Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Elf Owl (*Micrathene whitneyi*) (ELOW) Basic Conceptual Ecological Model for the Lower Colorado River

Photo courtesy of the Bureau of Reclamation

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BUREAU OF RECLAMATION

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Lower Colorado River
Multi-Species Conservation Program

Elf Owl (*Micrathene whitneyi*) (ELOW)
Basic Conceptual Ecological Model for the Lower Colorado River

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Multi-Species Conservation Program
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ACRONYMS AND ABBREVIATIONS

CEM	conceptual ecological model
ELOW	elf owl (*Micrathene whitneyi*)
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
Reclamation	Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service

Symbols

°C	degrees Celsius
>	greater than
<	less than
±	plus or minus

Definitions

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

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

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

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

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

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Foreword

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

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

- A synthesis of the current understanding of how a species' habitat works. This synthesis can be based on the published literature, technical reports, or professional experience.

- Help in understanding and diagnosing underlying issues and identifying land management opportunities.

- A basis for isolating cause and effect and simplifying complex systems. These models also document the interaction among system drivers.

- A common (shared) framework or "mental picture" from which to develop management alternatives.

- A tool for making qualitative predictions of ecosystem responses to stewardship actions.

- A way to flag potential thresholds from which system responses may accelerate or follow potentially unexpected or divergent paths.

- A means by which to outline further restoration, research, and development and to assess different restoration scenarios.

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

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

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

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

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

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

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

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

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

How to Use the Models

There are three important elements to each CEM:

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

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

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

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

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

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

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

Executive Summary

This document presents a conceptual ecological model (CEM) for the elf owl (*Micrathene whitneyi*) (ELOW). 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 ELOW ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure ELOW 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 ELOW expands on the methodology developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012). The model distinguishes the major life stages or events through which the individuals of a species must pass to complete a full life cycle. It then identifies the factors that shape the likelihood that individuals in each life stage will survive to the next stage in the study area and thereby shapes the abundance, distribution, and persistence of the species in that area.

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

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

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

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

- **Habitat elements** – These consist of the specific habitat conditions, the abundance, spatial and temporal distributions, and other qualities that 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 ELOW conceptual ecological model addresses ELOW throughout its breeding range. The model thus addresses the landscape as a whole rather than any single reach or managed area. The model does not address the biology of ELOW during migration or in its winter range.

The most widely used sources of the information for the ELOW conceptual ecological model are Ligon (1968) and Henry and Gehlbach (1999). These publications summarize and cite large bodies of earlier studies. Where appropriate and accessible, those earlier studies are directly cited. The model also integrates numerous additional sources, particularly reports and articles completed since these publications, information on current research projects, and the expert knowledge of LCR MSCP biologists. Our purpose is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

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

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

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

The model distinguishes 9 critical biological activities and processes relevant to 1 or more of these 3 life stages and their outcomes, 19 habitat elements relevant to 1 or more of these 9 critical biological activities and processes for 1 or more life stages, and 11 controlling factors that affect 1 or more of these 19 habitat elements. Because the lower Colorado River (LCR) is a highly regulated system, the controlling factors exclusively concern human activities.

The nine critical biological activities and processes identified across all life stages are: disease, eating, foraging, molt, nest attendance, nest predation, nest site selection, predation, and temperature regulation. The 19 habitat elements identified across all life stages are: anthropogenic disturbance, brood size, canopy closure, cavity availability, community type, food availability, genetic diversity and infectious agents, local hydrology, parental feeding behavior, parental nest attendance, patch size, predator density, soil salinity, stand height, temperature, tree cover, tree density, tree size, and understory density. The 11 controlling factors identified across all habitat elements are: fire management, grazing, irrigation, water storage-delivery system design and operation, mechanical thinning, natural thinning, nest box installation, nuisance species introduction and management, pesticide/herbicide application, planting regime, and recreational activities.

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:

- Predation, eating, and foraging are the most important critical biological activities and processes affecting survival of all life-stages. Other processes such as disease, molt and temperature regulation can be very important, but are less understood, especially within the LCR.

- Only two processes affect reproduction—nest attendance and nest site selection. Nest site selection is especially important, as it can indirectly influence survival of ELOW at all life stages. For example, good nest sites may have more food, few predators, and few diseases present.

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

- Nest site selection is by far affected by the most habitat variables, likely because this critical biological activity is the most researched element, but also because during the breeding season, this factor determines if the birds are present or not. However, most of the research has been focused on populations occupying saguaro cacti ecosystems instead of southwestern riparian systems. The result is that there is little available information on the range of values of specific habitat elements required to maintain and recruit members of this species to restoration areas. In addition, the effects of predator density and anthropogenic disturbance on nest site selection and nest attendance remains poorly understood for all species and have not been studied for ELOW.

- The effects of the molting process on survival are not well understood, yet the prevalence and consistency of molt within the avian world suggests very strong selective pressure supporting its high priority. Assessing molt for the ELOW population within the LCR may provide indicators of habitat quality and help identify issues individual birds may face if forced to suspend molt due to food shortages.

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

The research questions and gaps in scientific knowledge identified in this modeling effort serve as examples of topics the larger scientific community could explore to improve the overall understanding of the ecology of ELOW. 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 elf owl (*Micrathene whitneyi*) (ELOW). 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 ELOW ecology, the effects of specific stressors, the effects of specific management actions aimed at habitat and species restoration, and the methods used to measure ELOW habitat and population conditions. The CEM methodology is similar to 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 ELOW population along the river and lakes of the lower Colorado River (LCR) and other protected areas along the LCR managed as ELOW habitat. The model thus addresses the landscape as a whole rather than any single reach or managed area.

The most widely used sources of information for the ELOW conceptual ecological model are Ligon (1968) and Henry and Gehlbach (1999). 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 conceptual ecological model is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

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

ELF OWL REPRODUCTIVE ECOLOGY

The ELOW populations in the LCR region are considered complete migrants, breeding in North America and wintering in Mexico (Henry and Gehlbach 1999). Birds return to the LCR from their wintering grounds in mid-March to begin the breeding season (range, mid-February to mid-April) (Ligon 1968). Male birds arrive before females, with courtship beginning immediately upon the arrival of the females, often resulting in pairing within the first night (Ligon 1968). Males attract mates with song, cavity presentation, and nuptial gifts of food (Ligon 1968). The first egg is laid approximately 4 weeks later.

Along the LCR, ELOW have most often been found nesting in mature stands of cottonwood-willow-mesquite habitat larger than 2 hectares, with a closed canopy, lower presence of tamarisk (*Tamarix* spp.) (< 50–75 percent), and with some areas free of human disturbance (Halterman et al. 1987, 1989). ELOW nest in cavities excavated by multiple medium-sized woodpecker species, including gilded flicker (*Colaptes chrysoides*), acorn woodpecker (*Melanerpes formicivorus*), Gila woodpecker (*Melanerpes uropygialis*), and ladder-back woodpecker (*Dryobates scalaris*) (Ligon 1968; Goad and Mannan 1987; Henry and Gehlbach 1999). The quantity of woodpecker cavities is an important predictor for ELOW occupancy, with a preference for a greater number of cavities (Goad and Mannan 1987; Hardy and Morrison 2001). ELOW have been shown to use artificial nest boxes with success (McKinney 1996). ELOW typically lay eggs on the wooden base of the cavity. The typical clutch consists of two or three eggs (one to four in canyon riparian environments) (Ligon 1968).

Incubation begins after the second egg is laid and lasts approximately 24 days (Ligon 1968). The third and fourth eggs, when present, hatch on an accelerated schedule. The young are primarily fed by the adult male (Ligon 1968). Young birds fledge from the nest in 28 to 33 days and the length of their dependency period remains unknown (Ligon 1968).

The diet of ELOW is primarily flying insects (Ligon 1968). Their diet shifts from moths and crickets to scarab beetles during the summer rains to reflect the abundance in the environment (Ligon 1968; Earhart and Johnson 1970). ELOW have been observed taking scorpions (Scorpionida) and, on a few occasions, vertebrate prey (lizards [Iguanidae] and blind snakes [*Leptotyphlops dulcis*]) (Ligon 1968).

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 ELOW

The CEM methodology used here expands on that developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012). The expansion incorporates recommendations of Wildhaber et al. (2007, 2011), Kondolf et al. (2008), and Burke et al. (2009) to provide greater detail on causal linkages and outcomes and explicit demographic notation in the characterization of life-stage outcomes (McDonald and Caswell 1993). Attachment 1 provides a detailed description of the methodology. The resulting model is a "life history" model, as is common for CEMs focused on individual species (Wildhaber et al. 2007, 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 ELOW conceptual ecological model has five core components as explained further in attachment 1:

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

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

- **Critical biological activities and processes** – These consist of the activities in which the species engages and the biological processes that take place during each life stage that significantly affect its life-stage outcomes rates. Examples of activities and processes for a bird species may include nest site selection, foraging, molt, and temperature regulation. Critical biological activities and processes typically are "rate" variables; the rate (intensity) of the activities and processes, taken together, determine the rate of recruitment of individuals to the next life stage.

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

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

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

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

Chapter 2 – ELOW 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 ELOW along the LCR on which to build the CEM.

INTRODUCTION TO THE ELOW LIFE CYCLE

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

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

The migratory nature of ELOW complicates its management. Under the LCR MSCP, management of the breeding grounds is a primary responsibility; we therefore focus on three life stages occurring within LCR MSCP lands—nest, juvenile, and breeding adult. ELOW management during migration and winter are certainly important but are outside of the scope of LCR MSCP's responsibilities.

ELOW LIFE STAGE 1 – NEST

We consider the nest stage to be the first in the life cycle of ELOW. It begins when the egg is laid and ends either when the young fledge or the nest fails. Eggs are usually laid in mid-May to mid-June, and incubation lasts around 24 days, with all eggs in a clutch hatching within 2 days of each other (Ligon 1968). The average clutch size in canyon habitat is 2.3, and the average productivity (fledglings per eggs) is 90 percent (Ligon 1968). Young birds fledge from the nest in 28–33 days (Ligon 1968). The life-stage outcome from the nest stage is the survival of eggs and associated nestlings until fledging. It is important to note that the outcome of the nest stage is inherently tied to the behavior and condition of the parents.

ELOW Life Stage 2 – Juvenile

The juvenile stage begins at fledging and ends when the bird returns to the breeding area the following year. However, for the sake of this report, the influences are only evaluated through the bird's departure from the natal area on fall migration. Migration begins in September and sometimes as late as October (Ligon 1968; Henry and Gehlbach 1999). ELOW have been observed gathered in flocks during the migration season, but little else is known about their migratory behavior (Ligon 1961; Ligon 1968). The life-stage outcome from the juvenile stage is the survival of the bird from fledging until the return to the breeding grounds the next calendar year. There are no studies available analyzing the juvenile survival rates in this species.

ELOW Life Stage 3 – Breeding Adult

The adult stage begins when the bird returns to the breeding grounds after its first winter and ends when it departs the breeding grounds during fall migration. Generally, adults arrive on the breeding grounds between around mid-March, with males arriving earlier—and setting up territories before females arrive (Ligon 1968). Males attract mates with song, cavity presentation, and nuptial gifts of food (Ligon 1968). The first egg is laid approximately 4 weeks later (Ligon 1968). ELOW are believed to be single brooded but may replace clutches after loss (Henry and Gehlbach 1999).

Along the LCR, ELOW have most often been found nesting in mature stands of cottonwood-willow-mesquite habitat larger than 2 hectares, with a closed canopy, lower presence of tamarisk (< 50–75 percent), and with some areas free of human disturbance (Halterman et al. 1987, 1989). ELOW nest in cavities excavated by multiple medium-sized woodpecker species, including gilded flicker, acorn woodpecker, Gila woodpecker, and ladder-back woodpecker (Ligon 1968; Goad and Mannan 1987; Henry and Gehlbach 1999). ELOW have been shown to use artificial nest boxes with success (McKinney 1996). ELOW typically lay eggs on the wooden base of the cavity (Ligon 1968).

Incubation begins after the second egg is laid and lasts approximately 24 days (Ligon 1968). The female performs all incubating (Ligon 1968). The adult male feeds the adult female from the completion of pair formation until the nestlings are half way to fledging (Ligon 1968). The adult male also provides most of the food for the developing young, but it may be handed off to the female for delivery (Ligon 1968). The length of the fledgling's dependency period remains unknown (Henry and Gehlbach 1999).

The life-stage outcomes for breeding adults are survival and reproduction—here defined as the production of eggs. Most studies of bird demography define fecundity—or the reproductive rates of adults—as the number of offspring fledged (Etterson et al. 2011). We have separated the nest stage from adult fecundity to more clearly display the information regarding nest success so that it can be better assessed by management. Therefore, adult reproduction involves the acts of pairing, site selection, nest building, and the production of eggs. Survival studies have not been performed on this species, but banding activities have established the current longevity record of 4 years, 11 months (Klimkiewicz and Futcher 1989).

It is important to note that the post-breeding period—after breeding but before migration—is a significant part of a bird's life cycle. Although males, females, and post-breeding individuals have different goals and responsibilities on the breeding grounds, we have included them all within the breeding adult life stage because their habitat use is similar, and thus, management directed at breeding adults will likely benefit all demographics present on the breeding grounds.

LIFE STAGE MODEL SUMMARY

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

Table 1.—Outcomes of each of the three life stages of ELOW

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

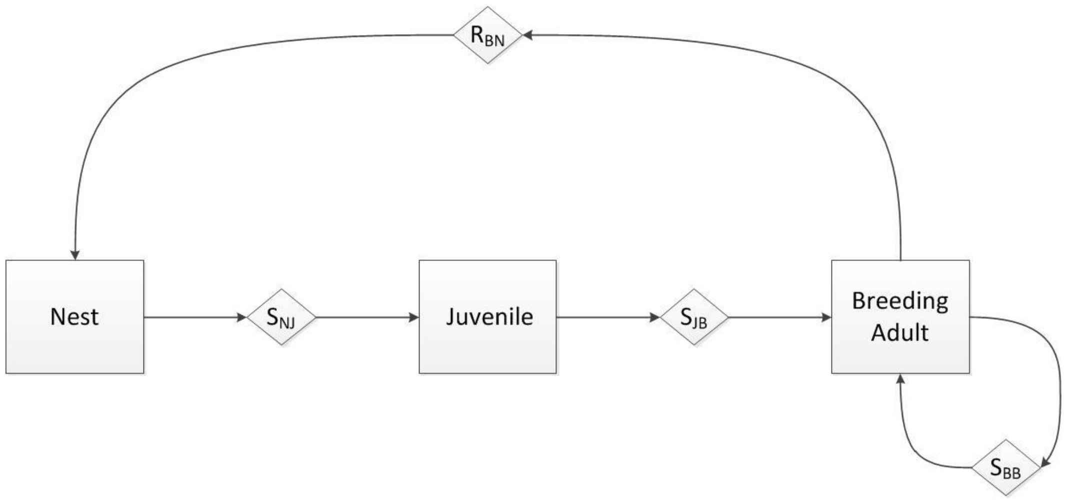


Figure 1.—Proposed ELOW life history model.
Squares indicate the life stages, and diamonds indicate life-stage outcomes.
S_{NJ} = survivorship rate, nest; S_{JB} = survivorship rate, juveniles; S_{BB} = survivorship rate, breeding adults; and R_{BN} = reproduction rate, breeding adults.

Chapter 3 – Critical Biological Activities and Processes

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

The CEM identifies nine critical biological activities and processes that affect one or more ELOW 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 ELOW critical biological activities and processes among life stages
(Xs indicate that the critical biological activity or process is applicable to that life stage.)

Life stage ➔ / **Critical biological activity or process ➔**	**Nest**	**Juvenile**	**Breeding adult**
Disease	X	X	X
Eating	X	X	
Foraging		X	X
Molt	X	X	X
Nest attendance			X
Nest predation	X		
Nest site selection			X
Predation		X	X
Temperature regulation	X	X	X

The most widely used sources of the information used to identify the critical biological activities and processes are Ligon (1968) and Henry and Gehlbach (1999). These publications summarize and cite large bodies of earlier studies. Where appropriate and accessible, those earlier studies are directly cited. The identification also integrates information from both older and more recent works as well as the expert knowledge of LCR MSCP biologists. The following paragraphs discuss the nine critical biological activities and processes in alphabetical order.

DISEASE

This process refers to diseases caused by infectious agents, including the effects of ecto- and endo-parasites. Disease prevalence and intensity can be influenced by lack of genetic diversity. Little research has focused on specific diseases inflicting ELOW. Only one ecto-parasite has been observed on the species: fly larvae (Calliphoridae) (Ligon 1968). However, there is a wealth of knowledge regarding avian diseases and parasites that affect birds within North America, which indicates a large number of diseases (Morishita et al. 1999) that can be difficult to detect (Jarvi et al. 2002) and that have differing effects on different species (Merino et al. 2000; Palinauskas et al. 2008). All life stages are conceivably susceptible to disease.

EATING

This process only applies to the nest and juvenile stages because nestlings must eat to stay alive and develop but do not actively forage within their environment in the same way as the juveniles and adults. A nestling's ability to eat is determined by the provisioning rate of its parents. Juveniles may still be fed by adults for some time after fledging, decreasing their dependence on foraging.

FORAGING

ELOW catch their prey in the air, on the ground, and from plant surfaces (Marshall 1957; Ligon 1968; Henry and Gehlbach 1999). ELOW change low canopy perches often and have been observed hovering above prey, capturing them as they take flight (Ligon 1968; Henry and Gehlbach 1999). Foraging is done by juveniles and adults, but it is important to note that foraging by the parents affects the provisioning rate to nestlings and nest attendance by adults.

MOLT

Nestling ELOW must molt from natal down into juvenile plumage while in the nest. The success of this molt is dependent upon the adult provisioning rate (Howell 2010). Molting is an energetically costly process that may make nestlings more susceptible to death when resources are scarce (Howell 2010). Feather quality may be negatively affected by poor diet, and the nestlings may compensate by shifting resources from other critical functions, such as the immune system, putting them at further risk (Birkhead et al. 1999). Juvenile birds molt again in late summer into adult-like plumage (Walters 1981). Breeding adult birds molt on the breeding grounds after the breeding season and just before autumn migration and face the same challenges as other age classes with respect to energy allocation (Walters 1981).

NEST ATTENDANCE

Female ELOW do all of the incubating and brooding, but the males exclusively provide food for the young (Ligon 1968). Breeding adults attend the nest, and this affects nestling survival.

NEST PREDATION

Nest predation is known to occur by gopher snakes (*Pituophis melanoleucus*), green ratsnakes (*Senticolis triaspis*) and ringtails (*Bassariscus astutus*) (Ligon 1968; Boal et al. 1997; Henry and Gehlbach 1999). Siblicide also occurs in this species (Henry and Gehlbach 1999). Adults actively defend the nest, sometimes with physical contact, against these predators (Ligon 1968; Boal et al. 1997). Nearby pairs have been observed joining in group defense (Boal et al. 1997).

NEST SITE SELECTION

Breeding males select the territory and multiple potential nesting cavities (Henry and Gehlbach 1999). The male presents the cavities to the female during the courtship process, and the female appears to select the cavity (Ligon 1968). Nest site selection is important for reproductive success because nest success varies spatially as a result of vegetation characteristics, food availability, predator types and densities, hydrology, or unique events such as flooding (Saab 1999).

PREDATION

Predation is a threat in all life stages, and it obviously affects survival. Predation on juveniles and adults is not as easily quantified, but it affects juveniles and adults and indirectly affects nest survival through abandonment. Predation risk can result in many behavioral adaptations in passerines, including nest locations, densities, clutch size, egg size, etc. (Lima 2009). Great horned owls (*Bubo virginianus*), Cooper's hawks, Mexican jays (*Aphelocoma wollweberi*), gopher snakes (*Pituophis melanoleucus*), green ratsnakes, and ringtails are among the species that have been observed or suspected of preying upon ELOW (Henry and Gehlbach 1999). Adult ELOW actively defend the nest and fledglings, sometimes with physical contact, against these predators (Ligon 1968; Boal et al. 1997). Nearby pairs have been observed joining in group defense (Boal et al. 1997). Predator density can be influenced by anthropogenic disturbance, recreational activities, canopy closure, and understory density.

TEMPERATURE REGULATION

Temperature regulation is important for any organism inhabiting a region with temperatures as high as the LCR. ELOW have low amounts of insulation, have inefficient mechanisms for shedding heat, and easily succumb under high body temperatures (Ligon 1969). Although overheating is possible in all life stages, most of the concern has been toward eggs and nestlings (Hunter et al. 1987; Rosenberg et al. 1991). Adults can affect the temperature regulation of eggs and nestlings through their own behavior (incubation, brooding, or shading) and through nest cavity selection (Grant 1982; Hardy and Morrison 2001). Disease can also influence temperature regulation of individual birds (Hawley et al. 2012).

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

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

Table 3 lists the 19 habitat elements and the critical biological activities and processes that *directly* affect across all ELOW life stages.

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

The most widely used sources of the information used to identify the habitat elements are Ligon (1968) and Henry and Gehlbach (1999). These publications summarize and cite large bodies of earlier studies. Where appropriate and accessible, those earlier studies are directly cited.

Along the LCR, ELOW have most often been found nesting in mature stands of cottonwood-willow-mesquite habitat larger than 2 hectares, with a closed canopy, lower presence of tamarisk (< 50–75 percent), and with some areas free of human disturbance (Halterman et al. 1987, 1989; Gamel and Brush 2001). The quantity of woodpecker cavities is an important predictor, with a preference for a greater number of cavities (Goad and Mannan 1987; Hardy and Morrison 2001). The diet of ELOW consists primarily of arthropods in at least 22 families, 77 percent of which are insects. Moths (Sphingidae, Noctuidae), beetles (Scarabaeidae), and crickets (Gryllidae) make up the majority of their diet (Henry and Gehlbach 1999).

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

Critical biological activity or process ➔ **Habitat element 🡻**	**Disease**	**Eating**	**Foraging**	**Molt**	**Nest attendance**	**Nest predation**	**Nest site selection**	**Predation**	**Temperature regulation**
Anthropogenic disturbance		X	X		X	X	X	X	
Brood size		X							
Canopy closure						X	X	X	X
Cavity availability							X		
Community type			X			X	X	X	
Food availability			X		X		X		
Genetic diversity and infectious agents	X								
Local hydrology									
Parental feeding behavior		X	X						
Parental nest attendance		X				X			
Patch size						X	X	X	
Predator density					X	X	X	X	
Soil salinity									
Stand height							X		
Temperature									X
Tree cover							X	X	
Tree density						X	X	X	
Tree size							X		
Understory density						X	X	X	

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

ANTHROPOGENIC DISTURBANCE

Full name: **Human activity within or surrounding a given habitat patch, including noise, pollution, and other disturbances associated with human activity**. Anthropogenic disturbance can affect both breeding success and survival of birds (reviewed by Barber et al. 2010; Francis and Barber 2013). Noise might mask conspecific cues, such as songs or calls, making it more difficult for ELOW to attract or find mates or defend territories. Noise may also affect foraging, eating, nest attendance, predators, etc. Anthropogenic disturbance effects have not been thoroughly studied on ELOW or within the LCR, so specific impacts are not quantified.

BROOD SIZE

Full name: **The number of young in the nest**. This element refers to the number of young that the parents must rear. Brood size is related to maternal health, and the well-being of both parents depends in part on the availability of sufficient food resources in close proximity to the breeding territory as well as other factors such as predator density. The typical clutch consists of two or three eggs (one to four in canyon riparian environments) (Ligon 1968; Henry and Gehlbach 1999).

CANOPY CLOSURE

Full name: **The proportion of the sky hemisphere obscured by vegetation when viewed from a single point as measured with a spherical densitometer (Jennings et al. 1999)**. This element refers to the percent canopy closure of canopy vegetation in the vicinity of ELOW nest sites. Canopy closure of riparian vegetation, especially higher density in the upper canopy, has been shown to be important to ELOW (Halterman et al. 1987, 1989). Dense vegetation around nests may provide more optimal microclimate for thermal regulation, which has been shown to be important for ELOW (Ligon 1969), and may provide camouflage from nest predators, but this has not been substantiated.

CAVITY AVAILABILITY

Full name: **The abundance of previously excavated cavities available for adults to use for nesting**. This element refers to the presence and quantity of appropriately sized, available cavities for ELOW to use for nesting within. ELOW nest in cavities excavated by multiple medium-sized woodpecker species, including gilded flicker, acorn woodpecker, Gila woodpecker, and ladder-back woodpecker (Ligon 1968; Goad and Mannan 1987; Henry and Gehlbach 1999). The adult male ELOW will often introduce the female to a number of available cavities during the courtship process (Ligon 1968). The quantity of woodpecker cavities is an important predictor for ELOW occupancy, with a preference for a greater number of cavities (Goad and Mannan 1987; Hardy and Morrison 2001). Cavity availability could be decreased through competition with European starlings (*Sturnus vulgaris*); however, Koenig (2003) failed to find a population level impact on 27 species of cavity-nesting birds.

COMMUNITY TYPE

Full name: **The species composition of the riparian forest patch**. This element refers to the species composition of riparian habitat used for breeding by ELOW. Across their range, ELOW are found in a variety of habitats (Henry and Gehlbach 1999). Within the LCR, ELOW primarily are found in mature cottonwood, willow, mesquite, palo verde, and scattered stands of saguaro (Halterman et al. 1987, 1989).

FOOD AVAILABILITY

Full name: **The abundance of food available for adults and their young**. This element refers to the taxonomic and size composition of the invertebrates that an individual ELOW will encounter during each life stage as well as the density and spatial distribution of the food supply in proximity to the nest. ELOW primarily consume arthropods during the breeding season, relying heavily on arthropods in at least 22 families, 77 percent of which are insects. Moths, beetles, and crickets make up the majority of their diet (Henry and Gehlbach 1999). Other families of prey include Acrididae, Tettigoniidae, Mantidae, Chrysopidae, Cerambycidae, and Curculionidae (Ligon 1968). In addition, ELOW have been observed feeding on scorpions, lizards, and blind snakes (Ligon 1968). The abundance and condition of the food supply affects adult health, growth and development of nestlings and juveniles, the progress of molt, and the success of later stages in annual cycles (e.g., migration).

GENETIC DIVERSITY AND INFECTIOUS AGENTS

Full name: **The genetic diversity of ELOW individuals and the types, abundance, and distribution of infectious agents and their vectors**. The genetic diversity component of this element refers to the genetic homogeneity versus heterogeneity of a population during each life stage. The greater the heterogeneity, the greater the possibility that individuals of a given life stage will have genetically encoded abilities to survive their encounters with the diverse stresses presented by their environment and/or take advantage of the opportunities presented. Unfortunately, no genetic studies have been performed on LCR ELOW.

The infectious agent component of this element refers to the spectrum of bacteria, fungi, ecto-parasites, endo-parasites, and viruses that individual ELOW are likely to encounter during each life stage. There have been few specific studies of the infectious agents and their effects on ELOW. Only one ecto-parasite has been reported on the species: fly larvae (Calliphoridae) (Ligon 1968). However, there is a wealth of knowledge regarding avian diseases and parasites that affect birds within North America, which indicates a large number of diseases (Morishita et al. 1999) that can be difficult to detect (Jarvi et al. 2002) and that have differing effects on different species (Merino et al. 2000; Palinauskas et al. 2008).

LOCAL HYDROLOGY

Full name: **Aspects such as the distance to standing water or the presence of adjacent water bodies, the timing and volume of floods, the depth to the water table, and soil moisture levels**. This element refers to anything that affects soil moisture, such as the proximity of water to the nesting habitat, elevation, irrigation practices, and soil texture. The local hydrological conditions of a given patch might be the single most important determinant of ELOW habitat quality in riparian areas because it affects other aspects of habitat such as vegetation structure, cottonwood recruitment, and abundance of arthropods (Ahlers and Moore 2009; Burke et al. 2009). Wetter conditions might also provide cooler temperatures and more humid conditions necessary for egg and chick survival in these desert systems (Rosenberg et al. 1991; McLeod and Pellegrini 2013). Local hydrology can also affect prey composition and overall food abundance (Ellis et al. 2001).

PARENTAL FEEDING BEHAVIOR

Full name: **The ability and behavior of parents to feed and care for juveniles after they fledge from the nest**. This element refers to the capacity of both parents to provision food for recently fledged birds. 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 share nesting and brood rearing responsibilities until fledging. It is affected by the presence of predators and competitors, food availability, and the ability to thermal regulate. Female ELOW have the sole responsibility of brooding young, but the territory is actively defended by the male, and most food is provided by the male (Ligon 1968; Henry and Gehlbach 1999).

PATCH SIZE

Full name: **The size of riparian habitat patches**. This element refers to the areal extent of a given patch of riparian vegetation. Although the average patch size may differ between riverine and reservoir systems (Paxton et al. 2007), patch size affects the number of breeding pairs that an area can support as well as the density of predators, competitors, and brood parasites. Little solid information is available about the importance of patch size to ELOW occupancy, but it is suspected that it plays a role in nest site selection.

PREDATOR DENSITY

Full name: **The abundance and distribution of predators that affect ELOW during the nestling, post-fledgling, and adult stages**. This element refers to a set of closely related variables that affect the likelihood that different kinds of predators will encounter and successfully prey on ELOW during the nestling, juvenile, or adult life stages. The variables of this element include the species and size of the fauna that prey on ELOW during different life stages, the density and spatial distribution of these fauna in the riparian habitat used by ELOW, and whether predator activity may vary in relation to other factors (e.g., time of day, patch size, etc.). The full list of potential predators of ELOW has not been studied (Henry and Gehlbach 1999). However, great horned owls, Cooper's hawks, Mexican jays, gopher snakes, green ratsnakes, and ringtails are among the species that have been observed or suspected of preying upon ELOW (Henry and Gehlbach 1999).

The effect of predator density can have impacts more subtle than survival by altering prey behavior, nest site selection, breeding behavior, and foraging behavior (Lima 1998, 2009; Chalfoun and Martin 2009).

SOIL SALINITY

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

STAND HEIGHT

Full name: **The average height of the core stand area being evaluated**. Gamel and Brush (2001) found an insignificant positive association with stand height and ELOW occupancy within chaparral environments. This suggests that stand height may be important for ELOW occupancy in riparian environments, but quantifiable studies have not been performed.

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 the summer can kill eggs and stress young in the nest (Ligon 1968; Hunter et al. 1987; Rosenberg et al.1991). The maximum temperature recorded in an ELOW nest cavity was 40 °C in a sycamore tree (Ligon 1968) and 41 °C in a saguaro-based nest (Soule 1964). Additionally, the temperature outside of the nest can have an impact on fledglings and adults (Ligon 1969). ELOW suffer from increased body temperature when ambient temperatures reach 34 °C, resulting in increased risk of dehydration and disease, and it often requires behavioral changes (Ligon 1969)

TREE COVER

Full name: **The horizontal width of a tree's canopy at its widest point, averaged across the stand**. Gamel and Brush (2001) found that tree cover was a significant predictor of ELOW occupancy within chaparral environments, suggesting that it may also be important in riparian systems.

TREE DENSITY

Full name: **The stem density of trees reported as the number of trees per acre**. The greater the tree and/or shrub density, the greater the likelihood of denser vegetative cover. Tree density can be correlated with canopy closure and total vegetation density. ELOW nest in areas with higher vegetation coverage and volume in the overstory (Halterman et al. 1987, 1989; Gamel and Brush 2001). However, Gamel and Brush (2001) found a higher likelihood of occupancy in areas with lower tree density within chaparral environments.

TREE SIZE

Full name: **The diameter of a tree at breast height, averaged across the stand**. Gamel and Brush (2001) found an insignificant positive association with tree diameter at breast height and ELOW occupancy within chaparral environments. Goad and Mannan (1987) found that ELOW disproportionately use larger saguaros than generally available. These results suggests that tree diameter at breast height may be important for ELOW occupancy in riparian environments, but quantifiable studies have not been performed.

UNDERSTORY DENSITY

Full name: **The density of the understory layer**. This element refers to the visual density of vegetation (i.e., concealment) below the uppermost canopy layer. Gamel and Brush (2001) report that ELOW were more abundant in chaparral environments with lower understory density, at least in the first 1.5 meters (m) above the ground and above 5.5 m. Gamel and Brush (2001) suggest that ELOW require some understory but did not provide a quantified measure to confirm this observation.

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 directly affect some critical biological activities or processes. A hierarchy of such factors exists, with long-term dynamics of climate and geology at the top. However, this CEM focuses on 11 immediate controlling factors that are within the scope of potential human manipulation. The 11 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 11 controlling factors and the habitat elements they directly affect. Table 4 shows five habitat elements that are not directly affected by any controlling factor. These latter habitat elements are directly shaped by the condition of one or more other habitat elements rather than by any of the controlling factors.

Table 4.—Habitat elements directly affected by controlling factors

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

Fire Management

This factor addresses any fire management (whether prescribed or suppression) that could affect ELOW or their habitat. Effects may include creation of habitat that supports or excludes ELOW, a reduction in the food supply of invertebrates, or support of a species that pose threats to ELOW such as altering canopy closure or recruiting/excluding predators, competitors, or carriers of infectious agents. Climate change is also projected to affect fire frequency along the LCR (U.S. Fish and Wildlife Service [USFWS] 2013).

Grazing

This factor addresses the grazing activity on riparian habitats along the LCR and in surrounding areas that could affect ELOW or their habitat. Grazing by cattle, burros, or mule deer across the arid Southwestern United States has substantially degraded riparian habitat (see references 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 prevent the establishment of cottonwood and willow seedlings (Kauffman et al. 1997; Powell and Steidl 2002).

Irrigation

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

Mechanical Thinning

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

NATURAL THINNING

This factor addresses the natural death of trees within a patch of a riparian forest or the surrounding matrix. As overstory trees die, they leave openings in the canopy, thereby allowing light to reach lower vegetation layers, and creating the horizontal and vertical foliage profiles. This structural complexity may increase food availability.

NEST BOX INSTALLATION

This factor addresses the installation of artificial nest boxes in areas where nesting cavities may be limited. ELOW have been shown to successfully use artificial nest boxes (McKinney 1996). Even if they do not nest in the artificial cavity, the increase in the quantity of available cavities in a stand increases the attractiveness of the stand for ELOW nesting (Goad and Mannan 1987; Hardy and Morrison 2001) but may also attract greater numbers of European starlings.

NUISANCE SPECIES INTRODUCTION AND MANAGEMENT

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

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

PESTICIDE/HERBICIDE APPLICATION

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

PLANTING REGIME

This factor addresses the active program to restore cottonwood-willow riparian habitat along the LCR and includes both the community planted as well as the manner in which it is planted within restoration areas (e.g., density, age, and patch size). The composition of the species planted can affect not only the vertical and horizontal structure of the vegetation but also the insect community within a given patch.

RECREATIONAL ACTIVITIES

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

WATER STORAGE-DELIVERY SYSTEM DESIGN AND OPERATION

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

The dynamic nature of a free-flowing river creates a mosaic of riparian habitats, and thus, a natural flow regime might be beneficial to ELOW. Natural floods can decrease understory vegetation, improving ELOW habitat and food availability. Natural floods can also impact soil salinity levels, returning them to more natural levels (San Joaquin River Restoration Program 2014).

Chapter 6 – Conceptual Ecological Model by Life Stage

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

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

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

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

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

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

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

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

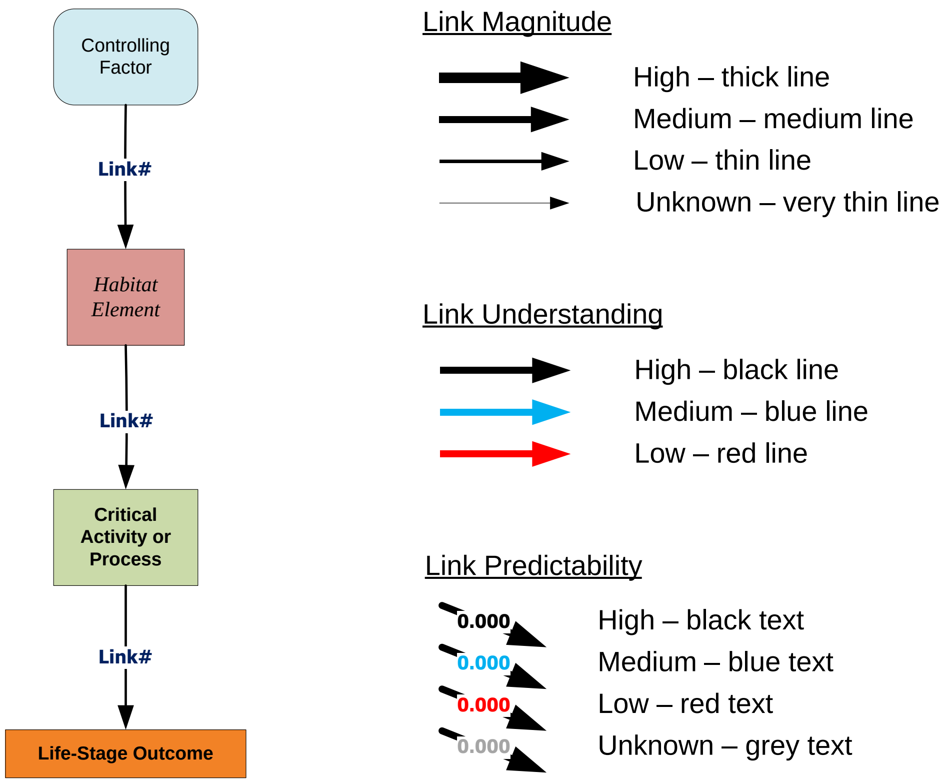


Figure 2.—Diagram conventions for LCR MSCP conceptual ecological models.

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

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

ELOW LIFE STAGE 1 – NEST

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

The CEM (figures 3 and 4) recognizes five (of nine) critical biological activities and processes for this life stage, and they 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 ELOW, we still feel that disease bears mentioning. Diseases and parasites are prevalent in avian populations, so it is safe to assume they have an impact on ELOW (Morishita et al. 1999; Lachish et al. 2011). Disease and parasite impacts along the LCR is an area recommended for further research.

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

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

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

3. **Nest Predation** – Nest predation affects the survival of a nest and is affected by habitat elements. Nest predation has anecdotally been reported as low for ELOW (Ligon 1968).

   The CEM recognizes anthropogenic disturbance, canopy closure, parental nest attendance, patch size, predator density, tree density, and understory density as habitat elements affecting nest predation.

4. **Molt** – The nestling must molt into juvenile plumage.

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

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

5. **Temperature Regulation** – The eggs and nestlings must maintain an optimum temperature to develop and survive. ELOW have low levels of natural insulation and are highly sensitive to high temperatures (Ligon 1968 Ligon 1969).

   The CEM recognizes temperature as the primary habitat element directly affecting temperature regulation. Other biological activities having impacts on temperature regulation include eating and disease.

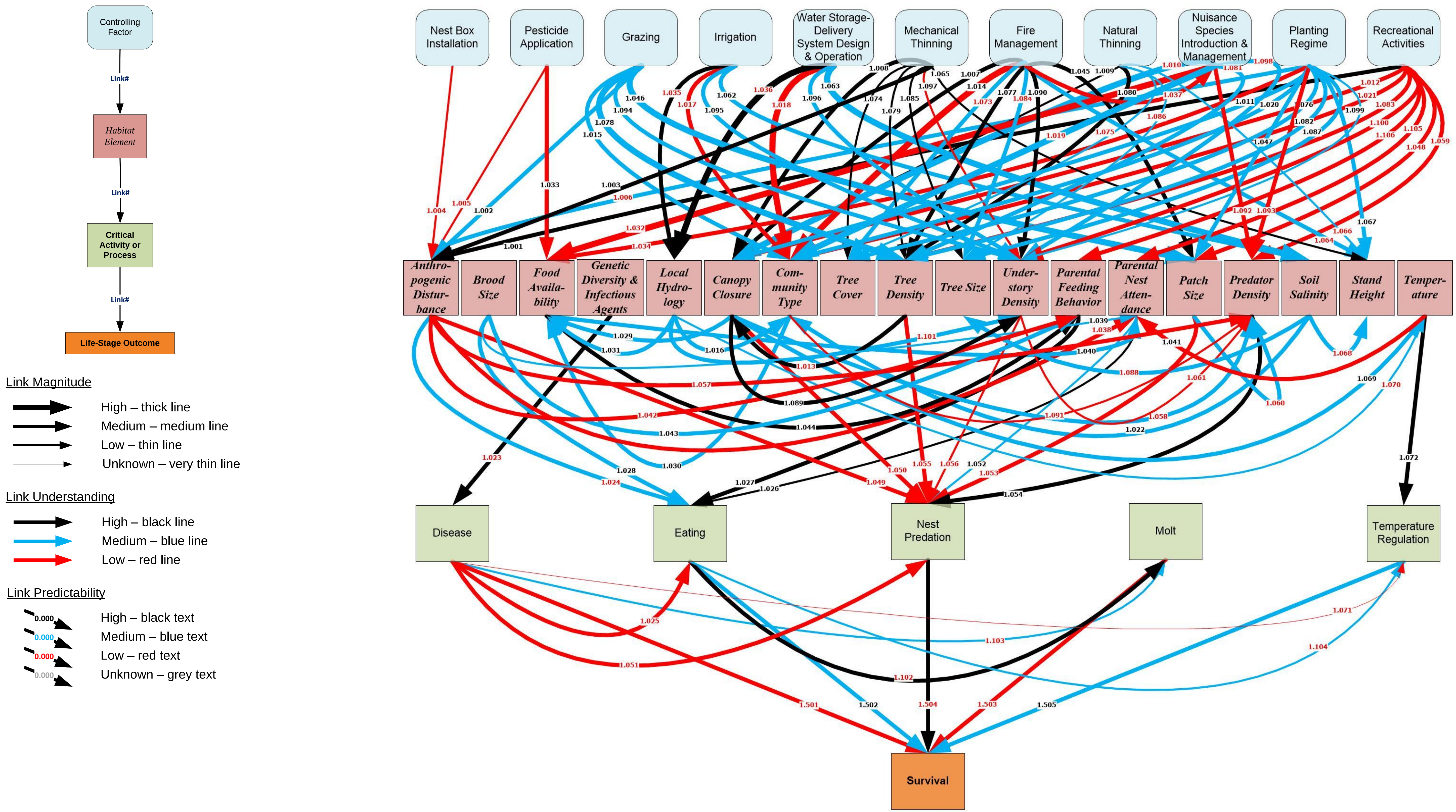


Figure 3.—ELOW Life Stage 1 – Nest, basic CEM diagram showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

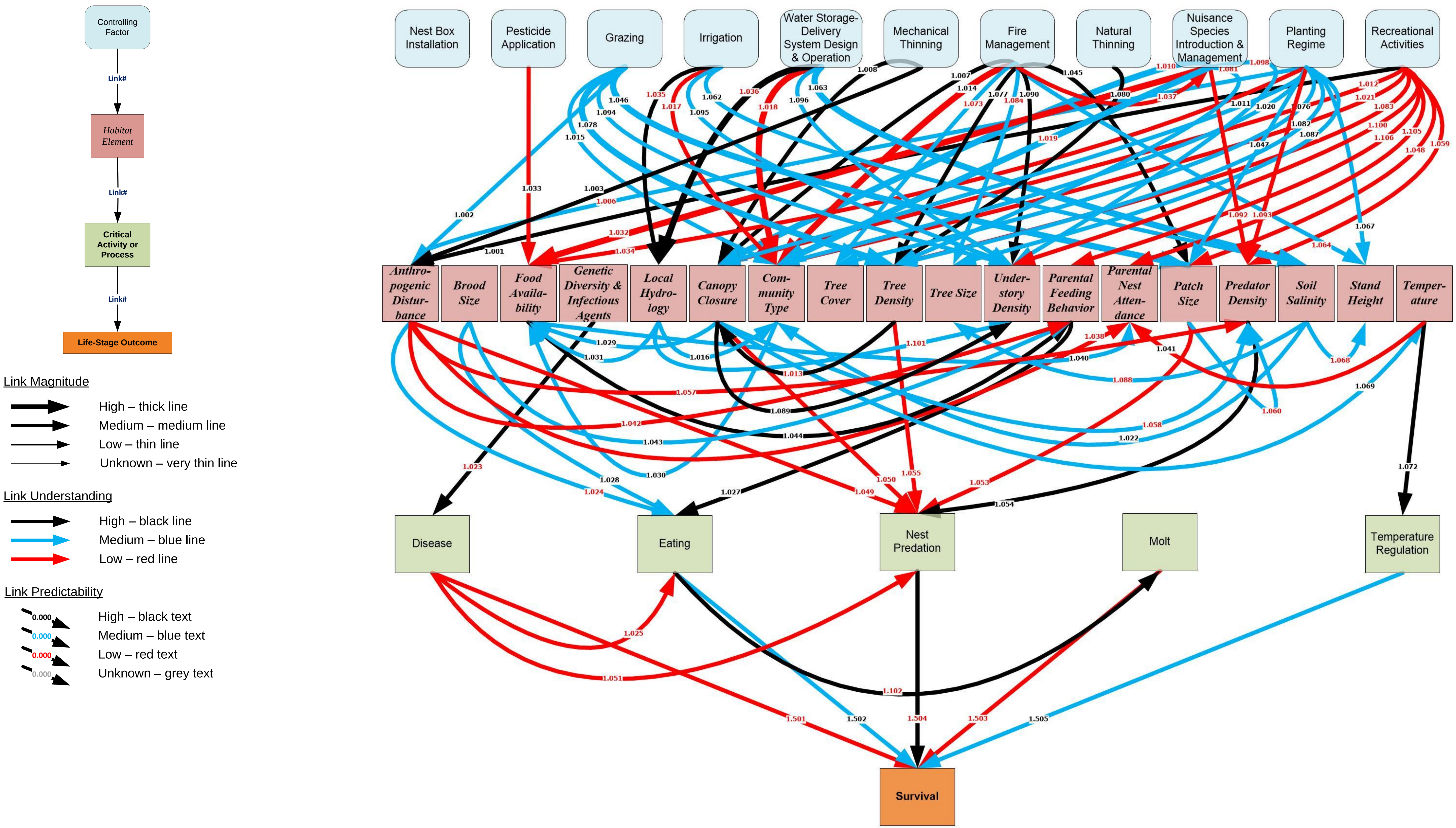


Figure 4.—ELOW Life Stage 1 – Nest, high- and medium-magnitude relationships showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

ELOW LIFE STAGE 2 – JUVENILE

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

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

The CEM (figures 5 and 6) recognizes six (of nine) critical biological activities and processes for this life stage, and they 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 ELOW, we still feel that disease bears mentioning. Diseases and parasites are prevalent in avian populations, so it is safe to assume they have an impact on ELOW (Morishita et al. 1999; Lachish et al. 2011). Disease and parasite impacts along the LCR is an area recommended for further research

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

2. **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 anthropogenic disturbance and food availability as habitat elements affecting foraging. In addition, disease can affect the foraging efficiency of a juvenile, but it is not known to what extent.

3. **Eating** – The juvenile is still dependent upon its parents for food for some unknown period of time after fledging. Increased eating can improve all aspects of health and development and may enable the individual to be more effective at foraging.

   The CEM recognizes brood size, foraging, and parental feeding behavior as habitat elements influencing eating by juvenile birds. Anthropogenic disturbance and disease may also affect eating during this phase, but it is less understood.

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

   The CEM recognizes anthropogenic disturbance, canopy closure, patch size, predator density, tree cover, and tree density as habitat elements directly affecting predation rates.

5. **Molt** – Juvenile birds molt into adult-like plumage shortly after fledging. No habitat elements directly influence molt, but many do indirectly affect it through their impacts on foraging and eating.

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

   The CEM recognizes temperature as a habitat element directly affecting temperature regulation. Disease, eating, and foraging are activities that can have influences on temperature regulation.

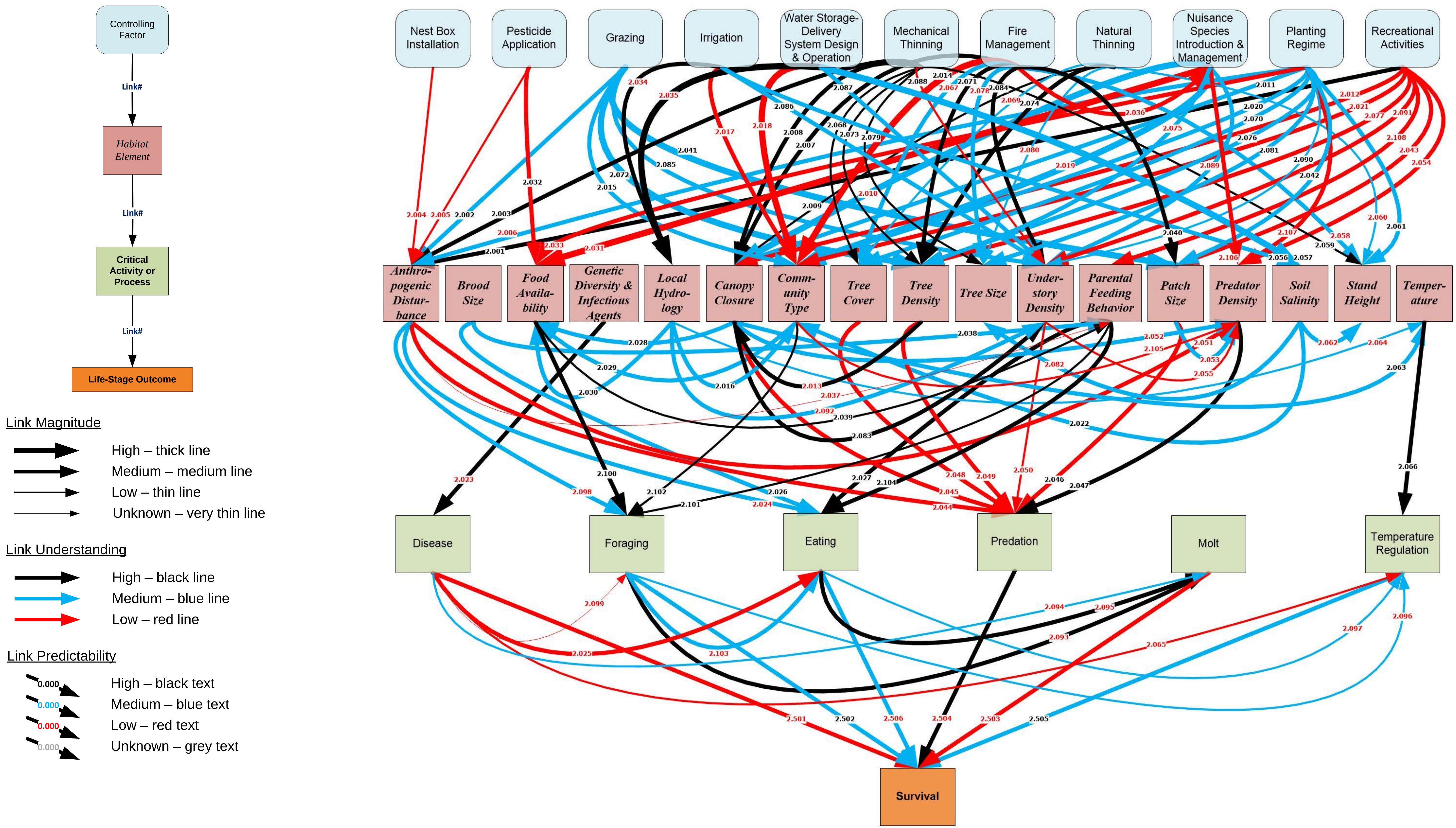


Figure 5.—ELOW Life Stage 2 – Juvenile, basic CEM diagram showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

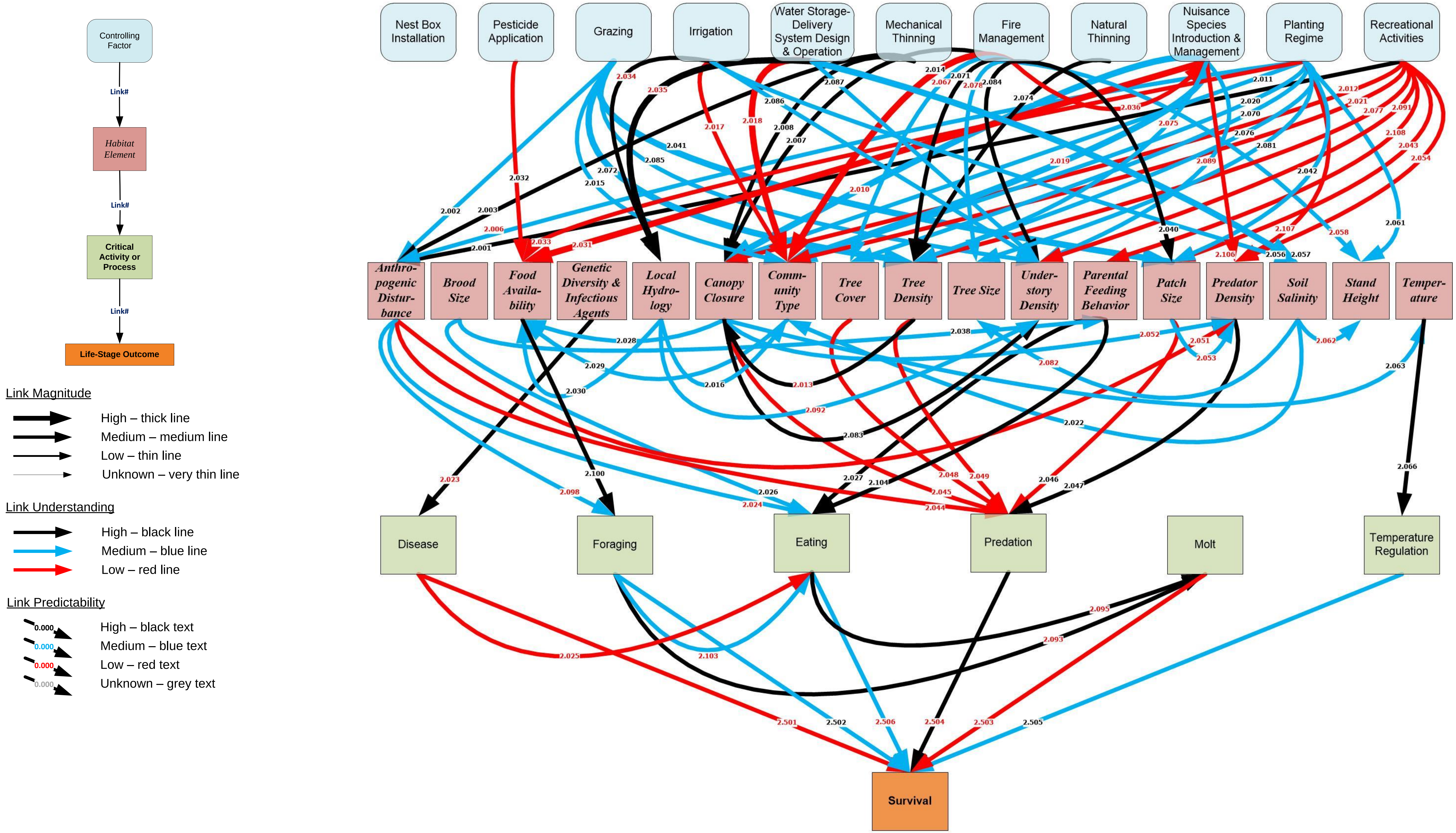


Figure 6.—ELOW Life Stage 2 – Juvenile, high- and medium-magnitude relationships showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

ELOW LIFE STAGE 3 – BREEDING ADULT

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

The CEM (figures 7 and 8) recognizes seven (of nine) critical biological activities and processes for this life stage, and they 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 ELOW, we still feel that disease bears mentioning. Diseases and parasites are prevalent in avian populations, so it is safe to assume they have an impact on ELOW (Morishita et al. 1999; Lachish et al. 2011). Disease and parasite impacts in the LCR is an area recommended for further research

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

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

   The CEM recognizes food availability as the primary habitat element affecting foraging. Secondary habitat elements affecting foraging include anthropogenic disturbance, parental feeding behavior, and possibly disease.

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

   The CEM recognizes anthropogenic disturbance and predator density as the primary elements affecting predation. Canopy closure, parental nest attendance, tree density, and understory density may also have influences.

4. **Molt –** The breeding adults molt their flight feathers just before they depart on autumn migration (Henry and Gehlbach 1999). This activity takes resources that must be directed from other biological processes. Molt requires food (through foraging) and is impacted by disease. The result is that other aspects of survival may be affected, but flight capability should improve.
5.

   The CEM does not recognize any habitat variables that directly influence molt.

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

   The CEM recognizes anthropogenic disturbance, canopy closure, cavity availability, food availability, predator density, and tree density as the primary habitat elements affecting nest site selection. In addition, understory density may also have influences.

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

   The CEM recognizes anthropogenic disturbance and foraging as the top influencers of nest attendance

8. **Temperature Regulation** – The adult must maintain an optimum temperature to survive. ELOW are very sensitive to thermal stress (Ligon 1969).

   The CEM recognizes canopy closure and temperature as the top habitat elements, and foraging and disease as secondary habitat elements, directly affecting temperature regulation.

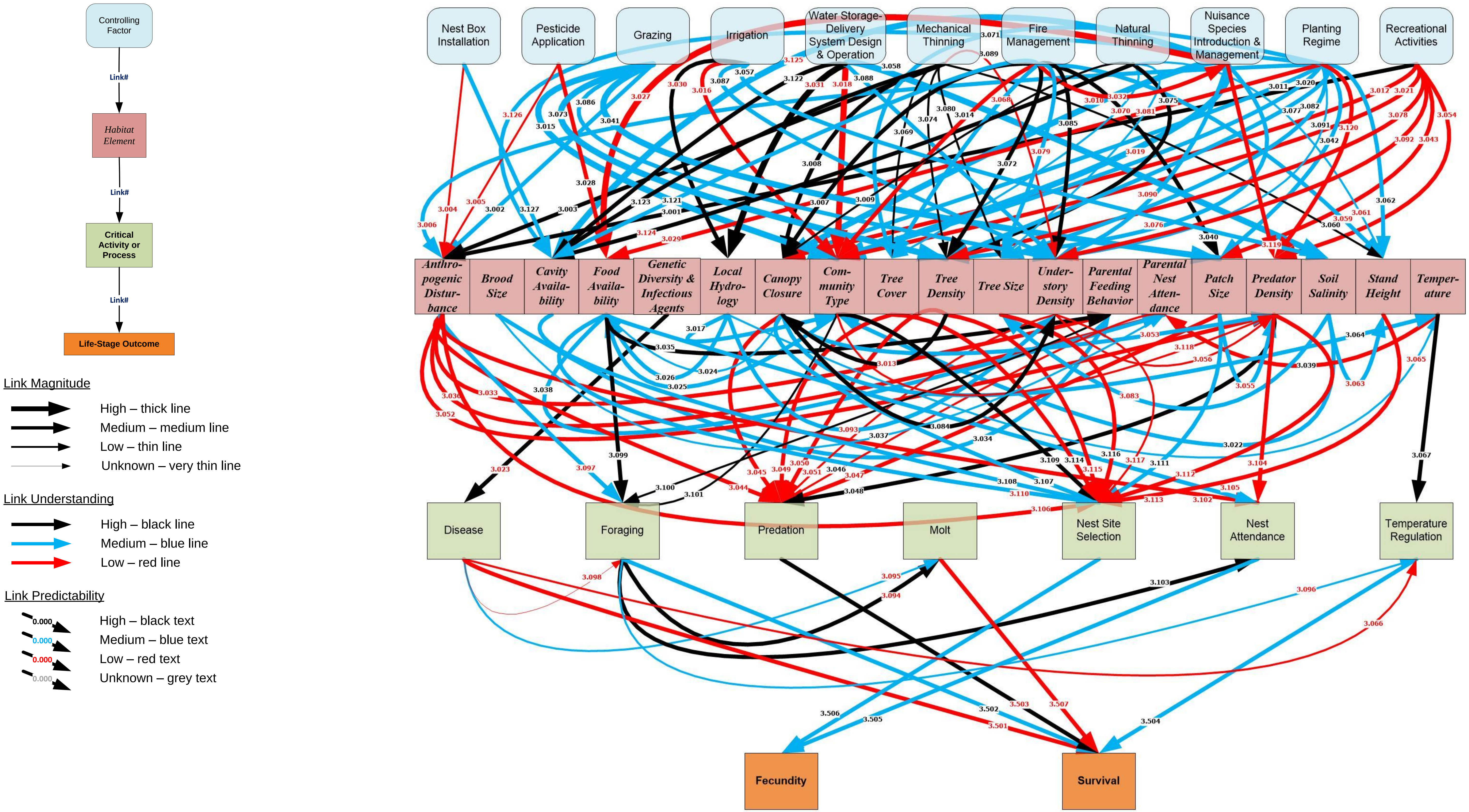


Figure 7.—ELOW Life Stage 3 – Breeding Adult, basic CEM diagram showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

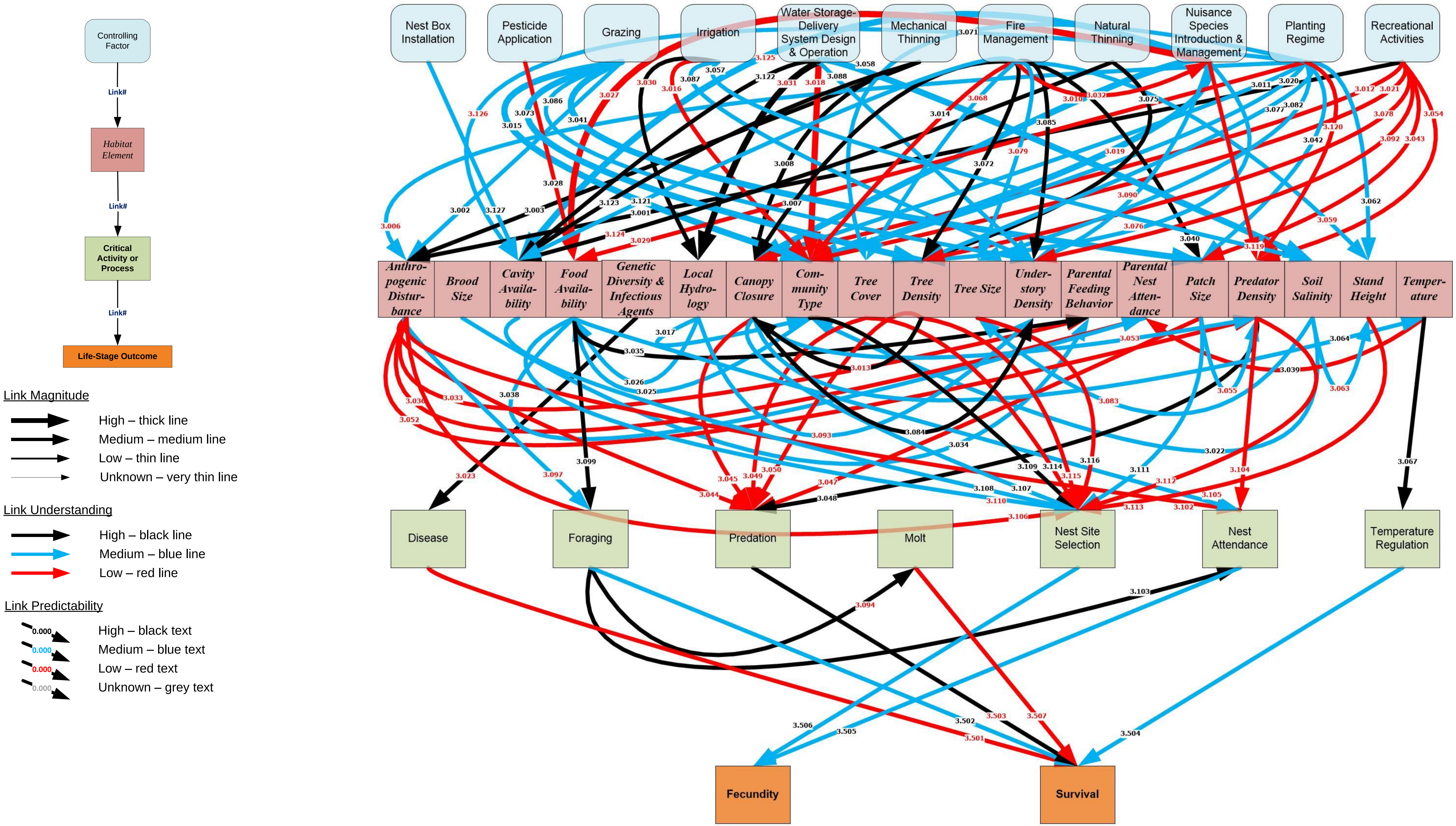


Figure 8.—ELOW Life Stage 3 – Breeding Adult, high- and medium-magnitude relationships showing the relevant controlling factors, habitat elements, and critical biological activities and processes at this life stage.

Chapter 7 – Causal Relationships Across All Life Stages

The 11 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 11 controlling factors on the 19 habitat elements. The structure of table 5 is the same as for table 4, but table 5 shows the magnitudes of the relationships instead of just their presence/absence. The paragraphs following the table discuss the relative effects of the different controlling factors on each habitat element. The magnitudes of direct influences of controlling factors on habitat elements is color coded in the table as follows:

High = H, Medium = M, Low = L

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

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

ANTHROPOGENIC DISTURBANCE

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

CANOPY CLOSURE

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

Fire affects many aspects of vegetation structure and composition and can destroy ELOW habitat (Engstrom et al. 1984). Fire management can have great effects on vegetation structure and is usually implemented over large areas. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely last less than a decade.

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

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

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

Finally, the potential impact of recreation on ELOW habitat is great, although it depends on the activity. Decisions regarding management of recreational activities can affect large areas, but the dynamic nature of both human activity and riparian communities means that effects of recreation will likely last less than a decade, assuming that the activity is limited and does not cause a permanent transition in the habitat.

CAVITY AVAILABILITY

The controlling factors that directly affect cavity availability include fire management, water storage-delivery system design and operation, mechanical thinning, natural thinning, nest box installation, nuisance species introduction and management, and planting regime. Fire, thinning, floods, and nuisance species can all decrease the availability of suitable cavities either in the short or long term. Planting preferred native plants may help attract woodpeckers and, thus, increase suitable cavities for ELOW nesting in the longer term. Installation of nest boxes has a direct positive effect on cavity availability and can be performed quickly, but it is difficult to scale.

The quantity of woodpecker cavities is an important predictor for ELOW occupancy, with a preference for a greater number of cavities (Hardy and Morrison 2001). The quantity of cavities is generally high in larger patches of native trees with higher stem density and greater average tree size. Any actions that remove usable cavities are expected to decrease habitat quality for ELOW. ELOW have been shown to use artificial nest boxes when available (McKinney 1996).

COMMUNITY TYPE

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

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

Grazing affects many aspects of riparian vegetation structure and composition (Kauffman et al. 1997). Grazing activity can have great effects on community composition and is often implemented over large and long scales (Kauffman et al.

1997). However, the dynamic nature of riparian communities means that effects of grazing will likely last less than a decade unless a complete transformation of the community type occurs.

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

Nuisance species can change the structure of entire communities, with lasting effects. However, although the effects are experienced at a patch level, invasive species can spread across entire regions, and their effects can last decades if not cause a permanent transition to a new community type.

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

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

FOOD AVAILABILITY

The controlling factors that directly affect the food available to ELOW include nuisance species introduction and management and pesticide/herbicide application. Invasive species can change an arthropod community; however, other factors also affect arthropod availability. Effects of nuisance species can spread across entire regions and last for decades. The magnitude of the effect of pesticides/herbicides depends on many factors, but the potential magnitude is very high. However, the most likely scenario involves pesticide/herbicide applications at individual agricultural fields affecting nearby patches and the effects dissipating less than a decade after application.

LOCAL HYDROLOGY

Two controlling factors influence local hydrology— irrigation and water storage-delivery system design and operation—it is not possible to put a direction on the effect. The amount of water released or stored in dams affects water levels and therefore distance to water, soil moisture, and other hydrological conditions. Irrigation can be implemented to simulate these processes but may have other effects such as increasing soil salinity. Water storage and flow regimes can affect vegetation communities and food abundance (Nilsson and Svedmark 2002; Burke et al. 2009). Water storage-delivery system design and operation also has a direct influence on floods, which can have a more direct and immediate impact upon nesting stands. The effects of water storage-delivery system design and operation spreads over large scales, but the effects of changes in flow regimes likely last less than a decade unless a complete transformation of the habitat occurs. Irrigation processes are more limited in temporal and spatial scale.

PATCH SIZE

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

Fire affects many aspects of vegetation structure and composition and can destroy habitat (Engstrom et al. 1984). Fire management can have great effects on vegetation structure, and thus patch size, and can be implemented over either small or large areas. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely be short term.

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

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

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

PREDATOR DENSITY

The controlling factors directly affecting predator density include nuisance species introduction and management, planting regime, and recreational activities. The direction and size of these effects are difficult to quantify. Some studies have shown predator presence differs among community types, native, and non-native habitats (Schmidt et al. 2005). Recreational activities can influence predator densities by increasing predator success rates by interfering with prey, distracting the predator, or by decreasing success rates by predator disturbance or predator interference (Mason 2015; Ware et al. 2015). Any change in the composition of the predator community can have a large and lasting impact on the ELOW population (Lima 2009).

SOIL SALINITY

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

STAND HEIGHT

The controlling factors directly affecting stand height include fire management, mechanical and natural thinning, and planting regime.

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

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

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

TREE COVER

The controlling factors directly affecting tree cover include fire management, mechanical and natural thinning, and planting regime.

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

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

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

TREE DENSITY

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

Fire affects many aspects of vegetation structure and composition and can destroy ELOW habitat (Engstrom et al. 1984). Fire management can have great effects on vegetation structure and is usually implemented over large areas. However, the dynamic nature of both fire and riparian communities means that effects of fire management will likely last less than a decade.

Grazing affects many aspects of riparian vegetation structure and composition (Kauffman et al. 1997). Grazing activity can have great effects on community composition and is often implemented over large and long scales (Kauffman et al. 1997). However, the dynamic nature of riparian communities means that effects of grazing will likely last less than a decade, but only if grazing is removed and a permanent transition of the habitat has not occurred.

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

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

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

Finally, the potential impact of recreation on ELOW habitat is great, although it depends on the activity. Decisions regarding management of recreational activities can affect large areas.

TREE SIZE

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

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

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

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

UNDERSTORY DENSITY

The controlling factors that directly affect understory density include fire management, grazing, irrigation, water storage-delivery system design and operation, mechanical thinning, nuisance species introduction and management, planting regime, and recreational activities. Recreational activities, fire, and mechanical/natural thinning will generally reduce understory density, whereas the effects of planting regime, nuisance species introduction and management, and water storage-delivery system design and operation depends on the management actions and species involved.

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

Grazing affects many aspects of riparian vegetation structure and composition (Kauffman et al. 1997). Grazing activity can have great effects on community composition and is often implemented over large and long scales (Kauffman et al. 1997). However, the dynamic nature of riparian communities means that effects of grazing will likely last less than a decade, but only if grazing is removed and a permanent transition of the habitat has not occurred.

The amount of water released or stored affects water levels and therefore distance to water, soil moisture, and other hydrological conditions. Water storage and flow regimes, specifically floods, can affect understory density (Hunter et al. 1987; Lite et al. 2005). Irrigation can also affect understory density.

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

Invasive species can change the structure of entire communities, with lasting effects. Although effects are experienced at a patch level, invasive species can spread across entire regions, and their effects can last decades. Planting regimes have the ability to greatly affect vegetation. However, planting decisions are made at the scale of individual restoration sites.

Finally, the potential impact of recreation on ELOW habitat is great, although it depends on the activity. Decisions regarding management of recreational activities can affect large areas.

Chapter 8 – Discussion and Conclusions

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

MOST INFLUENTIAL ACTIVITIES AND PROCESSES ACROSS ALL LIFE STAGES

Figure 9 identifies the critical biological activities and processes that 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:

- Eating, foraging, and predation are the most important critical biological activities and processes affecting survival of all life stages. 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 of ELOW at all life stages. For example, good nest sites may have more food, few predators, and few diseases present.

POTENTIALLY PIVOTAL ALTERATIONS TO HABITAT ELEMENTS

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

- Nest site selection is by far affected by the most habitat variables likely because this critical biological activity is the most researched element, but also because during the breeding season, this factor determines if the birds are present or not.

- A number of factors influence an individual's ability to get sufficient food, most directly may be food availability and noise. However, competition through brood size and parental behavior can also have a significant influence.

- Nest predation and predation are influenced by many factors, most directly by the number of predators, but also by the habitat elements that may influence the predators to be present and more or less successful. Predator density affects predation rates (Lima 2009).

- Nest attendance is only strongly affected by food availability, predator density, and disturbance-related factors such as anthropogenic disturbance.

- Disease and temperature regulation are important physiological concerns that can be impacted strongly by habitat elements such as canopy closure as well as the presence of diseases and vectors.

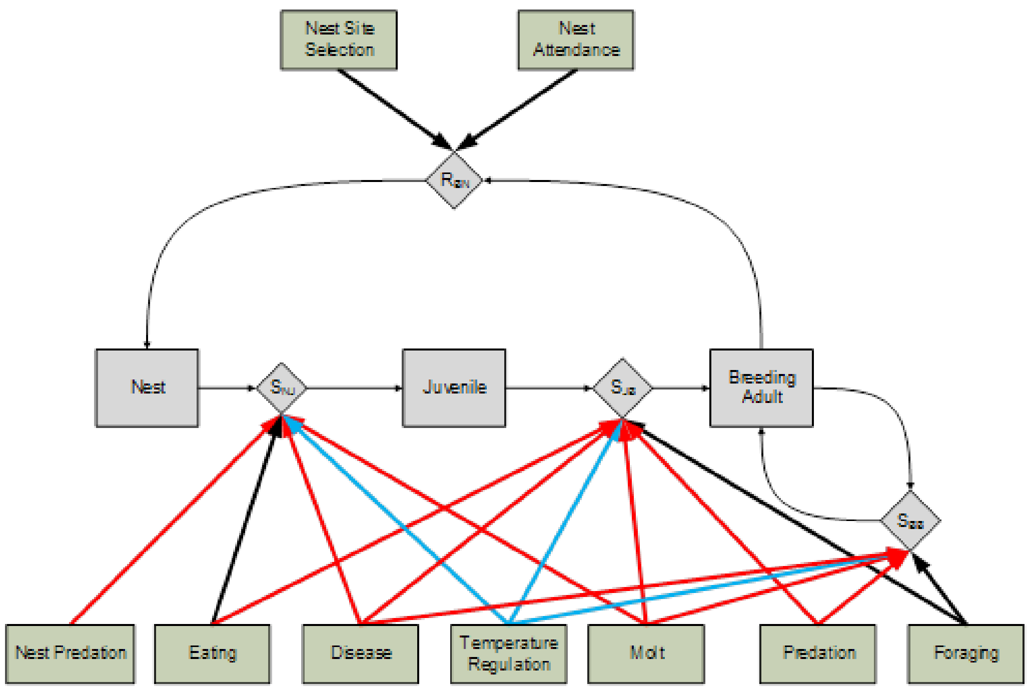
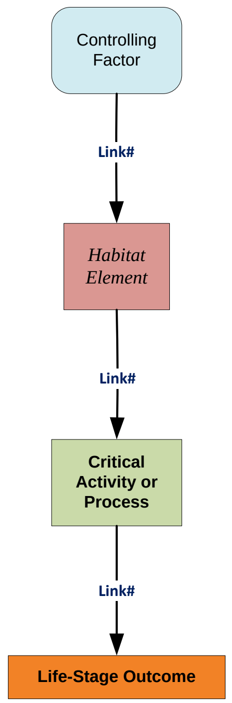
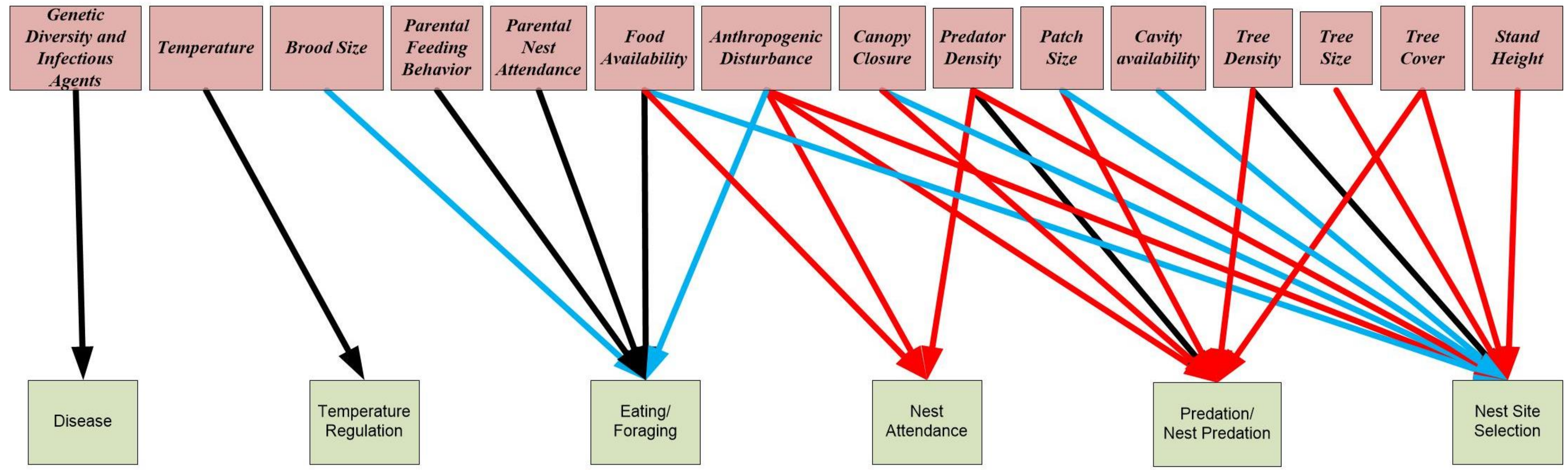


Figure 9.—Most influential biological activities and processes affecting each life stage of ELOW.





Link Magnitude

- High – thick line
- Medium – medium line
- Low – thin line
- Unknown – very thin line

Link Understanding

- High – black line
- Medium – blue line
- Low – red line

Link Predictability

- High – black text
- Medium – blue text
- Low – red text
- Unknown – grey text

Figure 10.—Habitat elements that directly or indirectly affect the most influential biological activities and processes across all life stages of ELOW.

GAPS IN UNDERSTANDING

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

- Nest site selection is by far affected by the most habitat variables and is one of the most well-studied processes for this species. However, most of the research has been focused on populations occupying saguaro cacti ecosystems instead of southwestern riparian systems. The result is that there is little available information on the range of values of specific habitat elements required to maintain and recruit members of this species to restoration areas. In addition, the effects of predator density and anthropogenic disturbance on nest site selection and nest attendance remains poorly understood for all species and has not been studied for ELOW.

- The effects of the molting process on survival is not well understood, yet the prevalence and consistency of molt within the avian world suggests very strong selective pressure, supporting its high priority. Assessing molt for the ELOW population within the LCR may provide indicators of habitat quality and help identify issues individual birds may face if forced to suspend molt due to food shortages.

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

This list of uncertainties is not meant to be exhaustive but only to highlight topics the literature identifies as potentially pivotal to ELOW 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 LCR MSCP, nor are these knowledge gaps expected to be addressed under the program.

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ATTACHMENT 1

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

OVERVIEW OF METHODOLOGY

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

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

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

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

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

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

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

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

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

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

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

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

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

(1) The effect of one controlling factor on another

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

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

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

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

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

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

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

Conceptual Ecological Models as Hypotheses

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

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

Characterizing Causal Relationships

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

(1) The character and direction of the effect

(2) The magnitude of the effect

(3) The predictability (consistency) of the effect

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

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

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

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

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

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

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

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

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

Conceptual Ecological Model Documentation

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

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

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

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

Link Attribute Ratings, Spreadsheet Fields, and Diagram Conventions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

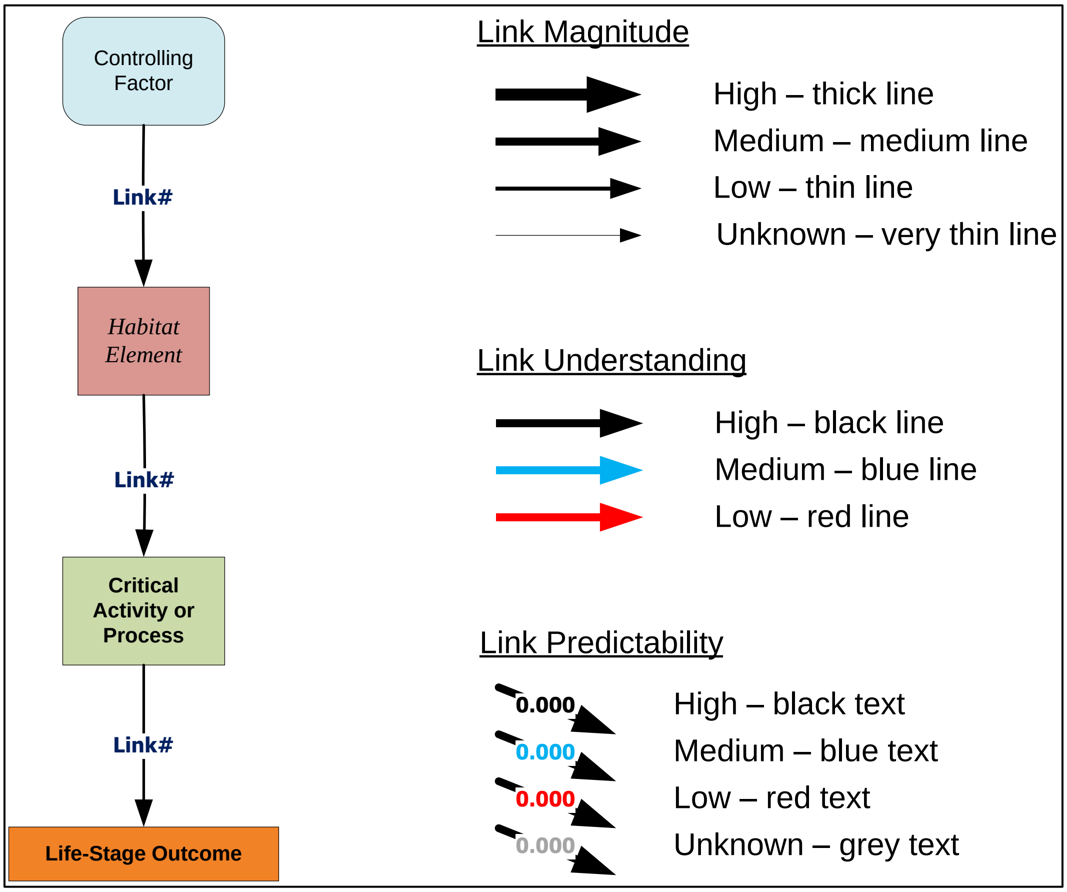

Figure 1-1.—Conventions for displaying cause and effect nodes, linkages, link magnitude, link understanding, and link predictability.

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ATTACHMENT 2

Elf Owl Habitat Data

Habitat element	Value or range	Location	Reference
Canopy closure	> 2 acres of dense canopy closure	Lower Colorado River	Halterman et al. 1987, 1989
	55.20 ± 0.06 percent (Chaparral – not significant)	Santa Ana National Wildlife Refuge, Texas	Gamel and Brush 2001
Community type	Mature cottonwood, willow-mesquite-palo verde	Lower Colorado River	Halterman et al. 1987, 1989
	Chaparral more than riparian.	Santa Ana National Wildlife Refuge, Texas	Gamel and Brush 2001
Human disturbance	Some areas free of human disturbance	Lower Colorado River	Halterman et al. 1987, 1989
Patch size	> 5 acres	Lower Colorado River	Halterman et al. 1987, 1989
Presence of tamarisk	< 50–75 percent	Lower Colorado River	Halterman et al. 1987, 1989
Tree cover (meters)	3.35 + 0.22 (Chaparral)	Santa Ana National Wildlife Refuge, Texas	Gamel and Brush 2001
Tree density	0.41 + 0.07 square meters	Santa Ana National Wildlife Refuge, Texas	Gamel and Brush 2001

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

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