversity and infectious agents as a habitat element influencing the prevalence of disease. Additionally, anthropogenic disturbance can increase stress, which impacts immune function, and can thus increase the prevalence of disease.

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

   The CEM recognizes canopy closure, genetic diversity and infectious agents, and local hydrology as habitat elements directly affecting temperature regulation. Additionally, anthropogenic disturbance can increase stress, which impacts immune function, and can thus affect temperature regulation. Disease and eating may also have an effect.

3. **Predation** – Adults must avoid predation to survive.

   The CEM recognizes anthropogenic noise, canopy closure, community type, patch size, and predator density as the primary elements affecting predation.

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

   The CEM recognizes food availability as the primary habitat element affecting eating/foraging. Secondary habitat elements affecting eating/foraging include anthropogenic disturbance, brood size, and possibly disease.

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, community type, foliage density and diversity, food availability, genetic diversity and infectious agents, local hydrology, nest cavity competitor density, patch size, predator density, snag density, and tree size as primary habitat elements affecting nest site selection.

6. **Nest Attendance** – The breeding adult must attend the nest to incubate eggs, brood young, defend young, and feed young.

   The CEM recognizes anthropogenic disturbance, brood size, food availability, parental feeding behavior, and predator density as the major factors affecting nest attendance.

   The CEM recognizes anthropogenic disturbance, brood size, and food availability as primary habitat elements affecting foraging. In addition, disease can affect the foraging efficiency of an adult.

7. **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 foraging.

8. **Nest Cavity Competition** – GIWO must have and defend an excavated cavity for nesting. GIWO usually excavate cavities in late summer or over winter (Kerpez and Smith 1990a; Edwards and Schnell 2000). If they are evicted from a cavity, they may not be able to reproduce in a given year.

   The CEM recognizes nest cavity competitor density as the primary factor affecting nest cavity competition. Kerpez and Smith (1990a) note that starlings, known cavity competitors, are only present on plots within 4 kilometers of agricultural areas.

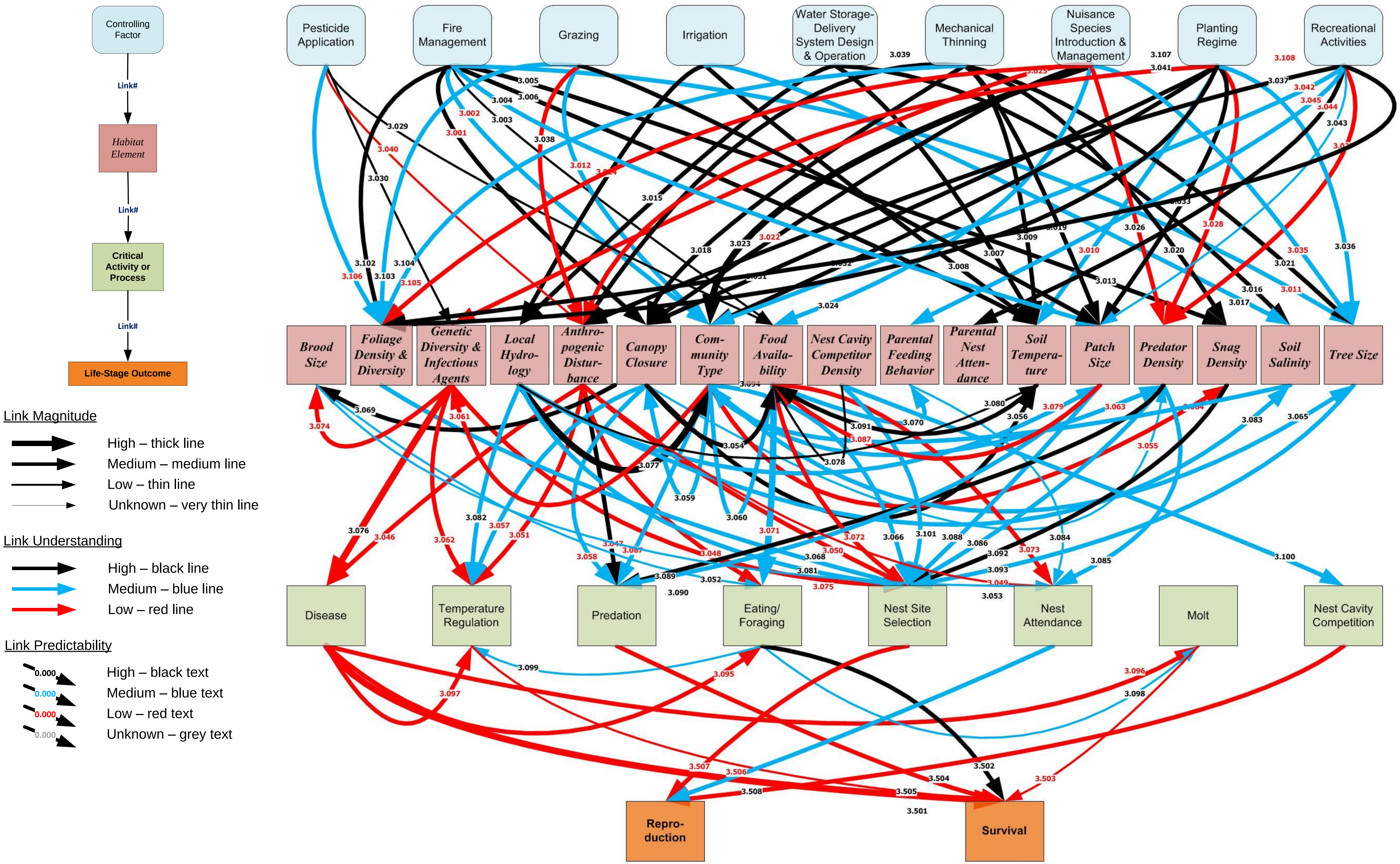

Figure 7.—GIWO life stage 3 – breeding adult, basic CEM diagram. Only elements with connections within this life stage are presented.

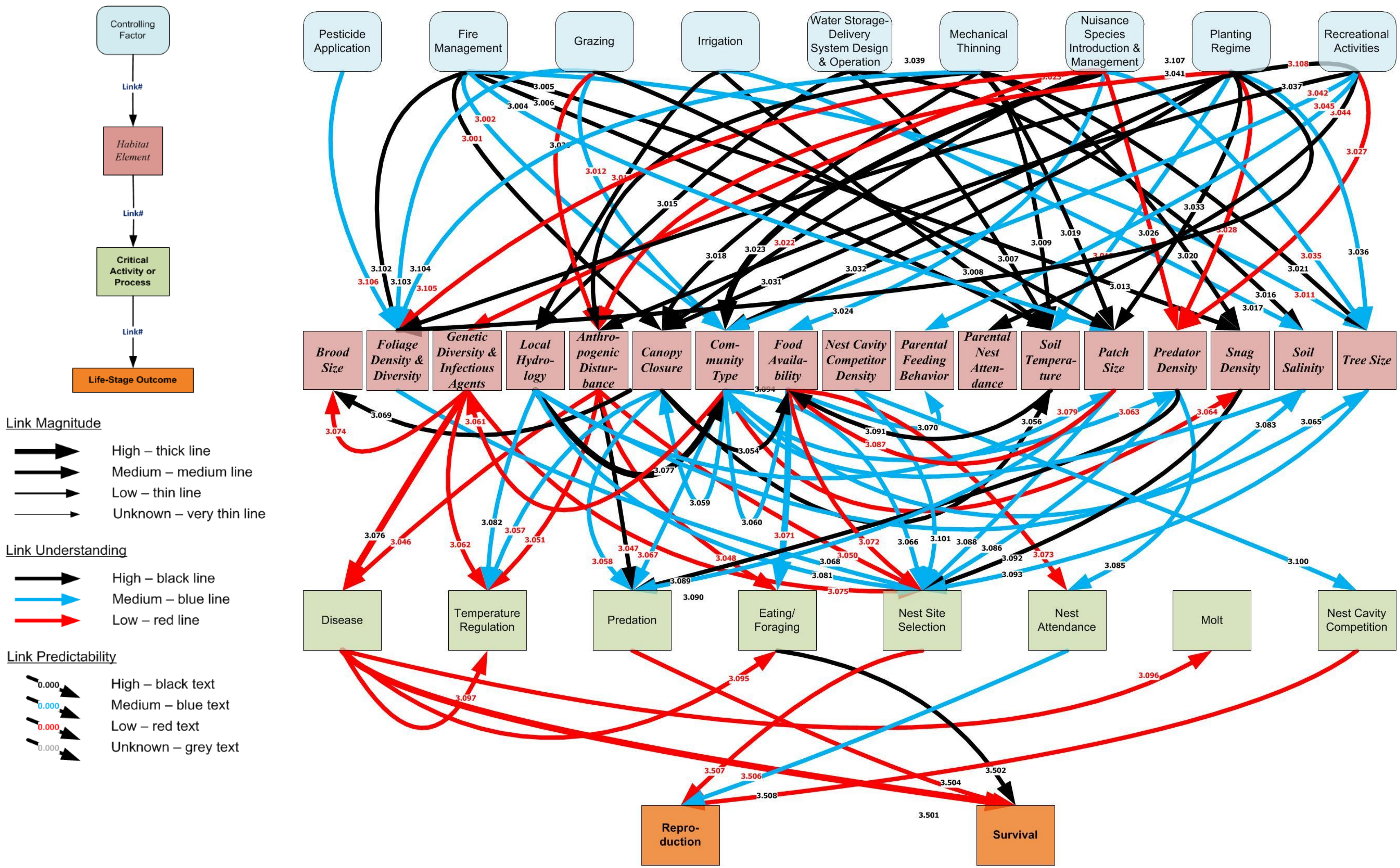

Figure 8.—GIWO life stage 3 – breeding adult, high- and medium-magnitude relationships. Only elements with high- or medium-magnitude connections within this life stage are presented.

Chapter 7 – Causal Relationships Across All Life Stages

The nine 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 9 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.

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

Controlling factor ➔ **Habitat element affected ➔**	**Fire management**	**Grazing**	**Irrigation**	**Mechanical thinning**	**Nuisance species introduction and management**	**Pesticide/herbicide application**	**Planting regime**	**Recreational activities**	**Water storage-delivery system design and operation**
Anthropogenic disturbance		**Med.**		**Med.**		**Low**	**Med.**	**Med.**	
Brood size	N/A*								
Canopy closure	**Med.**			**Med.**	**Med.**		**Med.**		
Community type	**Med.**	**Med.**			**High**		**Med.**	**Med.**	
Foliage density and diversity	**Med.**	**Med.**		**Med.**	**Med.**	**Med.**	**Med.**	**Med.**	
Food availability	**Low**				**Med.**	**High**			
Genetic diversity and infectious agents					**Med.**	**Med.**			
Local hydrology			**Med.**						**Med.**
Nest cavity competitor density	N/A*								
Parental feeding behavior								**Med.**	
Parental nest attendance								**Med.**	
Patch size	**Med.**	**Med.**		**Med.**			**Med.**	**Low**	
Predator density					**Med.**		**Med.**	**Med.**	
Snag density	**Med.**			**Med.**					
Soil salinity			**Med.**						**Med.**
Soil temperature	**Med.**		**Med.**	**Med.**			**Med.**		**Med.**
Tree size	**Med.**			**Med.**	**Med.**		**Med.**		

* N/A value suggests 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 disturbance (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 GIWO 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 GIWO was one of the first species to re-colonize after a low-intensity fire.

Mechanical thinning is generally done at the patch level, with effects lasting until vegetation grows back, and can be as intense as managers wish. 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 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 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 GIWO 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 recreation will likely last less than a decade.

COMMUNITY TYPE

The controlling factors that directly affect community type are fire management, grazing, nuisance species introduction and management, planting regime, and recreational activities. 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, including the creation of habitat that supports or excludes GIWO, a reduction in the food supply of invertebrates, or support of species that pose threats to GIWO such as predators, competitors, or carriers of infectious agents. Most aspects of fire have a negative effect on the presence of GIWO, such as decreasing snags, decreasing cover, or decreasing vertical density and diversity, all of which can increase soil temperatures, decreasing food abundance. Fire may also be used as a tool to alter the community type back to a more native structure to the long-term benefit of GIWO. The dynamic nature of both fire and riparian communities means that the effects of fire management will be likely short term in nature.

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.

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.

FOLIAGE DENSITY AND DIVERSITY

Hunter (1984) reports a disproportionate use of habitats by GIWO with three or four layers of vegetation, with the majority of foliage above 6 m in height. Some controlling factors may benefit foliage density, such as planting regime or thinning, while most others, such as grazing, herbicide application, and recreational activities, will decrease foliage density and diversity. The effects of fire management and nuisance species introduction and management depend on the management actions and species involved.

FOOD AVAILABILITY

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

Fire affects many aspects of vegetation structure and composition, including the creation of habitat that supports or excludes GIWO, and can result in a reduction in the abundance of key invertebrates on which GIWO depend. The dynamic nature of both fire and riparian communities means that the effects of fire management will be likely short term in nature.

Nuisance species can change an arthropod community; however, other factors also affect arthropod availability. The effects of nuisance 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. GIWO 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; Edwards and Schnell 2000).

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 GIWO when the soils are well shaded and cooler (Smith et al. 2006). Controlling factors such as fire, thinning, and planting that affect canopy cover will in turn affect cicada abundance due to the effect on soil temperatures.

GENETIC DIVERSITY AND INFECTIOUS AGENTS

The genetic diversity and infectious agents within an area can be influenced by many factors. However, the most significant and important would be the result of the introduction of novel species to the area. The use of pesticides/herbicides can decrease vectors of diseases but can also decrease the food supply for insectivorous birds such as GIWO.

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 factor involving humans entering the nesting areas during the nesting phase. Recreational activities are the most widespread of these factors.

PARENTAL NEST ATTENDANCE

Parental nest attendance is influenced by any factors involving humans entering the 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, planting regime, and recreational activities. Fire, grazing, mechanical thinning, and recreational activities will generally reduce the size of a given patch, whereas the effects of planting regime depend on the management actions and species involved.

Fire affects vegetation structure and composition at multiple spatial scales. Fires can result in the creation of habitat that supports GIWO or can fragment habitat into patches unsuitable for GIWO. However, the dynamic nature of both fire and riparian communities means that the effects of fire management will be likely short term in nature.

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 unless a complete transformation of the community type occurs.

Mechanical thinning in generally performed at the patch level, with effects lasting until vegetation grows back, and can be as intense as managers wish.

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 structure and species composition of riparian forests, although the impact depends on the activity. The dynamic nature of riparian communities means that they can be resilient to the impacts of recreation after it is constrained or eliminated.

PREDATOR DENSITY

The controlling factors directly affecting predator 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 GIWO population (Lima et al. 2009).

Snag Density

Snag density has been shown to have an influence on GIWO occupancy (Great Basin Bird Observatory 2010). Thinning may reduce the availability of snags, whereas fire management practices may increase or decrease the number of snags depending upon the management involved.

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 most of the factors affecting canopy closure (fire management, mechanical/natural thinning, and planting regime), with the addition of irrigation and water storage-delivery system design and operation. Fire and mechanical/natural thinning will generally reduce canopy closure, increasing soil temperatures, whereas the effects of water storage-delivery system design and operation planting regime, and nuisance species introduction and management depend on the management actions and species involved.

Tree Size

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

Fire can reduce tree size if large trees are burned, but low-intensity fires can reduce competition and promote growth.

Mechanical thinning may also reduce competition and promote growth in larger trees.

The effects of nuisance species introduction and management and planting regime depend on the management actions and species involved.

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 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 the assessment found most strongly directly affect the success of GIWO at each life stage (high or medium magnitude). The findings presented in this diagram may be summarized as follows:

- Disease, eating/foraging, and predation are the most important critical biological activities processes affecting survival of GIWO at all life stages. The effects of eating/foraging are direct and well understood. Depredation of nests can be high within the LCR, but it has not been studied in GIWO specifically (exceeding 80 percent for other species) (Powell and Steidl 2000). Disease has effects on nearly all avian populations and is thus assumed to be a factor within the LCR, although it has not been studied in the area or in GIWO.

- Nest cavity competition, particularly by European starlings, depending upon the timing and form it takes, may prevent GIWO from breeding in a given season (affecting reproduction) or may be a type of predation if displacement occurs after eggs are laid (affecting nest survival). The extent of displacement by nest competitors has been noted, but its impact on the GIWO population has not been studied.

- Three processes directly affect reproduction as we have defined it (i.e., just through egg laying)— nest attendance, nest cavity competition, and nest site selection. These critical biological activities and processes are especially important because they also affect the survival of the nest.

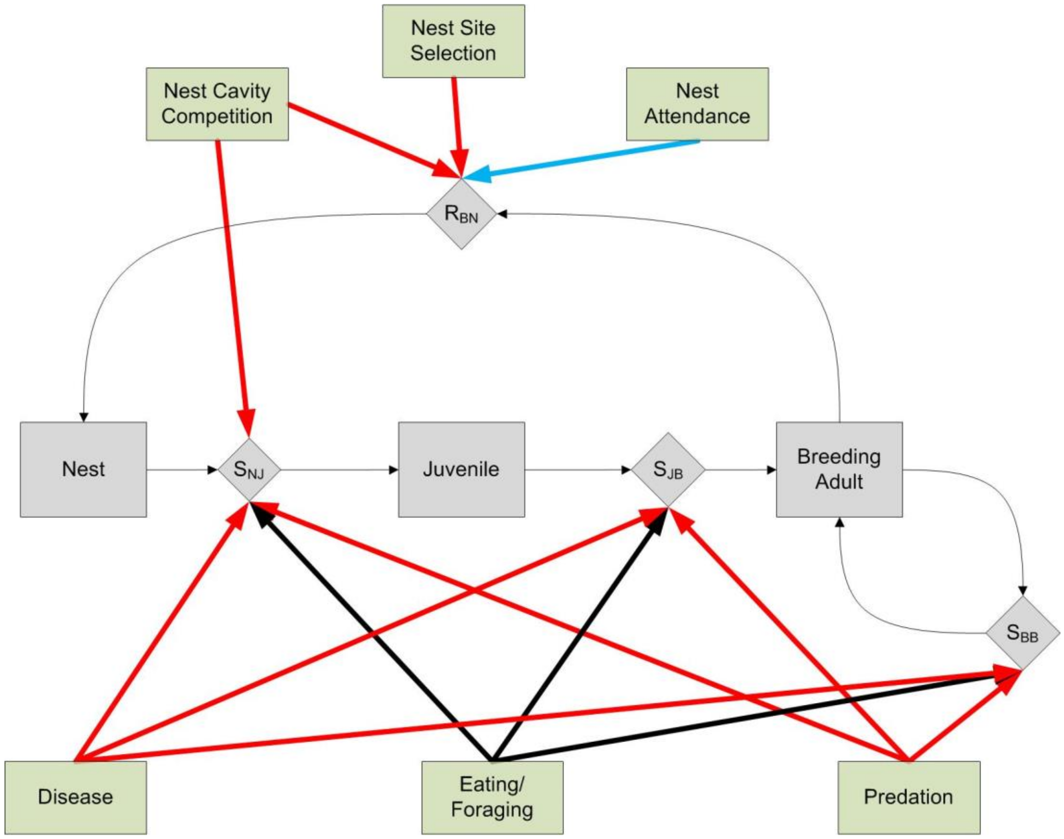

Figure 9.—Most influential biological activities and processes affecting each life stage of GIWO. Only elements with high- or medium-magnitude connections are presented. The legend is provided on figure 2.

POTENTIALLY PIVOTAL ALTERATIONS TO HABITAT ELEMENTS

Figure 10 identifies the habitat elements that the assessment indicates most strongly directly 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. This is not a surprise, as adult birds are expected to choose nest site locations that optimize all of the factors affecting survival for themselves and their young. However, significant uncertainty still exists with regard to the specific ranges of habitat and the sensitivity to subtle changes within the breeding environment.

- Predation is the next most affected process. Predators use many of the habitat variables chosen by their prey to identify suitable habitat. Patch size affects predation rates because of its effects on the proportion of stand area near the edge of the patch, a factor which has been shown to influence predation (Chalfoun and Martin 2009; Theimer et al. 2011). Predator density affects predation rates (Lima 2009). Nest cavity competition may resemble predation if nest displacement occurs after the eggs are laid; otherwise, it may directly affect fecundity.

- Nest attendance is affected by food availability and predator density. Predator density can influence nest defense behavior and thus nest attendance.

- Food availability drives the ability of GIWO at each life stage to acquire needed energy and nutrients, but foraging may be disrupted by anthropogenic disturbance.

- Disease is an important physiological concern that can be impacted strongly by habitat elements, such as the presence of diseases and vectors, and by stress caused by disturbance. Similarly, temperature regulation can be affected by both biotic and abiotic factors.

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.

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

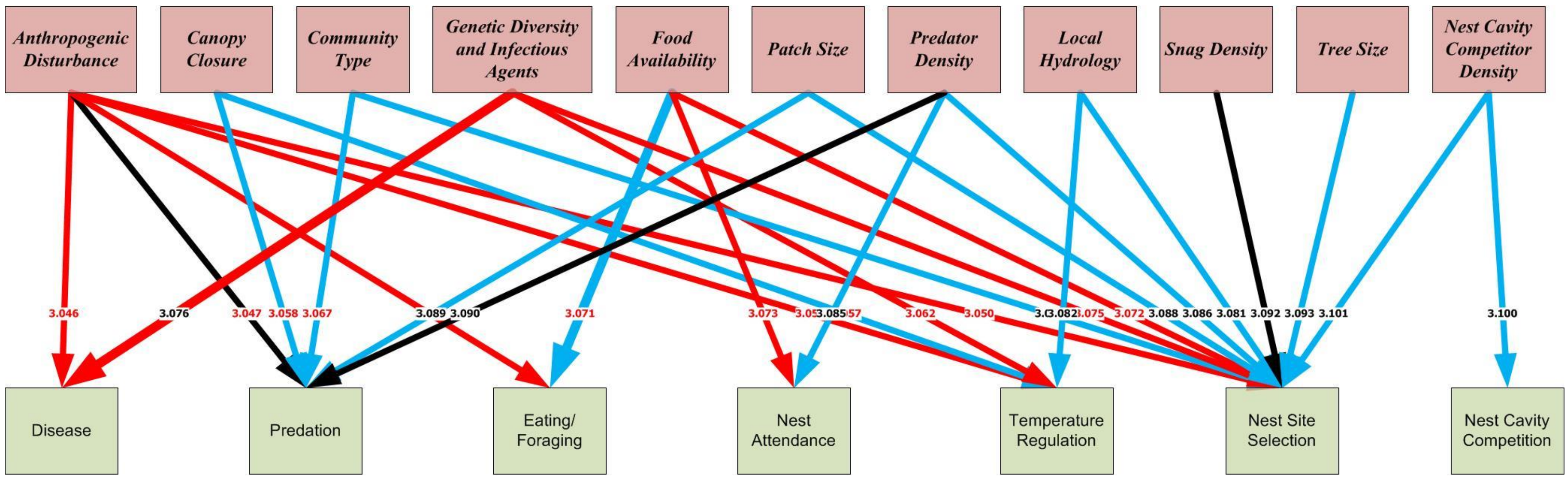

Figure 10.—Habitat elements that directly affect the most influential biological activities and processes across all life stages of GIWO. Only elements with high- or medium-magnitude connections within this life stage are presented. The legend is provided on figure 2.

- Nest site selection is by far affected by the most habitat variables and is one of the most well understood. However, the sensitivity of the species to subtle changes in the nest stands is not well understood and should continue to be studied. The impacts of food availability and disease on nest site selection are not understood. Anthropogenic disturbance is expected to have a large impact, but it has not been studied in this species. The effects of food availability on nest attendance and nest site selection has not been studied. We presume that greater food availability decreases foraging time, thus increasing nest attendance, but the relative strength of the connections are not well understood.

- The effects of disease, ecto-parasites, and endo-parasites have not been studied in GIWO 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 GIWO recruitment along the LCR and to identify important gaps in these publications. They are not in any way to be considered guidance for Reclamation or the 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), Kondolf et al. (2008), Burke et al. (2009), and Wildhaber (2011) 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 closure, 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.

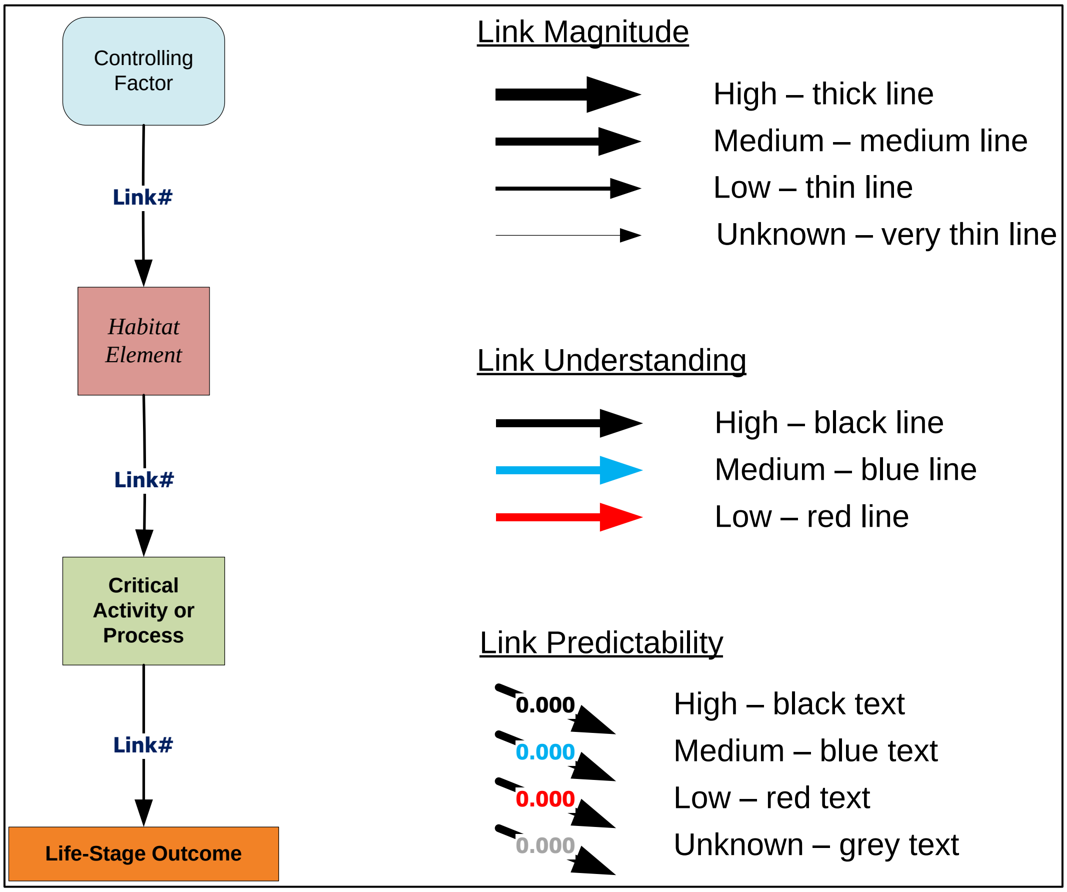

Figure 1-1.—Conventions for displaying cause and effect nodes, linkages, link magnitude, link understanding, and link predictability.

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ATTACHMENT 2

Gila Woodpecker Habitat Data

Table 2-1.—Gila woodpecker habitat data

Habitat element	Value or range	Location	Reference
Community type	Saguaro, cottonwood, willow, sycamore, and mesquite.	Southern Arizona	Bent 1939
	Cottonwood-willow, eucalyptus, athel tamarisk, honey mesquite, and screwbean mesquite. Of 29 nests in the Bill Williams River Delta in 1977–78, 18 in willows, 6 in saguaros, and 5 in cottonwoods.	Lower Colorado River	Rosenberg et al. 1991
	Fremont cottonwood, Goodding's willow, and mesquite. Also nest in exotics.	Arizona	Bradley 2005
	Desert riparian: Fremont cottonwood, Goodding's willow, and Arizona sycamore. Mesquite bosque: Blue Palo verde, honey mesquite, and screwbean mesquite. Urban: Athel tamarisk, eucalyptus, and blue fan palm.	Southeast California	McCreedy 2008
	Presence of mistletoe, willow, and cottonwood positively correlated with presence of gila woodpeckers	Lower Colorado River	Great Basin Bird Observatory 2010
	More often in tall cottonwood-willow with high foliage density and diversity.	Lower Colorado River	Hunter 1984
Patch size	> 20 hectares	Lower Colorado River	Rosenberg et al. 1991
Snag density	Greater numbers of snags in territory, within 100 meters (m), and within 1,000 m.	Lower Colorado River	Great Basin Bird Observatory 2010
Tree size	Palo verde – average plant height = 7.3 m, average nest height = 4.2 m, average diameter at breast height (DBH) = 39 centimeters (cm), and average DBH = 46 cm. Smallest – 25 cm DBH and 7.3 m in height.	Southeast California	McCreedy 2008
	> 12 cm DBH, > 10 m in height.	Lower Colorado River	Great Basin Bird Observatory 2010

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

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