Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

California Black Rail (*Laterallus jamaicensis coturniculus* Dickey) (BLRA) Basic Conceptual Ecological Model for the Lower Colorado River

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U.S. DEPARTMENT OF THE INTERIOR
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Lower Colorado River Multi-Species Conservation Program

California Black Rail (*Laterallus jamaicensis coturniculus* Dickey) (BLRA) Basic Conceptual Ecological Model for the Lower Colorado River

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ACRONYMS AND ABBREVIATIONS

BLRA	California black rail (*Laterallus jamaicensis coturniculus* Dickey)
CEM	conceptual ecological model
cm	centimeter(s)
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
Reclamation	Bureau of Reclamation

Symbols

<	less than
≤	less than or equal to

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.

CONTENTS

Page

Foreword ..... **v**

Executive Summary **ES-1**
Conceptual Ecological Models ES-1
Conceptual Ecological Model Structure ES-2
Results ES-4

Chapter 1 – Introduction **1**
California Black Rail Reproductive Ecology 2
Conceptual Ecological Model Purposes 2
Conceptual Ecological Model Structure for the BLRA 3

Chapter 2 – BLRA Life Stage Model **7**
Introduction to the BLRA Life Cycle 7
BLRA Life Stage 1 – Nest 7
BLRA Life Stage 2 – Juvenile 8
BLRA Life Stage 3 – Breeding Adult 8
Life Stage Model Summary 9

Chapter 3 – Critical Biological Activities and Processes **11**
Chemical Stress 12
Disease 12
Eating 12
Foraging 13
Molt 13
Nest Attendance 13
Nest Site Selection 13
Predation 14

Chapter 4 – Habitat Elements **15**
Anthropogenic Disturbance 16
Brood Size 16
Food Availability 16
Genetic Diversity and Infectious Agents 17
Invertebrate Community Composition 17
Local Hydrology 17
Matrix Community 18
Parental Nest Attendance 18
Patch Size 18
Plant Species Composition 18
Predator Density 19
Residual Vegetation Density 19

Page

Site Topography 19
Vegetation Density 19

Chapter 5 – Controlling Factors 21
Fire Management 22
Grazing 22
Habitat Restoration 22
Mechanical Soil Disturbance 23
Nuisance Species Introduction and Management 23
Pesticide/Herbicide Application 23
Water Storage-Delivery System Design and Operation 23

Chapter 6 – Conceptual Ecological Model by Life Stage 25
BLRA Life Stage 1 – Nest 28
BLRA Life Stage 2 – Juvenile 35
BLRA Life Stage 3 – Breeding Adult 41

Chapter 7 – Causal Relationships Across All Life Stages 47
Invertebrate Community Composition 48
Local Hydrology 48
Matrix Community 49
Patch Size 49
Plant Species Composition 49
Residual Vegetation Density 51
Site Topography 52
Vegetation Density 53

Chapter 8 – Discussion and Conclusions 55
Most Influential Activities and Processes Across All Life Stage 55
Potentially Pivotal Alterations to Habitat Elements 56
Gaps in Understanding 57

Literature Cited 61

Acknowledgments 65

Tables

Table Page

ES-1 Outcomes of each of the three life stages of BLRA 3
1 BLRA life stages and outcomes in the LCR ecosystem 9
2 Critical biological activities and processes by life stage 11
3 Habitat elements directly affecting critical biological activities and processes 15
4 Habitat elements directly affected by controlling factors 21
5 Magnitude of influence of controlling factors on habitat elements 47

Figures

Figure Page

1 Proposed BLRA life history model..... 9
2 Diagram conventions for LCR MSCP conceptual ecological models. 27
3 BLRA life stage 1 – nest, basic CEM diagram. 31
4 BLRA life stage 1 – nest, high- and medium-magnitude relationships. 33
5 BLRA life stage 2 –juvenile, basic CEM diagram. 37
6 BLRA life stage 2 –Juvenile, high- and medium-magnitude relationships. 39
7 BLRA life stage 3 – Breeding adult, basic CEM diagram..... 43
8 BLRA life stage 3 – Breeding adult, high- and medium-magnitude relationships. 45
9 Most influential biological activities and processes affecting each life stage of BLRA. Only elements with high- or medium-magnitude connections are presented. The legend is provided on figure 2. 56
10 Habitat elements that directly affect the most influential biological activities and processes across all life stages of BLRA. Only elements with high- or medium-magnitude connections within this life stage are presented. The legend is provided on figure 2. 58

Attachments

Attachment

1	Species Conceptual Ecological Model Methodology for the Lower Colorado River Multi-Species Conservation Program
2	California Black Rail Habitat Data

Foreword

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

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

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

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

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

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

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

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

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

- A means of identifying appropriate monitoring indicators and metrics.

- A basis for implementing adaptive management strategies.

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

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

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

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

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

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

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

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

How to Use the Models

There are three important elements to each CEM:

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

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

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

This narrative document is a basic guide, meant to summarize information on the species' most basic habitat needs, the figures are a graphic representation of how these needs are connected, and the accompanying workbook is a tool for land managers to see how on-the-ground changes might potentially change outcomes for the species in question. Reading, evaluating, and using these CEMs requires that the reader understand all three elements; no single 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 California black rail (*Laterallus jamaicensis coturniculus* Dickey) (BLRA). 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 BLRA ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure BLRA habitat and population conditions. (Note: Attachment 1 provides an introduction to the CEM process. We recommend that those unfamiliar with this process read the attachment before continuing with this document.)

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

CONCEPTUAL ECOLOGICAL MODELS

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

The CEM applied to the BLRA 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 BLRA conceptual ecological model has five core components:

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

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

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

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

CONCEPTUAL ECOLOGICAL MODEL STRUCTURE

The BLRA conceptual ecological model addresses the BLRA population along the river and lakes of the lower Colorado River (LCR) and other protected areas. The basic sources of information for the BLRA conceptual ecological model are

Repking and Ohmart (1977), Evens et al. (1991), Flores (1991), Eddleman et al. (1994), Taylor and van Perlo (1998), Conway and Sulzman (2007), Reclamation (2008), Nadeau et al. (2011), Butler et al. (2014), and Dudek (2014). 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 BLRA conceptual ecological model distinguishes and assesses three life stages as follows (table ES-1):

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

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

The model distinguishes 8 critical biological activities or processes relevant to 1 or more of these 3 life stages and their outcomes, 14 habitat elements relevant to 1 or more of these 8 critical biological activities or processes for 1 or more life stages, and 7 controlling factors that affect 1 or more of these 14 habitat elements. Because the LCR and its protected areas comprise a highly regulated system, the controlling factors almost exclusively concern human activities.

The eight critical biological activities and processes identified across all life stages are: chemical stress, disease, eating, foraging, molt, nest attendance, nest site selection, and predation. The 14 habitat elements identified across all life stages are: anthropogenic disturbance, brood size, food availability, genetic diversity and infectious agents, invertebrate community composition, local hydrology, matrix community, parental nest attendance, patch size, plant species composition, predator density, residual vegetation density, site topography, and vegetation density. The seven controlling factors identified across all habitat elements are: fire management, grazing, habitat restoration, mechanical soil disturbance, nuisance species introduction and management, pesticide/herbicide application, and water storage-delivery system design and operation.

RESULTS

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

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

- Habitat restoration and water storage-delivery system design and operation can have significant, lasting impacts on local hydrology, which may benefit or harm survival and reproduction.

- Repair leaking infrastructure or the lining of canals may reduce available seepage marsh habitat where BLRA are currently found.

- While nuisance species such as tamarisk (*Tamarix* sp.) may have negative impacts on habitat values, BLRA have been found utilizing habitat with a moderate density of this species, so consideration of how control activities might impact BLRA should be included in management planning.

- Fire management, mechanical soil disturbance, or some other strategy for managing vegetation in areas where scouring flows are not feasible to encourage growth of preferred vegetation such as bulrush (*Schoenoplectus* spp.) may be necessary to manage excess residual vegetation if it becomes too dense and is negatively impacting BLRA use of marsh habitat.

- Since juvenile BLRA appear to disperse into disparate areas on the fringes of marsh land habitat, surveys for BLRA and protection of larger patches of potential habitat is warranted.

- Maintaining appropriate hydrologic conditions for BLRA habitat is critical; therefore, management of water levels and soil moisture levels in known nesting areas needs to be carefully considered in habitat management planning.

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

- The ecology of predation on BLRA and its significance on survival across all life stages, how this may vary among predator species and across different habitat settings, and whether it may be possible to manipulate these habitat conditions to improve BLRA survival even in the presence of predators.

- The presence of disease in the BLRA population and its significance in affecting survival across all life stages within the LCR.

- The impacts of chemical stressors such as selenium, mercury, and pesticides/herbicides within the LCR and its impact on survival of BLRA across all life stages.

- BLRA movement patterns within the LCR, including the movement of juveniles into habitat associated with the fringes of marshes.

- Appropriate management to improve habitat conditions, including vegetation structure and species composition as well as appropriate hydrologic conditions for both Yuma clapper rails and BLRA where they co-occur.

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 BLRA. 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 California black rail (*Laterallus jamaicensis coturniculus* Dickey) (BLRA). 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 BLRA ecology, the effects of specific stressors, the effects of specific management actions aimed at species habitat restoration, and the methods used to measure BLRA habitat and population conditions. The CEM methodology follows that developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012), with modifications. (Note: Attachment 1 provides an introduction to the CEM process. We recommend that those unfamiliar with this process read the attachment before continuing with this document.)

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

The most widely used sources of information for the BLRA conceptual ecological model are Repking and Ohmart (1977), Evens et al. (1991), Flores (1991), Eddleman et al. (1994), Taylor and van Perlo (1998), Conway and Sulzman (2007), Reclamation (2008), Nadeau et al. (2011), Butler et al. (2014), and Dudek (2014). Many of these publications summarize and cite large bodies of earlier studies. Where appropriate and accessible, those earlier studies are directly cited. The CEM also integrates numerous additional sources, particularly reports and articles completed since the aforementioned publications; information on current research projects; and the expert knowledge of LCR MSCP avian biologists. The purpose of the CEM is not to provide an updated literature review but to integrate the available information and knowledge into a CEM so it can be used for adaptive management.

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

CALIFORNIA BLACK RAIL REPRODUCTIVE ECOLOGY

Pair formation begins the breeding cycle for BLRA typically in late February (Eddleman et al. 1994). Assuming calls indicate the dates of pair formation, then breeding along the LCR may span from February into July (Flores 1991). Nests are constructed on sites with both dead vegetation and new growth and placed over moist soil of very shallow water usually on slightly higher ground within marsh habitat (Eddleman et al. 1994). Flores and Eddleman (1993) studied BLRA nesting activity along the LCR and recorded an average of 4.8 eggs (range = 3–7 eggs). Incubation lasts 17–20 days, and both sexes participate in incubating and brood rearing.

BLRA eggs hatch one at a time, and the young are semiprecocial, requiring brooding by at least one parent for the first few days after hatching (Heaton 1937 *in* Eddleman et al. 1994). Along the LCR, Flores and Eddleman (1993) followed the fate of two nests, where they recorded parents and young leaving the nest within 24 hours after the clutches had hatched completely.

The habitat structure explains BLRA habitat use better than plant composition, with water depth being a critical factor (Flores 1991; Flores and Eddleman 1993). In their study of BLRA along the LCR, Flores and Eddleman (1993) found that BLRA selected areas with high stem densities and canopy coverage in shallow water (average depth = 2.2 centimeters) close to upland vegetation. Limited information is available about the BLRA's food habits, though they are likely opportunistic foragers (Eddleman et al. 1994). Small aquatic and terrestrial invertebrates, as well as seeds, are the main food items for BLRA (Eddleman et al. 1994). They likely feed during the day and are active throughout the day (Flores 1991).

CONCEPTUAL ECOLOGICAL MODEL PURPOSES

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

CEMs explicitly identify: (1) the variables or attributes that best characterize resource conditions, (2) the factors that most strongly shape or control these

variables under both natural and altered (including managed) conditions, (3) the character, strength, and predictability of the ways in which these factors do this shaping/controlling, and (4) how the characteristics of the resource vary as a result of the interplay of its shaping/controlling factors.

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

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

CONCEPTUAL ECOLOGICAL MODEL STRUCTURE FOR THE BLRA

The CEM methodology used here expands on that developed for the Sacramento-San Joaquin River Delta Regional Ecosystem Restoration Implementation Plan (DiGennaro et al. 2012). The expansion incorporates recommendations of Wildhaber et al. (2007), Kondolf et al. (2008), Burke et al. (2009), and Wildhaber (2011) to provide greater detail on causal linkages and outcomes and explicit demographic notation in the characterization of life-stage outcomes (McDonald and Caswell 1993). Attachment 1 provides a detailed description of the methodology. The resulting model is a “life history” model, as is common for CEMs focused on individual species (Wildhaber et al. 2007; Wildhaber 2011). That is, it distinguishes the major life stages or events through which the individuals of a species must pass to complete a full life cycle, including

reproducing, and the biologically crucial outcomes of each life stage. These biologically crucial outcomes typically include the number of individuals recruited to the next life stage (e.g., fledgling to adult) or next age class within a single life stage (recruitment rate), or the number of viable offspring produced (fertility rate). It then identifies the factors that shape the rates of these outcomes in the study area and thereby shapes the abundance, distribution, and persistence of the species in that area.

The BLRA 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 individual 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., fledgling to adult), or the number of viable offspring produced (fertility rate). The rates of the outcomes for an individual life stage depend on the rates of the critical biological activities and processes for that life stage.

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

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

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

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 – BLRA 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 BLRA along the LCR on which to build the CEM.

INTRODUCTION TO THE BLRA LIFE CYCLE

The BLRA is one of two subspecies of black rail that breeds in North America (Eddleman et al. 1994). Discovered relatively recently along the LCR (Snider 1969), the majority of known populations of BLRA found within the LCR MSCP boundaries prior to 2008 were in Reaches 5 and 6 (Reclamation 2008). Since 2008, BLRA have been detected in Topock Gorge and other locations within Reach 3 (Kahl 2013). The black rail is the smallest rail in North America and is a very secretive bird. Little information is available on pair formation, but the species may form pairs as early as February based on when calling is initiated (Flores 1991).

We have chosen to combine the egg and chick phases of development into a single life stage in our model even though they undergo different processes—e.g., eggs do not need to eat or molt. We have done this because both eggs and chicks occupy the same nest; therefore, management focused on the nest will cover eggs and chicks.

The BLRA is a year-round resident along the LCR (Flores 1991), so the focus of habitat management for the species is on both the breeding and wintering grounds. We focus on three life stages occurring within LCR MSCP lands—nest, juvenile, and breeding adult. The extent and importance of seasonal migration is not known, so the focus of this study is on management activities within the scope of Reclamation's responsibilities.

BLRA LIFE STAGE 1 – NEST

We consider the nest stage to be the first in the life cycle of the BLRA. It begins when the egg is laid and ends either when the young fledge or the nest fails. Nesting ranges from March to July, though the later nesting records may represent second nests (Eddleman et al. 1994). Flores and Eddleman (1993) recorded a mean clutch size of 4.8 eggs, with an incubation period lasting around 17–22 days.

Both males and females participate in incubation. Chicks are thought to hatch one at a time and require brooding by one parent for the first few days after hatching (Eddleman et al. 1994). The life-stage outcome from the nest stage is the survival of eggs and associated chicks until they become independent. It is important to note that the outcome of the nest stage is inherently tied to the behavior and condition of the parents.

BLRA LIFE STAGE 2 – JUVENILE

This life stage begins when the chick has become independent from the parents and ends when the individual reaches sexual maturity. The precise timing of the end of this life stage for BLRA is unknown but is presumed to be around 1 year of age (Taylor and van Perlo 1998). While there is a tremendous amount of overlap in the biological activities and processes, habitat elements, and controlling factors affecting both the juvenile and breeding adult life stages, we felt that differences in behavior and the way in which BLRA in these life stages interact with the environment were potentially significantly different enough to warrant the split.

BLRA LIFE STAGE 3 – BREEDING ADULT

This life stage begins when the rail reaches sexual maturity and ends when the rail stops reproducing. It is estimated that adult BLRA reach sexual maturity around 1 year of age (Taylor and van Perlo 1998). Breeding begins in February with pair formation (Dudek 2014). Nesting occurs from March through July, with peak nesting in early May (Eddleman et al. 1994). The average clutch size was recorded in one study along the LCR by Flores and Eddleman (1993) to be approximately five eggs. BLRA are known to re-nest (Eddleman et al. 1994).

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.

LIFE STAGE MODEL SUMMARY

Based on the information presented above, the BLRA 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 life stage.

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

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

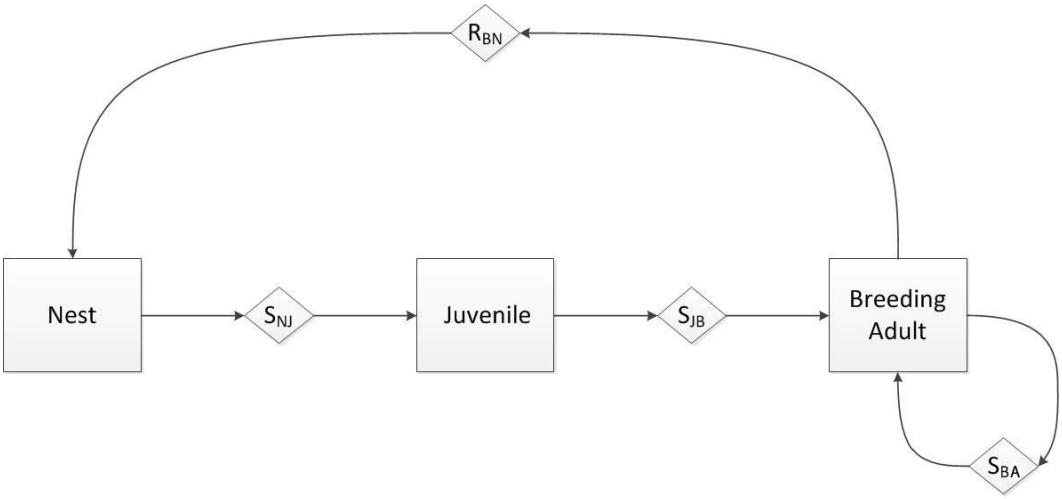


Figure 1.—Proposed BLRA life history model.
Squares indicate the life stages, and diamonds indicate the life-stage outcomes. S_{NJ} = survivorship rate, nest; S_{JB} = survivorship rate, juvenile; S_{BA} = survivorship rate, breeding adult; and R_{BN} = reproduction rate, breeding adult.

Chapter 3 – Critical Biological Activities and Processes

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

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

Table 2.—Critical biological activities and processes by life stage (Xs indicate that the critical biological activity or process is applicable to that life stage)

Life stage ➔ / **Critical biological activity or process 🡻**	**Nest**	**Juvenile**	**Breeding adult**
Chemical stress	X	X	X
Disease	X	X	X
Eating	X		
Foraging		X	X
Molt	X	X	X
Nest attendance			X
Nest site selection			X
Predation	X	X	X

The basic sources of information used to identify the critical biological activities and processes are Repking and Ohmart (1977), Evens et al. (1991), Flores (1991), Eddleman et al. (1994), Taylor and van Perlo (1998), Conway and Sulzman (2007), Reclamation (2008), Nadeau et al. (2011), Butler et al. (2014), and Dudek

(2014). The identification also integrates information from both older and more recent works as well as the expert knowledge of LCR MSCP biologists. The following paragraphs discuss the eight critical biological activities and processes in alphabetical order.

CHEMICAL STRESS

BLRA in every life stage are vulnerable to stress and mortality due to exposure to harmful chemicals, including selenium, mercury, and pesticides/herbicides. Environmental contaminants such as selenium and mercury may have negative impacts on BLRA populations due to the bioaccumulation of these chemicals (Tsao et al. 2009). The effects of chemical contaminants such as pesticides/ herbicides on BLRA populations along the LCR are virtually unknown, but slightly elevated selenium levels were found in LCR birds and eggs analyzed in 1988 (Flores and Eddleman 1993). No information is available regarding the impacts of chemical contamination on BLRA along the LCR; however, other species, including the Yuma clapper rail are known to have elevated levels of selenium in their feathers and tissues (Eddleman 1989). Rusk (1991) measured selenium concentrations in sediment, invertebrates, and two marsh bird species: Virginia rails (*Rallus limicola*) and least bitterns (*Ixobrychus exilis*) along the LCR. She concluded that adult marsh bird species (and presumably juveniles) along the LCR were at low risk for mortality but moderate to high risk of teratogenicity.

DISEASE

This process refers to diseases caused either by lack of genetic diversity or by infectious agents. The prevalence of disease as a source of rail mortality is poorly known for most bird species and is difficult to separate from other causes of mortality. BLRA in all life stages are conceivably susceptible to disease.

EATING

This process only applies to the nest life stage because the chick must eat to stay alive and develop but do not actively forage within their environment in the same way as juveniles and adults. A chick's ability to eat during the first weeks of life is determined by the foraging and provisioning rate of its parents. Some elements, such as siblings, number of chicks in the nest, and genetic diversity, are not traditionally considered aspects of habitat but are included in this section because of their effects on critical biological activities and processes.

FORAGING

BLRA forage in marsh habitat on terrestrial and aquatic invertebrates (Repking and Ohmart 1977; Eddleman et al. 1994). Foraging is done by chicks, juveniles, and adults, but it is important to note that foraging by the parents affects the provisioning rate to chicks and nest attendance by adults.

MOLT

BLRA hatchlings molt from natal down into juvenal plumage in about 6 weeks, though this timing is uncertain (Eddleman et al. 1994). Hatch year birds undergo a partial/incomplete pre-formative molt between July and September following the pre-juvenile molt. Adult (after hatch year) birds undergo a definitive pre-basic molt after breeding (July – September) each year on their breeding grounds (Pyle 2008). Adults lose their tail feathers during this molt and are flightless for 3 to 4 weeks, making them more susceptible to predation (Flores 1991; Eddleman et al. 1994). Molting is an energetically costly process that may make nestlings more susceptible to death when resources are scarce.

NEST ATTENDANCE

Adequate nest attendance is important for successful reproduction. Both parents incubate the eggs in the nest and are responsible for feeding of the young (Eddleman et al. 1994). Breeding adults attend the nest, and this affects the survival of the nestlings.

NEST SITE SELECTION

Nest site selection is important for reproductive success. Nest success varies spatially as a result of vegetation characteristics, food availability, predator types and densities, hydrology, and other factors (Flores and Eddleman 1993; Eddleman et al. 1994). Various aspects of local hydrology are critical for nest site selection of BLRA, including depth and fluctuation rates of water levels, timing and severity of seasonal flooding, and the amount of open water areas, to name a few (Eddleman et al. 1994; Dudek 2014). The plant species composition preferred by nesting BLRA along the LCR appears to be dense bulrush stands and grasses (Repking and Ohmart 1977). Flores (1991) documented BLRA using microhabitats with very high stem densities of plants. Nests are placed on top of moist soil or above shallow water areas and constructed on sites with higher elevations than the surrounding habitat (Eddleman et al. 1994; BIO-WEST, Inc. 2005).

PREDATION

Predation is a threat to BLRA in all life stages, and it obviously affects survival. Common predators of BLRA include northern harriers (*Cyaneus circus)*, great egrets (*Ardea alba)*, great blue herons (*A. Herodias*), ring-billed gulls (*Larus delawarensis*), great horned owls (*Bubo virginianus*), and short-eared owls (*Asio flammeus*) (Eddleman et al. 1994; Butler et al. 2014). Other predators have been rarely documented, though feral cats (*Felis silvestris catus*) are known predators of BLRA in California (Evens and Page 1986).

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 14 habitat elements that affect 1 or more critical biological activities or processes across the 3 BLRA life stages. Some of these habitat elements differ in their details among life stages. Table 3 lists the 14 habitat elements and the 8 critical biological activities and processes that they *directly* affect across all BLRA life stages.

Table 3.—Habitat elements directly affecting critical biological activities and processes
(Xs indicate that the habitat element is applicable to that critical biological activity or process.)

Critical biological activity or process ➔ / **Habitat element 🡻**	**Chemical stress**	**Disease**	**Eating**	**Foraging**	**Molt**	**Nest attendance**	**Nest site selection**	**Predation**
Anthropogenic disturbance				X		X	X	
Brood size				X		X		
Food availability				X		X	X	
Genetic diversity and infectious agents		X						
Invertebrate community composition				X				
Local hydrology							X	X
Matrix community	X			X			X	
Parental nest attendance			X					X
Patch size				X			X	X
Plant species composition				X			X	
Predator density				X			X	X
Residual vegetation density				X			X	
Site topography							X	
Vegetation density				X			X	

The diagrams and other references to habitat elements elsewhere in this document identify the habitat elements by a one-to-three-word short name. However, each short name in fact refers to a longer, complete name. For example, the habitat

element "patch size" is the short name for "the size of wetland habitat patches." The following paragraphs provide the full name for each habitat element and a detailed definition, addressing the elements in alphabetical order.

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**. This element refers to the existence and level of human disturbance within proximity of BLRA habitat. These human disturbances may be a cause for rail decline along the LCR in areas that are in proximity to development and/or areas that receive varying levels of human use. Human activities typically affect the behavior of individual birds, though chronic disturbance can impact habitat quality more significantly as well. Anthropogenic disturbance, including noise from human recreation and activity of researchers, may impact BLRA activity (Dudek 2014).

BROOD SIZE

Full name: **The number of young in the nest**. This element refers to the number of young that the parents must rear. Clutch size is related to the health of the parents, 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.

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 BLRA will encounter during the nest, juvenile, and adult stages as well as the density and spatial distribution of the food supply in proximity to the nest location. The abundance and condition of the food supply affects adult health as well as the growth and development of the young during the nest and juvenile stages. Chicks rely on their parents for nutrition for a very brief period before they begin to forage independently.

GENETIC DIVERSITY AND INFECTIOUS AGENTS

Full name: **The genetic diversity of BLRA 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. The infectious agent component of this element refers to the spectrum of viruses, bacteria, fungi, and parasites that individual BLRA are likely to encounter during each life stage.

INVERTEBRATE COMMUNITY COMPOSITION

Full name: **The composition of the aquatic and terrestrial invertebrate community**. The composition of the aquatic and terrestrial invertebrate community directly affects BLRA prey abundance and foraging activity. Though foraging behavior in BLRA is poorly understood, BLRA appear to be opportunistic foragers, known to eat a mix of terrestrial and aquatic invertebrates (Eddleman et al. 1994). BLRA are thought to shift their habitat use depending on the seasonal availability of prey (BIO-WEST, Inc. 2005).

LOCAL HYDROLOGY

Full name: **Aspects such as the depth and fluctuations of standing water or the presence of adjacent water bodies, the timing and volume of floods, depth to the water table, and soil moisture levels**. This element refers to anything that affects local water fluctuations, such as the proximity of water to the nesting habitat, elevation, irrigation practices, soil texture. The local hydrological conditions of a given patch might be the single most important determinant of BLRA habitat quality because they affect other aspects of habitat such as abundance of prey and vegetation structure. Various aspects of local hydrology are critical for nest site selection, including the depth and fluctuation rates of water levels and the timing and severity of seasonal flooding, to name a few (Eddleman et al. 1994; Flores and Eddleman 1995; Nadeau et al. 2011; Dudek 2014). Additionally, habitat created from leaking water storage and conveyance infrastructure may be critical for the survival of BLRA along the LCR (Evens et al. 1991).

MATRIX COMMUNITY

Full name: **The type of habitat surrounding the wetland habitat used by BLRA**. This element refers to the types of plant communities and land-use activities surrounding the wetland habitat patches used by BLRA. For example, adjacent agricultural landscapes may have elevated pesticide/herbicide loads, which may affect foraging and survival of BLRA.

PARENTAL NEST ATTENDANCE

Full name: **The ability of parents to care for young during the egg/incubation and nestling stages**. This element refers to the capacity of the parents to tend to the young. It is affected primarily by the presence of predators and food availability.

PATCH SIZE

Full name: **The size of wetland habitat patches**. This element refers to the areal extent of a given patch of wetland vegetation. Patch size may affect the number of breeding pairs that an area can support as well as the density of predators and competitors. Few studies are available that address the effect of patch size on BLRA activity directly though Flores (1991) recorded year-round home ranges between 0.11 and 1.8 hectares in Arizona. In general, home ranges increased outside of the breeding season.

PLANT SPECIES COMPOSITION

Full name: **The composition of plant species in the plant community**. This element refers to the species composition of the plant community where BLRA are active. The plant species composition preferred by nesting BLRA along the LCR appears to be dense bulrush stands and grasses (Repking and Ohmart 1977). Flores (1991) documented BLRA using microhabitats with very high stem densities of plants.

Flores and Eddleman (1995) suggest that habitat structure rather than plant species composition better explains BLRA use of habitat; however, the two are difficult to separate. Generally, high stem densities of bulrush and higher cover of residual vegetation are considered suitable habitat for BLRA (Repking and Ohmart 1977; Flores 1991). In a study of BLRA habitat use of restored habitat in the Imperial National Wildlife Refuge, Nadeau et al. (2011) found that BLRA

were more likely to be found in areas with higher densities of chairmaker's bulrush (*Schoenoplectus americanus*) and low densities of river bulrush (*Schoenoplectus robustus*). They also found a slight negative association of BLRA use and southern cattail (*Typha domingensis*).

PREDATOR DENSITY

Full name: **The abundance and distribution of predators**. 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 BLRA during all life stages. The variables of this element include the species and size of the fauna that prey on BLRA during different life stages, the density and spatial distribution of these fauna in the habitat used by BLRA, and whether predator activity may vary in relation to other factors (e.g., time of day, patch size and width, matrix community type, etc.).

RESIDUAL VEGETATION DENSITY

Full name: **The density of senescent foliage surrounding the nest**. Repking and Ohmart (1977) noted that the highest densities of BLRA were found in areas with heavy matting by fallen vegetation, indicating that BLRA may prefer sites with more residual vegetation.

SITE TOPOGRAPHY

Full name: **The topographic relief of the land surrounding the nest**. The preferred habitat of BLRA includes shallow, stable water levels; gently sloping shorelines; and appropriate dense vegetation (Repking and Ohmart 1977).

VEGETATION DENSITY

Full name: **The density of foliage surrounding the nest**. This element refers to the percent cover of vegetation in the vicinity of the BLRA nest site. The vegetation structure preferred by BLRA along the LCR appears to be dense bulrush stands and grasses (Repking and Ohmart 1977). Flores (1991) also documented BLRA using microhabitats with very high stem densities of plants. Nadeau et al. (2011) found the probability of BLRA occupancy in restored marsh habitat to be positively correlated with higher densities of chairmaker's bulrush and low densities of river bulrush. Dense vegetation around the nest may provide camouflage from nest predators.

Chapter 5 – Controlling Factors

Controlling factors consist of environmental conditions and dynamics, both natural and anthropogenic, which significantly affect the abundance, spatial and temporal distributions, and quality of critical habitat elements. They 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 seven immediate controlling factors that are within the scope of potential human manipulation. The seven controlling factors identified in this CEM do not constitute individual variables; rather, each identifies a category of variables (including human activities) that share specific features that make it useful to treat them together. Table 4 lists the seven controlling factors and the habitat elements they directly affect. Table 4 also lists the six habitat elements that are not directly affected by any controlling factor (anthropogenic disturbance, brood size, food availability, genetic diversity and infectious agents, parental nest attendance, and predator density). 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**	**Habitat restoration**	**Mechanical soil disturbance**	**Nuisance species introduction and management**	**Pesticide/herbicide application**	**Water storage-delivery system design and operation**
Anthropogenic disturbance	N/A						
Brood size	N/A						
Food availability	N/A						
Genetic diversity and infectious agents	N/A						
Invertebrate community composition					X	X	
Local hydrology			X				X
Matrix community			X				
Parental nest attendance	N/A						
Patch size	X		X				
Plant species composition	X	X	X	X	X		X
Predator density	N/A						
Residual vegetation density	X	X	X	X			
Site topography			X	X			X
Vegetation density	X	X	X	X			

FIRE MANAGEMENT

This factor addresses any fire management (whether prescribed fire or fire suppression) that may occur along the LCR that could affect BLRA or their habitat. Effects may include creation of habitat that supports or excludes BLRA, a reduction in the food supply of invertebrates, or support of species that pose threats to BLRA such as predators, competitors, or carriers of infectious agents. Although typically not a major threat in most wetland habitats, fire has the potential to be a source of mortality during the breeding season (Reclamation 2008). Fire may have positive impacts on habitat for other rail species along the LCR by removing decadent vegetation and encouraging growth of early-successional emergent vegetation, but a study looking at the effects of prescribed fire on rails along the LCR did not detect an effect on BLRA (Conway et al. 2010). An earlier study by Conway and Nadeau (2005) indicated BLRA were more abundant in burned areas. In Kansas, black rails were shown to prefer areas burned every 2 years (Kane 2011 *in* Butler et al. 2014).

Climate change is also projected to affect fire frequency along the LCR (U.S. Fish and Wildlife Service 2013).

GRAZING

This factor addresses grazing by wild, domesticated, and feral animals in marsh habitat along the LCR that could affect BLRA or their habitat. Currently, grazing is minimal in LCR MSCP marsh habitat. Since BLRA occupy habitat on the fringes of marshes, livestock grazing near marshes occupied by BLRA may impact the species (Eddleman 1989). Grazing alters the vegetation structure through loss of emergent cover via trampling and direct removal (Butler et al. 2014).

HABITAT RESTORATION

This factor addresses activities to restore wetland and riparian habitat along the LCR, including manipulation of soils, vegetation, and water to restore structure and function to the community.

MECHANICAL SOIL DISTURBANCE

This factor covers the use of mechanical means to manipulate soil, such as disking and grading. Mechanical soil disturbance associated with river management activities may impact plant species establishment and marsh formation (Reclamation 2008).

NUISANCE SPECIES INTRODUCTION AND MANAGEMENT

This factor addresses the intentional or unintentional introduction of nuisance species (animals and plants) and their control that affects BLRA survival and reproduction. Nuisance species may infect, prey on, compete with, or present alternative food resources for BLRA during one or more life stages; cause other alterations to the wetland food web that affect BLRA; or affect physical habitat features such as vegetation structure and cover. For example, feral pigs (*Sus scrofa*) have been observed in marsh habitat at Topock Gorge and Beal Lake within the Havasu National Wildlife Refuge (J. Kahl 2015, personal communication).

PESTICIDE/HERBICIDE APPLICATION

This factor addresses biocide applications that may occur on or adjacent to BLRA habitat in the LCR region. Effects may include pollution of runoff into wetland habitats that are toxic to prey of BLRA and a reduced invertebrate food supply.

WATER STORAGE-DELIVERY SYSTEM DESIGN AND OPERATION

The LCR consists of a chain of reservoirs separated by flowing reaches. 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 amount of water released or stored affects water levels and therefore distance to water, soil moisture, and other hydrological conditions. The dynamic nature of a free-flowing river creates a mosaic of riparian and wetland habitats, and thus, a natural flow regime may be beneficial to some of the marsh species along the LCR such as the Yuma clapper rail (Reclamation 2008). However, BLRA are much more sensitive to fluctuations in

water levels and, therefore, may be negatively impacted by sudden and extreme changes in hydrology in the marsh habitat they occupy (Eddleman et al. 1994; BIO-WEST, Inc. 2005; Nadeau et al. 2011).

Additionally, leaky canals used for water delivery and agricultural irrigation runoff create seepage marshes – microhabitats that are preferred by BLRA (Evens et al. 1991). Repair of leaking infrastructure and lining of canals may negatively impact this seepage marsh habitat.

Chapter 6 – Conceptual Ecological Model by Life Stage

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

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

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

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

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

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

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

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

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

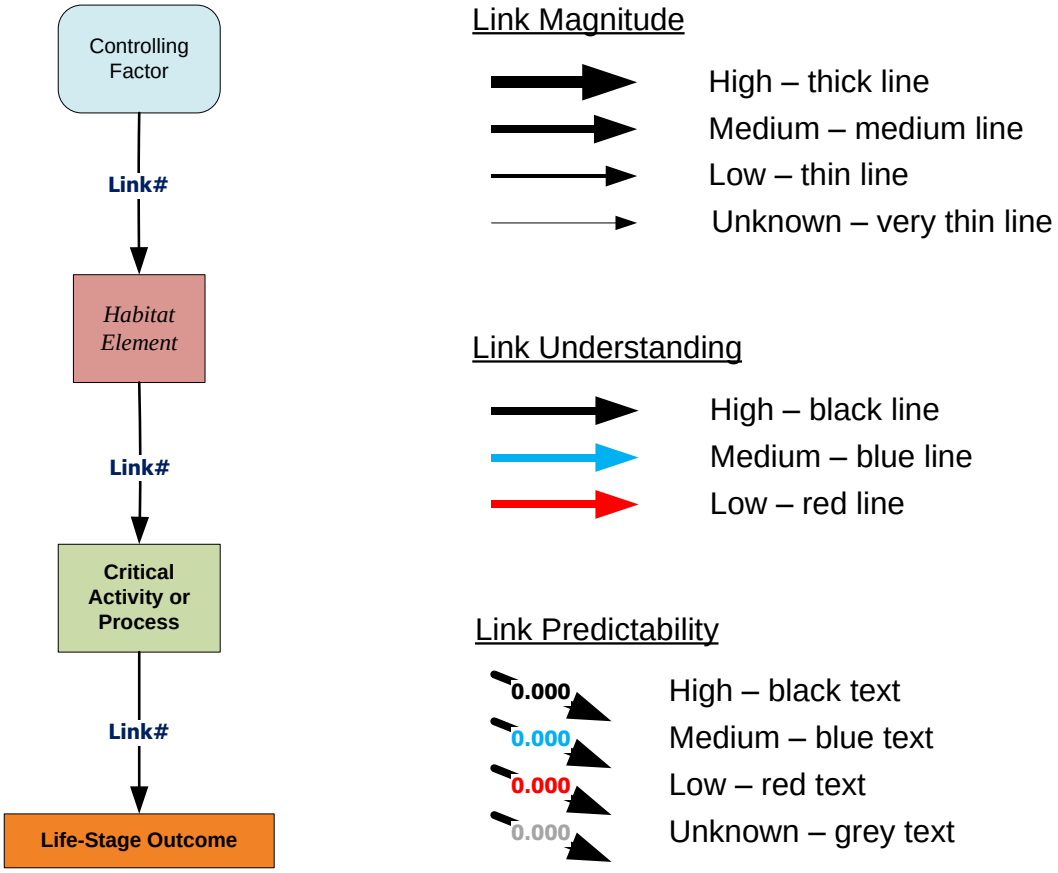


Figure 2.—Diagram conventions for LCR MSCP conceptual ecological models.

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

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

BLRA LIFE STAGE 1 – NEST

We consider the nest stage to be the first stage in the life cycle of the BLRA. It begins when the egg is hatched and ends when the chick has become independent from the mother. Success during this life stage – successful transition to the next stage – involves egg survival and chick survival and maturation.

The CEM (figures 3 and 4) recognizes six (of eight) critical biological activities and processes for this life stage, ordered as they appear on the following figures.

1. **Chemical Stress** – Chicks may suffer deformity or mortality by direct exposure to chemicals such as selenium, mercury, and pesticides/ herbicides if nests are located within an area of high concentrations of these chemicals, such as within an agricultural matrix or other areas with high chemical sediment concentrations (Rusk 1991; Tsao et al. 2009).

   The CEM identifies the matrix community surrounding a nest site as a secondary habitat element affecting chemical stress.

2. **Disease** – Although the literature does not emphasize disease as affecting population levels of BLRA, we believe disease bears mentioning. Little information is available on disease prevalence in black rails in general, though it is likely that black rails, like most birds, are subject to infectious disease and to parasitism by invertebrates such as mites (Acari) and protozoans (Eddleman et al. 1994).

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

3. **Eating** – The chick must eat in order to maintain metabolic processes.

   The CEM recognizes brood size and parental nest attendance as secondary habitat elements affecting eating.

4. **Foraging** – The chick learns to forage very soon after hatching and must learn to effectively feed itself in order to maintain metabolic processes.

   The CEM recognizes anthropogenic disturbance, brood size, food availability, invertebrate community composition, the matrix community, patch size, plant species composition, predator density, residual vegetation density, and vegetation density as secondary habitat elements affecting foraging.

5. **Molt** – The chick must molt into juvenile plumage.

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

6. **Predation** – Predation may affect the survival of eggs and chicks. There is no information for the LCR on the survival rates for chicks, which are subject to a variety of potential avian and mammalian predators (Eddleman et al. 1994).

   The CEM recognizes parental nest attendance, patch size, and predator density as secondary habitat elements affecting predation.

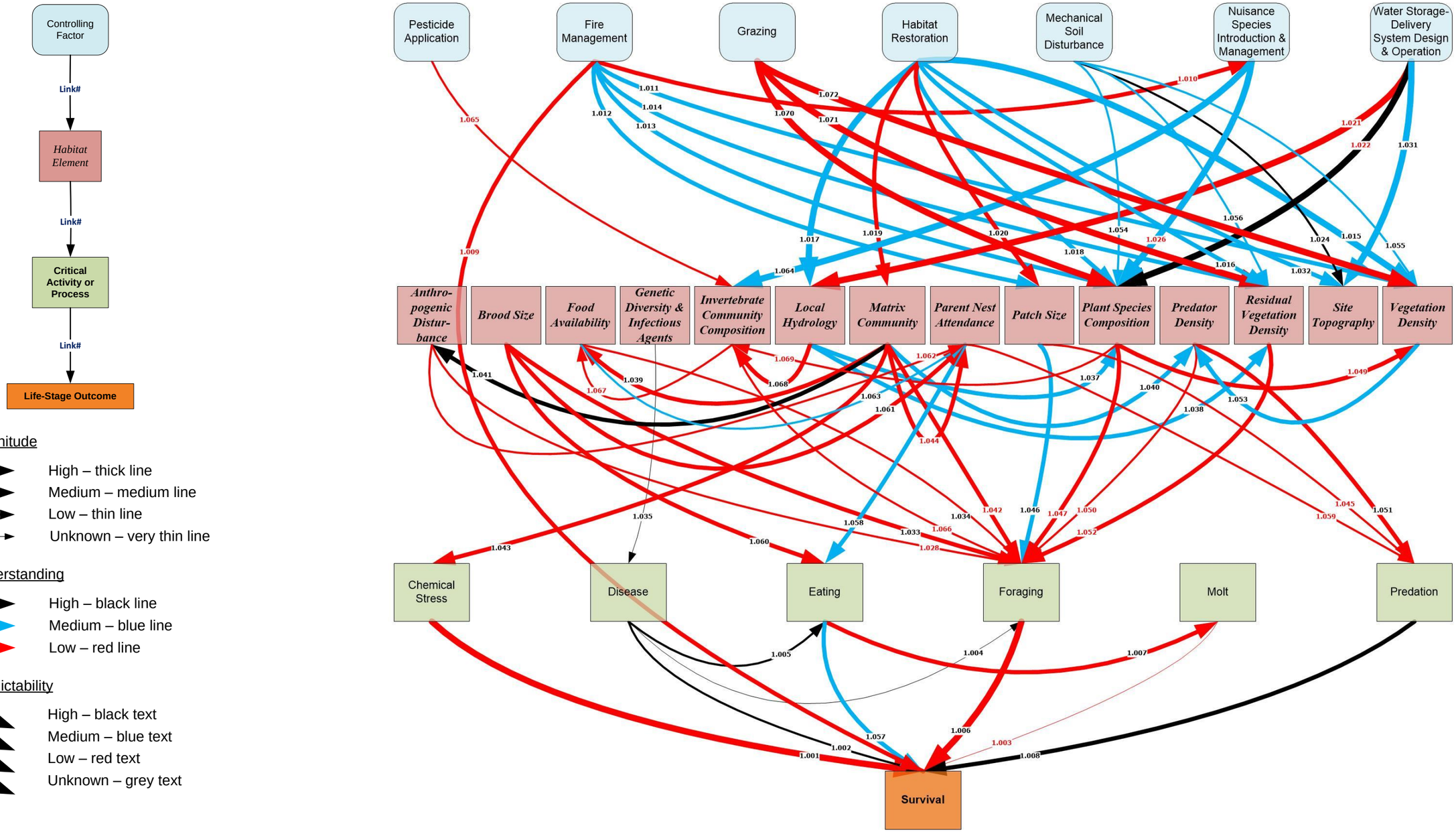
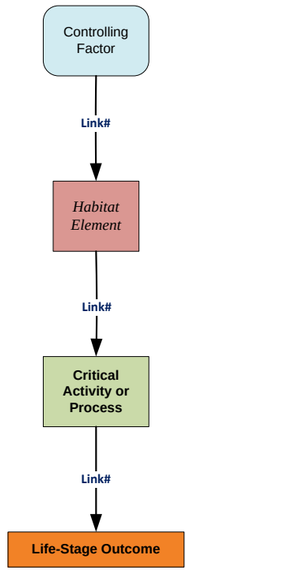


Figure 3.—BLRA life stage 1 – nest, basic CEM diagram.



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

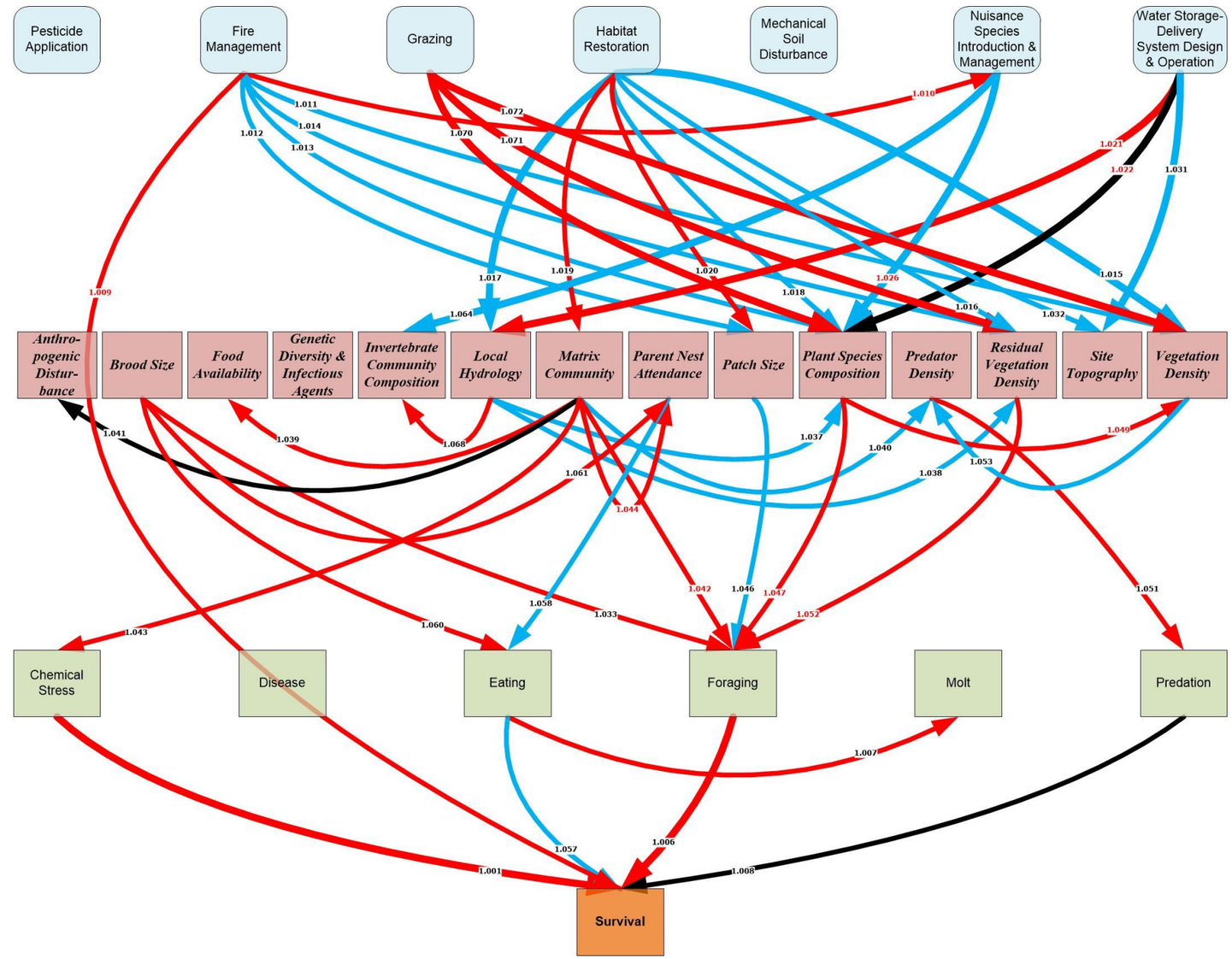


Figure 4.—BLRA life stage 1 – nest, high- and medium-magnitude relationships.

BLRA LIFE STAGE 2 – JUVENILE

The juvenile life stage begins when the chick has become independent from the parents and ends when the individual reaches sexual maturity. Success during this life stage – successful transition to the next stage – involves organism survival and maturation.

The CEM (figures 5 and 6) recognizes five (of eight) critical biological activities and processes for this life stage, ordered as they appear on the following figures.

1. **Chemical Stress** – Juvenile BLRA may suffer mortality by direct exposure to chemicals such as selenium, mercury and pesticides/herbicides if active within an area of high concentrations of these chemicals, such as within an agricultural matrix. Environmental contaminants such as selenium and mercury may have negative impacts on BLRA populations due to the bioaccumulation of these chemicals (Tsao et al. 2009). No information is available regarding impacts of chemical contamination on BLRA along the LCR; however, other species, including the Yuma clapper rail, are known to have elevated levels of selenium in their feathers and tissues (Eddleman 1989). Rusk (1991) measured selenium concentrations in sediment, invertebrates, and two marsh bird species (though not BLRA) along the LCR and concluded that adults (and presumably juveniles) were at low risk for mortality but moderate to high risk of teratogenicity.

   The CEM identifies the matrix community surrounding a nest site as a secondary habitat element affecting chemical stress.

2. **Disease** – Although the literature does not emphasize disease as affecting population levels of BLRA, we believe disease bears mentioning. Little information is available on disease prevalence in black rails in general, though it is likely that black rails, like most birds, are subject to infectious disease and to parasitism by invertebrates such as mites and protozoans (Eddleman et al. 1994).

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

3. **Foraging** – The juvenile BLRA must forage effectively to feed itself and maintain metabolic processes.

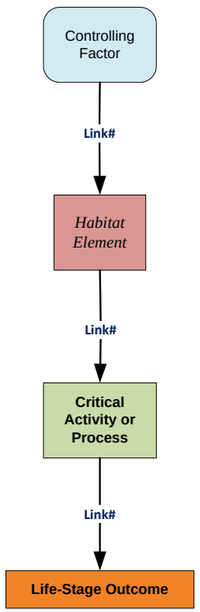
   The CEM recognizes anthropogenic disturbance, brood size, food availability, invertebrate community composition, the matrix community, patch size, plant species composition, predator density, residual vegetation density, and vegetation density as secondary habitat elements affecting foraging.

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

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

5. **Predation** – Predation may affect the survival of juvenile BLRA. There is no information for the LCR on the survival rates for juveniles, which are subject to a variety of potential avian and mammalian predators (Eddleman et al. 1994).

   The CEM recognizes local hydrology, patch size, and predator density as secondary habitat elements affecting predation.



Link Magnitude

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- 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 (0.000)
- Medium – blue text (0.000)
- Low – red text (0.000)
- Unknown – grey text (0.000)

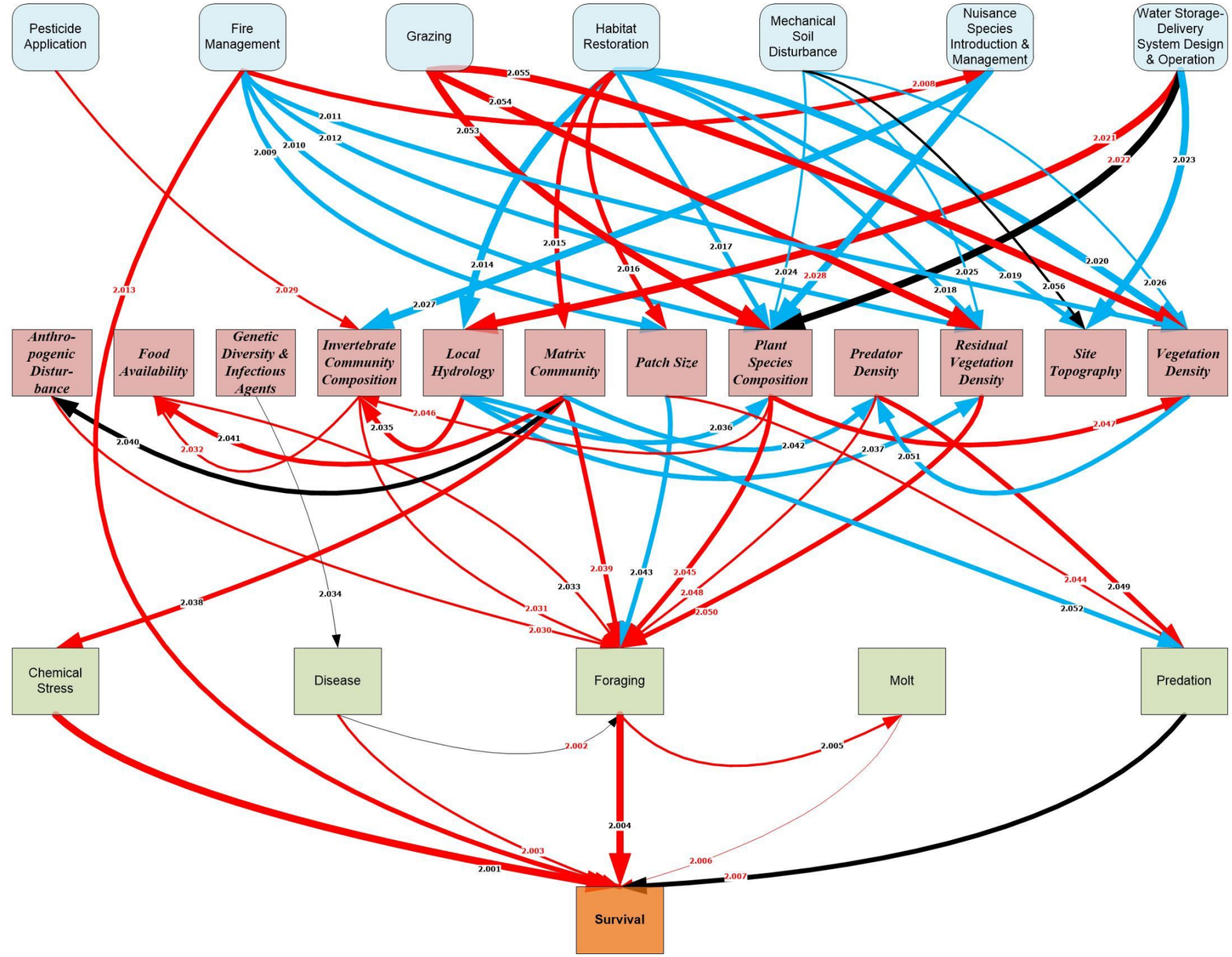


Figure 5.—BLRA life stage 2 –juvenile, basic CEM diagram.

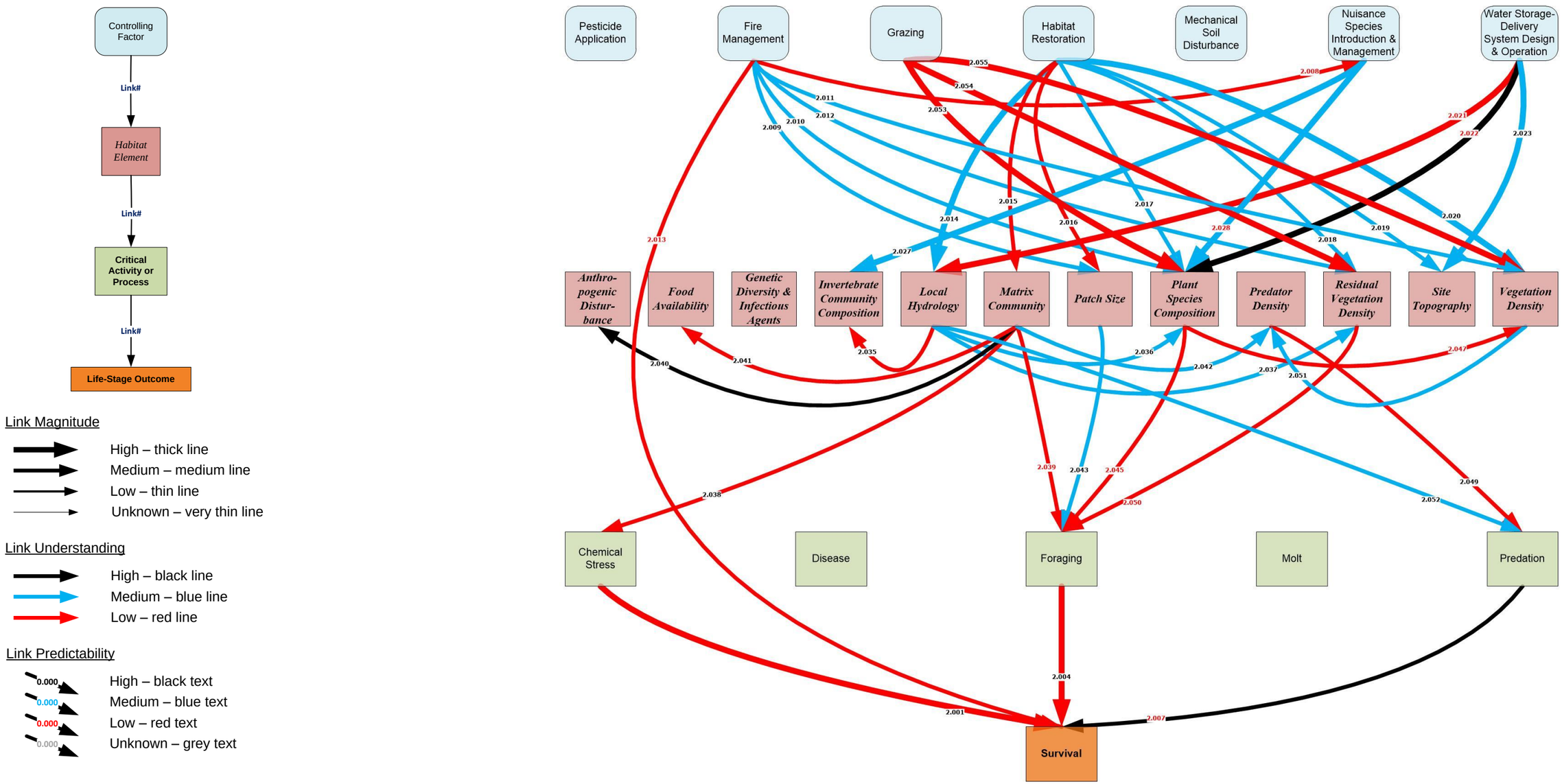


Figure 6.—BLRA life stage 2 –juvenile, high- and medium-magnitude relationships.

BLRA LIFE STAGE 3 – BREEDING ADULT

The breeding adult life stage begins when the rail reaches sexual maturity and ends when the rail stops reproducing. Success during this life stage involves organism survival and breeding.

The CEM (figures 7 and 8) recognizes seven (of eight) critical biological activities and processes for this life stage, ordered as they appear on the following figures.

1. **Chemical Stress** – Adults may suffer mortality by direct exposure to chemicals such as selenium, mercury, and pesticides/herbicides if occupied habitat is located within an area of high concentrations of these chemicals, such as within an agricultural matrix.

   The CEM identifies the matrix community surrounding a nest site as a secondary habitat element affecting chemical stress.

2. **Disease** – Although the literature does not emphasize disease as affecting population levels of BLRA, we believe disease bears mentioning. Little information is available on disease prevalence in black rails in general, though it is likely that black rails, like most birds, are subject to infectious disease and to parasitism by invertebrates such as mites and protozoans (Eddleman et al. 1994).

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

3. **Foraging** – The adult BLRA must forage effectively to feed itself and its young.

   The CEM recognizes anthropogenic disturbance, brood size, food availability, invertebrate community composition, the matrix community, patch size, plant species composition, predator density, residual vegetation density, and vegetation density as secondary habitat elements affecting foraging.

4. **Molt** – The adult rail molts after breeding each season.

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

5. **Nest Attendance** – The breeding adult must attend to the nest to protect and feed the young.

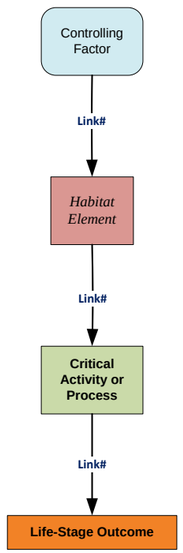
   The CEM recognizes anthropogenic disturbance, brood size, and food availability as secondary habitat elements affecting nest attendance.

6. **Nest Site Selection** – This process involves nest site selection by breeding males and females and is important for reproductive success.

   The CEM recognizes anthropogenic disturbance, food availability, local hydrology, matrix community, patch size, plant species composition, predator density, residual vegetation density, site topography, and vegetation density as secondary habitat elements affecting nest site selection.

7. **Predation** – Predation may affect the survival of adult BLRA.

   The CEM recognizes local hydrology, patch size, and predator density as secondary habitat elements affecting predation.



Link Magnitude

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

Link Understanding

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

Link Predictability

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

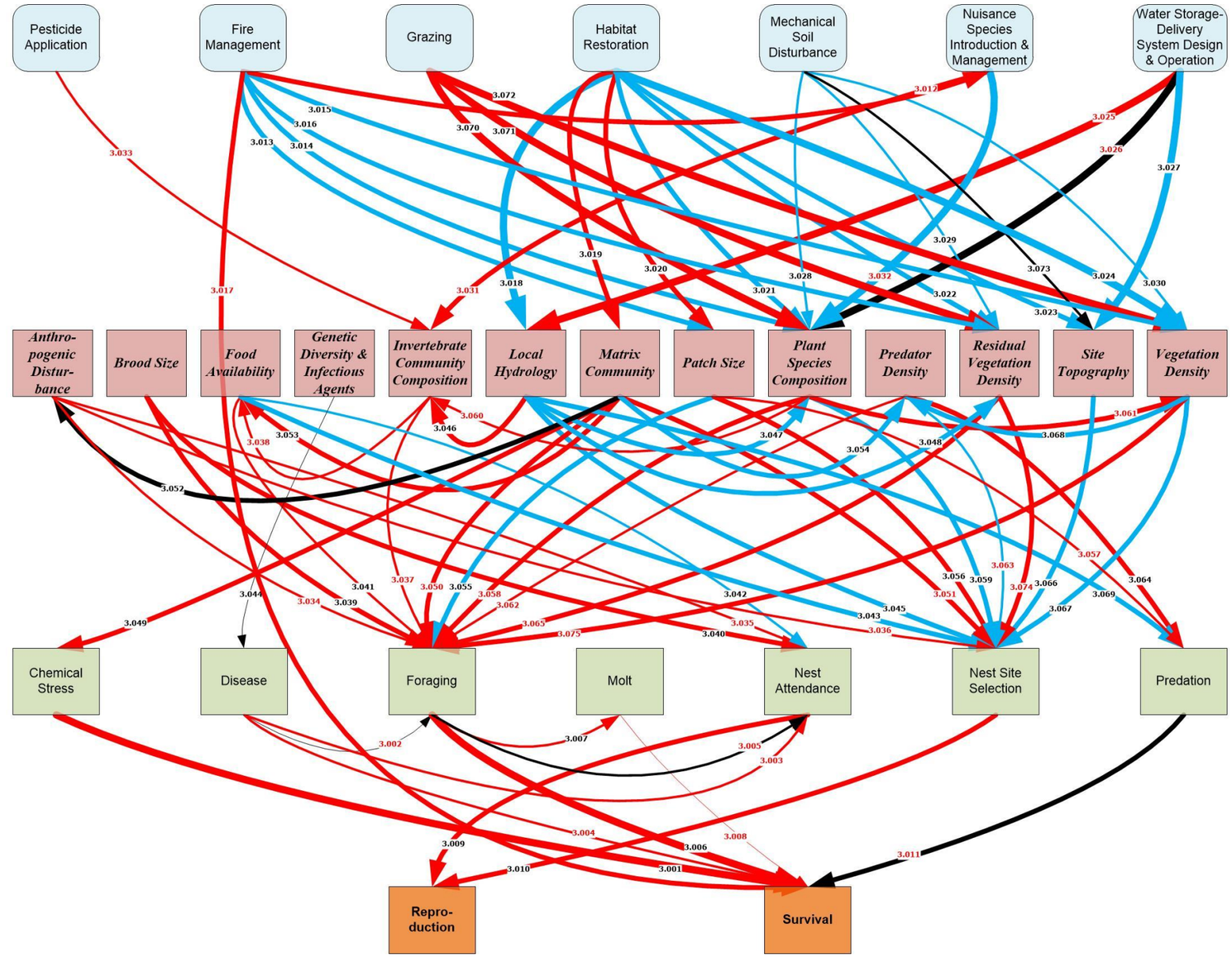

Figure 7.—BLRA life stage 3 – breeding adult, basic CEM diagram.

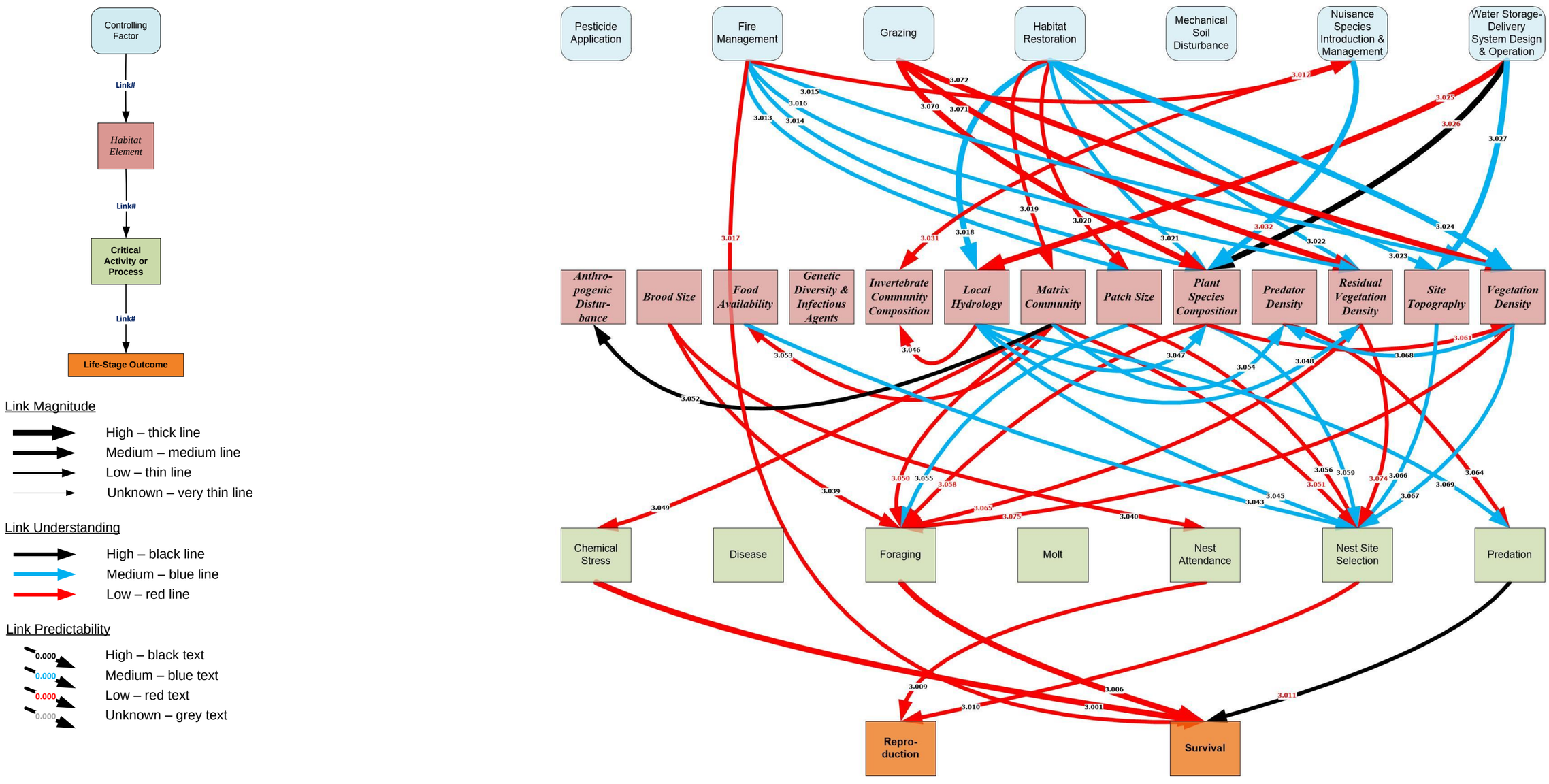

Figure 8.—BLRA life stage 3 – breeding adult, high- and medium-magnitude relationships.

Chapter 7 – Causal Relationships Across All Life Stages

The seven controlling factors discussed in chapter 5 have the same influence on the same habitat elements for all life stages for which those habitat elements matter. Table 5 shows the magnitudes of *direct* influence of the seven controlling factors on 8 of the 14 habitat elements. The structure of table 5 is the same as for table 4, but table 5 shows the magnitudes of the relationships instead of just their presence/absence. The paragraphs following the table discuss the relative effects of the different controlling factors on each habitat element.

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

Controlling factor ➔ / **Habitat element 🡻**	**Fire management**	**Grazing**	**Habitat restoration**	**Mechanical soil disturbance**	**Nuisance species introduction and management**	**Pesticide/herbicide application**	**Water storage-delivery system design and operation**
Anthropogenic disturbance	N/A*						
Brood size	N/A*						
Food availability	N/A*						
Genetic diversity and infectious agents	N/A*						
Invertebrate community composition					**High**	**Low**	
Local hydrology			**High**				**High**
Matrix community			**Med**				
Parental nest attendance	N/A*						
Patch size	**Med**		**Med**				
Plant species composition	**Med**	**High**	**Med**	**High**	**Low**		**High**
Predator density	N/A*						
Residual vegetation density	**Med**	**High**	**Med**	**Low**			
Site topography			**Med**	**High**			**Low**
Vegetation density	**Med**	**High**	**High**	**Low**			

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

INVERTEBRATE COMMUNITY COMPOSITION

The controlling factors that affect the composition of the aquatic and terrestrial invertebrate community include nuisance species introduction and management and pesticide/herbicide application.

Nuisance species can change the structure of entire communities in ways that negatively impact listed species (Lodge et al. 2006). BLRA appear to be opportunistic foragers but are known to eat a mix of terrestrial and aquatic invertebrates (Eddleman et al. 1994). It is not known how the introduction of many exotic species will affect the natural community; however, exotic species may exclude native species or alter habitat conditions sufficiently to negatively impact BLRA prey.

The management of nuisance species using pesticides/herbicides and the runoff from areas where they are applied may impact the composition of aquatic and terrestrial invertebrates in the foraging areas of BLRA.

LOCAL HYDROLOGY

The primary controlling factors affecting local hydrology are habitat restoration and water storage-delivery system design and operation.

Habitat restoration for the BLRA is driven primarily by alterations to the hydrology of marsh habitat to improve conditions for the species. Various aspects of local hydrology are critical for nest site selection and foraging of BLRA, including depth and fluctuation rates of water levels, the timing and severity of seasonal flooding, and the amount of open water areas, to name a few (Eddleman et al. 1994; Nadeau et al. 2011; Dudek 2014).

The complexity of water management opportunities and constraints involved with alterations to water storage-delivery system design and operation are great. While the ideal of a free-flowing river creating a mosaic of riparian and wetland habitats, and thus, a natural flow regime to benefit the BLRA appears optimal on the surface, in some ways, current water management on the LCR has created more suitable BLRA habitat than would have existed historically. Large and small dams and diversions also create hydrologic conditions that help establish new marsh habitat (Dudek 2014). Unfortunately, a lack of scouring natural flows in the LCR leads to decadent vegetation that degrades habitat values for various marsh species, including BLRA (Conway et al. 2010). Alternate management prescriptions such as fire management or mechanical soil disturbance are needed to reduce the decadent vegetative residue present in many of the marsh sites inhabited by BLRA.

BLRA are much more sensitive to fluctuations in water levels than other marsh birds along the LCR and, therefore, may be negatively impacted by sudden and extreme changes in hydrology in the marsh habitat they occupy (Eddleman et al. 1994, BIO-WEST, Inc. 2005). Nadeau et al. (2011) suggest that restored habitat utilize automated irrigation procedures to stabilize water depths and reduce the time and money needed to maintain water delivery.

Leaky canals used for water delivery and agricultural irrigation runoff create seepage marshes – microhabitats that are preferred by BLRA (Evens et al. 1991). Repair of leaking infrastructure and lining of canals may negatively impact this seepage marsh habitat.

MATRIX COMMUNITY

The controlling factor that affects the matrix community is habitat restoration, which may change the matrix community if type conversion occurs (e.g., from farmed fields to riparian forest or marsh habitat).

PATCH SIZE

The controlling factors that directly affect patch size include fire management and habitat restoration.

Fire affects many aspects of vegetation structure and composition, and severe fire may reduce overall patch size (Busch 1995).

Habitat restoration would increase overall patch size.

PLANT SPECIES COMPOSITION

The controlling factors that directly affect plant species composition include fire management, grazing, habitat restoration, mechanical soil disturbance, nuisance species introduction and management, and water storage-delivery system design and operation.

Fire affects many aspects of vegetation structure and composition. Little evidence exists that burning was extensive in marsh environments historically in the Southwest. Native wetland vegetation is not well adapted to fire, so lightning and human-induced fires can severely alter riparian species composition and, thus, BLRA habitat (Busch 1995). Some evidence exists that fire in riparian habitats can increase the cover of some nuisance species like tamarisk (Di Tomaso 1998).

Fire is an effective means of removing residual vegetative growth from marsh habitat, thus improving foraging habitat for some marsh birds, but a study looking at the effects of prescribed fire on rails along the LCR did not detect an effect on BLRA (Conway et al. 2010). An earlier study by Conway and Nadeau (2005) indicated BLRA were more abundant in burned areas. In Kansas, black rails were shown to prefer areas burned every 2 years (Kane 2011 *in* Butler et al. 2014).

Currently, grazing is minimal in LCR MSCP marsh habitat. Since BLRA occupy habitat on the fringes of marshes, livestock grazing near marshes occupied by BLRA may impact the species (Richmond et al. 2012). Grazing alters vegetation structure and species composition through the loss of emergent cover via trampling and direct removal (Butler et al. 2014).

Habitat restoration must consider both plant species composition as well as density to provide suitable habitat for BLRA. Nadeau et al. (2011) found that BLRA prefer higher densities of chairmaker's bulrush, low densities of river bulrush, and had a slight negative association of use with southern cattail.

Mechanical soil disturbance, such as disking or grading, is another way to remove decadent vegetation in marsh habitat; however, it may have negative side effects, including the reduction of crayfish abundance in the marsh (Eddleman 1989), and it is only an option when water can be drained from the marsh to initiate the activity.

Nuisance species such as feral pigs occur within the LCR MSCP area and may negatively impact plant community composition in marsh habitat where they forage and wallow (J. Kahl 2015, personal communication). Tamarisk (*Tamarix ramosissima*) is a common invader of marshes and riparian areas along the LCR. Conway and Sulzman (2007) found BLRA use areas with tamarisk as long the density of the plant was lower than 67 percent. BLRA appeared to avoid areas with higher densities. The authors caution that habitat suitability for BLRA may decline if tamarisk is not controlled to maintain a low level of cover.

The complexity of water management opportunities and constraints involved with alterations to water storage-delivery system design and operation are great. While the ideal of a free-flowing river creating a mosaic of riparian and wetland habitats, and thus, a natural flow regime to benefit the BLRA appears optimal on the surface, in some ways, current water management on the LCR has created more suitable BLRA habitat than would have existed historically. Large and small dams and diversions also create hydrologic conditions that help establish new marsh habitat (Dudek 2014). Unfortunately, a lack of scouring natural flows in the LCR leads to decadent vegetation that degrades habitat values for various marsh species, including BLRA (Conway et al. 2010). Alternate management prescriptions such as fire management or mechanical soil disturbance are needed to reduce the decadent vegetative residue present in many of the marsh sites inhabited by BLRA.

BLRA are much more sensitive to fluctuations in water levels than other marsh birds along the LCR and, therefore, may be negatively impacted by sudden and extreme changes in hydrology in the marsh habitat they occupy (Eddleman et al. 1994, BIO-WEST, Inc. 2005). Nadeau et al. (2011) suggest that restored habitat utilize automated irrigation procedures to stabilize water depths and reduce the time and money needed to maintain water delivery.

Leaky canals used for water delivery and agricultural irrigation runoff create seepage marshes – microhabitats that are preferred by BLRA (Evens et al. 1991). Repair of leaking infrastructure and lining of canals may negatively impact this seepage marsh habitat.

RESIDUAL VEGETATION DENSITY

The controlling factors that affect the amount of residual vegetation in a marsh site include fire management, grazing, habitat restoration, and mechanical soil disturbance. Repking and Ohmart (1977) noted that the highest densities of BLRA were found in areas with heavy matting by fallen vegetation, indicating that BLRA may prefer sites with more residual vegetation.

Fire affects many aspects of vegetation structure and composition. Little evidence exists that burning was extensive in marsh environments historically in the Southwest. Native wetland vegetation is not well adapted to fire, so lightning and human-induced fires can severely alter riparian species composition and, thus, BLRA habitat (Busch 1995). Some evidence exists that fire in riparian habitats can increase the cover of some nuisance species like tamarisk (Di Tomaso 1998). Fire is an effective means of removing residual vegetative growth from marsh habitat, thus improving foraging habitat for some marsh birds, but a study looking at the effects of prescribed fire on rails along the LCR did not detect an effect on BLRA (Conway et al. 2010). An earlier study by Conway and Nadeau (2005) indicated BLRA were more abundant in burned areas. In Kansas, black rails were shown to prefer areas burned every 2 years (Kane 2011 *in* Butler et al. 2014).

As mentioned above, grazing is minimal in LCR MSCP marsh habitat. Since BLRA occupy habitat on the fringes of marshes, livestock grazing near marshes occupied by BLRA may impact the species (Richmond et al. 2012). Grazing alters vegetation structure and reduces residual vegetation through loss of emergent cover via trampling and direct removal (Butler et al. 2014).

Habitat restoration efforts must take into consideration both plant species composition as well as density to provide suitable habitat for BLRA. Nadeau et al. (2011) found that BLRA prefer higher densities of chairmaker's bulrush, low densities of river bulrush, and had a slight negative association of use with southern cattail.

Mechanical soil disturbance, such as disking or grading, is another way to remove decadent vegetation in marsh habitat; however, it may have negative side effects, including the reduction of crayfish abundance in the marsh (Eddleman 1989), and it is only an option when water can be drained from the marsh to initiate the activity.

SITE TOPOGRAPHY

The controlling factors that affect site topography include habitat restoration, mechanical soil disturbance, and water storage-delivery system design and operation.

Habitat restoration efforts aiming to improve hydrologic conditions that favor BLRA could include the addition or removal of dams and diversions possibly in conjunction with alterations in water movement within the main stem. Careful consideration needs to be given to the design of restored habitat to ensure the water depths are appropriate for BLRA (Nadeau et al. 2011).

Mechanical soil disturbance, such as disking or grading, is another way to remove decadent vegetation in marsh habitat; however, it may have negative side effects, including the reduction of crayfish abundance in the marsh (Eddleman 1989), and it is only an option when water can be drained from the marsh to initiate the activity.

The complexity of water management opportunities and constraints involved with alterations to water storage-delivery system design and operation are great. While the ideal of a free-flowing river creating a mosaic of riparian and wetland habitats, and thus, a natural flow regime to benefit the BLRA appears optimal on the surface, in some ways, current water management on the LCR has created more suitable BLRA habitat than would have existed historically. Large and small dams and diversions also create hydrologic conditions that help establish new marsh habitat (Dudek 2014). Unfortunately, a lack of scouring natural flows in the LCR leads to decadent vegetation that degrades habitat values for various marsh species, including BLRA (Conway et al. 2010). Alternate management prescriptions such as fire management or mechanical soil disturbance are needed to reduce the decadent vegetative residue present in many of the marsh sites inhabited by BLRA.

BLRA are much more sensitive to fluctuations in water levels than other marsh birds along the LCR and, therefore, may be negatively impacted by sudden and extreme changes in hydrology in the marsh habitat they occupy (Eddleman et al. 1994, BIO-WEST, Inc. 2005). Nadeau et al. (2011) suggest that restored habitat utilize automated irrigation procedures to stabilize water depths and reduce the time and money needed to maintain water delivery.

Leaky canals used for water delivery and agricultural irrigation runoff create seepage marshes – microhabitats that are preferred by BLRA (Evens et al. 1991). Repair of leaking infrastructure and lining of canals may negatively impact this seepage marsh habitat.

VEGETATION DENSITY

The controlling factors that affect the density of vegetation in a marsh site include fire management, grazing, habitat restoration, and mechanical soil disturbance.

Fire affects many aspects of vegetation structure and composition. Little evidence exists that burning was extensive in marsh environments historically in the Southwest. Native wetland vegetation is not well adapted to fire, so lightning and human-induced fires can severely alter riparian species composition and, thus, BLRA habitat (Busch 1995). Some evidence exists that fire in riparian habitats can increase the cover of some nuisance species like tamarisk (Di Tomaso 1998). Fire is an effective means of removing residual vegetative growth from marsh habitat, thus improving foraging habitat for some marsh birds, but a study looking at the effects of prescribed fire on rails along the LCR did not detect an effect on BLRA (Conway et al. 2010). An earlier study by Conway and Nadeau (2005) indicated BLRA were more abundant in burned areas. In Kansas, black rails were shown to prefer areas burned every 2 years (Kane 2011 *in* Butler et al. 2014).

Currently, grazing is minimal in LCR MSCP marsh habitat. Since BLRA occupy habitat on the fringes of marshes, livestock grazing near marshes occupied by BLRA may impact the species (Richmond et al. 2012). Grazing alters vegetation structure and species composition through loss of emergent cover via trampling and direct removal (Butler et al. 2014).

Habitat restoration that balances a mosaic of senescent and actively growing vegetative cover in marsh habitat will likely improve conditions for BLRA (Eddleman et al. 1994). Special consideration should be given to species selection in restoration efforts to maximize favorable habitat for BLRA (Nadeau et al. 2011).

Mechanical soil disturbance, such as disking or grading, is another way to remove decadent vegetation in marsh habitat; however, it may have negative side effects, including the reduction of crayfish abundance in the marsh (Eddleman 1989), and it is only an option when water can be drained from the marsh to initiate the activity.

Chapter 8 – Discussion and Conclusions

This chapter summarizes the findings of the assessment by posing three questions: (1) which critical biological activities and processes most strongly affect the individual life states 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 the least understood in ways that could affect their management?

MOST INFLUENTIAL ACTIVITIES AND PROCESSES ACROSS ALL LIFE STAGE

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

- Foraging, chemical stress, and predation are the most important critical biological activities and processes affecting survival of BLRA in all life stages. Other processes, such as disease and molt, 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 BLRA at all life stages. For example, good nest sites may be in close proximity to more food, have fewer predators, and may have fewer diseases present.

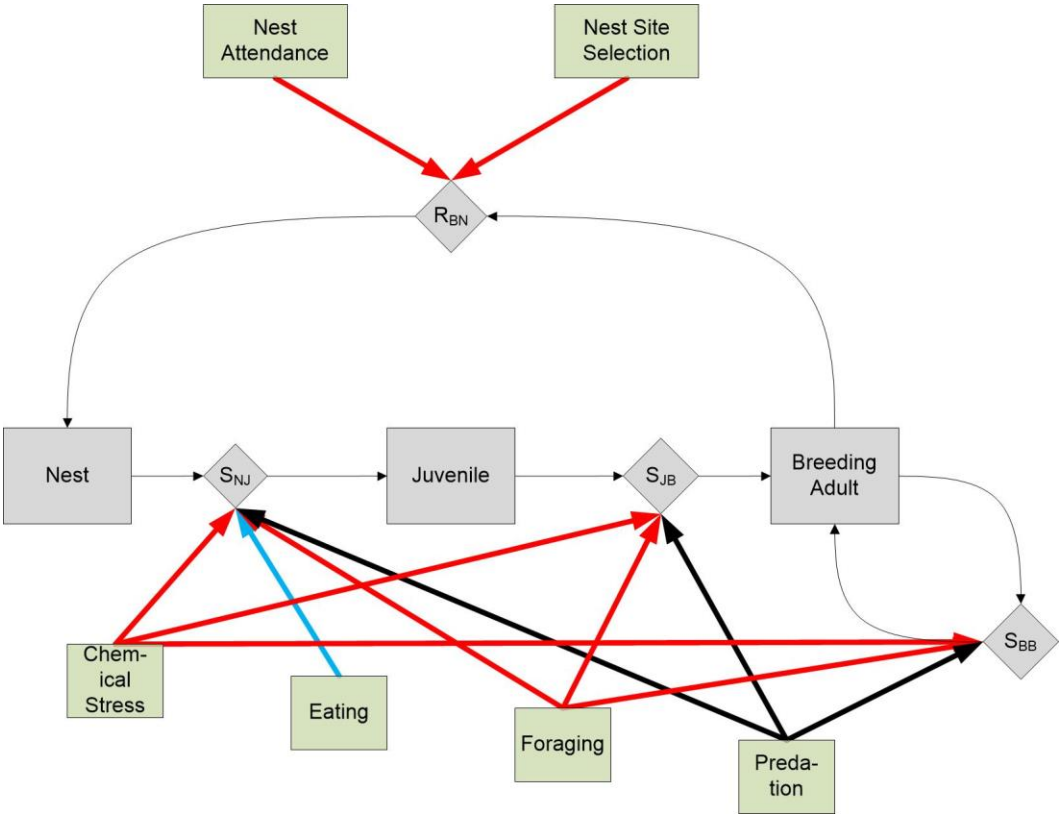

Figure 9.—Most influential biological activities and processes affecting each life stage of BLRA. Only elements with high- or medium-magnitude connections are presented. The legend is provided on figure 2.

POTENTIALLY PIVOTAL ALTERATIONS TO HABITAT ELEMENTS

Figure 10 identifies the habitat elements that the assessment indicates most strongly 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:

- Habitat restoration and water storage-delivery system design and operation can have significant, lasting impacts on local hydrology, which may benefit or harm BLRA survival and reproduction.

- Repair of leaking infrastructure and lining of canals may reduce available seepage marsh habitat where BLRA are currently found.

- While nuisance species such as tamarisk may have negative impacts on habitat values, BLRA have been found utilizing habitat with a moderate density of this species, so consideration of how control activities might impact BLRA should be included in management planning.

- Fire management, mechanical soil disturbance, or some other strategy for managing vegetation in areas where scouring flows are not feasible to encourage growth of preferred vegetation such as bulrush may be necessary to manage excess residual vegetation if it becomes too dense and is negatively impacting BLRA use of marsh habitat.

- Since juvenile BLRA appear to disperse into disparate areas on the fringes of marsh land habitat, surveys for BLRA and protection of larger patches of potential habitat is warranted.

- Maintaining appropriate hydrologic conditions for BLRA habitat is critical; therefore, management of water levels and soil moisture levels in known nesting areas needs to be carefully considered in habitat management planning.

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 and its protected areas. The figures highlight that the level of understanding of how the various controlling factors impact the habitat elements is fairly well understood. However, the large numbers of red arrows for relationships between habitat elements and biological activities and processes indicate that these relationships have a low level of scientific understanding. Each of these red arrows identifies a causal relationship that may warrant further field, laboratory, or literature investigation. The following paragraphs highlight some potentially important areas of low understanding; however, these are not meant to represent a list of required or even feasible areas for research. Decisions about which research issues to pursue will be determined by LCR MSCP staff based on a variety of factors.

California black rail (*Laterallus jamaicensis coturniculus*) (BLRA)
Basic Conceptual Ecological Model

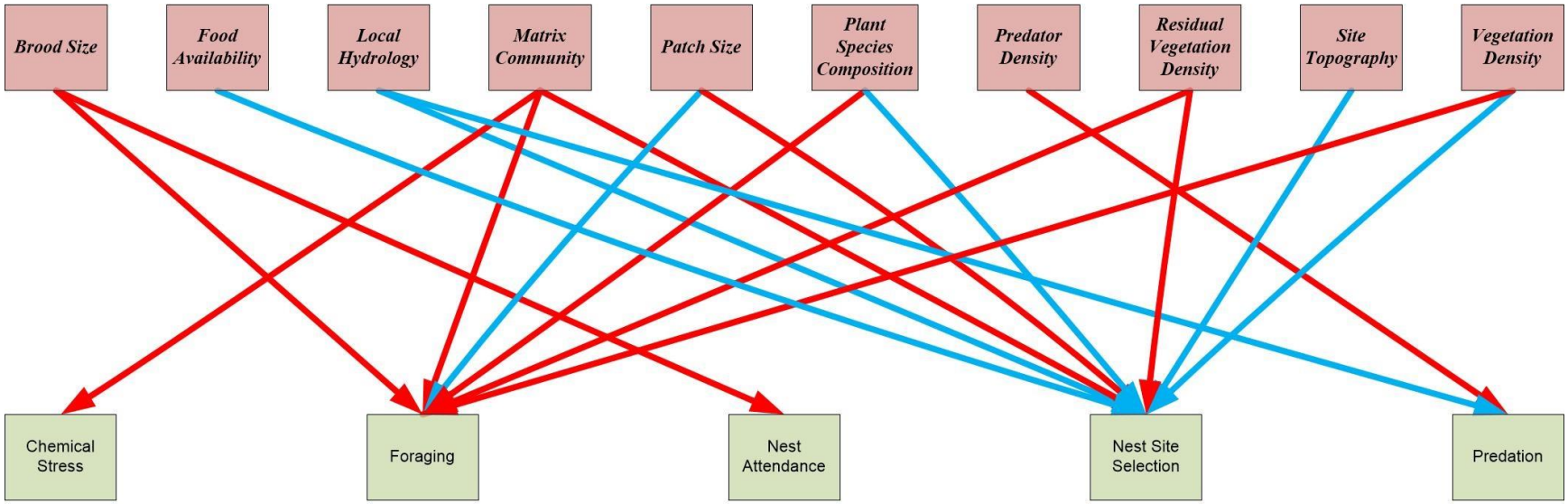

Figure 10.—Habitat elements that directly affect the most influential biological activities and processes across all life stages of BLRA. Only elements with high- or medium-magnitude connections within this life stage are presented. The legend is provided on figure 2.

Specifically, the findings suggest a need to improve the understanding of:

- The ecology of predation on BLRA and its significance on survival across all life stages, how this may vary among predator species and across different habitat settings, and whether it may be possible to manipulate these habitat conditions to improve BLRA survival even in the presence of predators.

- The presence of disease in the BLRA population and its significance in affecting survival across all life stages within the LCR.

- The impacts of chemical stressors such as selenium, mercury, and pesticides/herbicides within the LCR and its impact on survival of BLRA across all life stages.

- BLRA movement patterns within the LCR, including the movement of juveniles into habitat associated with the fringes of marshes.

- Appropriate management to improve habitat conditions, including vegetation structure and species composition as well as appropriate hydrologic conditions for both Yuma clapper rails and BLRA where they co-occur.

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

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ATTACHMENT 1

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

OVERVIEW OF METHODOLOGY

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(1) The effect of one controlling factor on another

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

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

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

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

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

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

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

Conceptual Ecological Models as Hypotheses

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

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

Characterizing Causal Relationships

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

(1) The character and direction of the effect

(2) The magnitude of the effect

(3) The predictability (consistency) of the effect

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

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

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

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

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

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

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

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

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

Conceptual Ecological Model Documentation

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

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

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

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

Link Attribute Ratings, Spreadsheet Fields, and Diagram Conventions

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

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

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

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

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

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

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

Link magnitude – the overall relative magnitude of the effect of the causal node on the affected node based on the numerical average for link intensity, spatial scale, and temporal scale. (Calculated by assigning a numerical value of 3 to “High” or “Large,” 2 to “Medium,” 1 to “Low” or “Small,” and not counting missing or “Unknown” ratings.)	
High	Numerical average $\geq$ 2.67
Medium	Numerical average $\geq$ 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.

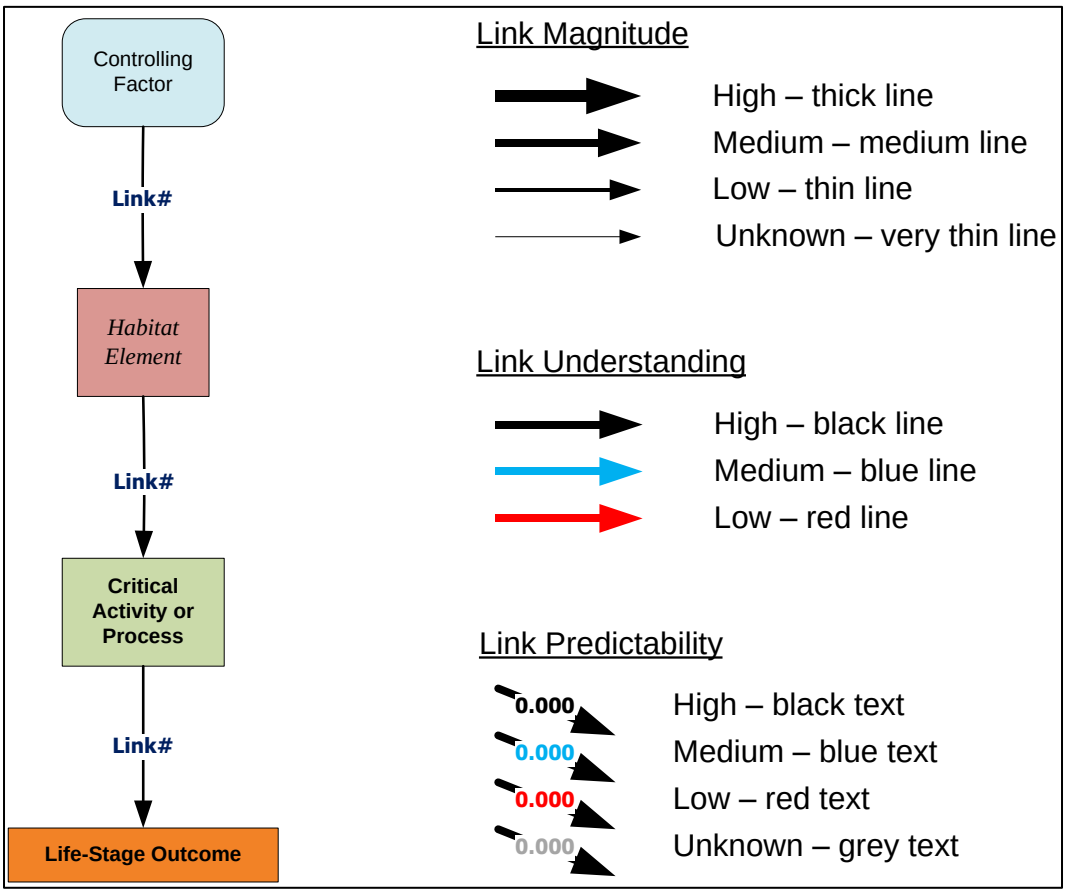

Figure 1-1.—Conventions for displaying cause and effect nodes, linkages, link magnitude, link understanding, and link predictability.

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ATTACHMENT 2

California Black Rail Habitat Data

Table 1.—California black rail (BLRA) habitat data

Habitat element	Value or range	Location	Reference
Local hydrology	Standing water < 3 centimeters (cm) deep	Lower Colorado River	Flores and Eddleman 1995; Conway and Sulzman 2007
	Standing water < 2.5 cm; < 25 percent of substrate covered in water	Lower Colorado River	Flores 1991
	Leaky canal infrastructure creates seepage marshes that are important habitat	Lower Colorado River	Evens et al. 1991
	Sensitive to sudden changes in water levels	Lower Colorado River	Eddleman et al. 1994; Flores and Eddleman 1995
Patch size	Year-round home range mean ≤ 0.43 hectare; range = 0.11 to 1.8 hectares	Lower Colorado River	Flores 1991
Plant species composition	Plants most common where BLRA detected: common threesquare (*Schoenoplectus pungens)*, arrowweed (*Pluchea sericea)*, Fremont cottonwood (*Populus fremontii)*, seepwillow (*Baccharis salicifolia*), and mixed shrubs	Lower Colorado River	Conway and Sulzman 2007
	Bulrush (*Schoenoplectus* spp.) and grasses	Lower Colorado River	Repking and Ohmart 1977
	Tolerant of tamarisk (*Tamarix* spp.) cover < 67 percent	Lower Colorado River	Conway and Sulzman 2007
Residual vegetation density	Higher BLRA densities in areas with heavy matting of fallen vegetation	Lower Colorado River	Repking and Ohmart 1977
Vegetation density	High stem densities	Lower Colorado River	Flores 1991

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