



Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Gilded Flicker (*Colaptes chrysoides*) (GIFL) Basic Conceptual Ecological Model for the Lower Colorado River



Photo courtesy of Curtis Marantz



June 2015

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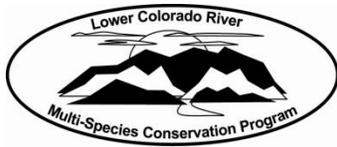
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Lower Colorado River Multi-Species Conservation Program

Gilded Flicker (*Colaptes chrysoides*) GIFL Basic Conceptual Ecological Model for the Lower Colorado River

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ACRONYMS AND ABBREVIATIONS

CEM	conceptual ecological model
GIFL	gilded flicker (<i>Colaptes chrysoides</i>)
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
Reclamation	Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service
WNV	West Nile Virus

Symbols

>	greater than
<	less than
%	percent

Definitions

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

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

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

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

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

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Attachments

Attachment

- 1 Species Conceptual Ecological Model Methodology for the Lower Colorado River Multi-Species Conservation Program
- 2 Gilded Flicker Habitat Data

Foreword

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

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

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

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

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

Model building consists of determining system parts, identifying the relationships that link these parts, specifying the mechanisms by which the parts interact, identifying missing information, and exploring the model's behavior (Heemskerk et al. 2003¹). 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.

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
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September 2015*

Executive Summary

This document presents a conceptual ecological model (CEM) for the gilded flicker (*Colaptes chrysoides*) (GIFL). 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 GIFL ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure GIFL 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 GIFL 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.

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

- **Life stages** – These consist of the major growth stages and critical events through which an individual GIFL must pass in order to complete a full reproductive cycle.
- **Life-stage outcomes** – These consist of the biologically crucial outcomes of each life stage, including the number of individuals recruited to the next life stage or age class within a single life stage (recruitment rate), or the number of offspring produced (fertility rate).
- **Critical biological activities and processes** – These consist of activities in which the species engages and biological processes that take place during each life stage that significantly beneficially or detrimentally shape the life-stage outcome rates for that life stage.
- **Habitat elements** – These consist of the specific habitat conditions, the abundance, spatial and temporal distributions, and other qualities of which significantly beneficially or detrimentally affect the rates of the critical biological activities and processes for each life stage.
- **Controlling factors** – These consist of environmental conditions and dynamics – including human actions – that determine the abundance, spatial and temporal distributions, and other qualities of the habitat elements for each life stage. Controlling factors are also called “drivers.”

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

CONCEPTUAL ECOLOGICAL MODEL STRUCTURE

The GIFL conceptual ecological model addresses the GIFL throughout its breeding and overwintering range, as GIFL are year-round residents of the lower Colorado River (LCR). The model thus addresses the landscape as a whole rather than any single reach or managed area.

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The most widely used sources of the information for the GIFL conceptual ecological model are Moore (1995), Reclamation (2008), Sabin (2012), and NatureServe (2014). 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 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 GIFL conceptual ecological model distinguishes and assesses four life stages and their associated outcomes as follows (table ES-1):

Table ES-1.—Outcomes of each of the four life stages of GIFL

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

The model distinguishes nine critical biological activities and processes relevant to one or more of these four life stages and their outcomes, nine habitat elements relevant to one or more of these nine critical biological activities and processes for one or more life stages, and seven controlling factors that affect one or more of these seven habitat elements. Because the LCR comprises a highly regulated system, the controlling factors exclusively concern human activities.

The nine critical biological activities and processes identified across all life stages are: competition, disease, eating, foraging, molt, nest attendance, nest site selection, predation, and temperature regulation. The nine habitat elements identified across all life stages are: brood size, cavity trees, food availability, foraging habitat, infectious agents, parental feeding behavior, parental nest attendance, predator/competitor density, and temperature. The seven controlling factors identified across all habitat elements are: fire management, grazing, nuisance species introduction and management, pesticide/herbicide application, planting regime, site management, 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:

- Foraging stands out as one of the more important critical biological activities and processes for GIFL. Predation is ever-present and directly affects survival, but gaps in knowledge about predation rates remain. Other processes, such as disease, molt, and temperature regulation, can be very important, but are less understood, especially within the LCR.
- Only two processes directly affect reproduction—nest attendance and nest site selection. Nest site selection is especially important, as it can indirectly influence survival in all life stages. For example, good nest sites may have more food, fewer predators, and fewer diseases present.
- The habitat elements that most influenced critical biological processes and activities and GIFL breeding success were the presence of cavity trees and food availability, which in turn is directly affected by the quality of the foraging habitat. Ensuring that suitable foraging habitat is available along the LCR year round and in proximity to nesting sites may be an important management goal.
- The link magnitude for infectious agents was strong, but this is a reflection of a lack of knowledge about this element in the LCR system (coupled with the process of disease). With further research, it may be that this is a less important habitat element (and critical process) than for other bird species along the LCR.

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 GIFL survivorship and recruitment along the LCR. Specifically, the findings suggest a need to improve the understanding of the following:

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- Disease can affect most critical biological activities and processes, yet the effects of disease on GIFL along the LCR are unknown, as are the infectious agents that may be present (other than West Nile Virus).
- Predation rates on GIFL along the LCR are unknown, as are the effects of other management activities on predator/competitor density.
- GIFL habitat requirements need to be determined in more detail. Specifically, more information is needed on vegetation composition and structure, minimum patch size, and the effects of habitat fragmentation.
- There are past records of GIFL nesting in large cottonwoods (*Populus fremontii*) or willows (*Salix* sp.), but recent records are lacking. How do GIFL use riparian habitat these days? If these habitats are used mainly for foraging post-breeding, is there a minimal distance to the nest sites that these riparian habitats need to be? Is there a planting regime (e.g., planting not only cottonwood and willow but also Joshua trees [*Yucca brevifolia*] or mesquite [*Prosopis* sp.] in which they may forage) more optimally for GIFL?
- Interactions between GIFL and other cavity-nesting species, such as European starlings (*Sturnus vulgaris*), need to be studied. One paper suggests that competition with starlings is not a significant problem for these flickers (Kerpez and Smith 1990), but an additional look is warranted, as the presence of starlings affects nesting of Gila woodpeckers (*Melanerpes uropygialis*) and northern flickers (*Colaptes auratus*).
- The use of nest boxes has been proposed. Are nest cavities a limiting factor? Will GIFL use them? If so, what is the best design for them?
- Roosting habitats for GIFL remain unknown. Northern flickers will use tree cavities – do GIFL use cacti cavities at night or cavities in tree snags? (Note: GIFL have been reported roosting in palm trees [*Washingtonia* sp.] [B. Sabin and M.E. Chavez 2014, personal communication], but more information is needed.)
- GIFL are year-round residents along the LCR. Seasonal movements and overwintering ecology remain unknown. What habitats are overwintering GIFL using at the LCR? What is the pattern of their seasonal movements among habitats? How much time is spent in each habitat during the year foraging for food? Is there post-fledging dispersal by juveniles?

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- Ants typically comprise nearly one-half of the flicker's diet. Have any stomach analyses of gilded or other flicker species along the LCR been done to see what ant species are being consumed? What is the status of ant populations or colonies generally along the LCR? Are there activities in riparian or upland habitats detrimental to ant colony persistence (e.g., heavy grazing, pesticide/herbicide application, other significant soil disturbance)? (Note: Ants can be identified at least to genera in stomach analyses, as heads are usually well preserved [S. Cover 2014, personal communication].)
- What is the possibility of restoring saguaro cacti (*Carnegiea gigantea*) habitat in areas adjacent to the riparian corridor? It appears that optimal habitat for GIFL includes cacti for nesting, roosting, and foraging, and riparian habitat for foraging and roosting.
- Nuisance species introduction and management also deserves a closer look to better understand the effects of species introductions and control efforts to eradicate other pests along the LCR on GIFL and its habitats.

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 GIFL. 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 gilded flicker (*Colaptes chrysoides*) (GIFL). 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 GIFL ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure GIFL 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 GIFL population along the river and lakes of the lower Colorado River (LCR) and other protected areas. 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 GIFL conceptual ecological model are Moore (1995), Reclamation (2008), Sabin (2012), and NatureServe (2014). Where appropriate and accessible, those earlier studies are directly cited. These publications summarize and cite large bodies of earlier studies. The CEM also integrates numerous additional sources, particularly reports and articles completed since the aforementioned publications; information on current research projects; and the expert knowledge of LCR MSCP biologists. The purpose of the CEM is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

This document is organized as follows: The remainder of chapter 1 provides a general description of the reproductive ecology of the GIFL as presently understood, the purpose of the model, and introduces the underlying concepts and structure of the CEM. Succeeding chapters present and explain the model for GIFL along the LCR and evaluate the implications of this information for management, monitoring, and research needs. Although there is a lack of published research specifically on GIFL, the northern flicker (*Colaptes auratus*) has been well studied, and many of these resources have been used to help develop this model.

GILDED FLICKER REPRODUCTIVE ECOLOGY

GIFL are considered year-round residents of the LCR (Reclamation 2008 and references therein). In late winter or early spring, breeding adults form pair bonds and begin nest excavation, preferably in saguaro cacti (*Carnegiea gigantea*). Occasionally, they will reuse old cavities rather than excavate new ones. Egg laying peaks from mid-April to mid-May (Rosenberg et al. 1991; Corman 2005), with an average of four eggs laid per clutch. Both parents incubate for 11–12 days (NatureServe 2014) and tend to the hatched young. Fledging occurs in 21–27 days (Reclamation 2008), and juvenile flickers may remain with their parents as part of “family groups,” foraging together at least through July (B. Sabin and M.E. Chavez 2014, personal communication). There is little information about juvenile movements post-fledging or overwintering behavior and habitat use. GIFL feed mainly on insects during the spring and summer months (mostly ants, followed by beetles, grasshoppers, caterpillars, and other larvae). In addition, they will supplement their diet with seeds, berries, and other fruits (Bent 1939).

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 GIFL

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), Wildhaber (2011), Kondolf et al. (2008), and Burke et al. (2009) to provide greater detail on causal linkages and outcomes and explicit demographic notation in the characterization of life-stage outcomes (McDonald and Caswell 1993). Attachment 1 provides a detailed description of the methodology. The 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 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 GIFL conceptual ecological model has five core components as explained further in attachment 1:

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- **Life stages** – These consist of the major growth stages and critical events through which the individuals of a species must pass in order to complete a full life cycle.
- **Life-stage outcomes** – These consist of the biologically crucial outcomes of each life stage, including the number of individuals recruited to the next life stage (e.g., juvenile to adult), or the number of offspring produced (fertility rate). The rates of the outcomes for an individual life stage depend on the rates of the critical biological activities and processes for that life stage.
- **Critical biological activities and processes** – These consist of the activities in which the species engages and the biological processes that take place during each life stage that significantly affect its life-stage outcomes rates. Examples of activities and processes for a bird species may include 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 on 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, 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 climate, land use, vegetation, water demand, and watershed geology.

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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 and 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 – GIFL 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 GIFL along the LCR on which to build the CEM.

INTRODUCTION TO THE GIFL LIFE CYCLE

GIFL are year-round residents of the LCR, so we have developed a four-stage model that includes an overwintering life stage. Also, in many studies of avian demography, nest survival is considered integral in the reproduction of adults because adults are heavily invested in the care of eggs and nestlings (Etterson et al. 2011). We treat the nest stage as separate from adult reproduction due to the specific factors influencing the nest 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 GIFL 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.

GIFL LIFE STAGE 1 – NEST

This life stage includes both the egg and nestling phase. It begins when the first egg is laid and ends when the young fledge or if the nest fails. Peak egg laying activity occurs from Mid-April to mid-May, although eggs may be laid earlier in March in some locations (Rosenberg et al. 1991; Corman 2005). An average of four eggs are laid per clutch, with one brood per season most likely, although there are records of double brooding (Rosenberg et al. 1991). Incubation, by both parents, begins after the clutch is complete and lasts around 11–12 days (NatureServe 2014). Both parents attend the nest after the eggs hatch, feeding young with regurgitant (Bent 1939). The young typically fledge in 21–27 days (Reclamation 2008); however, there is no information on survivorship. The life-stage outcome from the nest stage is the survival of eggs and associated nestlings. It is important to note that the outcome of the nest stage is inherently tied to the behavior and condition of the parents.

GIFL LIFE STAGE 2 – JUVENILE

The juvenile stage is relatively short and lasts from the time the birds fledge and leave the nest until they molt into their first winter plumage in fall. There is no information on how long the recently fledged young remain in the vicinity of the nest and/or with adults, although LCR biologists have observed “family groups” of flickers foraging together through July (B. Sabin and M.E. Chavez 2014, personal communication). The life-stage outcome from the juvenile stage is the survival of the bird from successfully leaving the nest and fledging to molting into winter plumage later in fall.

GIFL LIFE STAGE 3 – OVERWINTERING INDIVIDUAL

The overwintering individual stage lasts from the time the juvenile birds molt into their first winter plumage until they are ready to breed the following spring. GIFL are considered year-round residents and do not migrate (Reclamation 2008 and references therein). It is assumed that birds remain onsite throughout the year, although there has been no research on flicker movements post-fledging. (Note: A new LCR MSCP project looking at GIFL seasonal movements is currently underway.) Northern flickers reach sexual maturity the following spring, so it is assumed that the same holds true for GIFL. The life-stage outcome from the overwintering stage is the survival of the bird post-molt to become a breeding adult along the LCR.

GIFL LIFE STAGE 4 – BREEDING ADULT

The breeding adult stage begins with pair bonding and nest excavation, usually beginning in January and February along the LCR region (B. Sabin and M.E. Chavez 2014, personal communication). Saguaro cacti are preferred nest sites, and although both parents excavate the cavity, the males may play a larger role. Excavation is typically done early in the season and may take 3 months (Juarez 2010), as cacti holes need time to cure before they can be used. GIFL will sometimes reuse old cavities. The breeding adult stage ends when the young are successfully fledged and are foraging completely on their own.

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 output 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

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can be better assessed by management. Therefore, adult reproduction involves the acts of pairing, site selection, nest building, and the production of eggs.

LIFE STAGE MODEL SUMMARY

Based on this information, the GIFL conceptual ecological model distinguishes four 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 life stage.

Table 1.—Outcomes of each of the four life stages of GIFL

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

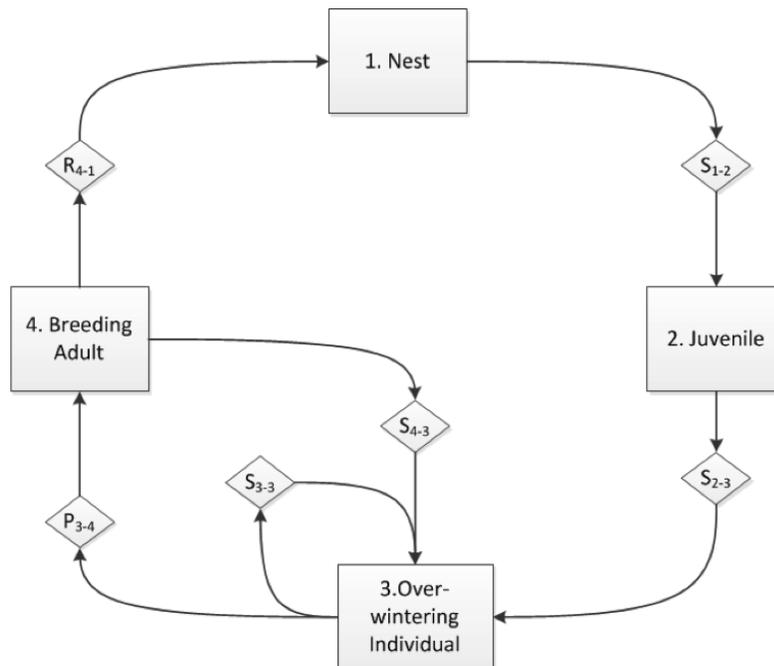


Figure 1.—Proposed GIFL life history model.

Squares indicate the life stage, and diamonds indicate the life-stage outcomes. S_{1-2} = survivorship rate, nest; S_{2-3} = survivorship rate, juveniles; S_{3-3} = annual survivorship rate of overwintering individuals that do not breed; P_{3-4} = annual rate of participation of adults in breeding; S_{4-3} = survivorship rate, breeding adults; and R_{4-1} = 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 nine critical biological activities and processes that affect one or more GIFL 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 nine critical biological activities and processes and their distribution across life stages.

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

Life stage →				
Critical biological activity or process ↓	Nest	Juvenile	Overwintering individual	Breeding adult
Competition				X
Disease	X	X	X	X
Eating	X			
Foraging		X	X	X
Molt	X	X		X
Nest attendance				X
Nest site selection				X
Predation	X	X	X	X
Temperature regulation	X	X	X	X

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The most widely used sources of the information used to identify the critical biological activities and processes are Moore (1995), Reclamation (2008), Sabin (2012), and NatureServe (2014). These publications summarize and cite large bodies of earlier studies. Where appropriate and accessible, those earlier studies are directly cited. The identification also integrates information from both older and more recent works as well as the expert knowledge of LCR MSCP biologists. The following paragraphs discuss the nine critical biological activities and processes in alphabetical order.

COMPETITION

This process refers specifically to competition for nest cavities with European starlings (*Sturnus vulgaris*), which have been identified as a concern in the LCR region, particularly for Gila woodpeckers (*Melanerpes uropygialis*) (Kerpez and Smith 1990). Although GIFL were less affected in that study, northern flickers have been shown to delay nesting in response to starling competition for nest cavities (Ingold 1996).

DISEASE

This process refers to diseases caused either by lack of genetic diversity or by infectious agents. Although there is little information available about GIFL in relation to disease susceptibility (Moore 1995), GIFL in all life stages are conceivably susceptible to disease. In recent years, West Nile Virus (WNV) has spread into the Western United States. Although corvids and raptors appear to be most vulnerable to WNV (e.g., American crows [*Corvus brachyrhynchos*] typically experience 100% mortality if infected), the disease can still kill or weaken other bird species, including flickers.

EATING

This process only applies to the nest life stage because nestlings must eat to stay alive and develop but do not actively forage within their environment in the same way as juveniles and adults. A nestling's ability to eat during the first weeks of life is determined by the foraging and provisioning rate of its parents. (Juveniles may still be fed by adults for some time after fledging [see the habitat element of parental feeding behavior.]

FORAGING

GIFL are mainly insectivores, feeding predominantly on ants, as well as beetles and other soil invertebrates, and occasionally on seeds and berries depending on insect availability (Moore 1995). Foraging is done by juveniles and adults; however, it is important to note that the foraging of parents affects the provisioning rate to nestlings and juveniles (see the habitat elements of parental feeding behavior and parental nest attendance).

MOLT

GIFL are altricial and must molt from natal down into juvenal plumage to fledge. In northern flickers, juveniles molt into their first winter plumage a few months later, and each year thereafter adults go through a fall (post-nuptial) molt (Bent 1939). GIFL likely go through the same molting sequence. This activity applies to both the nest stage, the juvenile stage, and to the breeding adult stage. Molt is an energetically costly process (Gill 2007), especially at the nest and juvenile stage, and may make nestlings more susceptible to death when resources are scarce.

NEST ATTENDANCE

Both males and females incubate, brood, and feed young chicks (Moore 1995). Nest attendance is performed by breeding adults (and is dependent in part on their survivorship) and affects the nest life stage (egg hatching and the provisioning rate to nestlings).

NEST SITE SELECTION

GIFL preferentially nest in mature saguaro cacti, with older records of nesting reported in riparian cottonwoods (*Populus fremontii*) and/or willows (*Salix* sp.) (see Reclamation 2008 and reference therein.) (Note: No breeding in LCR riparian habitat has been reported in recent years, although birds have been observed visiting the habitat – see Sabin 2012). It is unknown whether the male or female selects the site (Moore 1995 and references therein). Both parents excavate the nest hole, with males playing a larger role.

In general, nest placement can affect vulnerability to predation and competition, environmental conditions in the nest cavity, and foraging rates, depending on proximity to food resources. Inouye et al. (1981) found that Gila woodpeckers

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oriented their nest cavity entrances non-randomly, in a northerly direction (avoiding direct sunlight). Similarly, research by Zwartjes and Nordell (1998) found that GIFL nest cavities in cardón cacti (*Pachycereus pringlei*) in Mexico were typically oriented to the north or northwest, although this was modified depending on cacti architecture. A cavity entrance with greater visibility may also enhance nest protection efforts against predators (Zwartjes and Nordell 1998). In addition to the cavity entrance orientation effect on nest temperature, the thick saguaro cacti tissue may provide additional buffering. Environmental conditions in the nest are important, as Wiebe (2001) found that clutch size in northern flickers was affected by cavity temperature (and therefore by cavity orientation and substrate).

PREDATION

Predation is a threat to GIFL in all life stages, and it obviously affects survival to varying degrees. Although the most common predators of GIFL are well-known (see the habitat element of predator/competitor density), the rates of predation at any GIFL life stage are not known. Flickers typically feed on open ground in search of ants and other soil invertebrates, making adults vulnerable to avian predators, especially raptors (Fisher and Weibe 2006; Reclamation 2008 and references therein). Young in the nest are vulnerable to mammalian and reptilian predators predominantly (Moore 1995). (Note: Even if cavity nesters experience relatively less predation than open cup nesters, nest predation is still the largest source of nest loss overall, causing up to 80% of nest failures [Martin 1993].)

TEMPERATURE REGULATION

Temperature regulation is important for any organism inhabiting a region as hot as that along the LCR. Although overheating is possible during all life stages, most of the concern has been directed at eggs and nestlings (Rosenberg et al. 1991). However, adults can affect the temperature regulation of eggs and nestlings through their own behavior (incubation or brooding) and through nest placement and construction. For example, in northern flickers, cavity placement in larger trees (versus those with smaller trunks or with more dead wood) has been shown to moderate daily temperature and humidity fluctuation, as does the orientation of the cavity opening (Wiebe 2001). GIFL may face more thermal stress than smaller woodpeckers in desert regions, and the orientation of GIFL cavities in cardón cacti in Mexico is usually in a north-northwesterly direction, facing away from direct sun and possibly capturing prevailing winds (Zwartjes and Nordell 1998). Temperatures inside saguaro cacti nest cavities may be markedly cooler in summer than outside daytime air temperatures (e.g., Soule [1964] in Inouye et al. [1981] report cavity nest temperatures 12.6 degrees Fahrenheit [7 degrees Celsius] cooler.)

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 nine habitat elements that affect one or more critical biological activities and processes across the four GIFL life stages. Some of these habitat elements differ in their details among life stages. For example, different GIFL at different life stages may experience different predation rates. 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.

The habitat elements included here were chosen based upon scientific literature demonstrating a direct influence on GIFL, influence on similar species or species in similar habitats, or based upon the experience of the author and reviewers with GIFL or related species.

Table 3 lists the nine habitat elements and the critical biological activities and processes that they *directly* affect across all GIFL life stages.

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

Critical activity or process →									
	Competition	Disease	Eating	Foraging	Molt	Nest attendance	Nest site selection	Predation	Temperature regulation
Habitat element ↓									
Brood size			X	X		X			
Cavity trees	X						X		
Food availability				X			X		
Foraging habitat								X	
Infectious agents		X							
Parental feeding behavior				X				X	
Parental nest attendance			X					X	
Predator/competitor density	X					X	X	X	
Temperature						X	X		X

Note: No habitat element directly affects molt; rather, the effects are indirect from infectious agents via disease and food availability via foraging.

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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, the habitat element label, “food availability,” is the short name for “the diversity, sizes, abundance, and spatial and temporal distributions of the species on which GIFL feed.” The following paragraphs provide the full name for each habitat element and a detailed definition, addressing the elements in alphabetical order.

The most widely used sources of the information used to identify the habitat elements are Moore (1995), Reclamation (2008), Sabin (2012), and NatureServe (2014). These publications summarize and cite large bodies of earlier studies. Where appropriate and accessible, those earlier studies are directly cited. The identification also integrates information from both older and more recent works as well as the expert knowledge of LCR MSCP biologists.

Briefly, typical GIFL breeding habitat consists of Sonoran desert habitat with saguaro cacti in which flickers construct nest cavities. Flickers forage for ground insects, mainly ants, in the vicinity of the nest “tree” but may also visit nearby riparian areas to forage (Rosenberg et al. 1991). Riparian habitats with cottonwood and willow have supported GIFL in the past (Reclamation 2008).

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).

BROOD SIZE

Full name: **The number of young in the nest.** This element refers to the number of young that the parents must rear. Clutch 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 (Gill 2007) as well as other factors such as predator density. The typical brood consists of four eggs (Rosenberg et al. 1991).

CAVITY TREES

Full name: **The abundance and spatial distribution of the arborescent cacti or tree species in which GIFL nest.** The presence of nesting sites for cavity construction, in particular saguaro cacti, but may include cottonwood, willow, and in some cases, honey mesquite (*Prosopis glandulosa*) along the LCR

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(Reclamation 2008). Cacti and nest trees, if used, must be of sufficient size and condition to support cavity excavation. GIFL typically excavate their nest cavity toward the top of saguaro cacti, and in one study, they did not nest in saguaros less than 5 meters tall (Kerpez and Smith 1990).

Large cavity trees may also serve as roost sites, and northern flickers are known to use cavities for roosting year round, even during migration (Gow et al. 2015). However, little is known about GIFL habitat use along the LCR outside the breeding season or the extent to which they rely on cavities for roosting, if at all. For this reason, cavity use for roosting has not been incorporated into the current model.

FOOD AVAILABILITY

Full name: **The diversity, size, abundance, and spatial and temporal distributions of the species on which GIFL feed.** This element refers to the availability of food resources, whether ants, beetle larvae, or seeds and berries, which individual GIFL will encounter during each life stage, and the density and spatial and temporal distributions of the food supply in proximity to the nest. Flickers feed predominantly on insects during the spring and summer months (mostly ants, followed by beetles, grasshoppers, caterpillars, and other larvae), supplementing their diet with plant matter (seeds and berries) when insects are less numerous (Bent 1939). Other important spring food sources include nectar from ocotillo (*Fouquieria splendens*) and saguaro cacti as well as the saguaro fruits later in the season (E. Best 2015, personal communication). Food availability determines, in part, not only clutch size, but also winter survivorship (Koenig 1984; Gill 2007).

FORAGING HABITAT

Full name: **The abundance and spatial distribution of suitable foraging habitat.** GIFL feed on ground insects (primarily ants) and other invertebrates. Flickers have also been known to feed on insects in flowers, foraging on ocotillo, Palo verde (*Parkinsonia florida*), and on ironwood (*Olneya*) trees (B. Sabin and M.E. Chavez 2014, personal communication). In fact, Kerpez and Smith (1990) found that flicker nesting density was positively correlated with ironwood volume. During winter, when insects are less abundant and ant colony populations are smaller (Hölldobler and Wilson 1990), GIFL also will feed on seeds and berries (Terres 1980). For example, they have been observed feeding on mistletoe berries in mesquite (*Prosopis* sp.) (Sabin 2012). Optimal foraging habitat may include open areas with friable soil suitable for ant colony establishment and maintenance, presence of flowering shrubs that support insect

populations, as well as areas that provide berries and seeds, and may vary throughout the year. Riparian habitats may be used for foraging and roosting, especially after the young fledge (B. Sabin and M.E. Chavez 2014, personal communication). Although there is little information available, the proximity of riparian habitat to saguaro cacti nest sites may be important to successful nesting and/or juvenile or overwintering survival.

INFECTIOUS AGENTS

Full name: **The types, abundance, and distribution of infectious agents.**

Infectious agents refer to the spectrum of viruses, bacteria, fungi, and parasites capable of infecting GIFL that individual GIFL are likely to encounter during each life stage. The effects of disease and other infectious agents are poorly understood. In recent years, WNV has spread into the Western United States. Although corvids and raptors appear to be most vulnerable to WNV (e.g., American crows typically experience 100% mortality if infected), the disease can still kill or weaken other bird species, including flickers.

PARENTAL FEEDING BEHAVIOR

Full name: **The ability and behavior of parents to feed and care for juveniles after they leave the nest.** This element refers to the capacity of both parents to provision food for GIFL young that have left the nest. The length of time that juveniles are fed after fledging is unknown in this species. The feeding rate is dependent upon food availability and the number of young in the brood. This rate influences the amount of food and time spent foraging by the juvenile birds.

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 tend to the young. It is affected primarily by the presence of predators and food availability.

PREDATOR/COMPETITOR DENSITY

Full name: **The taxonomic and functional composition, abundance, and spatial and temporal distributions of species that may prey on or compete with GIFL during each life stage.** This element refers to a set of closely related

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variables that affect the likelihood that different kinds of predators or competitors will encounter and successfully prey on or compete with GIFL during any life stage. The variables of this element include the species and sizes of the fauna that prey on or compete with GIFL during different life stages and the density and spatial distribution of these fauna in the riparian or desert habitat used by GIFL. Predators typically include raptors and crows; mammals such as raccoons (*Procyon lotor*) and weasels (*Mustela* sp.); and lizards and bull snakes (*Pituophis* sp.) etc. (Moore 1995; Kucera 1997). Susceptibility of northern flickers to predation is related to ground cover (as GIFL feed mostly on the ground) and nest location (e.g., height above the ground and vegetation cover at the nest entrance) (Wiebe 2001). Little is known about depredation rates of juveniles or adults.

Competitors may include European starlings. Starlings are known to compete for nest cavities with other flicker species but may not be an issue for GIFL, which are larger than Gila woodpeckers, with which starlings usually compete (Kerpez and Smith 1990; Reclamation 2008). Competition from starlings may also differ from habitat to habitat, depending on which communities support more starlings and whether cavities are a limiting factor.

TEMPERATURE

Full name: **The mean temperature in a habitat patch or nest site.** This element refers to the average temperature in the nesting habitat around the nest site (or during the nesting season). High temperatures typical of the LCR region in summer can kill eggs and stress young in the nest (Rosenberg et al.1991).

Chapter 5 – Controlling Factors

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

Table 4.—Habitat elements directly affected by controlling factors

Controlling factor →	Fire management	Grazing	Nuisance species introduction and management	Pesticide/herbicide application	Planting regime	Site management	Water storage-delivery system design and operation
Habitat element ↓							
Brood size	N/A*						
Cavity trees	X	X	X		X		X
Food availability				X		X	X
Foraging habitat	X	X	X		X	X	X
Infectious agents			X				X
Parental feeding behavior	N/A*						
Parental nest attendance	N/A*						
Predator/competitor density			X				
Temperature	N/A*						

* N/A values suggest that none of the identified controlling factors *directly* affect the habitat element. Brood size, parental feeding behavior, and parental nest attendance are affected indirectly through other habitat elements. Temperature is determined by regional climate and local weather conditions.

FIRE MANAGEMENT

This factor addresses any fire management (whether prescribed fire or fire suppression) along the LCR that could affect GIFL or their habitat. Effects may include the creation of habitat that supports or excludes GIFL or reduces the food supply for ants and other ground invertebrates on which GIFL feed. (Note: The underground location of many ant colonies can buffer them from direct mortality [Andersen 1991].) Habitat alterations due to fire may also support species that pose threats to GIFL such as predators (Wiebe 2014), competitors, or carriers of infectious agents. Although typically not a major threat in most riparian habitats, severe wildfires have affected cottonwood-willow riparian habitat in the past decade (Graber et al. 2007). The U.S. Fish and Wildlife Service (USFWS) (2013) specifically recommends fire management for the recovery of southwestern willow flycatcher (*Empidonax traillii extimus*) populations, which breed in habitats similar to those that GIFL use for foraging (and possibly nesting). In addition, the presence of flammable exotic species, such as grasses, may increase fire frequency and/or intensity in desert systems, destroying saguaro cacti (Bock and Block 2005; Juarez 2010). Climate change is also projected to affect fire frequency along the LCR (USFWS 2013).

GRAZING

This factor addresses the grazing activity on riparian habitats along the LCR, which could affect GIFL or their habitat. Grazing by cattle, burros, or mule deer across the arid Southwestern United States has substantially degraded riparian habitat (see Appendix G 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 or even prevent the establishment of cottonwood and willow seedlings (Kauffman et al. 1997), affecting foraging habitat quality and the potential for future nest cavity trees should GIFL nest in riparian habitat. Overgrazing may remove upland grasses, reducing the seed supply for ants on which GIFL feed (B. Sabin and M.E. Chavez 2014, personal communication) and may impede ant foraging and nest construction (S. Cover 2014, personal communication).

NUISANCE SPECIES INTRODUCTION AND MANAGEMENT

This factor addresses the intentional or unintentional introduction of nuisance species (animals and plants) and their control that affect GIFL survival and reproduction. The nuisance species may infect, prey on, compete with, or present

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alternative food resources for GIFL during one or more life stages; cause other alterations to the riparian food web that affect GIFL; or affect physical habitat features such as vegetation cover. Exotic species, such as grasses, have increased wildfire frequency and intensity, with effects on preferred nesting sites in saguaro cacti (see “Fire Management,” above). Invasive salt cedar (*Tamarisk* sp.) has degraded riparian habitat generally in the LCR region, preventing germination and establishment of new cottonwood or willow trees. This may affect GIFL foraging as well as reduce the potential for suitable nesting sites in the future.

PESTICIDE/HERBICIDE APPLICATION

This factor addresses pesticide/herbicide applications (e.g., herbicide, insecticide, fungicide, etc.) that may occur on or adjacent to riparian habitat along the LCR. Effects may include sublethal poisoning of GIFL via ingestion of treated insects and a reduced invertebrate food supply. Any pesticide/herbicide application that targets ant colonies or other ground-dwelling arthropods is particularly problematic, as flickers feed primarily on ants. In addition, herbicide treatment of cheatgrass (*Bromus tectorum*) that affects other grass species on which ants depend may be problematic (see “Nuisance Species Introduction and Management,” above).

PLANTING REGIME

This factor addresses the active restoration 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. GIFL are known to forage in riparian habitats post-breeding and over the winter. They may also nest or roost in older cottonwoods or willows and often frequent mesquite shrub habitat (B. Sabin and M.E. Chavez 2014, personal communication).

SITE MANAGEMENT

This factor addresses any site management activities related to infrastructure, such as road maintenance, which affect GIFL habitat. For example, road grading, mowing, and/or vegetation removal from the sides of roads and adjacent berms may interfere with GIFL feeding at ant colonies along these road edges. Such activities can destroy colonies directly or remove grasses and seeds on which desert seed-collecting ants feed (B. Sabin and M.E. Chavez 2014, personal communication) (northern flickers that winter along the LCR feed at ant colonies

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along the road edges, so likely GIFL do as well.) (Note: Arizona has more ant species than any other State.) Once established, some desert ant colonies can “live” for a decade or more (Wheeler and Rissing 2014), likely providing a relatively stable food source for feeding flickers from year to year.

WATER STORAGE-DELIVERY SYSTEM DESIGN AND OPERATION

Riparian habitat that may be used by GIFL is along regulated waterways. The water moving through these systems is highly managed to allow for storage and delivery (diversion) to numerous international, Federal, State, Tribal, and municipal users and for hydropower generation. Along the LCR, GIFL are thought to use riparian habitats for foraging and roosting (Rosenberg et al. 1991; B. Sabin and M.E. Chavez 2014, personal communication), although there are past records of nesting in cottonwoods/willows (Reclamation 2008 and references therein).

Chapter 6 – Conceptual Ecological Model by Life Stage

This chapter contains three sections, each presenting the CEM for a single GIFL 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 model sections specifically refer to the river and lakes of the LCR and other protected areas managed as GIFL habitat and thus addresses 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

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terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link magnitude provide information analogous to the size of a correlation coefficient.

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

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

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

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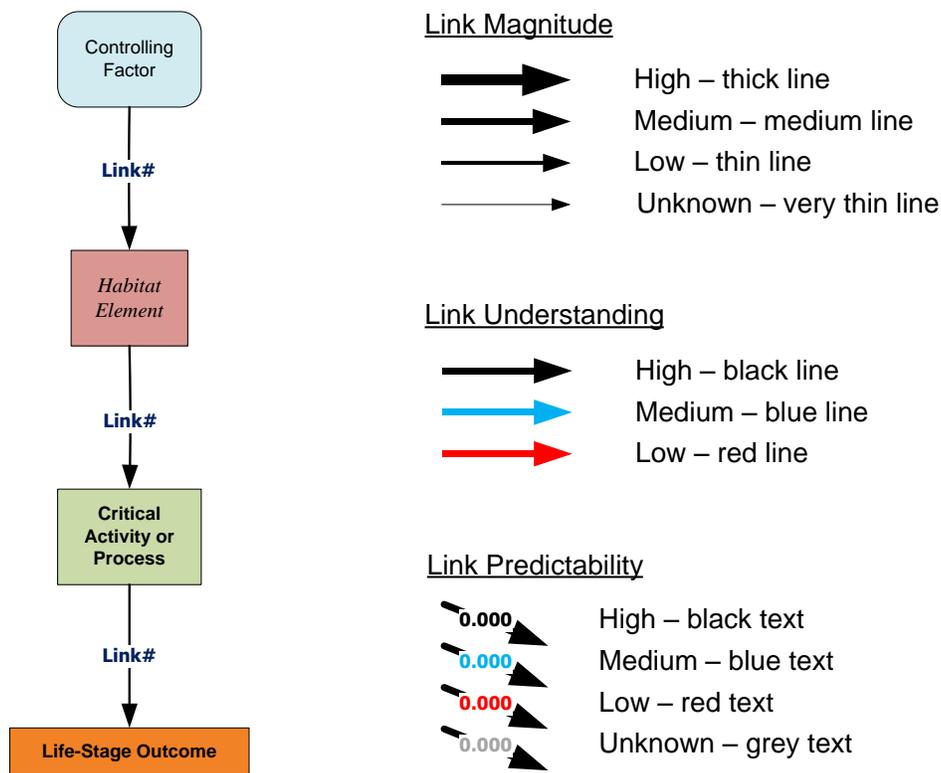


Figure 2.—Diagram conventions for LCR MSCP conceptual ecological models.

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 four life stages. For this reason, the discussion of controlling factor-habitat element linkages across all four life stages appears in a subsequent chapter.

GIFL LIFE STAGE 1 – NEST

The GIFL CEM addresses the time spent in the nest as egg and nestling as the first life stage in the overall GIFL life cycle. It begins when the egg is laid and ends when the young fledge from the nest or the nest fails. Success during this life stage – successful transition to the next stage – involves egg survival,

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maturation, and hatching followed by organism survival, maturation, and molt. The organisms actively interact with their environment. Critical biological activities and processes therefore consist of both activities and processes.

The CEM (figures 3 and 4) recognizes five (of nine) critical biological activities and processes for this life stage. Competition, foraging, nest attendance, and nest site selection are not included, as they are biological activities and processes of other life stages. The critical biological processes and activities are presented here, ordered as they appear on the following figures:

1. **Disease** – Although the literature does not emphasize disease as affecting population levels of GIFL, we still feel that disease bears mentioning. Flickers are affected less by WNV than other bird species (e.g., corvids), but there is still the possibility of direct mortality. In addition, infections may weaken birds, affecting their foraging ability and increasing vulnerability to other stressors. In fact, disease may affect molt, eating, temperature regulation, and survival. Because it has been so little studied, there is no information on the magnitude of the effect. The habitat element that directly and strongly affects disease transmission is the presence of infectious agents in the habitat. Disease and parasite impacts along the LCR is an area recommended for further research.

The CEM recognizes the presence of infectious agents as a habitat element affecting disease transmission.

2. **Eating** – The nestling must eat to maintain metabolic processes and relies on the parent to provide food.

The CEM recognizes brood size and parental nest attendance as habitat elements directly affecting eating. The critical biological process that directly affects eating is disease.

3. **Molt** – The nestling must molt into juvenile plumage. This transition relies in part on successful foraging by the parent for energy-rich food.

The CEM recognizes the critical biological activity and process of disease as directly affecting molt, as does eating. Molt directly affects survivorship. There are no habitat elements that directly affect molt.

4. **Predation** – Predation affects survival.

The CEM recognizes parental nest attendance and predator/competitor density as the habitat elements directly affecting predation.

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5. **Temperature Regulation** – The eggs and nestlings must maintain an optimum temperature to develop and survive, and parents provide the necessary conditions through parental nest attendance. Disease is a critical biological activity and process that directly affects temperature regulation at the nest.

The CEM recognizes temperature as the primary habitat element directly affecting temperature regulation.

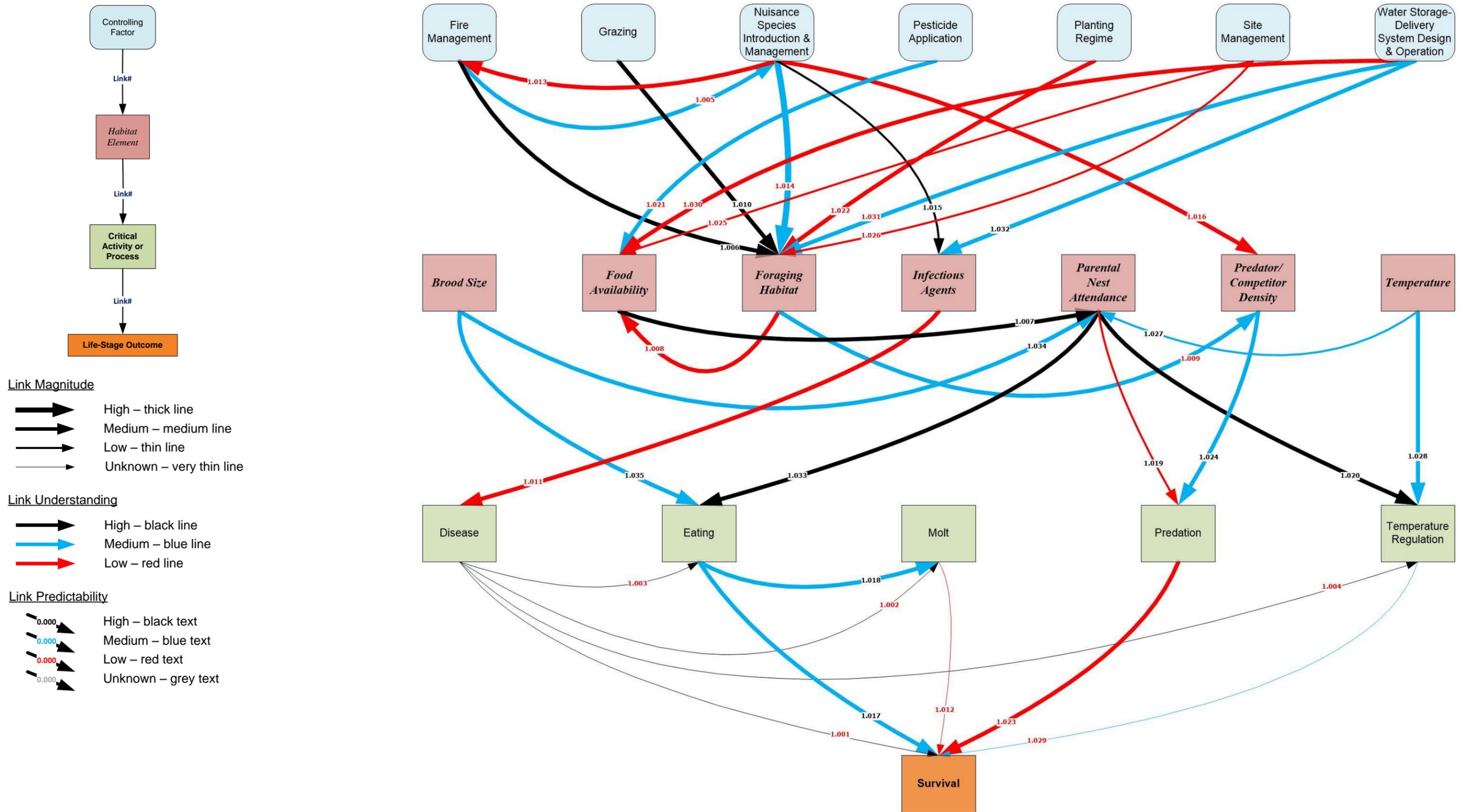


Figure 3.—GIFL life stage 1 – nest, basic CEM diagram.

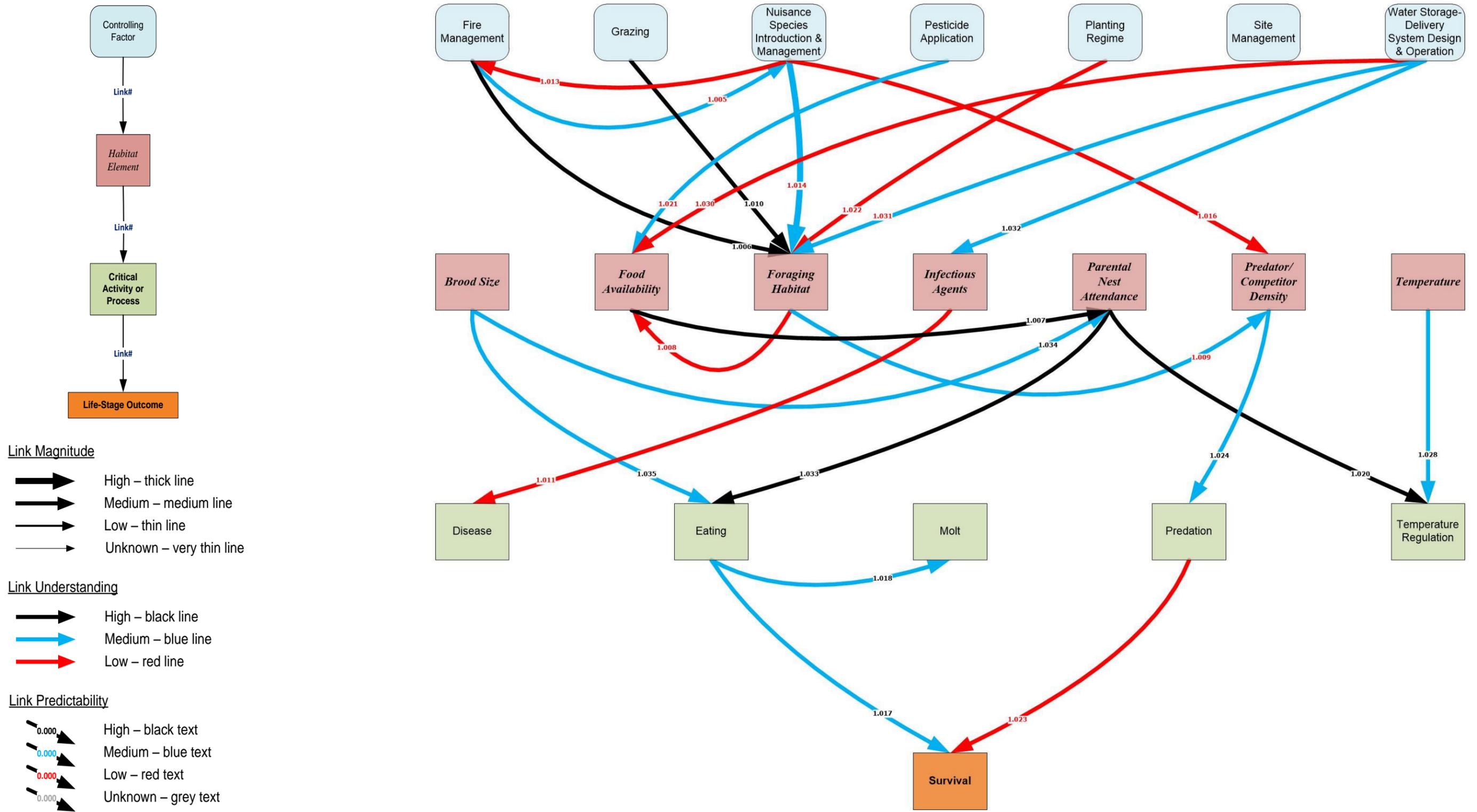


Figure 4.—GIFL life stage 1 – nest, high- and medium-magnitude relationships.

GIFL LIFE STAGE 2 – JUVENILE

As defined for this model, the juvenile stage begins when the young fledge and leave the nest and ends when the birds molt into their first winter plumage in the fall. Success during this life stage – successful transition to the next stage – involves completion of molt and fledging, organism survival, and maturation. The organisms actively interact with their environment.

The CEM (figure 5 and 6) recognizes five (of nine) critical biological activities and processes for this life stage. Eating, competition, nest attendance, and nest site selection are not included, as those are biological activities and processes of the nest and/or breeding adult stage. The critical biological activities and processes are presented here, ordered as they appear on the following figures:

1. **Disease** – Although the literature does not emphasize disease as affecting population levels of GIFL, we still feel that disease bears mentioning. Flickers are affected less by WNV than other bird species (e.g., corvids), but there is still the possibility of direct mortality. In addition, infections may weaken birds, affecting their foraging ability and increasing vulnerability to other stressors. In fact, disease may affect molt and temperature regulation. Because it has been so little studied, there is no information on the magnitude of the effect.

The CEM recognizes infectious agents as a habitat element directly and strongly affecting disease transmission.

2. **Foraging** – Although still fed by its parents, the juvenile can now also forage for its own food in order to eat and maintain metabolic processes. The degree to which it is dependent upon foraging relates to the feeding rate of the parents and all of the factors affecting parent survival.

The CEM recognizes the critical biological activity and process of disease as directly affecting juvenile foraging activity. Foraging, in turn, is directly affected by the habitat elements of food availability and parental feeding behavior and indirectly by foraging habitat.

3. **Molt** – The juvenile must molt into juvenile plumage. This transition relies in part on successful foraging for energy-rich food.

The CEM recognizes the critical biological activities and processes of disease and foraging as directly affecting molt. Molt directly affects survivorship. Indirect effects of habitat elements include foraging habitat and food availability, which affect molt via foraging success.

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4. **Predation** – Avoiding predation helps ensure that an individual will survive to the next life stage.

The CEM recognizes foraging habitat, parental feeding behavior, and predator/competitor density as habitat elements directly affecting predation. Foraging habitat may provide cover to the juvenile and determines, in part, which predators may be present.

5. **Temperature Regulation** – The juvenile must maintain an optimum temperature to develop and survive. The critical biological process of disease affects temperature regulation.

The CEM recognizes temperature as the habitat element directly affecting temperature regulation.

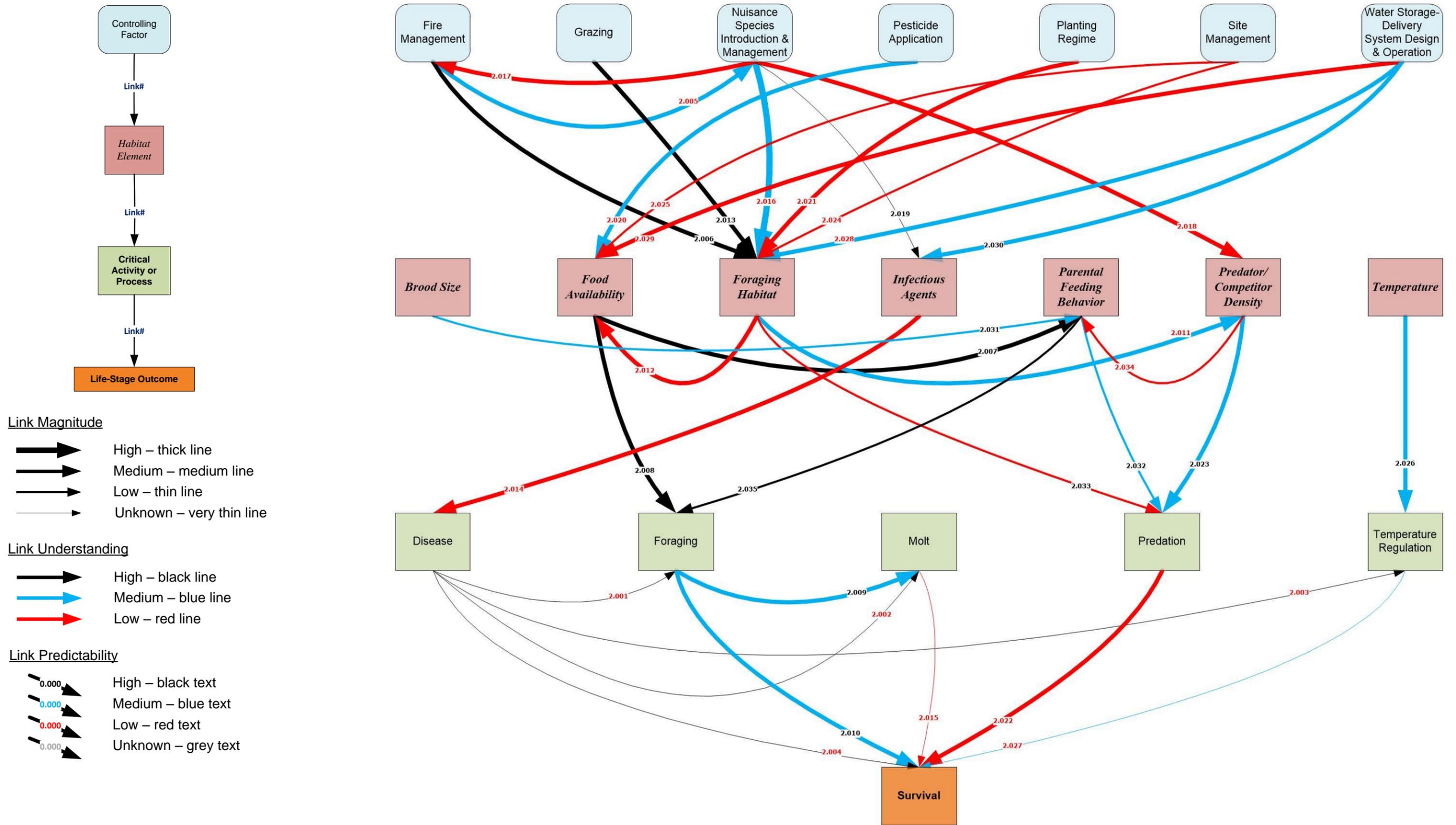


Figure 5.—GIFL life stage 2 – juvenile, basic CEM diagram.

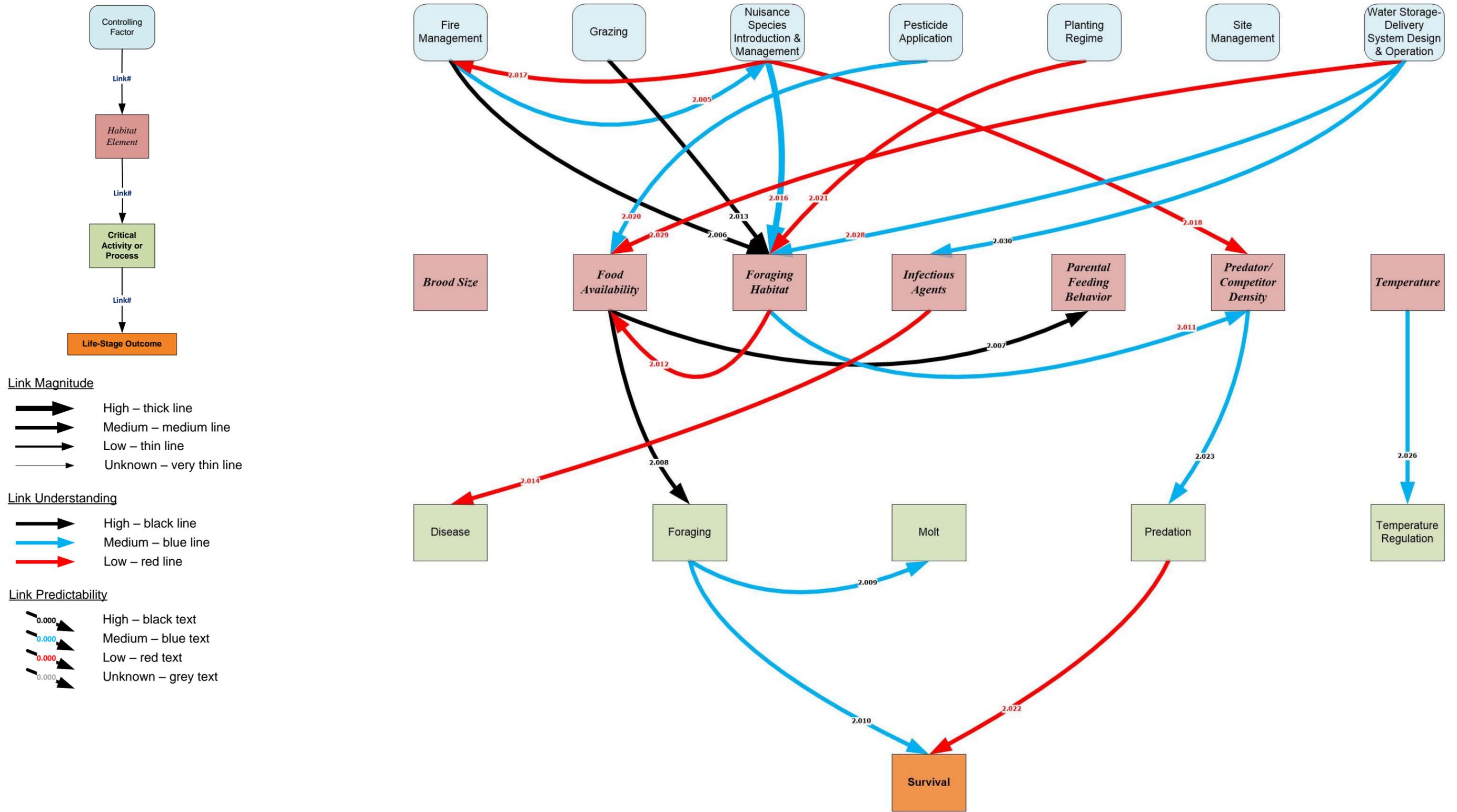


Figure 6.—GIFL life stage 2 – juvenile, high- and medium-magnitude relationships..

GIFL LIFE STAGE 3 – OVERWINTERING INDIVIDUAL

GIFL are year-round residents along the LCR. The overwintering individual stage refers to the time period after the first winter molt in juveniles (or the post-nuptial molt in adults) until the breeding season begins the following spring. Success during this life (population) stage – successful transition to the next stage – involves organism survival. The organisms actively interact with their environment.

The CEM (figures 7 and 8) recognizes four (of nine) critical biological activities and processes for this life stage. Competition for nest cavities, eating, molt, nest attendance, and nest site selection are not activities or processes of overwintering individuals. The critical biological activities and processes are presented here, ordered as they appear on the following figures:

1. **Disease** – Although the literature does not emphasize disease as affecting population levels of GIFL, we still feel that disease bears mentioning. Flickers are affected less by WNV than other bird species (e.g., corvids), but there is still the possibility of direct mortality. In addition, infections may weaken birds, affecting their foraging ability and increasing vulnerability to other stressors. In fact, disease may affect foraging and temperature regulation. Because it has been so little studied, there is no information on the magnitude of the effect.

The CEM recognizes infectious agents as a habitat element directly and strongly affecting disease transmission.

2. **Foraging** – The overwintering individual must forage to feed itself.

The CEM recognizes the critical biological activity and process of disease as directly affecting foraging. Food availability is recognized as a habitat element directly affecting foraging. Foraging is indirectly affected by foraging habitat (via food availability) and by infectious agents (via disease).

3. **Predation** – Avoiding predation helps ensure that an individual will survive to the next life stage.

The CEM recognizes foraging habitat and predator/competitor density as habitat elements directly affecting predation.

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4. **Temperature Regulation** – The overwintering individual must avoid thermal stress and maintain an optimal temperature to survive. The critical biological activity and process that directly affects temperature regulation is disease.

The CEM recognizes temperature as the habitat element directly affecting temperature regulation.

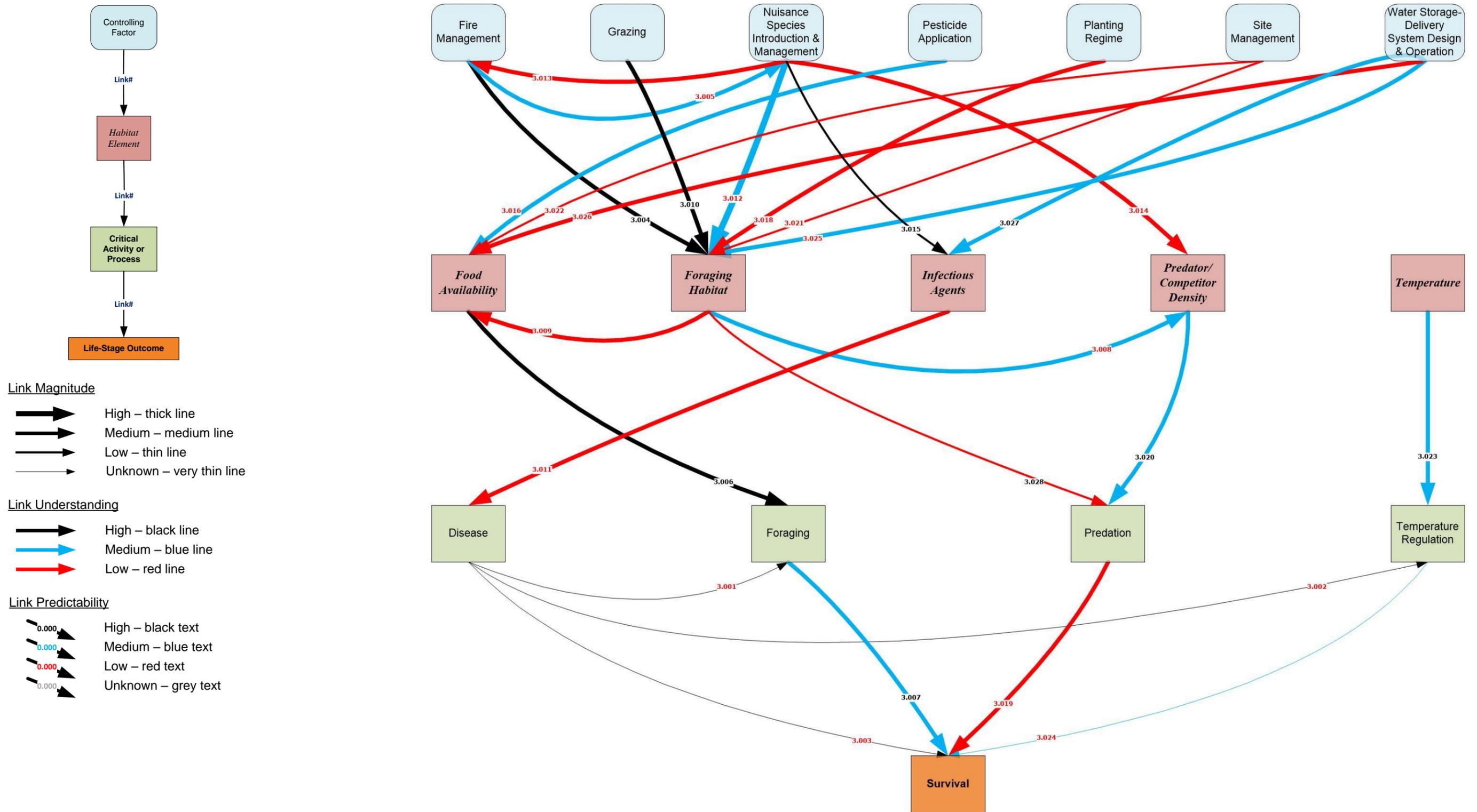


Figure 7.—GIFL life stage 3 – overwintering individual, basic CEM diagram.

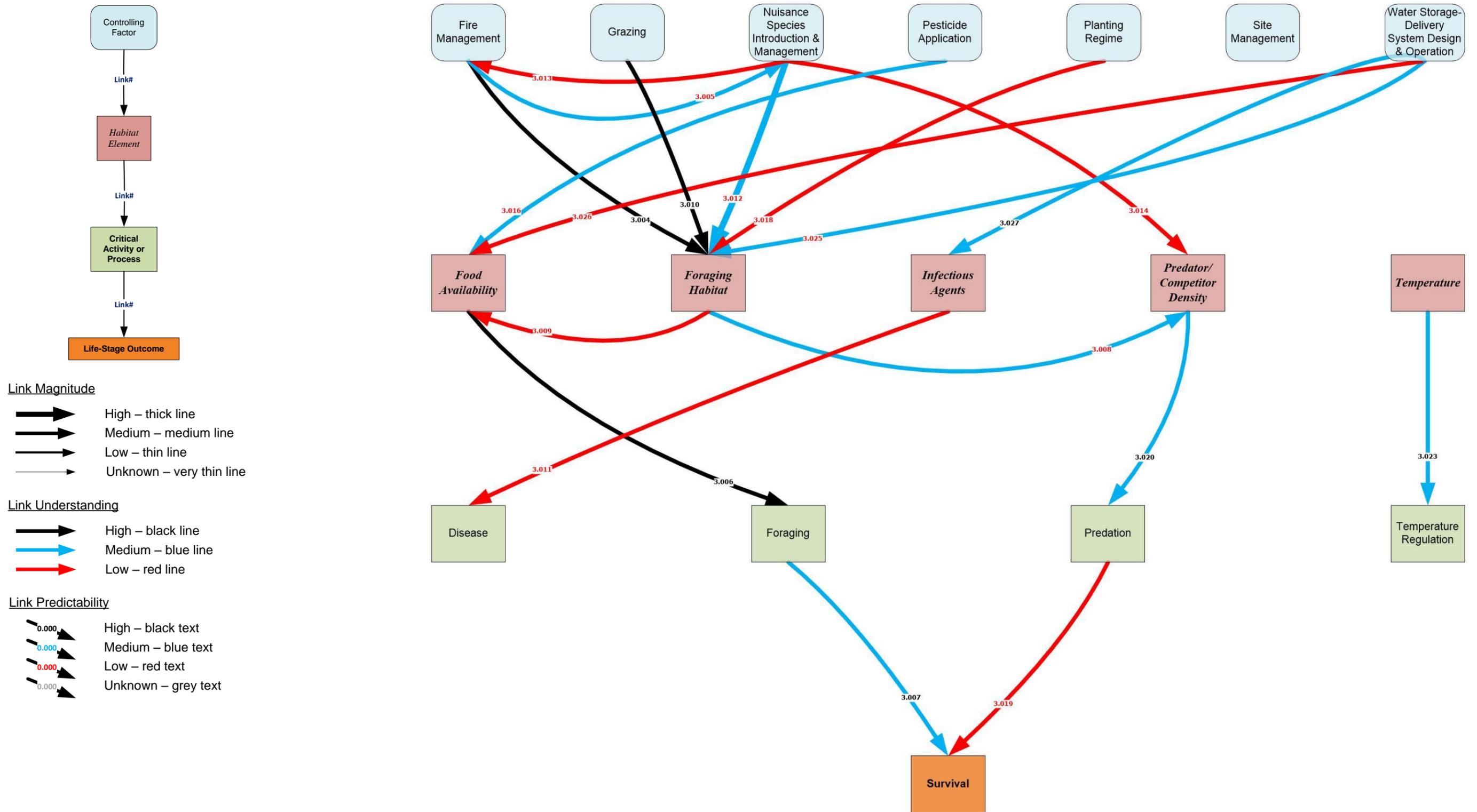


Figure 8.—GIFL life stage 3 – overwintering individual, high- and medium-magnitude relationships.

GIFL LIFE STAGE 4 – BREEDING ADULT

The breeding adult stage begins when the bird begins pair bonding and territory establishment in spring. Success during this life stage – successful transition to the next stage – involves organism survival and breeding. Individuals that do not successfully find a territory, floaters, are also included in this category even though they do not breed. The organisms actively interact with their environment.

The CEM (figures 9 and 10) recognizes eight (of nine) critical biological activities and processes for this life stage. Eating is not included, as it is an activity of the nest life stage. The critical biological activities and processes are presented here ordered as they appear on the following figures:

1. **Competition** – Competition for cavity nest sites has been identified as a potential process affecting nest site selection and breeding success. The CEM does not recognize any critical biological activities and processes that directly affect competition.

The CEM recognizes cavity trees and predator/competitor density as habitat elements directly affecting competition for nest sites.

2. **Disease** – Although the literature does not emphasize disease as affecting population levels of GIFL, we still feel that disease bears mentioning. Flickers are affected less by WNV than other bird species (e.g., corvids), but there is still the possibility of direct mortality. In addition, infections may weaken birds, affecting their foraging ability and increasing vulnerability to other stressors. In fact, disease may affect foraging, molt, nest attendance, and temperature regulation. Because it has been so little studied, there is no information on the magnitude of the effect.

The CEM recognizes infectious agents as a habitat element directly and strongly affecting disease transmission.

3. **Foraging** – The breeding adult must forage to feed itself and its young. The survival of adult and young depends upon the foraging rate, which can be influenced by a number of factors. The critical biological process and activity that directly affects foraging includes disease.

The CEM recognizes brood size and food availability as primary habitat elements affecting foraging. Secondary habitat elements indirectly affecting foraging include foraging habitat (via food availability) and infectious agents (via disease).

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4. **Molt** – Breeding adults must go through a post-nuptial molt each fall. Molt is an energetically costly process (Gill 2007). The critical biological activity and process of disease directly affects molt.

The CEM does not recognize any habitat variables that directly influence molt. However, indirect effects of habitat elements include food availability and foraging habitat, which affect molt via foraging success.

5. **Nest Attendance** – The breeding adult must attend the nest to incubate eggs and brood and feed young. Critical biological activities and processes that directly affect nest attendance include disease and foraging.

The CEM recognizes brood size, predator/competitor density, and temperature as habitat elements directly affecting nest attendance. Food availability and foraging habitat indirectly affect nest attendance via foraging.

6. **Nest Site Selection** – The breeding adult must choose where to place territories and select or excavate the nest cavity, thereby affecting breeding success. The critical biological activity and process of competition for nest sites directly affects nest site selection.

The CEM recognizes cavity trees, food availability, predator/competitor density, and temperature as habitat elements directly affecting nest site selection. Foraging habitat affects nest site selection indirectly via food availability.

7. **Predation** – Avoiding predation helps ensure that an individual will survive to the next life stage. The critical biological process and activity of molt can affect directly affect susceptibility to predation.

The CEM recognizes foraging habitat and predator/competitor density as the primary habitat elements affecting predation.

8. **Temperature Regulation** – The breeding adult must avoid thermal stress and maintain an optimum temperature to survive. The critical biological activities and processes that directly affect temperature regulation include disease and nest site selection.

The CEM recognizes temperature as a habitat element directly affecting temperature regulation.

The habitat elements that most strongly affect all life-stage outcomes through their cumulative effects across all critical biological activities and processes include the optimal combination of suitable cavity trees and the quality of foraging habitat, which determines food availability.

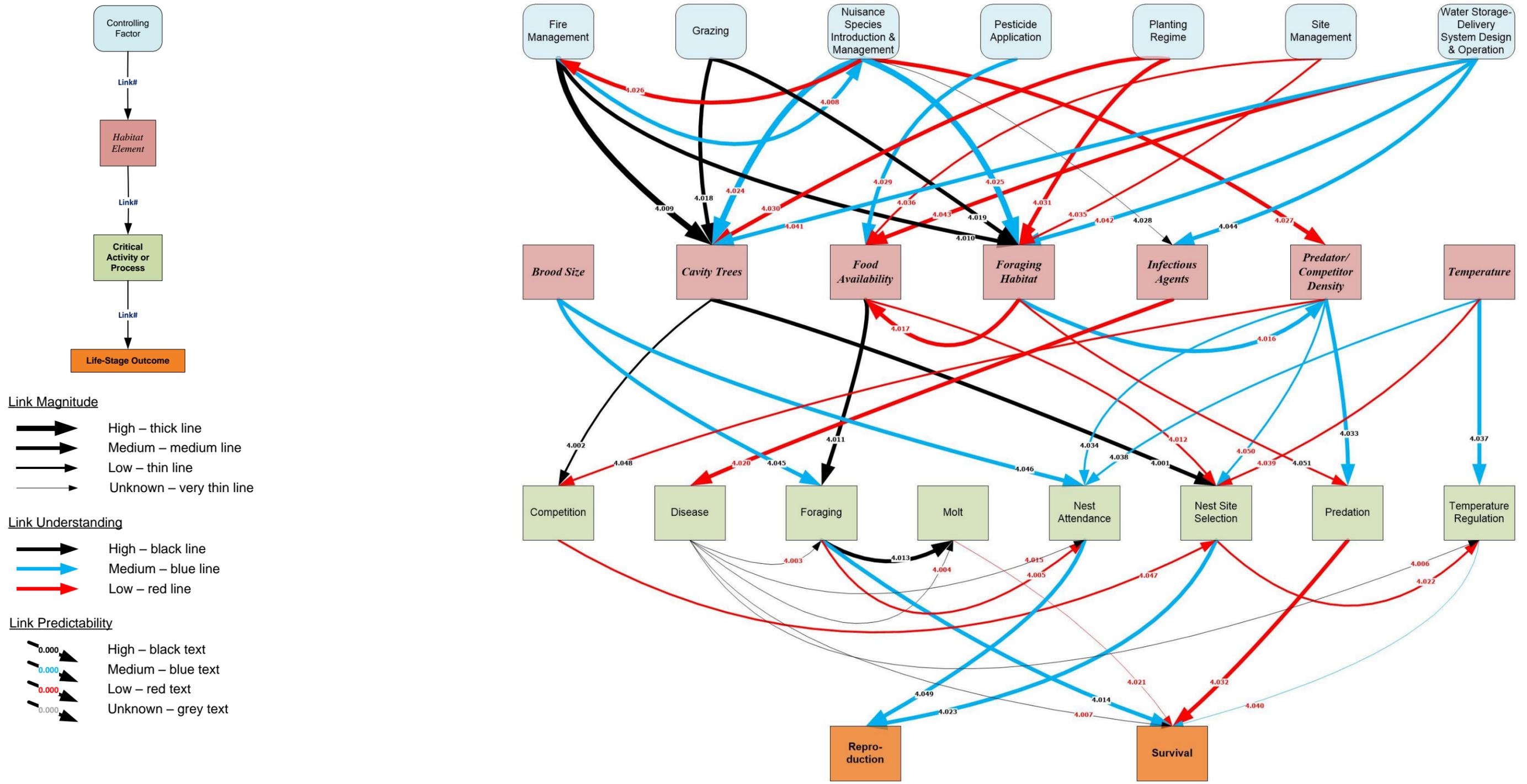


Figure 9.—GIFL life stage 4 – breeding adult, basic CEM diagram.

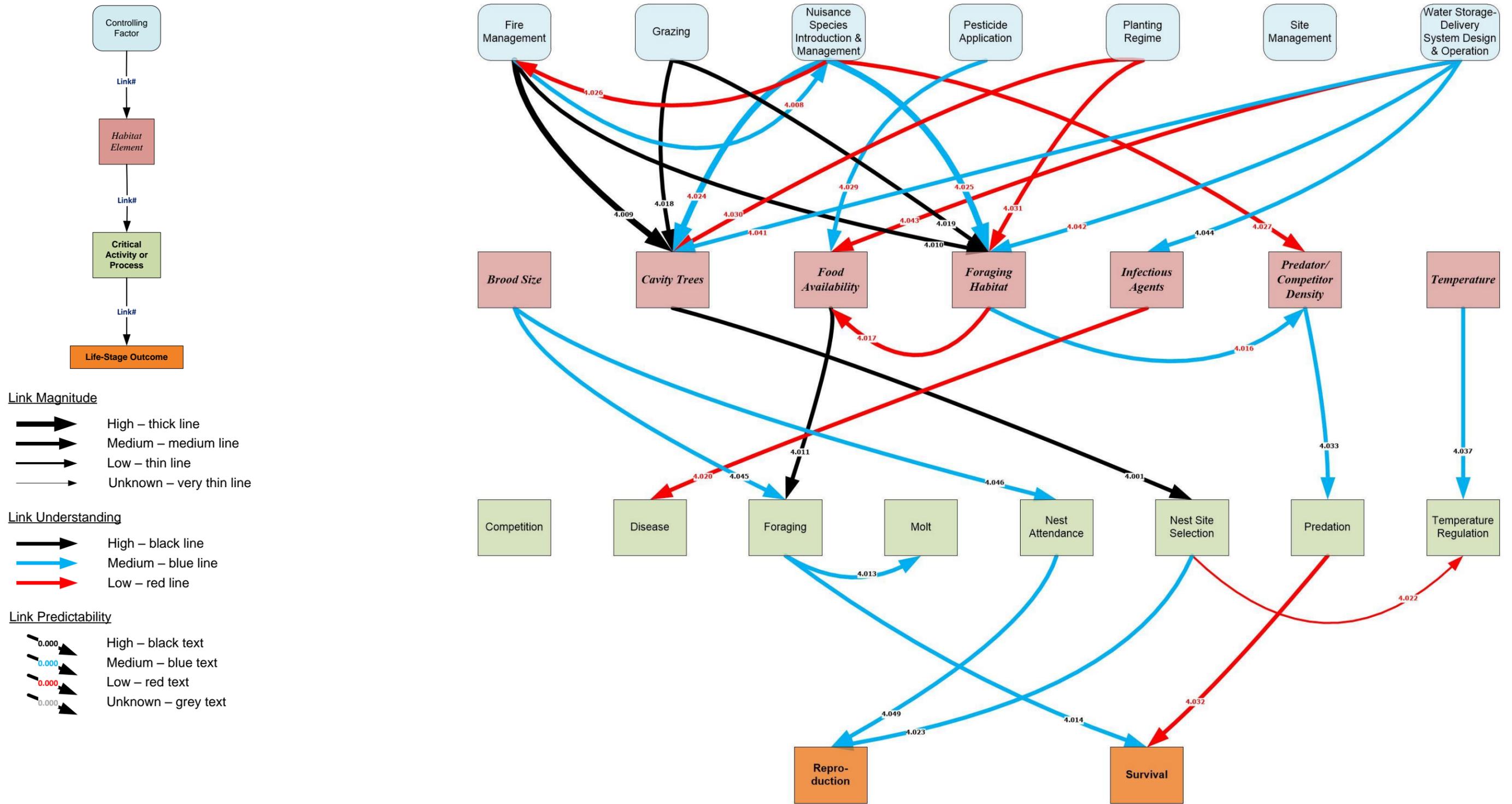


Figure 10.—GIFL life stage 4 – breeding adult, high- and medium-magnitude relationships.

Chapter 7 – Causal Relationships Across All Life Stages

The seven 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 seven controlling factors on the five habitat elements. The structure of table 5 is the same as for table 4, but table 5 shows the magnitudes of the relationships instead of just their presence/absence. The paragraphs following the table discuss the relative effects of the different controlling factors on each habitat element. The magnitudes of direct influences of controlling factors on habitat elements is color coded in the table as follows:

High = **H**, Medium = **M**, Low = **L**, and Unknown = **?**

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

Controlling factor →	Fire management	Grazing	Nuisance species introduction and management	Pesticide/herbicide application	Planting regime	Site management	Water storage-delivery system design & operation
Habitat element affected ↓							
Brood size	N/A*						
Cavity trees	H	M	H		M		M
Food availability	M			M		L	M
Foraging habitat	M	M	H		M	L	M
Infectious agents			?				M
Parental feeding behavior	N/A*						
Parental nest attendance	N/A*						
Predator/competitor density			M				
Temperature	N/A*						

* N/A values suggest that none of the identified controlling factors *directly* affect the habitat element. Controlling factors affect brood size, parental feeding behavior, and parental nest attendance indirectly. Temperature is determined by regional climate and weather conditions at a site.

CAVITY TREES

The controlling factors that directly affect the presence of cavity trees include fire management, grazing, nuisance species introduction and management, planting regime, and water storage-delivery system design and operation.

Fire management can directly influence the presence of nesting sites for cavity construction, particularly if a wildfire destroys large cacti or cottonwoods and willows. Generally, 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. Effects of a severe wildfire may take longer to recover from, as it does take time for trees to reach a size suitable for cavity excavation and nesting.

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.

Nuisance species introduction and management affects cavity trees directly if non-native species such as salt cedar prevent germination and growth of cottonwoods or willows in riparian habitats. Indirectly, nuisance species might affect cavity trees via fire management, as the presence of exotic species, such as some exotic grasses, may increase fire intensity and frequency. Invasive species can change the structure of entire communities with lasting effects.

Planting regimes have the ability to greatly affect vegetation, hence the availability of cavity trees. 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.

Water storage-delivery system design and operation might also directly affect cavity trees, as the amount and duration of flooding in riparian habitat will determine whether cottonwood or willow become established and grow to a size class suitable for cavity construction. Effects can be long term.

FOOD AVAILABILITY

The controlling factors that directly affect food availability to GIFL include fire management, pesticide/herbicide application, site management, and water storage-delivery system design and operation.

This habitat element is strongly affected by fire management that might affect ants and other invertebrates directly or indirectly by altering the habitat on which they depend (reducing seed availability for ants, for example).

Fire management can have great effects on vegetation and the arthropod community 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.

The magnitude of the effect of pesticide/herbicide application 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.

Site management that includes road excavation and grading may destroy ant colonies and other soil invertebrates on which GIFL feed. Unless maintenance is ongoing and widespread, effects will be site specific and last less than a decade.

Water storage-delivery system design and operation may directly affect food availability if flooding is long term or if the flooding or drying regime is not compatible with the life cycle of the food source (invertebrate or plant).

FORAGING HABITAT

The controlling factors that directly affect foraging habitat for GIFL include fire management, grazing, nuisance species introduction and management, planting regime, site management, and water storage-delivery system design and operation. Each of these actions can affect the amount and quality of foraging habitat that supports large ant colonies, a diversity of other invertebrates, and/or shrubs that provide blooms, seeds, and/or berries. Destruction or modification of foraging habitat will affect food availability at the local scale, and the effect can be long lasting.

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Fire management can have great effects on vegetation and the arthropod community 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.

Grazing affects many aspects of the riparian vegetation structure and composition and is often implemented over large and long scales (Kauffman et al. 1997). In addition, changes in vegetation diversity can reduce the production of grass seeds on which ants feed. However, the dynamic nature of riparian communities means that the effects of grazing will likely last less than a decade.

Nuisance species introduction and management can directly affect foraging habitat (depending on the species introduced and type of management). Nuisance species can also affect foraging habitat via fire, as the presence of exotic grasses may increase fire intensity and frequency. Effects of nuisance species can spread across entire regions and last for decades.

The planting regime has the ability to greatly affect foraging habitat; 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.

Site management that includes road excavation and grading may remove grasses and seed sources for ant colonies on which GIFL feed. Unless maintenance is ongoing and widespread, effects will last less than a decade and are localized.

Water storage-delivery system design and operation directly affect the vegetation community and structure, hence foraging habitat for GIFL, and the effects can be long term.

INFECTIOUS AGENTS

Water storage-delivery system design and operation that enhances mosquito production may increase disease transmission of agents such as WNV. Nuisance species introduction and management may also introduce new disease elements to the riparian habitat; however, nothing is known about the magnitude of this effect.

PREDATOR/COMPETITOR DENSITY

The controlling factor of nuisance species introduction and management directly affects predator/competitor density, particularly the presence of nest cavity competitors such as European starlings. The effects of nuisance species introduction can spread widely and be long lasting.

Other controlling factors affect predator/competitor density indirectly via other habitat elements (e.g., foraging habitat that is affected by fire management, grazing, planting regime, and site management).

Chapter 8 – Discussion and Conclusions

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

MOST INFLUENTIAL ACTIVITIES AND PROCESSES ACROSS ALL LIFE STAGES

Figure 11 identifies the critical biological activities and processes that this assessment found most strongly directly or indirectly affect the success of each life stage (high or medium magnitude). The findings presented in this diagram may be summarized as follows:

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

- Foraging stands out as one of the more important critical biological activities and processes for GIFL. Predation is ever-present and directly affects survival, but gaps in knowledge about predation rates remain. Other processes, such as disease, molt, and temperature regulation, can be very important, but are less understood, especially within the LCR.
- Only two processes directly affect reproduction—nest attendance and nest site selection. Nest site selection is especially important, as it can indirectly influence survival in all life stages. For example, good nest sites may have more food, fewer predators, and fewer diseases present.

Gilded Flicker (*Colaptes chrysoides*) (GIFL)
Basic Conceptual Ecological Model for the Lower Colorado River

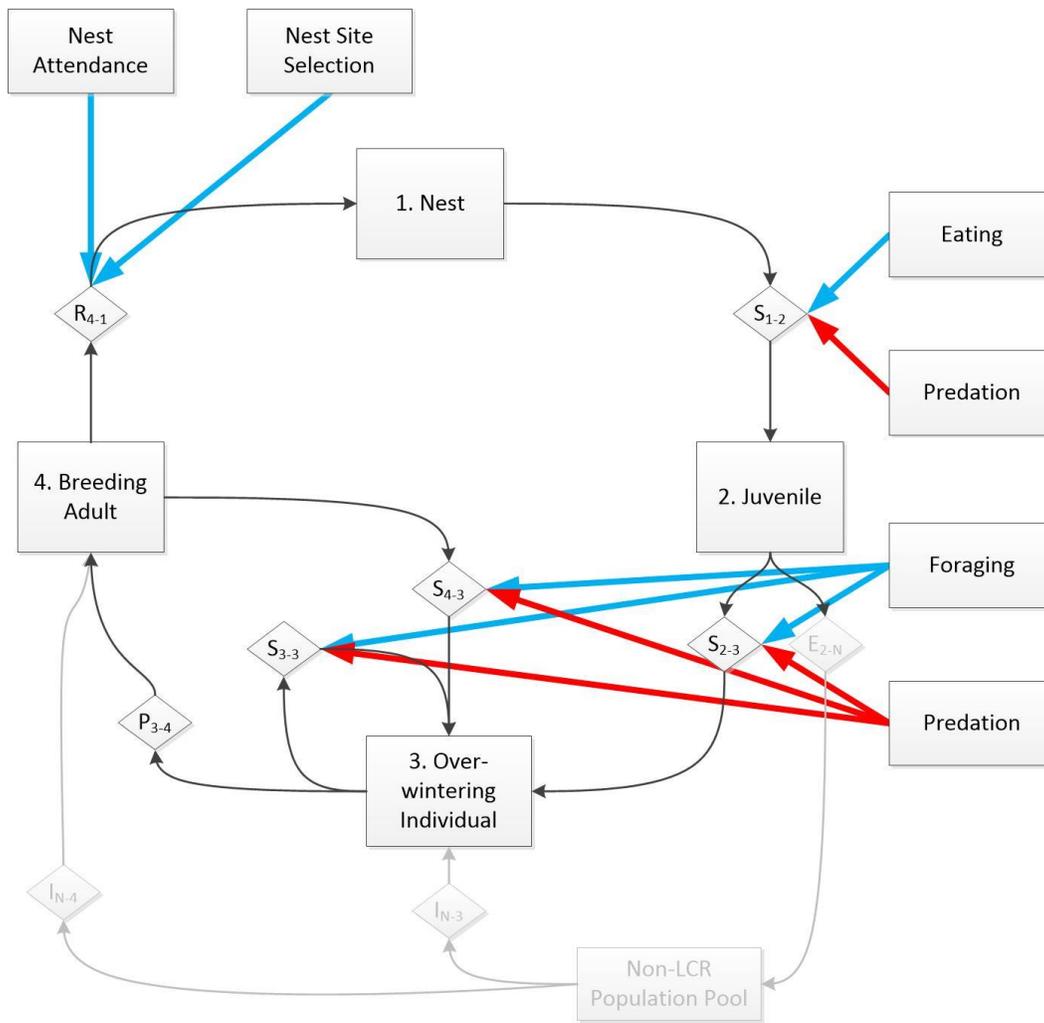


Figure 11.—Most influential biological activities and processes affecting each life stage of GIFL.

POTENTIALLY PIVOTAL ALTERATIONS TO HABITAT ELEMENTS

Figure 12 identifies the habitat elements that this assessment indicates most strongly directly or indirectly affect the critical biological activities and processes identified on figure 11 across all life stages (high or medium magnitude). The findings presented in this diagram may be summarized as follows:

- The habitat elements that most influenced critical biological processes and activities and GIFL breeding success were the presence of cavity trees and food availability, which in turn is directly affected by the quality of the foraging habitat. Ensuring that suitable foraging habitat is available along the LCR year round and in proximity to nesting sites may be an important management goal.
- The link magnitude for infectious agents was strong, but this is a reflection of a lack of knowledge of this element in the LCR system (coupled with the process of disease). With further research, it may be that this is a less (or more) important habitat element (and critical process) than for other bird species along the LCR.

In addition, the following controlling factors were important habitat element determinants:

- Fire management as a controlling factor ranked particularly high for GIFL partly due to the increased chance for wildfire in nesting and foraging habitats due to the presence of inflammable exotic species such as grasses.
- Nuisance species introduction and management and water storage-delivery system design and operation also are primary controlling factors affecting a majority of habitat elements and critical biological activities and processes of GIFL, either directly or indirectly. However, more research is needed to better understand their effects on GIFL along the LCR.

**Gilded Flicker (*Colaptes chrysoides*) (GIFL)
Basic Conceptual Ecological Model for the Lower Colorado River**

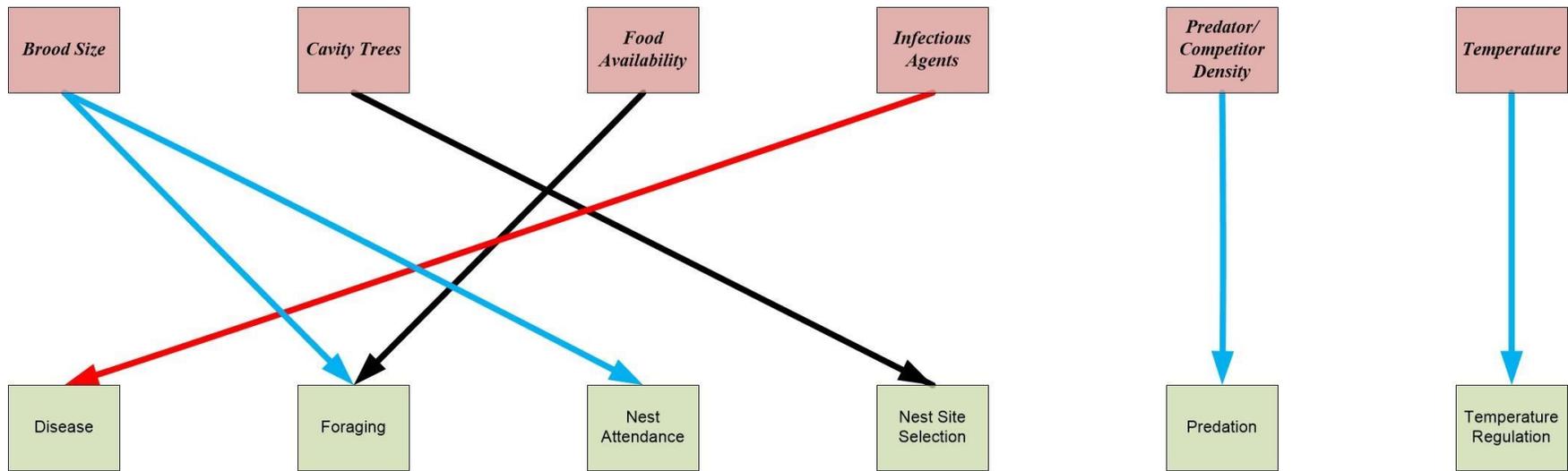


Figure 12.—Habitat elements that directly or indirectly affect the most influential biological activities and processes across all life stages of GIFL. Legend is provided on figure 2.

GAPS IN UNDERSTANDING

Figures 11 and 12 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 following highlights some potentially important areas of low understanding:

- Disease can affect most critical biological activities and processes, yet the effects of disease on GIFL along the LCR are unknown, as are the infectious agents that may be present (other than WNV).
- Predation rates on GIFL along the LCR are unknown, as are the effects of other management activities on predator/competitor density.
- GIFL habitat requirements need to be determined in more detail. Specifically, more information is needed on vegetation composition and structure, minimum patch size, and the effects of habitat fragmentation.
- There are past records of GIFL nesting in large cottonwoods or willows, but recent records are lacking. How do GIFL use riparian habitat these days? If these habitats are used mainly for foraging post-breeding, is there a minimal distance to the nest sites that these riparian habitats need to be? Is there a planting regime (e.g., planting not only cottonwood and willow but also Joshua trees or mesquite in which they may forage) more optimal for GIFL?
- Interactions between GIFL and other cavity-nesting species, such as European starlings, need to be studied. One paper suggests that competition with starlings is not a significant problem for these flickers (Kerpez and Smith 1990), but an additional look is warranted, as starlings have been shown to affect nesting of Gila woodpeckers and northern flickers.
- The use of nest boxes has been proposed. Are nest cavities a limiting factor? Will GIFL use them? If so, what is the best design for them?

Gilded Flicker (*Colaptes chrysoides*) (GIFL)
Basic Conceptual Ecological Model for the Lower Colorado River

- Roosting habitats for GIFL remain unknown. Northern flickers will use tree cavities throughout the year – do GIFL use cacti cavities at night or cavities in tree snags? GIFL have been reported roosting in palm trees (*Washingtonia* sp.) (B. Sabin and M.E. Chavez 2014, personal communication), but more information is needed.
- GIFL are year-round residents along the LCR. Seasonal movements and overwintering ecology remain unknown. What habitats are overwintering GIFL using at the LCR? What is the pattern of their seasonal movements among habitats? How much time is spent in each habitat during the year foraging for food? Is there post-fledging dispersal by juveniles?
- Ants typically comprise nearly one-half of the flicker's diet. Have any stomach analyses of gilded or other flicker species along the LCR been done to see what ant species are being consumed? What is the status of ant populations or colonies generally along the LCR? Are there activities in riparian or upland habitats detrimental to ant colony persistence (e.g., heavy grazing, pesticide/herbicide application, other significant soil disturbance)? (Note: Ants can be identified at least to genera in stomach analyses, as heads are usually well preserved [S. Cover 2014, personal communication].)
- What is the possibility of restoring saguaro cacti habitat in areas adjacent to the riparian corridor? It appears that optimal habitat for GIFL includes cacti for nesting, roosting, and foraging and riparian habitat for foraging and roosting.
- Nuisance species introduction and management also deserves a closer look to better understand the effects of species introductions and control efforts to eradicate other pests along the LCR on GIFL and its habitats.

This list of uncertainties is not meant to be exhaustive but only to highlight topics the literature identifies as potentially pivotal to GIFL 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.

LITERATURE CITED

- Andersen, A.N. 1991. Responses of ground-foraging ant colonies to three experimental fire regimes in a savanna forest of tropical Australia. *Biotropica* 23(4b):575–585.
- Bent, A.C. 1939. Life histories of North American woodpeckers. U.S. National Museum Bulletin 174.
- Best, E. 2015. Bureau of Reclamation, Boulder City, Nevada, personal communication.
- Bock, C.E. and W.M. Block. 2005. Fire and birds in the southwestern United States. *Studies in Avian Biology* No. 30:14–32.
- Bureau of Reclamation (Reclamation). 2008. Species Accounts for the Lower Colorado River Multi-Species Conservation Program. Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada. 188 p.
- Burke, M., K. Jorde, and J.M. Buffington. 2009. Application of a hierarchical framework for assessing environmental impacts of dam operation: changes in streamflow, bed mobility and recruitment of riparian trees in a western North American river. *Journal of Environmental Management* 90:S224–S236.
- Corman, T.E. 2005. Gilded Flicker. Pages 292–293 *in* T.E. Corman and C. Wise-Gervais (editors). *Arizona Breeding Bird Atlas*. University of New Mexico Press, Albuquerque.
- Cover, S. 2014. Harvard University Museum of Comparative Zoology, Cambridge, Massachusetts, personal communication.
- DiGennaro, B., D. Reed, C. Swanson, L. Hastings, Z. Hymanson, M. Healey, S. Siegel, S. Cantrell, and B. Herbold. 2012. Using Conceptual Ecological Models and Decision-Support Tools to Guide Ecosystem Restoration Planning and Adaptive Management: an Example from the Sacramento–San Joaquin Delta, California. *San Francisco Estuary and Watershed Science* 10(3):1–15. <http://escholarship.org/uc/item/3j95x7vt>
- Etterson, M.A., S.N. Ellis-Felege, D. Evers, G. Gauthier, J.A. Grzybowski, B.J. Mattssonb, L.R. Nagyg, B.J. Olsenh, C.M. Peasei, M.P. van der Burgj, and A. Potvienk. 2011. Modeling fecundity in birds: conceptual overview, current models and considerations for future developments. *Ecological Modeling* 222:2178–2190.

Gilded Flicker (*Colaptes chrysoides*) (GIFL)
Basic Conceptual Ecological Model for the Lower Colorado River

- Fischenich, J.C. 2008. The application of CEMs to ecosystem restoration. U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), Ecosystem Management and Restoration Research Program (EMRRP), Technical Note ERDC/EBA TN-08-1, February 2008. Vicksburg, Mississippi.
- Fisher, R.J. and K.L. Wiebe. 2006. Nest site attributes and temporal patterns of northern flicker nest loss: effects of predation and competition. *Oecologia* 147(4):744–753.
- Gill, F.B. 2007. *Ornithology*. W.H. Freeman and Company, New York.
- Gow, E.A., K.L. Wiebe, and J.W. Fox. 2015. Cavity use throughout the annual cycle of a migratory woodpecker revealed by geolocators. *Ibis* 157(1):167–170.
- Graber, A.E., D.M. Weddle, H.C. English, S.D. Stump, H.E. Telle, and L.A. Ellis. 2007. Southwestern Willow Flycatcher 2006 Survey and Nest Monitoring Report. Technical Report 249. Nongame and Endangered Wildlife Program, Arizona Game and Fish Department, Phoenix.
- Hölldobler, B. and E.O. Wilson. 1990. *The Ants*. The Belknap Press, Cambridge, Massachusetts.
- Ingold, D.J. 1996. Delayed nesting decreases reproductive success in northern flickers: implications for competition with European starlings. *Journal of Field Ornithology* 67:321–326.
- Inouye, R.S., N.J. Huntly, and D.W. Inouye. 1981. Non-random orientation of Gila woodpecker nest entrances in saguaro cacti. *The Condor* 83:88–89.
- Juarez, E. 2010. Gilded flicker. *Arizona Wildlife Views*. July – August 2010. p 36.
- Kauffman, J.B., R.L. Beschta, N. Otting, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. *Fisheries* 22(5):12–24.
- Kerpez, T.A. and N.S. Smith. 1990. Competition between European starlings and native woodpeckers for nest cavities in saguaros. *The Auk*:367–375.
- Koenig, W.D. 1984. Clutch size of the gilded flicker. *The Auk* 101:698–706

**Gilded Flicker (*Colaptes chrysoides*) (GIFL)
Basic Conceptual Ecological Model for the Lower Colorado River**

- Kondolf, G.M., J.G. Williams, T.C. Horner, and D. Milan. 2008. Assessing physical quality of spawning habitat. Pages 249–274 in D.A. Sear and P. DeVries (editors). *Salmonid Spawning Habitat in Rivers: Physical Controls, Biological Responses, and Approaches*. American Fisheries Society Symposium 65. American Fisheries Society, Bethesda, Maryland.
- Kucera, T. 1997. Life History Account for the GIFL. Last revised 1997. <https://nrmsecure.dfg.ca.gov/FileHandler.ashx?DocumentVersionID=17727>
- Martin T.E. 1993. Nest predation and nest sites: new perspectives on old patterns. *Bioscience* 43:523–533.
- McDonald, D.B. and H. Caswell. 1993. Matrix methods for avian demography. Pages 139–185 in D.M. Power (editor). *Current Ornithology*. Plenum Press: New York, New York.
- Moore, W.S. 1995. Northern flicker (*Colaptes auratus*) in A. Poole and F. Gill (editors). *The Birds of North America*, No. 413. The Birds of North America, Inc., Philadelphia, Pennsylvania.
- NatureServe. 2014. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. <http://explorer.natureserve.org>
- Rosenberg, K.V., R.D. Ohmart, W.C. Hunter, and B.W. Anderson. 1991. *Birds of the Lower Colorado River Valley*. University of Arizona Press, Tucson.
- Rosenfeld, J.S. 2003. Assessing the habitat requirements of stream fishes: an overview and evaluation of different approaches. *Transactions of the American Fisheries Society* 132:953–968.
- Rosenfeld, J.S. and T. Hatfield. 2006. Information needs for assessing critical habitat of freshwater fish. *Canadian Journal of Fisheries and Aquatic Sciences* 63:683–698. DOI:10.1139/F05-242.
- Sabin, B. 2012. Literature Search and Exploratory Surveys for the GIFL Along the Lower Colorado River, 2012. Lower Colorado River Multi-Species Conservation Program, Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada.
- Sabin, B. and M.E. Chavez. 2014. Bureau of Reclamation, Boulder City, Nevada, personal communication.
- Terres, J.K. 1980. *The Audubon Society Encyclopedia of North American Birds*. Knoph, New York.

Gilded Flicker (*Colaptes chrysoides*) (GIFL)
Basic Conceptual Ecological Model for the Lower Colorado River

- U.S. Fish and Wildlife Service (USFWS). 2002. Southwestern Willow Flycatcher Recovery Plan, Appendix G: Management of Livestock Grazing in the Recovery of the Southwestern Willow Flycatcher. Albuquerque, New Mexico.
- _____. 2013. Designation of critical habitat for southwestern willow flycatcher; final rule. Federal Register 78(2):344–534.
- Wheeler, D.E. and S.W. Rissing. 2014. Ants. Arizona-Sonora Desert Museum Web site Tucson, Arizona.
https://www.desertmuseum.org/books/nhsd_ants.php
- Wiebe, K.L. 2001. Microclimate of tree cavity nests: is it important for reproductive success in northern flickers? The Auk 118(2):412–421.
- _____. 2014. Response of cavity-nesting birds to fire: testing a model with data from the northern flicker. Ecology 95(9):2537–2547.
- Wildhaber. 2011. Identifying structural elements needed for development of a predictive life-history model for pallid and shovelnose sturgeons. Journal of Applied Ichthyology 27:462–469.
- Wildhaber, M.L., A.J. DeLonay, D.M. Papoulias, D.L. Galat, R.B. Jacobson, D.G. Simpkins, P.J. Baaten, C.E. Korschgen, and M.J. Mac. 2007. A conceptual life-history model for pallid and shovelnose sturgeon. U.S. Geological Survey, Circular 1315. Reston, Virginia.
- Zwartjes P.W. and S.E. Nordell. 1998. Patterns of cavity-entrance orientation by gilded flickers (*Colaptes chrysoides*) in cardón cactus. The Auk 115(1):119–126.

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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), Wildhaber (2011), Kondolf et al. (2008), and Burke et al. (2009) for a more hierarchical approach and adds explicit demographic notation for the characterization of life-stage outcomes (McDonald and Caswell 1993). This expanded approach provides greater detail on causal linkages and outcomes. The expansion specifically calls for identifying **four** types of model components for each life stage, and the causal linkages among them, as follows:

- **Life-stage outcomes** are outcomes of an individual life stage, including the recruitment of individuals to the next succeeding life stage (e.g., juvenile to adult). For some life stages, the outcomes, alternatively or additionally, may include the survival of individuals to an older age class within the same life stage or the production of offspring. The rates of life-stage outcomes depend on the rates of the critical biological activities and processes for that life stage.
- **Critical biological activities and processes** are activities in which a species engages and the biological processes that must take place during each life stage that significantly affect life-stage outcomes. They include activities and processes that may benefit or degrade life-stage outcomes. Examples of critical activities and processes include mating, foraging, avoiding predators, avoiding other specific hazards, gamete production, egg maturation, leaf production, and seed germination. Critical activities and processes are “rate” variables. Taken together, the rate (intensity) of these activities and processes determine the rates of different life-stage outcomes.
- **Habitat elements** are specific habitat conditions that significantly ensure, allow, or interfere with critical biological activities and processes. The full suite of natural habitat elements constitutes the natural habitat template for a given life stage. Human activities may introduce habitat elements not present in the natural habitat template. Defining a habitat element may involve estimating the specific ranges of quantifiable properties of that element *whenever the state of knowledge supports such estimates*. These properties concern the abundance, spatial and temporal distributions, and other qualities of the habitat element that significantly affect the ways in which it ensures, allows, or interferes with critical activities and processes.
- **Controlling factors** are environmental conditions and dynamics – both natural and anthropogenic – that determine the quality, abundance, and spatial and temporal distributions of one or more habitat elements. In some instances, a controlling factor alternatively or additionally may directly affect a critical biological activity or process. Controlling factors are also called “drivers.” A hierarchy of controlling factors will exist, affecting the system at different temporal and spatial scales. Long-term dynamics of climate and geology define the domain of this hierarchy (Burke et al. 2009). For example, the availability of suitable nest sites for a riparian nesting bird may depend on factors such as canopy cover, community type, humidity, and intermediate structure which, in turn, may depend on factors such as water storage-delivery system design and operation (dam design, reservoir morphology, and dam operations) which, in turn, is shaped by watershed geology, vegetation, climate, land use, and water demand. *The LCR MSCP conceptual ecological models focus*

on controlling factors that are within the scope of potential human manipulation, including management actions directed toward the species of interest.

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

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

- (1) The effect of one controlling factor on another
- (2) The effect of a controlling factor on the abundance, spatial and temporal distributions, and other qualities of a habitat element
- (3) The effect of the abundance, spatial and temporal distributions, and other qualities of one habitat element on those of another
- (4) The effect of the abundance, spatial and temporal distributions, and other qualities of a habitat element on a critical biological activity or process
- (5) The effect of one critical biological activity or process on another
- (6) The effect of a critical biological activity or process on a specific life-stage outcome

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

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

Conceptual Ecological Models as Hypotheses

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

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

Characterizing Causal Relationships

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

- (1) The character and direction of the effect
- (2) The magnitude of the effect
- (3) The predictability (consistency) of the effect
- (4) The certainty of present scientific understanding of the effect

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

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

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

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

- **Link character** – This attribute categorizes a causal relationship as positive, negative, involving a threshold response, or “complex.” “Positive” means that an increase in the causal node results in an increase in the affected node, while a decrease in the causal node results in a decrease in the affected node. “Negative” means that an increase in the causal node results in a decrease in the affected element, while a decrease in the causal node results in an increase in the affected node. Thus, “positive” or “negative” here do *not* mean that a relationship is beneficial or detrimental. The terms instead provide information analogous to the sign of a correlation coefficient. “Threshold” means that a change in the causal agent must cross some value before producing an effect. “Complex” means that there is more going on than a simple positive, negative, or threshold effect. In addition, this attribute categorizes a causal relationship as uni- or bi-directional. Bi-directional relationships involve a reciprocal relationship in which each node affects the other.
- **Link magnitude** – This attribute refers to “... the degree to which a linkage controls the outcome *relative to other drivers*” (DiGennaro et al. 2012). Magnitude takes into account the spatial and temporal scale of the causal relationship as well as the strength (intensity) of the relationship in individual locations. The present methodology provides separate ratings for the intensity, spatial scale, and temporal scale of each link, as defined above, and assesses overall link magnitude by averaging these three elements. Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link magnitude provide information analogous to the size of a correlation coefficient. Tables 1-1 through 1-4 present the rating framework for link magnitude.
- **Link predictability** – This attribute refers to “... the degree to which the current understanding of the system can be used to predict the role of the driver in influencing the outcome. Predictability ... captures variability ... [and recognizes that] effects may vary so much that properly measuring and statistically characterizing inputs to the model are difficult” (DiGennaro et al. 2012). A causal relationship may be unpredictable because of natural variability in the system or because its effects depend on the interaction of other factors with independent sources for their own variability. Just as the terms for link character provide information analogous to the sign of a correlation coefficient, the terms for link predictability provide information analogous to the size of the range of error for a correlation coefficient. Table 1-5 presents the scoring framework for link predictability.

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

Conceptual Ecological Model Documentation

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

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

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

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

Link Attribute Ratings, Spreadsheet Fields, and Diagram Conventions

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

Link intensity – the relative strength of the effect of the causal node on the affected node <i>at the places and times where the effect occurs.</i>	
High	Even a relatively small change in the causal node will result in a relatively large change in the affected node <i>at the places and times where the effect occurs.</i>
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 <i>at the places and times where the effect occurs.</i>
Low	Even a relatively large change in the causal node will result in only a relatively small change in the affected node <i>at the places and times where the effect occurs.</i>
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	<i>(The “Low” rank includes this condition).</i>

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 <i>management actions and options</i> , 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 <i>basic scientific knowledge</i> , 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.

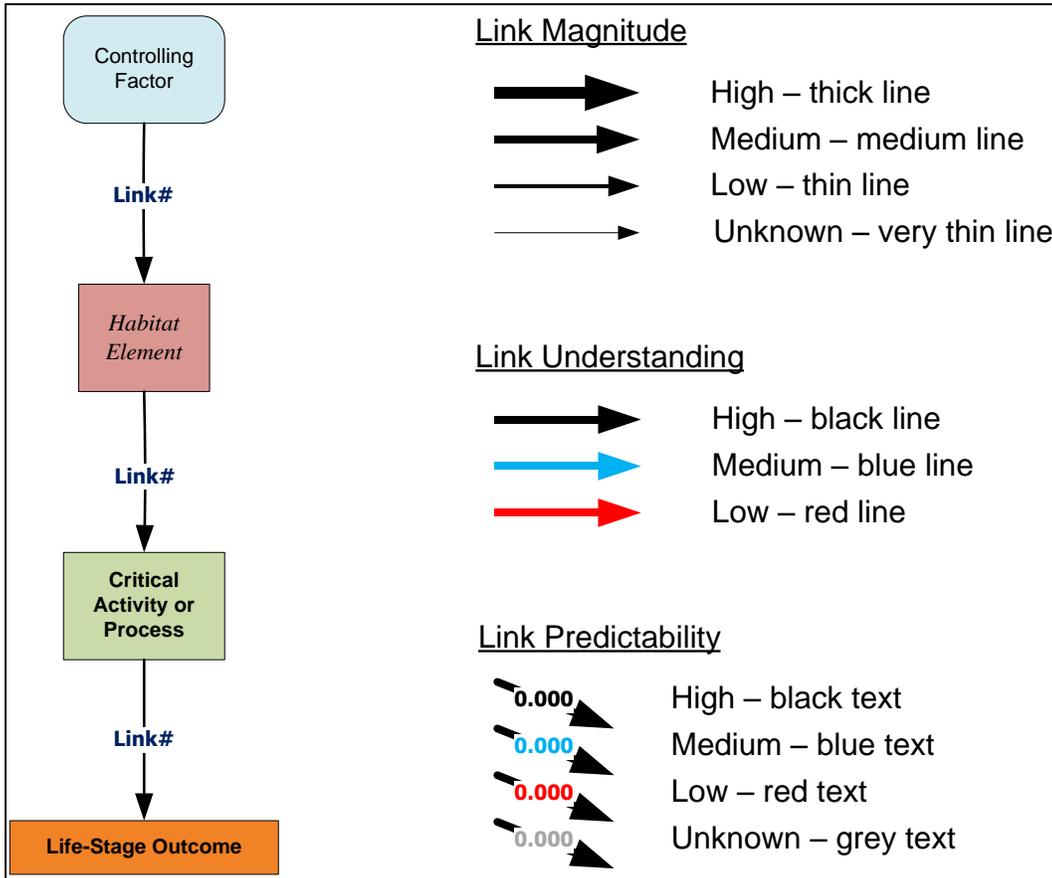


Figure 1-1.—Conventions for displaying cause and effect nodes, linkages, link magnitude, link understanding, and link predictability.

Literature Cited

- Burke, M., K. Jorde, and J.M. Buffington. 2009. Application of a hierarchical framework for assessing environmental impacts of dam operation: changes in streamflow, bed mobility and recruitment of riparian trees in a western North American river. *Journal of Environmental Management* 90:S224–S236.
- DiGennaro, B., D. Reed, C. Swanson, L. Hastings, Z. Hymanson, M. Healey, S. Siegel, S. Cantrell, and B. Herbold. 2012. Using conceptual models and decision-support tools to guide ecosystem restoration planning and adaptive management: an example from the Sacramento–San Joaquin Delta, California. *San Francisco Estuary and Watershed Science* 10(3):1–15. <http://escholarship.org/uc/item/3j95x7vt>
- Fischenich, J.C. 2008. The application of conceptual models to ecosystem restoration. U.S. Army Engineers, Engineer Research and Development Center (ERDC), Ecosystem Management and Restoration Research Program (EMRRP), Technical Note ERDC/EBA TN-08-1, February 2008. Vicksburg, Mississippi.
- Kondolf, G.M., J.G. Williams, T.C. Horner, and D. Milan. 2008. Assessing physical quality of spawning habitat. Pages 249–274 *in* D.A. Sear and P. DeVries (editors). *Salmonid Spawning Habitat in Rivers: Physical Controls, Biological Responses, and Approaches*. American Fisheries Society Symposium 65. American Fisheries Society, Bethesda, Maryland.
- McDonald, D.B. and H. Caswell. 1993. Matrix methods for avian demography. Pages 139–185 *in* D.M. Power (editor). *Current Ornithology*. Plenum Press: New York, New York.
- Wildhaber. 2011. Identifying structural elements needed for development of a predictive life-history model for pallid and shovelnose sturgeons. *Journal of Applied Ichthyology* 27:462–469.
- Wildhaber, M.L., A.J. DeLonay, D.M. Papoulias, D.L. Galat, R.B. Jacobson, D.G. Simpkins, P.J. Baaten, C.E. Korschgen, and M.J. Mac. 2007. A conceptual life-history model for pallid and shovelnose sturgeon. U.S. Geological Survey, Circular 1315. Reston, Virginia.

ATTACHMENT 2

Gilded Flicker Habitat Data

Table 2-1.—Gilded flicker habitat data

Habitat element	Value or range	Location	Reference
Cavity trees	Saguaro cacti, cottonwood, willow, honey mesquite.	Lower Colorado River	Bureau of Reclamation 2008
	Nest cacti > 5 meters tall.	Lower Colorado River	Kerpez and Smith 1990
Food availability	Diet consists of ants and ant larvae, ground beetles, and other soil invertebrates; seeds, berries, and cacti fruits.	United States – general diet for flickers	Bureau of Reclamation 2008 and references therein
Foraging habitat	Includes open areas, friable soil for ants, flowering shrubs that attract insects, and seeds and berries.	Lower Colorado River	Sabin and Chavez 2014, personal communication
	Includes ocotillo, Palo verde, and ironwood.	Lower Colorado River	Sabin and Chavez 2014, personal communication; Kerpez and Smith 1990

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. There are no data available about typical habitat variables such as canopy cover, patch size, tree density, etc. More research is needed to better describe habitat parameters for the gilded flicker.

Literature Cited

Bureau of Reclamation (Reclamation). 2008. Species Accounts for the Lower Colorado River Multi-Species Conservation Program. Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada. 188 p.

Kerpez, T.A. and N.S. Smith. 1990. Competition between European starlings and native woodpeckers for nest cavities in saguaros. *The Auk*:367–375.

Sabin, B. and M.B. Chavez. 2014. Bureau of Reclamation, Boulder City, Nevada, personal communication.