# Middle Rio Grande Endangered Species Collaborative Program

# Science & Adaptive Management Plan

*Approved by the Executive Committee*

*December 17, 2020*

**Prepared for:**

**Middle Rio Grande Endangered Species Collaborative Program**

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# FORWARD

This Science & Adaptive Management (S&AM) Plan is a living document that will be updated annually to reflect changes in our understanding of the Middle Rio Grande ecosystem, species interactions, and the management approaches used, as well as the Middle Rio Grande Endangered Species Collaborative Program's (Collaborative Program) approach to incorporating that knowledge into its recommendations. This S&AM Plan builds on past efforts to incorporate adaptive management into the Collaborative Program's operations, including the 2011 Murray et al. *Adaptive Management Plan Version 1* and the 2018 Caplan et al. *Middle Rio Grande Adaptive Management Framework: Identifying Critical Scientific Uncertainties*.

Modifications to this S&AM Plan will serve to document iterative learning within the Collaborative Program.

The Collaborative Program's Executive Committee (EC) approved this S&AM Plan at its December 17, 2021 meeting.

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| 2014 Bernalillo to Belen BO | Biological Opinion on the Effects of the U.S. Army Corps of Engineers' Mountain View, Isleta, and Belen Levee Units for Middle Rio Grande Flood Protection, Bernalillo County to Belen, New Mexico |
| 2016 MRG BO | Final Biological and Conference Opinion for Bureau of Reclamation, Bureau of Indian Affairs, and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico |
| ABCWUA | Albuquerque Bernalillo County Water Utility Authority |
| APA | Assessment Payers Association of the Middle Rio Grande Conservancy District |
| AM | adaptive management |
| BDD | Buckman Direct Diversion |
| BEMP | Bosque Ecosystem Monitoring Program |
| BO | biological opinion |
| CEM | conceptual ecological model |
| CoA | City of Albuquerque |
| EC | Executive Committee |
| ESA | Endangered Species Act |
| FPC | Fiscal Planning Committee |
| MOA | Memorandum of Agreement |
| MRG | Middle Rio Grande |
| MRGCD | Middle Rio Grande Conservancy District |
| Collaborative Program | Middle Rio Grande Endangered Species Collaborative Program |
| NMAGO | New Mexico Attorney General's Office |
| NMDGF | New Mexico Department of Game and Fish |
| NMISC | New Mexico Interstate Stream Commission |
| NMMJM | New Mexico meadow jumping mouse |
| PESU | Pecos sunflower |
| PST | Program Support Team |
| Reclamation | U.S. Bureau of Reclamation |
| RIO | River Integrated Operations |
| RIP | Recovery Implementation Program |
| RGSM | Rio Grande silvery minnow |
| S&AM Plan | Science & Adaptive Management Plan |
| S&T Ad Hoc Group | Science & Technical Ad Hoc Group |
| SAMC | Science and Adaptive Management Committee |
| SWFL | southwestern willow flycatcher |
| UNM | University of New Mexico |
| USACE | U.S. Army Corps of Engineers |
| USFWS | U.S. Fish and Wildlife Service |
| YBCU | yellow-billed cuckoo |

# 1.0 INTRODUCTION

The Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) is a partnership of federal, state, and local governmental entities, Indian Tribes and Pueblos, and non-governmental organizations that aims to protect and recover federally listed species in the riparian corridor of the Middle Rio Grande (MRG), while preserving the area's existing and future water uses in compliance with applicable state, federal, and tribal laws, rules, and regulations. The Collaborative Program currently aids in the recovery of five species listed under the Endangered Species Act (ESA): the endangered Rio Grande silvery minnow (*Hybognathus amarus*; RGSM), the endangered southwestern willow flycatcher (*Empidonax traillii extimus*; SWFL), the endangered New Mexico meadow jumping mouse (*Zapus hudsonius luteus*; NMMJM), the threatened yellow-billed cuckoo (*Coccyzus americanus*; YBCU), and the threatened Pecos sunflower (*Helianthus paradoxus*; PESU).

## 1.1 Purpose and Role of Adaptive Management in the Collaborative Program

It has become increasingly difficult to protect and recover listed species in the MRG due to increased environmental and administrative challenges, such as persisting drought and diminishing administrative resources. To better utilize resources to meet challenges in the area, the Collaborative Program signatories agreed to use and support the use of adaptive management (AM) in the MRG. The primary role of the Collaborative Program in AM of the MRG is developing scientific evidence that informs decision-making. The Collaborative Program then provides scientifically defensible recommendations for management actions that benefit listed species to the MRG's natural resource managers.

Together, the Science & Adaptive Management Plan (herein referred to as the S&AM Plan) and the Long-Term Plan (See Section 4.2 and the 2020 Long-Term Plan) provide the framework for implementing the Collaborative Program's science and AM process.

## 1.2 Collaborative Program Guiding Principles

In 2019, the Collaborative Program adopted a revised mission statement (Box 1), which expanded on the 2008 Memorandum of Agreement's (MOA) statement of purpose. The revised mission statement maintains the Collaborative Program's intent to recover listed species and protect water uses, while further emphasizing the need for and use of scientific analysis to support AM in the MRG.

**Box 1. Collaborative Program Mission Statement.**

| |
|---|
| The Middle Rio Grande Endangered Species Collaborative Program provides a collaborative forum to support scientific analysis and implementation of adaptive management to the benefit and recovery of the listed species pursuant to the Endangered Species Act within the Program Area, and to protect existing and future water uses while complying with applicable state, federal and tribal laws, rules, and regulations. |

In 2020, the Executive Committee (EC) approved species-specific goals in support of its revised mission (Box 2). These are large-scale goals that are meant to be continually strived for. As such, they serve to guide the Collaborative Program's science and AM process.

**Box 2. Collaborative Program Goals.**

- Establish and maintain a self-sustaining population of endangered RGSM distributed throughout the MRG.
- Maintain and protect the MRG recovery unit goals for endangered SWFL.
- Maintain and protect suitable threatened YBCU habitat in the MRG.
- Establish and maintain a self-sustaining endangered NMMJM population in the MRG.
- Maintain and protect the threatened PESU in the MRG.
- Avoid the future listing or up-listing of species in the Collaborative Program area.
- Manage available water to meet the needs of endangered species and their habitat.

The Collaborative Program's mission and goals inform development of objectives and strategies, which guide the direction of scientific initiatives. These links ensure the Collaborative Program produces initiatives that serve its mission and goals. To increase the efficiency and effectiveness of Collaborative Program efforts, goals and objectives are informed by to species recovery plans. By developing strategies that build on recovery criteria, the Collaborative Program can document the progress made on each recovery objective and goal. Given the connection between strategies and species recovery plans, the Collaborative Program is poised to inform recovery plans during their five-year reviews.

Preliminary objectives and strategies were designed to achieve Collaborative Program goals by focusing efforts on essential aspects of species recovery criteria. Appendix D presents a list of suggested preliminary objectives and strategies that is meant to offer a starting point for the development of Collaborative Program objectives. The preliminary objectives were developed using past Collaborative Program objective development efforts and a compiled list of recovery goals, criteria, and actions from species recovery plans.

## 1.3 Area of Interest

The geographic area of interest covered by the Collaborative Program follows the Rio Grande, including its tributaries, stretching from the New Mexico/Colorado border downstream to the elevation of the spillway crest of Elephant Butte Reservoir, excluding the land reserved for the full pool of Elephant Butte Reservoir. Under the S&AM Plan, five reaches have been delineated within the MRG (Figure 1). From north to south, the reaches are delineated as follows:

- Northern Reach (from the Colorado-New Mexico border to Cochiti Dam)
- Cochiti Reach (from Cochiti Dam to Angostura Diversion Dam)
- Angostura (or Albuquerque) Reach (from Angostura Diversion Dam to Isleta Diversion Dam)
- Isleta Reach (from Isleta Diversion Dam to San Acacia Diversion Dam)
- San Acacia Reach (from San Acacia Diversion Dam to the elevation of the spillway crest of Elephant Butte Reservoir)

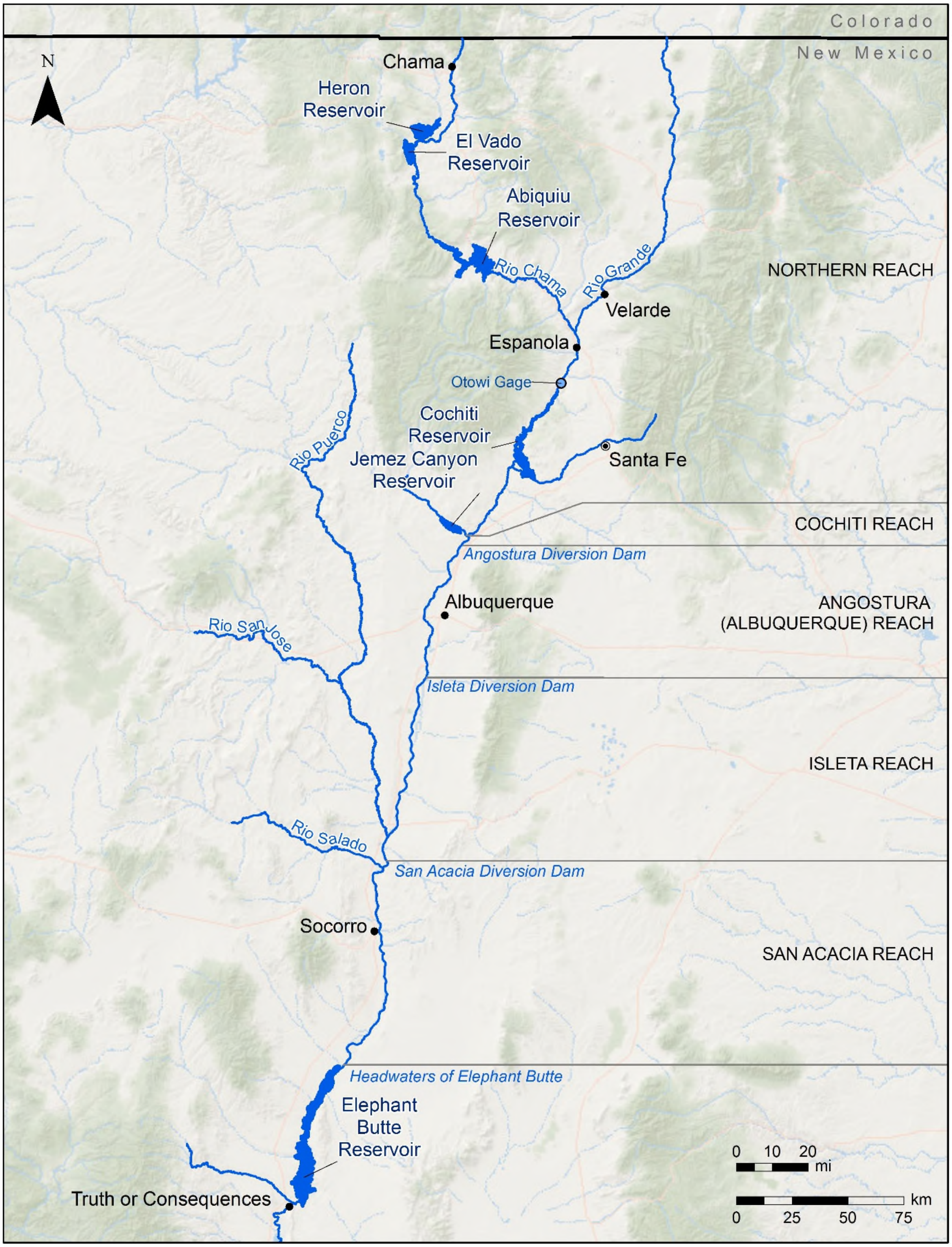


**Figure 1. Collaborative Program Area of Interest.**

## 1.4 Stakeholders

A Collaborative Program stakeholder is an organization whose members have vested interests in listed species recovery and protection of water uses in the MRG. Primarily, the Collaborative Program stakeholders are the seventeen signatories to the 2008 MOA:

- Albuquerque Bernalillo County Water Utility Authority (ABCWUA)
- Assessment Payers Association of the Middle Rio Grande Conservancy District (APA)
- Audubon New Mexico
- Bosque Ecosystem Monitoring Program (BEMP)
- Buckman Direct Diversion (BDD)
- City of Albuquerque (CoA)
- Middle Rio Grande Conservancy District (MRGCD)
- New Mexico Attorney General's Office (NMAGO)
- New Mexico Department of Game and Fish (NMDGF)
- New Mexico Interstate Stream Commission (NMISC)
- Pueblo of Isleta
- Pueblo of Sandia
- Pueblo of Santa Ana
- U.S. Army Corps of Engineers (USACE)
- U.S. Bureau of Reclamation (Reclamation)
- U.S. Fish and Wildlife Service (USFWS)
- University of New Mexico (UNM)

Beyond the Collaborative Program signatories, MRG stakeholder groups include soil and water conservation districts, Acequia Associations, the New Mexico Environment Department, the Mid-Region Council of Governments, and other land and natural resource management entities and interest groups not listed as signatories. The Minnow Action Team is a group of Collaborative Program signatory and non-signatory resource managers, contractors, and scientists that produce biologic, hydrologic, and monitoring recommendations to benefit the RGSM. Although the group operates outside of the Collaborative Program, its vested interest in listed species recovery make it a Collaborative Program stakeholder. Input by external stakeholders adds value to the Collaborative Program and strengthens the impact of its work. These entities also benefit from interacting with the Collaborative Program and its work.

## 1.5 Operational Space

Signatories have varied missions, interests, obligations, and authorities under which they participate in the Collaborative Program. Participation by signatory scientists, technical experts, natural resource managers, and administrators is necessary for navigating the Collaborative Program's operational space, which is defined by scientific uncertainty and regulatory obligations. This section frames the assumptions around the Collaborative Program's science support role in AM, including its opportunities and boundaries, and describes the administrative foundation for that role.

### *1.5.1 Operational Assumptions*

Several assumptions shape the Collaborative Program's operations as a science-based program that provides recommendations for scientific activities and management actions in the MRG. These assumptions are listed in Box 3.

**Box 3. Collaborative Program Operational Assumptions.**

1. The Collaborative Program aids in the systematic reduction of uncertainty related to species vulnerabilities, resulting in science-based recommendations that help guide management of the MRG.
2. Collaborative Program efforts contribute valuable research to inform the recovery of the listed species; however, the Collaborative Program is not an entity that is collectively bound by any legal responsibility to recover the threatened and endangered species of the MRG.
3. Resource management decisions by individual Collaborative Program signatories often require consideration of species response to system changes.
4. The Collaborative Program has no authority to implement adaptive management in the MRG.
5. There is no central decision-making or funding authority in the MRG; the Collaborative Program does not have decision-making authority on any individual signatory's budget, contracts, or management actions.

### *1.5.2 Preceding Adaptive Management Efforts*

The Collaborative Program's current position on AM of the MRG is one developed over many years. Since the mid-2000's, the Collaborative Program has worked towards incorporating an AM framework into its efforts. The S&AM Plan builds from preceding Collaborative Program AM endeavors and aims to complement other AM efforts in the MRG.

In *Middle Rio Grande Endangered Species Collaborative Program Adaptive Management Plan Version 1*, Murray et al. (2011) were contracted to provide a comprehensive concept for implementing an AM approach for management of the RGSM and SWFL. The report identified tasks needed for implementation of AM and recommended next steps for subsequent Collaborative Program AM plans, including guidance for each step of the AM cycle.

In tandem with the 2011 effort, the Collaborative Program drafted a Recovery Implementation Program (RIP) document to restructure the Collaborative Program's governance, and develop processes to support an AM framework. In response to the *2016 Final Biological and Conference Opinion for Bureau of Reclamation, Bureau of Indian Affairs, and Non-Federal Water*

*Management and Maintenance Activities on the Middle Rio Grande, New Mexico* (herein referred to as the 2016 MRG BO; (described below), the Collaborative Program decided not to implement the RIP, and instead focused on renewed efforts to develop an AM framework to complement its position in the MRG.

Following up on the initial 2011 effort, USACE contracted GeoSystems Analysis, Inc. to complete the *Middle Rio Grande Adaptive Management Framework: Identifying Critical Scientific Uncertainties* (Caplan et al. 2018) report, which built on recommendations from Murray et al. (2011). As recommended by Murray et al. (2011), the Caplan et al. (2018) report used a structured process to identify critical scientific uncertainties and recommended studies to reduce those uncertainties for RGSM, SWFL, YBCU, and NMMJM. As outlined by the Caplan et al. (2018) report, the next steps for continuing development of the Collaborative Program's AM strategy are as follows:

- Use a structured decision-making process to prioritize study recommendations based on direct linkages to well-defined management objectives and performance measures;
- Develop a multi-year strategic science plan that incorporates results from the structured decision-making process; and
- Establish a standing independent science advisory group to provide outside peer review and to support the Collaborative Program's implementation of the strategic science plan through various stages of the AM cycle.

The Collaborative Program's science and AM process outlined in this S&AM Plan builds on previous AM efforts by incorporating the next steps and recommendations identified in past documents. Box 4 synthesizes the evolution of the Collaborative Program's science and AM process with a list of accomplishments made under an AM framework, beginning with the Murray et al. (2011) report. This evolution has helped refine the Collaborative Program's role in AM of the MRG.

**Box 4. Collaborative Program Accomplishments Under an Adaptive Management Framework.**

- Established a framework for conducting activities to deliberately and explicitly reduce management uncertainties.[1]
- Identified a preliminary adaptive management (AM) design and carried it through the AM cycle.[1]
- Identified scientific uncertainties and data gaps (by species) considered important for supporting management decisions and informing AM experiments.[2]
- Prioritized uncertainties and provided preliminary study plan considerations for four of the listed species.[2]
- Adopted a revised mission focused on science and AM (see Section 1.2).
- Developed and adopted long-term species-specific Collaborative Program goals (see Section 1.2).

[1]Murray et al. 2011 [2]Caplan et al. 2018

### *1.5.3 Operational Considerations*

Collaborative Program stakeholders work within a fully allocated and highly regulated river system, which poses challenges for management related to the recovery of listed species. Following is a brief overview of existing Biological Opinions (BO) and non-ESA obligations, other AM-specific efforts in the MRG, and opportunities for Collaborative Program engagement in AM.

#### Biological Opinions

Several signatories operate within the MRG under programmatic and/or project specific BOs (Table 1). One of the more expansive BOs in the MRG is the 2016 MRG BO. Signatory partners to this BO include Reclamation, NMISC, and MRGCD. ABCWUA and BDD operate under separate programmatic BOs in the MRG (Table 1).

In addition to programmatic BOs, several signatories consult with USFWS on specific projects. More information on these projects can be found using the following links to the USFWS website: https://www.fws.gov/southwest/es/NewMexico/ES_bio_op.cfm and https://ecos.fws.gov/ecp/.

**Table 1. Current Middle Rio Grande Signatories' Biological Opinions.**

| Signatory Parties | Year Issued | Title |
|---|---|---|
| ABCWUA | 2004 | Biological Opinion on the Effects of Actions Associated with the Programmatic Biological Assessment for the City of Albuquerque Drinking Water Project |
| BDD | 2007 | Biological Opinion on the Effects of Actions Associated with the Biological Assessment for the Buckman Water Diversion Project, Santa Fe National Forest, USDA Forest Service |
| USACE | 2014 | Biological Opinion on the Effects of the U.S. Army Corps of Engineers' Mountain View, Isleta, and Belen Levee Units for Middle Rio Grande Flood Protection, Bernalillo County to Belen, New Mexico (Bernalillo to Belen BO) |
| Reclamation<br>NMISC<br>MRGCD | 2016 | Final Biological and Conference Opinion for Bureau of Reclamation, Bureau of Indian Affairs, and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico |

Sources: U.S. Fish and Wildlife Service (2004, 2007, 2014, 2016).

ABCWUA = Albuquerque Bernalillo County Water Utility Authority, BDD = Buckman Direct Diversion, USACE = U.S. Army Corps of Engineers, Reclamation = U.S. Bureau of Reclamation, NMISC = New Mexico Interstate Stream Commission, MRGCD = Middle Rio Grande Conservancy District, USDA = U.S. Department of Agriculture, BO = biological opinion.

#### Obligations Beyond Endangered Species Act Compliance

The Rio Grande supports numerous water uses, including for ecological, tribal, agricultural, municipal, and recreational purposes. Water allocation and delivery in the MRG is highly managed and regulated by multiple entities. This includes several individual signatories that have water delivery obligations within the MRG and to downstream users.

### *1.5.4 Other Regulatory Adaptive Management Efforts*

As part of the 2016 MRG BO, BO partners plan to implement River Integrated Operations (RIO), an AM approach for river operations designed to address species and water management needs, while improving sustainable management of the MRG. Efforts on the RIO are currently underway. Additionally, the BO for USACE's Bernalillo to Belen flood risk management project (USFWS 2014; Table 1) includes measures for integrating AM in monitoring projects and evaluating their success in order to determine if mitigation actions are sufficient to avoid, minimize, or compensate for adverse impacts.

As the Collaborative Program progresses with implementation of its S&AM Plan, its efforts to provide science-based recommendations are expected to complement all AM efforts in the MRG. By reducing uncertainty around the management of listed species and their habitats, the Collaborative Program intends to improve management of the MRG.

### *1.5.5 Opportunities for Science Support*

Collaborative Program operations, lacks the authority to implement or direct river management actions. Although this limits the Collaborative Program's involvement in regulatory activities, it does not reduce its value to management of the MRG's listed species. Instead, this limitation presents several unique opportunities.

As the Collaborative Program operates outside the purview of signatory BOs and other non-ESA obligations, it is free to use BO requirements as guidance for its activities, while expanding beyond them. This freedom has allowed the Collaborative Program to address ecosystem-level questions and habitat considerations not specified by species recovery plans. Under the S&AM Plan, the Collaborative Program's charge is to develop scientifically defensible solutions and recommend evidence-based best management alternatives for the recovery of listed species in the MRG. With a diverse group of collaboratively engaged signatory members, the Collaborative Program is distinctly positioned to support the work of its signatories and other MRG stakeholders. Furthermore, each signatory contributes individually to Collaborative Program operations (Table 2), which collectively strengthens its work.

Given its unique strengths and limitations, the Collaborative Program has had to carve its own operational space in AM of the MRG. Within this space, the Collaborative Program's role has been refined to one of scientific support. Backed by empirical evidence, recommendations originating from the science-based Collaborative Program are designed to influence management of listed species in the MRG and garner public and political support.

**Table 2. Opportunities for Signatory Involvement under the Science and Adaptive Management Plan.**

| Signatory Contributions | ABCWUA | APA | Audubon | BEMP | BDD | CoA | MRGCD | NMAGO | NMDGF | NMISC | PoI | PoS | PoSA | USACE | Reclamatio | USFWS | UNM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scientific and Technical Expertise: SAMC Positions and S&T Ad Hoc Groups** | | | | | | | | | | | | | | | | | |
| Aquatic biology | | | | | | X | | | X | X | | | | X | X | X | X |
| Terrestrial biology | | | X | | | | | | X | | | | | X | X | X | |
| Ecosystem function and structure | | | X | X | | X | X | | | X | X | X | X | X | | X | |
| Hydrology | X | | X | | | | X | | | X | | | | X | X | | |
| Statistical analysis | | | | X | | | | | | X | | | | | | X | X |
| **Informing Management, Operations, and Activity Implementation** | | | | | | | | | | | | | | | | | |
| Conducting laboratory studies | X | | | | | X | X | | | X | | | | | X | X | X |
| Ability to conduct field studies | X | | X | X | | X | X | | X | X | X | X | X | X | X | X | X |
| Knowledge of system management | X | X | X | | X | X | X | | X | X | X | X | X | X | X | X | X |
| Routinely collect field observations | X | X | | X | | X | X | | X | X | X | X | X | | X | X | X |
| Conduct scientific activities | X | | X | X | | X | X | | X | X | X | X | X | X | X | X | X |
| Forecasting and modeling | X | | | X | | | X | | | X | | | | X | X | X | X |
| **Administrative Expertise: Administrative Ad Hoc Groups** | | | | | | | | | | | | | | | | | |
| Updates to By-laws | | X | | | X | | | X | | X | | | | X | X | | |
| Draft, review, and update administrative documents | X | X | | | | | X | | | X | | | | X | X | | |
| **Science Communication and Outreach** | | | | | | | | | | | | | | | | | |
| Contribute to public outreach | X | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | X |
| Communicate to the scientific community via peer-reviewed publications and presentations at conferences | X | | X | X | | X | X | | X | X | X | X | X | X | X | X | X |
| **Regulation and Policy Expertise: Executive Committee; other groups as needed** | | | | | | | | | | | | | | | | | |
| Conservation laws | | | | | X | | X | X | X | X | | | | X | X | X | |
| Water regulations and policy | X | | | | X | | X | X | | X | | | | X | X | | |
| Administrative policy | | | | | X | | | X | | X | | | | X | X | | |

ABCWUA = Albuquerque Bernalillo County Water Utility Authority; APA = Assessment Payers Association of the Middle Rio Grande Conservancy District; BEMP = Bosque Ecosystem Monitoring Program; BDD = Buckman Direct Diversion; CoA = City of Albuquerque; MRGCD = Middle Rio Grande Conservancy District; NMAGO = New Mexico Attorney General's Office; NMDGF = New Mexico Department of Game and Fish; NMISC = New Mexico Interstate Stream Commission; PoI = Pueblo of Isleta; PoS = Pueblo of Sandia; PoSA = Pueblo of Santa Ana; USACE = U.S. Army Corps of Engineers; Reclamation = U.S. Bureau of Reclamation; SAMC = Science and Adaptive Management Committee; S&T = Science and Technical.

# 2.0 ADAPTIVE MANAGEMENT APPLICATION

The Collaborative Program uses a science and AM process to determine how to best manage limited resources in the MRG to benefit listed species. Specifically, the Collaborative Program's science and AM process is designed to reduce uncertainty around species management and lead to recommendations for science-supported management alternatives and activities aimed at improving understanding of species-system interactions. This section outlines the general AM cycle, tailors each step of the AM cycle to the Collaborative Program, and defines the role of AM in the Collaborative Program.

## 2.1 The Adaptive Management Cycle

AM is a structured, science-based process that maximizes learning by incorporating management alternatives to reduce critical uncertainties (Williams et al. 2009; Murray et al. 2011). The AM process has been applied to a wide variety of natural resource and ecosystem management problems since the 1970s (Holling 1978; Environmental and Social systems Analysts 1982; McDonald et al. 1999; Gregory et al. 2006), and is summarized as an iterative cycle that involves six steps (Figure 2; Williams et al. 2009).

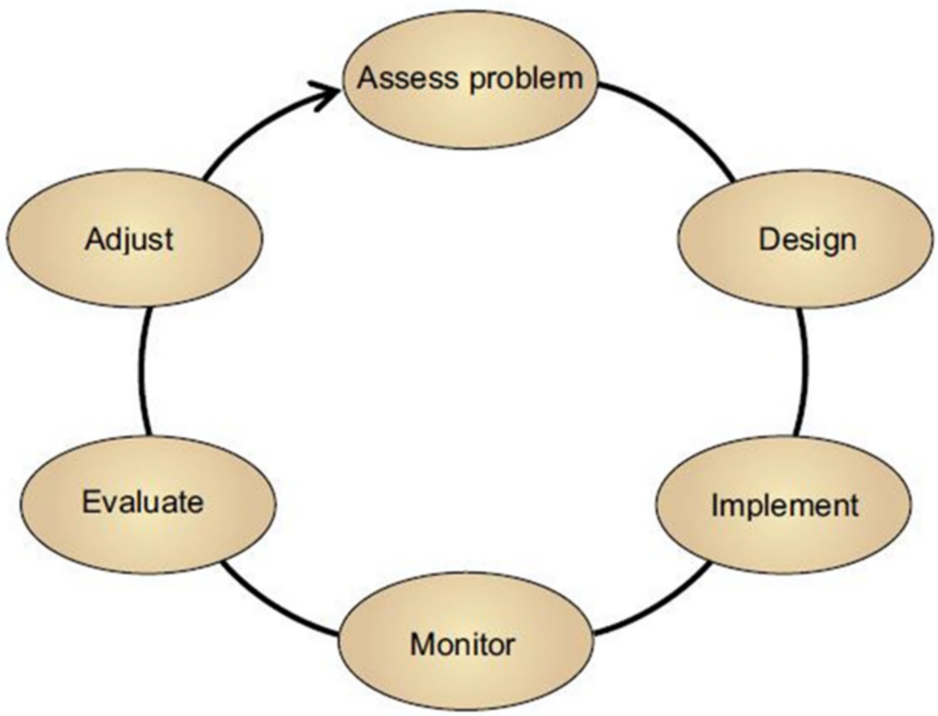


**Figure 2. Adaptive Management Cycle.**

Each step of the AM cycle contributes to the continual reduction of uncertainty around management actions, which ultimately leads to better-informed decision-making. Following are the Collaborative Program's definitions for the AM cycle steps:

- **Assess Step**: Sets the foundation for the rest of the AM cycle by identifying critical uncertainties about how a system functions. As the starting point for a new learning cycle, this step also involves consolidating, synthesizing, and incorporating information from previous cycles. Most importantly, assessment places scientific findings in the context of management and recovery objectives.
- **Design Step**: Alternative hypotheses are formulated around the critical uncertainties identified during assessment. Studies are designed to address these hypotheses as they relate to management decisions, thus increasing their relevance to Collaborative Program goals. Robust study designs to test hypotheses ensure economical use of money, time, and labor.
- **Implement Step**: Scientific activities are resourced and executed. Importantly, the Collaborative Program cannot implement or direct activities. Individual signatories and MRG stakeholders are responsible for carrying out scientific activities.
- **Monitor Step**: Monitoring is also implemented outside of the Collaborative Program and is defined as the systematic observation and documentation of responses (e.g., species population metrics, habitat quality) to management actions. Long-term monitoring and research strictly follows standardized data collection protocols to evaluate trends over time. Short-term monitoring aims to compare a response to an acute modification to that of an established baseline.
- **Evaluate Step**: Collected data are analyzed and synthesized in order to learn from new findings. Investigators document how listed species respond to changing conditions in a system, both natural and anthropogenic.
- **Adjust Step:** Modifications to management actions and AM decision tools (Section 4) are recommended based on what was learned. New scientific evidence is added to the knowledge base to reduce uncertainty and enhance understanding of the system and its species. Re-assessment of objectives is advisable following substantial changes to the knowledge base, but is not required with each iteration.

The specific steps required to complete an iteration of the AM cycle vary depending on a variety of factors, including the ecosystem of focus, the spatial and temporal scale of the management problem, the management options, the regulatory landscape, the species of interest, and stakeholder engagement. Adaptive management is a continuous learning process that increases the value of Collaborative Program products by subjecting them to a rigorous scientific process. The resulting products are designed to improve decision-making in management of the MRG. Documenting each iteration of the AM process tracks decision-making, ensuring that accumulated knowledge is incorporated into future decisions and choices are refined.

Adaptive management is useful to natural resource managers because of its use of structured decision-making to facilitate iterative learning. Structured decision-making ensures that a problem is decomposed into smaller, more manageable questions, each of which is addressed with a transparent, replicable, hypothesis-driven approach (Conroy and Peterson 2013). Martin et al.

(2009) proposes that iterative learning is most effective when a structured decision-making process is developed and implemented under a strong science-based program.

Caplan et al. (2018) began development of just such an approach and stated that structured decision-making is a stepwise process of generating and evaluating strategies, which are organized under a shared set of clear objectives. The process enables managers to evaluate how uncertainties influence their choices and target the uncertainties with the greatest potential impact or consequence. As an iterative form of structured decision-making, AM helps managers refine critical questions over time and allows them to focus on the “need to know” instead of “nice to know” aspects of the system they manage.

Structured-decision making has four primary components (Walters 1986, Conroy and Peterson 2013):

1. Clearly-stated, shared objectives;
2. Specific management alternatives to meet those objectives;
3. Use of decision-support models and tools to predict the effect of the alternatives; and
4. A sequential decision process (e.g., decisions through time build on previous iterations)

Additionally, the Collaborative Program’s operation incorporates the following complementary actions:

1. Re-organization of the Collaborative Program’s structure (Section 3), with the Science and Adaptive Management Committee (SAMC) translating and communicating scientific evidence to the EC;
2. Construction of the AM Database (Section 4.1), which stores and link goals, objectives, strategies, metrics, uncertainties, and the Project Bank (Section 4.1), to facilitate transparent prioritization of the Collaborative Program’s scientific activities; and
3. Commitment to iterative learning through tracking (via the AM Database), evaluating, and incorporating scientific evidence into experimental designs, decision support tools (Section 4), and Collaborative Program objectives (Appendix D) on at least an annual basis.

## 2.2 Defining Adaptive Management for the Collaborative Program

The Collaborative Program S&AM Plan presents a science-based process aimed at reducing uncertainty within the MRG ecosystem relating to management of listed species. The Collaborative Program’s definition of AM, as developed by the AM Work Group and approved by the EC, is stated in Box 5.

**Box 5. Collaborative Program Definition of Adaptive Management.**

| |
|---|
| Adaptive management is a process for integrating science and learning into management under changing conditions coupled with an iterative process for producing improved systematic understanding of needs to meet the established goals. |

This definition describes the Collaborative Program's understanding of its role in AM and the role of its signatories, both independently and as part of the Collaborative Program. In this definition, science and learning are posited as the central components of Collaborative Program activities. This positions science and learning as the primary tenets guiding production of the Collaborative Program's evidence-based recommendations to inform management decisions within the MRG.

# 3.0 COLLABORATIVE PROGRAM ORGANIZATIONAL AND OPERATIONAL STRUCTURES

Scientific activities take time to move through the AM cycle and require a structured, long-term planning approach. To meet the need for more intensive out-planning, the Collaborative Program's science and AM process has undergone restructuring. The resulting Collaborative Program structure promotes proactive, thorough, and timely Collaborative Program efforts. One of the biggest changes that occurred in restructuring of the Collaborative Program is the addition of the SAMC. Activating a small, focused committee of topical experts lends to the productive messaging of science into management-relevant recommendations.

The following outlines the Collaborative Program's operations and structure designed to facilitate the science and AM process. Figure 3 illustrates the hierarchical organization of the Collaborative Program, and Figure 4 depicts organizational operations under the S&AM Plan.

## 3.1 Organizational Structure

The EC directs the implementation of the Collaborative Program's science and AM process, which requires the formation of the SAMC and administrative groups. Under EC oversight, the SAMC is tasked with implementing the S&AM Plan. To do so, the SAMC forms and tasks Science and Technical (S&T) Ad Hoc Groups and collaborates with other Collaborative Program groups.

The EC forms Administrative Ad Hoc Groups to draft, review, and update administrative documents, such as the Collaborative Program By-Laws and Long-Term Plan. The Fiscal Planning Committee (FPC) serves as a platform for signatories to collaborate on financial and administrative resources for Collaborative Program-related scientific activities. The Program Support Team (PST), made up of the Program Manager, Science Coordinator, and supporting staff, are directed by the EC and provide administrative, scientific, and technical support to all Collaborative Program committees and groups. Details on each group's role and composition are provided in the Collaborative Program By-Laws, committee charters, and ad hoc group charges.

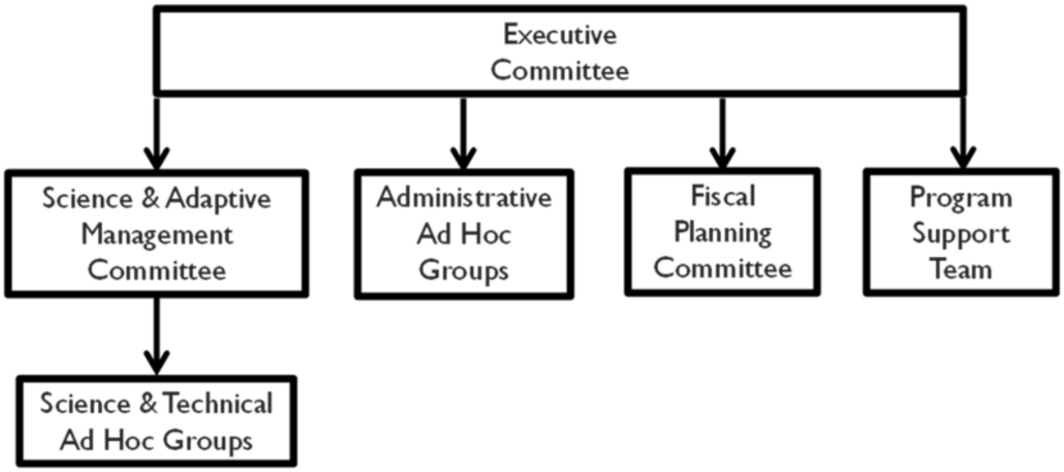


**Figure 3. Collaborative Program Hierarchical Structure.**

## 3.2 Operational Structure

The Collaborative Program is structured to include three components: 1) science and technical support, 2) policy and guidance, and 3) administrative support. This operational structure takes into account the assumptions outlined in Box 3 and the Collaborative Program's role as a science-based program. Following is a general description of the responsibilities of Collaborative Program groups and their roles related to the listed components. Figure 4 illustrates communication and workflow under the S&AM Plan.

### *3.2.1 Science and Technical Support*

Under the new operational structure, the Collaborative Program's role in the MRG is that of a science-based program providing recommendations for scientific activities and best management alternatives. Scientific and technical support is key to the success of the S&AM Plan. The SAMC is responsible for implementation of the S&AM Plan, with support from the S&T Ad Hoc Groups and PST, and in coordination with the EC and FPC. Specifically, the SAMC's responsibilities include:

- Forming S&T Ad Hoc Groups charged with addressing specified scientific uncertainties;
- Tasking S&T Ad Hoc Groups with work such as data analyses, study plan development, and model updates in support of the S&AM Plan;
- Compiling the results of S&T Ad Hoc Group analyses, and translating them into recommendations for scientific activities and best management alternatives;
- Communicating regularly with the EC on the progress of the S&AM Plan efforts, including a summary of modifications to Collaborative Program objectives and tools with scientific justifications;

- Communicating recommendations to the EC for consideration of next steps, which may include recommended modifications to the Long-Term Plan with scientific justifications, or recommended management alternatives with analysis and scientific justifications; and
- Following up with MRG resource managers post implementation of Collaborative Program recommendations to ensure results of implemented activities can be assessed.

The flow of information and relationships between the Collaborative Program's scientific groups is illustrated in Figure 4. As the name implies, S&T Ad Hoc Groups are formed by the SAMC to complete specific scientific and technical tasks directed at reducing uncertainty regarding species response to management actions. Lack of consensus around scientific topics will prompt the SAMC to direct internal reviews via topical executive summaries (Section 4.4), or engage independent expert reviews, with approval from the EC.

The PST also assists with the scientific and technical aspects of Collaborative Program activities. Support includes compilation and analyses of reports, data, and information; coordination with contracting agencies, Collaborative Program committees and groups, and independent external reviewers; data management oversight; and drafting, reviewing, and updating study designs, scopes of work, and other work products as necessary.

### Internal and External Work Product Reviews

The Collaborative Program's committees and ad hoc groups are tasked with producing scientific and administrative work products as part of their scientific investigations and/or technical endeavors. Work products from group activities include executive summaries, proposals, project descriptions, scopes of work, white papers, journal articles, modeling results, bibliographies, glossaries, and work plans. To ensure that work products are clear, accurate, and relevant to Collaborative Program efforts, they undergo various levels of internal and/or external review. The review process is designed to be rigorous enough to ensure document quality and support a range of scientific opinions. The Collaborative Program's internal and external review processes are described below.

### Internal Review

All work products from Collaborative Program committees and ad hoc groups undergo a standardized process of internal review, which may include in-group peer review, statistical review, editorial review, and contextual review. Not every work product requires the same type of internal review. For example, the intensity of a statistical review depends on the nature of the product (e.g., sampling design for an experimental protocol versus evaluation of empirical data). Additionally, some work products may require multiple rounds of statistical or editorial review. The SAMC directs all internal review processes and determines how work products will move through the review steps. The internal review process can be highly tailored to a product, which allows the degree of flexibility required for reviewing the Collaborative Program's wide array of work products.

#### External Review

The goal of an external review is to provide a rigorous scientific evaluation of the Collaborative Program's work from an independent perspective. External reviews are used to address and finalize specific work products that require an independent review or specialized expertise that is not available within the Collaborative Program. Previous examples of external reviews are Hubert et al. (2016), which evaluated the RGSM Population Monitoring Program, and Noon et al. (2017), which examined the state of the science pertaining to RGSM life history characteristics. The recommendations from these reviews and progress on their implementation is tracked in the AM Database. Although these efforts are highly important to the Collaborative Program, they require a high level of resources to bring about. Due to the resource intensity of planning, convening, and addressing external reviews, they are not meant to be a regular part of the AM review process.

External reviews are meant to examine foundational or big picture products or questions that would benefit from additional scientific and technical expertise. This type of scrutiny is necessary to ensure the Collaborative Program is following the most recent and prudent scientific methods, as well as to prevent institutional bias. External reviews occur infrequently on an as needed basis, as determined by the EC in collaboration with the SAMC.

### *3.2.2 Policy and Guidance*

While the SAMC is responsible for implementation of the S&AM Plan, the EC is the Collaborative Program's decision-making body. As such, the EC provides leadership, oversight, and approval for implementation of the S&AM Plan. EC representatives provide a collective knowledge of management regulations, policies, and operations related listed species in the MRG. Under the S&AM Plan, the EC holds the following responsibilities:

A. Reviewing recommendations and deciding next steps;
B. Communicating recommendations to natural resource management organizations; and
C. Evaluating Collaborative Program activities.

#### A. Reviewing Recommendations and Deciding Next Steps

The SAMC provides a variety of scientific and technical recommendations for which the EC decides next steps. The FPC may also provide recommendations for financing options to implement the SAMC's recommended activities. After deliberating recommendations, the EC may:

- Determine a recommendation is feasible or not in the context of existing policy;
- Incorporate a recommended activity into the Collaborative Program Project Bank, with a documented explanation of the decision to delay implementation and a timeline for future consideration;
- Request more information or further work from the SAMC or the FPC;

- Request independent external review of information upon SAMC recommendation;
- Instruct Administrative Ad Hoc Groups to complete an update, review, or draft administrative documents; or
- Communicate recommendations directly to implementing organizations and resource managers.

### B. Communicating Recommendations to Natural Resource Management Organizations

Under the S&AM Plan, the EC relays recommendations for scientific activities and science-based best management alternatives to the appropriate resource managers. Recommended scientific activities are organized in the Long-Term Plan (Section 4.2) based on management-relevant categories and priority planning objectives agreed on by the Collaborative Program. In addition to being a planning tool for the Collaborative Program, the Long-Term Plan can be used by resource managers to out-plan their own activities.

The EC makes recommendations on best management alternatives based on the current scientific understanding of species responses to conditions in the ecosystem. The Collaborative Program evaluates and adjusts its recommendations as understanding evolves with new scientific findings. The EC also encourages managers to bring questions to the Collaborative Program for consideration.

### C. Evaluating Science and Adaptive Management Activities

The EC annually (or more frequently at their discretion) evaluates Collaborative Program activities and committees/groups using guiding principles. Guiding principles include the Collaborative Program's mission, goals, and objectives. By performing regular reviews, decision-makers, including the EC members, Congressional and State representatives, and others, can be assured that the Collaborative Program actions are accomplishing the mission and benefitting the listed species. The EC assigns evaluation-related tasks to Administrative Ad Hoc Groups and the PST as appropriate. Collaborative Program activities and committees/groups are assessed based on how they address the up-to-date guiding criteria. Outcomes of the annual EC evaluation may include the following:

- Modifications to the composition of committees/groups
- Sunsetting groups
- Updates or clarifications to committee charters or group charges
- Adjustments of timelines and deadlines
- Amendments and updates to the S&AM Plan, Long-Term Plan, and/or by-laws
- Re-scoping work plans as necessary

### *3.2.3 Administrative Support*

Under the Collaborative Program's hierarchical structure (Figure 2), three administrative groups exist to support the operations portion of the S&AM Plan: Administrative Ad Hoc Groups, the FPC, and the PST. The EC provides direction to each group, and individual EC representatives may be tasked with participating in Administrative Ad Hoc Group and FPC meetings as necessary.

#### Administrative Ad Hoc Groups

The EC may task a small group of individuals with reviewing and revising Collaborative Program documents in regards to policy. For example, an Administrative Ad Hoc Group may be tasked with revising the Collaborative Program By-Laws, reviewing SAMC applications, reviewing science-backed management recommendations in a regulatory context, or with better defining a portion of the S&AM Plan or the Long-Term Plan. Administrative Ad Hoc Groups report findings and recommendations to the EC.

#### Fiscal Planning Committee

The FPC is composed of signatory staff appointed by the EC. At the direction of the EC, and in coordination with the SAMC, the FPC meets to determine resource availability for Collaborative Program-supported activities. The FPC recommends an implementation schedule for EC-approved activities based on funding availability and regulatory commitments. The FPC is also responsible for engaging authorized and interested signatories through lobbying efforts for funding and partnerships as directed by the EC.

#### Program Support Team

In addition to scientific and technical support, the PST serves as administrative support for each of the Collaborative Program's committees and groups. The PST's responsibilities include leading the development of the Collaborative Program and SAMC Annual Work Plans; data storage and Program Portal oversight; development and administration of processes and procedures; organizing and facilitating meetings; and drafting, reviewing, and editing charters, charges, and other documents as needed to support the S&AM Plan. The PST also coordinates overall Collaborative Program operations, as depicted in Figure 4.

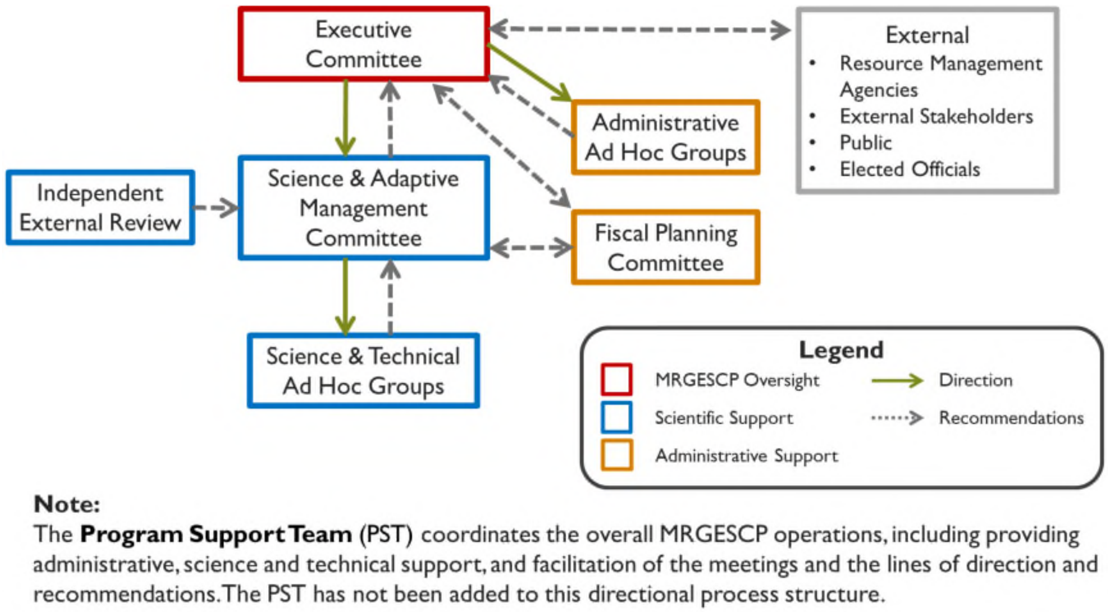


**Figure 4. Communication and work flow for implementing the Science and Adaptive Management Plan.**

# 4.0 TOOLS SUPPORTING THE SCIENCE AND ADAPTIVE MANAGEMENT PLAN

The Collaborative Program employs the use of several decision support, administrative, and planning tools to support the science and AM process. Below, these tools are described in regards to their relationship to the science and AM process.

## 4.1 Adaptive Management Database

The Collaborative Program's AM Database serves as a knowledge base that is regularly updated with new information to reflect current conditions in the MRG. The primary purposes of this information repository are to integrate Collaborative Program-supported science into system management, to evaluate past decisions, and to explore future scenarios. By linking information, such as critical uncertainties, planning objectives, proposed projects, management alternatives, and the state of the science, the AM Database gives much-needed context to Collaborative Program participants, enabling them to prioritize research needs and inform decision-making.

The AM Database provides a means for tracking the evolution of Collaborative Program work and MRG stakeholder endeavors. As a result, the tool allows the Collaborative Program to inform management of the system proactively, rather than reactively. The AM Database informs a variety of scientific and administrative processes, including the following:

- Maintenance of conceptual ecological models (CEM)
- Development of the Long-Term Plan

- Tracking reduction of scientific uncertainty
- Tracking status of scientific activities
- Justification of funding for Collaborative Program-related efforts via links to management authorities or obligations (where provided), and species recovery plans
- Systematic reduction of scientific uncertainties related to effects of management actions
- More frequent updates to the "state of the science" within the MRG
- Broader context for scientific analyses and management alternatives
- Generation of summaries for annual reports
- Summary of agency participation in Collaborative Program efforts
- Coordination and tracking of the development and review of work products

A common theme throughout AM literature, as well as in operational documents for the Collaborative Program, is the need to align scientific uncertainties, and the research efforts addressing them, with management questions (Walters, 1986, Williams et al. 2009, Murray et al. 2011, Caplan et al. 2018). In the 2011 description of a potential AM framework for the Collaborative Program, Murray et al. listed the conditions that must be met for successful implementation of AM:

- Feasibility for conducting a test of management actions
- Potential for learning about effectiveness of actions within a reasonable time frame
- Acceptable risk from failure of those tests
- Flexibility to change management practices based on what is learned

The AM Database fulfills the conditions for successful AM listed above. As a relational database, it aligns the Collaborative Program's scientific support with management objectives, critical uncertainties, past and current Collaborative Program efforts, and the Collaborative Program's guiding principles. The data are structured as a collection of tables linked to each other in relational pathways. Users have the flexibility and control to query and summarize data via an interface application. As the AM Database tracks learning in real time and relates scientific activities to the Collaborative Program's goals, it ensures regular stakeholder engagement and enables a long-term approach to AM, two concepts that Dreiss et al. (2017) found increased the effectiveness of AM.

One important component of the relational database is the Project Bank. The Project Bank is a cumulative list of scientific activities (proposed, in progress, and competed) and their descriptive details. The list is used to track progress, justify funding, and facilitate short- and long-term planning. Proposed activities are indexed according to their relevance to Collaborative Program objectives, which link to species recovery criteria. Associated metadata include conditions necessary for implementation (e.g., logistical concerns, hydrologic condition, presence/absence of a listed species) and feasibility criteria (i.e., cost, linkages to authorities and obligations). The Project Bank tracks activity status, from development to deliverable, while facilitating transparent and objective prioritization. This allows the Collaborative Program's scientific pursuits to proceed in a strategic and timely manner.

## 4.2 Long-Term Plan

A long-term plan is an important tool for implementing structured decision-making in AM of natural resources, as it uses clear and measurable goals to develop a vision for desired products. By using the Collaborative Program's goals to establish objectives and strategies, a long-term plan helps identify needed resources, develop contingencies, and prioritize strategic work along a meaningful timeline. Commitment to consistent updates makes the plan adaptive and ensures that tasks are adjusted and realigned to goals as conditions change. Providing a long-term plan with administrative schedules and deadlines facilitates the timely completion of tasks.

Development of the Collaborative Program's Long-Term Plan is guided by information in the AM Database, predominantly the Project Bank. In addition to serving as a tool for scientific planning, the Long-Term Plan informs the Collaborative Program's administrative needs (e.g., updates to science and AM decision-support tools, deadlines for work products, timetables for meaningful recommendations on management alternatives, tracking of project statuses). Using the AM Database to query priority Collaborative Program objectives and uncertainties generated a list of linked ongoing and proposed scientific activities with descriptive labels for sorting and filtering. This list helps managers prioritize activities, identify logistical concerns, and secure funding and other resources.

The Collaborative Program's Long-Term Plan provides program-wide context and describes the specific ways in which listed activities support the Collaborative Program's guiding principles, and reduce critical scientific uncertainties related to management needs. Additionally, the administrative tasks needed for carrying on normal operations and fulfilling upcoming obligations within the Collaborative Program are outlined in the plan. The Long-Term Plan is assessed and adjusted regularly in order to accommodate changing operational and/or environmental conditions.

## 4.3 Program Portal

The Program Portal serves as a communication and administrative support tool. The tool houses the Collaborative Program's document library, datasets, event calendar, Long-Term Plan, and Geospatial Mapping Application (Section 4.5).

The Portal's event calendar is regularly updated with upcoming Collaborative Program-related events, including meetings, presentations, and symposiums. One week before meetings, calendar events are tagged with meeting minutes, agendas, and meeting materials for download.

The document database facilitates the storage and sharing of important documents. Scientific documents concerning species, hydrology, and more can be accessed using the site search function. Signatories can also access administrative documents, including meeting minutes, agendas, work plans, and charters. The document database is regularly updated with new scientific reports, meeting materials, and references works, and will continue to be developed as needs arise and new documents and/or data become available.

## 4.4 Topical Executive Summaries

The SAMC will direct the completion of topical executive summaries, as needed, in an effort to condense relevant information about a particular topic and uncover uncertainties and research questions yet to be addressed. This exercise helps identify lack of consensus in study findings and alternative hypotheses by topic. The executive summaries will serve the following purposes:

1. Provide reference lists of relevant literature on each topic to identify and document knowledge gaps and points of non-consensus ;
2. Inform Collaborative Program recommendations for scientific activities designed to resolve key uncertainties related to listed species; and
3. Document progress in the reduction of uncertainty and provide a synopsis by topic to the SAMC, the EC, and Collaborative Program signatories, as necessary.

Each executive summary highlights findings from the latest relevant literature that provide evidence in support of (or against) key arguments. Understanding what is currently known and what remains unknown is crucial for prioritizing key scientific uncertainties and developing effective management alternatives.

The SAMC will use the executive summaries to direct activities that reduce key scientific uncertainties. These activities may include additional literature reviews, modeling exercises, monitoring activities, or field studies. Documenting progress supports the science and AM process.

## 4.5 Geospatial Mapping Application

The geospatial mapping application (mapper) on the Program Portal features interactive visualization tools that facilitate effective management of data resources in support of Collaborative Program goals and objectives. The map is a powerful visual aid for interagency collaboration and communication, as it allows users to examine the overlap of georeferenced data layers that are relevant to management of the MRG. The Program Portal mapper includes monitoring sites and territory boundaries for listed species, habitat restoration areas, water quality measurements, and control structures. In using the mapper, scientists and managers may discover data associations that were not discernible with non-spatial analyses.

Finding more connections, between biotic response metrics and habitat parameters in particular, improves the accuracy of models by accounting for variability in the response (i.e., reducing uncertainty). In addition, the identification of areas where critical habitat for two or more species overlaps may allow managers to focus resources more efficiently and provide enhanced justification for funding. The use of a single geospatial tool for coordination amongst Collaborative Program signatories generates an additional dimension for decision support, as new connections are revealed at multiple spatial scales. Mapping provides geographical context for activities, such as monitoring and habitat restoration, which helps demonstrate benefits to multiple species or the potential for unintended consequences. This type of information greatly enriches the AM process by directly addressing the objectives and values of the stakeholders.

### 4.6 Modeling Tools

A shared understanding of the dynamics of the MRG system and its influence on decision processes allows scientific and technical experts, natural resource managers, and decision-makers to communicate the purpose of a management action and its intended effects. The process of documenting the current understanding of system dynamics also prevents institutional knowledge from being lost as a result of personnel turnover.

One way to assess trends and compare/contrast the effects of different management actions is with models. The term “models” refers to anything that provides a reasonable representation of a system that is the setting for a natural resource management problem (Williams 2011). Models can be as basic as a verbal or written description, or as complicated as a series of mathematical models.

In the framework of AM, models connect management actions with stakeholder objectives (Conroy and Peterson 2013). Models used in the AM process should be viewed as useful, albeit imperfect, tools that are subject to continuous refinement as new information becomes available. A model does not make a decision but instead informs and often guides that process.

Conceptual ecological models, such as those in Appendix B and C, are useful for education and communication purposes, both internally and externally to the Collaborative Program. The Collaborative Program has four primary goals for using species-specific CEM tools:

1. Transparency around the decision-making process;
2. Communication of information;
3. Identification of critical uncertainties; and
4. Connection of management actions and objectives.

## 5.0 SCIENCE AND ADAPTIVE MANAGEMENT PLAN IMPLEMENTATION

Through the science and AM process, the Collaborative Program provides scientific and technical support to natural resource managers to inform the continual improvement of management actions for listed species. As discussed in Section 2, this process emphasizes learning from the results of scientific activities to inform management. Under the S&AM Plan, the Collaborative Program:

- Identifies critical uncertainties and develops research hypotheses to address them

- Designs experiments to test hypotheses and reduce uncertainties
- Evaluates new information and data gathered within the context of Collaborative Program objectives to determine what has been learned
- Translates the scientific evidence into management-relevant, constructive, timely recommendations for scientific activities and management alternatives
- Communicates the results of field and laboratory research, habitat restoration projects, and monitoring and modeling efforts
- Enables iterative learning through tracking, evaluation, and incorporation of scientific evidence into objectives and decision-support tools, such as the AM Database

As part of the science and AM process, the Collaborative Program determines the key scientific questions on which to focus efforts within specific management categories. These categories may pertain to any of the listed species and/or the MRG system, and include, but are not limited to, the list in Box 5.

**Box 6. Management Categories.**

- Applied Research: Field, Laboratory
- Flow Modification
- Habitat Restoration: Research, Construction, Monitoring
- Hydrologic Modeling
- Population Management: Monitoring, Modeling, Propagation
- River Modification: In-Channel, Off-Channel
- Water Quality Management: Land Use, Monitoring

Within these categories, the Collaborative Program:

1. Helps fill knowledge gaps or reduce uncertainties to enable implementing organizations to make more informed management decisions;
2. Recommends scientific activities that fill knowledge gaps or reduce uncertainties related to management actions for implementation by signatories; or
3. Evaluates management alternatives using scientific evidence.

The steps described below guided the Collaborative Program's implementation of the AM cycle (Figure 2.1). Appendix A complements these steps with a task list for implementation of the science and AM process, with the following three main tasks outlined:

1. Finalize and implement the S&AM Plan, the Long-Term Plan, and associated tools
2. Develop and agree on processes to support the implementation of the science and AM process
3. Implement the new organizational structure

Following is an outline of each AM cycle stage as it relates specifically to the Collaborative Program. Under each stage are the main steps the Collaborative Program must complete to implement and maintain the science and AM framework.

## 5.1 Assess Stage

### A. Agree on Collaborative Program Objectives

*Step 1. Assess objectives identified during previous efforts*
The Collaborative Program uses signatory values and species recovery expectations as a starting point for developing objectives. These AM objectives are informed by past efforts described in previous sections through a systematic assessment of each one. Evaluation of relevance, priority, and specification ensures that no work is discarded.

*Step 2. Convene a workshop to identify objectives that guide the S&AM Plan*
As part of the workshop, signatory members evaluate and/or refine the objectives identified from Step 1; add new objectives, if needed; and identify signatory expectations regarding participation in the science and AM process. In addition to clearly defining objectives, workshop participants develop strategies to meet objectives and identify metrics for success.

*Step 3. Adopt objectives*
The SAMC summarizes the results of the workshop and communicates them to the EC for review and approval. The approved objectives address critical uncertainties and direct work within the science and AM process.

### B. Identify Management Alternatives

*Step 4. Compile and organize management actions and scientific activities*
The Collaborative Program tracks current and proposed management actions, management alternatives, and scientific activities. These lists are stored in the AM Database.

*Step 5. Develop potential management alternatives*
The list of management alternatives developed in step 4 consists of potential actions for benefitting listed species in the MRG. The SAMC tasks S&T Ad Hoc Groups with developing new management approaches using innovative solutions, even if they are not currently feasible.

*Step 6. Relate management alternatives to hypotheses*
Management alternatives are connected to hypotheses via study designs using the AM Database. In this way, research hypotheses link scientific uncertainties with resource management.

### C. Develop Models

*Step 7. Continue developing additional species-specific CEMs*

The Collaborative Program developed CEMs for RGSM, SWFL, and YBCU (Appendices B and C). CEMs for NMMJM and PESU are in development. The SAMC directs S&T Ad Hoc Groups to finalize the NMMJM and PESU CEMs and incorporate them into the AM Database.

*Step 8. Additional CEM development based on identified critical uncertainties*
The Collaborative Program uses species-specific CEMs to depict relationships in the ecosystem. These models are developed and updated based on the current understanding of those relationships. The Collaborative Program evaluates uncertainties and their links to management, and prioritizes model improvements that clarify essential relationships. If appropriate, additional modules or refinements to existing models can be developed to more accurately represent a component group (e.g., hydrology, genetics).

*Step 9. Link CEMs to management alternatives and objectives*
The SAMC tasks S&T Ad Hoc Groups with deconstructing the CEMS into individual components and connecting those components with the management alternatives and objectives identified in the steps above. This provides an initial framework for determining what management actions can be used to test hypotheses related to those uncertainties. These linkages are documented in the AM Database.

These linkages can also be used to parameterize quantitative models using the science and AM process. Quantitative tools enable users to better understand how specific uncertainties influence the decision-making process and management strategies.

## 5.2 Design Stage

### D. Develop AM Planning Tools

*Step 10. Continue developing the AM Database*
The AM Database is the platform for the Collaborative Program's science and AM process, and is regularly updated.

*Step 11. Design scientific activities for reducing uncertainty*
The Collaborative Program develops research hypotheses to reduce scientific uncertainties that are not clarified with existing data and information. The SAMC directs the design of new scientific activities (e.g., scopes of work) to populate the Project Bank (Step 12).

*Step 12. Populate a Project Bank*
The Project Bank contains specifics for each Collaborative Program -related scientific activity and includes connections to scopes of work, required conditions, geospatial and temporal scales, collected data, and relation to objectives and scientific uncertainties. The Project Bank is used to prioritize scientific activities with which to update the Long-Term Plan. As new options for reducing scientific uncertainties are developed, they are incorporated into the Project Bank.

## 5.3 Implementation Stage

### E. Develop Administrative Tools to Support the Science and Adaptive Management Process

*Step 13. Identification of administrative resource availability and scheduling*

The FPC develops a schedule of funding and contracting deadlines with input from signatories. The schedule is not exhaustive but notes the key deadlines for contracting and funding opportunities. This allows the Collaborative Program to coordinate on activity implementation and fundraising efforts.

The FPC collaborates on leveraging signatory resources for Collaborative Program activities. These resources may be financial, personnel-related, administrative (e.g., administering contract, accepting grant money), or operational (e.g., laboratory space, equipment). This streamlines the FPC's efforts in identifying opportunities for funding and/or partnerships.

*Step 14. Refine the Long-Term Plan*

The Long-Term Plan is modified in response to changing administrative constraints and/or Collaborative Program objectives. The AM Database documents these changes and tracks the status of funded projects in real time, thus facilitating out-planning and evaluation of projects.

## 5.4 Monitor Stage

### F. Continue supporting monitoring efforts

*Step 15. Support monitoring efforts*

The Collaborative Program supports ongoing long-term monitoring and data collection efforts. These datasets establish trends through time, inform future scientific activities, and are key inputs into quantitative models. The Program Portal houses the datasets as appropriate.

## 5.5 Evaluate Stage

### G. Establish the Current State of the Science

*Step 16. Analyze existing data*

The Collaborative Program has amassed a large amount of information on the MRG system and its listed species. The SAMC, or the assigned S&T Ad Hoc Group(s), continue to refine understanding of system interactions. Consequently, new data pertaining to species life histories and relationships to management implications, as well as existing data is used to inform hypotheses identified in the previous steps.

*Step 17. Identify uncertainties and develop hypotheses*

As described above, the CEMs indicate uncertainty associated with biotic responses to certain environmental variables. If an uncertainty is linked to a Collaborative Program objective, the SAMC or assigned S&T Ad Hoc Group(s) first dissects the uncertainty into responses, drivers, individual questions, and hypotheses, then links the components to management alternatives, data resources, and the Project Bank. After, the SAMC tasks S&T Ad Hoc Group(s) with developing scientific activities around the identified research hypotheses.

*Step 18. Draft topical executive summaries*
When there is non-consensus on the state of the science around a topic, the SAMC tasks an S&T Ad Hoc Groups with drafting an executive summary that synthesizes relevant literature and provides evidence in support of alternative hypotheses.

## 5.6 Adjust Stage

### H. Incorporate New Findings

*Step 19. Communicate new scientific findings*
The S&AM Plan and its associated tools are specifically designed to improve communication within the Collaborative Program. The SAMC translates scientific results into coherent, management-relevant recommendations for the EC. The Program Portal and AM Database supplies scientists and managers with a common set of facts from which to initiate discussions. Signatory members and other experts communicate research findings at the Science Symposium, after which, the SAMC or an assigned S&T Ad Hoc Group compiles and evaluates new scientific evidence as it relates to Collaborative Program objectives. Additionally, formal documentation of study results in peer-reviewed journals strengthens recommendations generated by the Collaborative Program.

*Step 20. Incorporate results of data analyses into Executive Summaries and models*
When new information is generated, through data analysis, modeling, or literature reviews, the SAMC evaluates it within the broader context of the management landscape and state of the science. Research findings that improve on the understanding of species-system interactions are documented in the CEMs, quantitative models, and executive summaries.

*Step 21. Document the learning process*
When incorporating new scientific evidence, the Collaborative Program asks the following questions:

- Is the evidence supported and durable?
- Did we learn enough to justify a change to a model?
- Did we learn enough to modify a Program objective?

The SAMC evaluates whether there is sufficient evidence to modify the CEMs, quantitative models, and/or Collaborative Program objectives, and periodically reports to the EC on the state of the science.

*Step 22. Update the Long-Term Plan*
As changes are made in steps 1 through 21, adjustments to the Long-Term Plan may be necessary. The SAMC utilizes the AM Database to track changes.

**Table 3. Linking the Collaborative Program's Adaptive Management (AM) Cycle Steps to the Tasks Associated with Implementation of the Science and Adaptive Management (S&AM) Plan.**

| Steps to Implement the Collaborative Program AM Cycle (Section 5) | Tasks to Implement the S&AM Plan (Appendix A) |
|---|---|
| **ASSESS STAGE** | |
| **A. Agree on Collaborative Program Objectives** | |
| Step 1. Assess objectives identified during previous efforts | Task 1.3a |
| Step 2. Convene a workshop to identify objectives that guide the S&AM Plan process | Task 1.3b |
| Step 3. Adopt objectives | Task 1.3c |
| **B. Identify Management Alternatives** | |
| Step 4. Compile and organize management actions and scientific activities | Task 1.3d |
| Step 5. Develop potential management alternatives | Task 1.3e |
| Step 6. Relate management alternatives to hypotheses | Task 1.3f |
| **C. Develop Models** | |
| Step 7. Continue developing additional species-specific conceptual ecological models (CEMs) | Task 1.2a |
| Step 8. Additional CEM development based on identified critical uncertainties | Task 1.2b |
| Step 9. Link CEMs to management alternatives and objectives | Task 1.2d |
| **DESIGN STAGE** | |
| **D. Develop Adaptive Management Planning Tools** | |
| Step 10. Continue developing the AM Database | Task 1.3 |
| Step 11. Design scientific activities for reducing uncertainty | Task 1.3o |
| Step 12. Populate a Project Bank | Tasks 1.3n and 1.3o |
| **IMPLEMENTATION STAGE** | |
| **E. Develop Administrative Tools to Support the Science and AM Process** | |
| Step 13. Identification of administrative resource availability and scheduling | Task 1.5 |
| Step 14. Refine the Long-Term Plan | Task 1.6 |
| **MONITOR STAGE** | |
| **F. Continue supporting monitoring efforts** | |
| Step 15. Support monitoring efforts | Task 1.1 |
| **EVALUATE STAGE** | |
| **G. Establish the Current State of the Science** | |
| Step 16. Analyze existing data | Task 1.3i |
| Step 17. Identify uncertainties and develop hypotheses | Tasks 1.3g, 1.3h, 1.3j |
| Step 18. Draft topical executive summaries | Task 1.3k |
| **ADJUST STAGE** | |
| **H. Incorporate New Findings** | |
| Step 19. Communicate new scientific findings | Task 4.3 |
| Step 20. Incorporate results of data analyses into Executive Summaries and models | Task 1.7 |
| Step 21. Document the learning process | Task 1.8 |
| Step 22. Update the Long-Term Plan | Tasks 1.6 and 1.7 |

## 6.0 GLOSSARY

**Adaptive Management**: A rigorous approach for designing and implementing management actions to maximize learning about uncertainties that affect management decisions. It involves synthesizing existing knowledge, identifying uncertainties with management relevance, and developing hypotheses related to those uncertainties. The process then calls for exploring management alternatives to test hypotheses, making predictions of their outcomes, selecting one or more actions to implement, and conducting monitoring and research to see if the outcomes match those predicted. The results are used to learn and adjust future management and policy.

**Adaptive Management for the Collaborative Program (2018)**: Effective environmental management in the face of uncertainty by integrating science and learning into effective management under changing conditions coupled with a cyclic strategy producing improved systematic understanding of needs to meet the established goals.

**Management Alternatives:** Includes possible management actions that can be taken given the environmental and funding conditions at the time. "No action" is always an alternative. The Collaborative Program explores and compares the performance of management alternatives available to MRG managers.

**Management Relevance:** When an uncertainty has management relevance, activities performed to reduce that uncertainty will inform management of a system. The results of these activities enable managers to compare the performance of management alternatives in meeting stated objectives. Uncertainties without management relevance may limit understanding of system behavior, but have low to no impact on management decisions.

**Scientific Activities:** The collective of studies, projects, data collection, monitoring, and experimentation.

**Uncertainties:** Gaps in knowledge of a system; indeterminate or inexact understanding of a system state or feature in natural resource management. Being uncertain is not the same as knowing nothing. The Collaborative Program will work to reduce uncertainties that have management relevance as this practice enables natural resource managers to compare the performance of management alternatives in meeting stated objectives.

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# Appendix A. Science and Adaptive Management Plan Implementation Task List

**Table A1. Science & Adaptive Management (S&AM) Plan Implementation Task List.**

| Tasks | Responsible Group(s) | | | | | |
|---|---|---|---|---|---|---|
| | EC | SAMC | AAH | FPC | S&T | SIG |
| **1. FINALIZE AND IMPLEMENT THE S&AM PLAN, THE LONG-TERM PLAN, AND ASSOCIATED TOOLS** | | | | | | |
| **1.1 Support data collection efforts** | | | | | | |
| *1.1a* Provide statistical review for sampling designs | | X | | | X | |
| *1.1b* House collected datasets on the Program Portal, as appropriate | | X | | | | |
| **1.2 Continue development and refinement of conceptual ecological models (CEMs)** | | | | | | |
| *1.2a* Develop and refine the NMMJM and PESU CEMs | | | | | X | X |
| *1.2b* Continually refine the RGSM, YBCU, and SWFL CEMs, as appropriate | | | | | X | |
| *1.2c* Provide training on use of each species CEM | | X | | | X | |
| *1.2d* Link CEMs to management alternatives and objectives | | X | | | | |
| **1.3 Populate the Adaptive Management (AM) Database with the following:** | | | | | | |
| **A. Objectives** | | | | | | |
| *1.3a.* Assess the objectives identified during previous efforts | | X | | | | |
| *1.3b.* Convene an objectives workshop to:<br>• Solicit signatory values to inform development of the objectives<br>• Assess and refine preliminary objectives<br>• Identify additional objectives, as needed<br>• Develop strategies for each objective<br>• Determine and define any metrics | | X | | | | X |
| *1.3c.* Review and adopt approved objectives | X | | | | | |
| **B. Management Alternatives** | | | | | | |
| *1.3d.* Compile and categorize management alternatives | | X | | | X | |
| *1.3e.* Identify additional management alternatives | | X | | | X | |
| *1.3f.* Link management alternatives and Collaborative Program objectives | | X | | | | |
| **C. Scientific Uncertainties and Hypotheses** | | | | | | |
| *1.3g.* Review and update compiled list of scientific uncertainties | | X | | | X | |
| *1.3h.* Determine which scientific uncertainties are reducible | | X | | | X | |
| *1.3i.* Determine which reducible scientific uncertainties can be addressed using existing data | | X | | | X | |
| *1.3j.* Define alternative hypotheses for reducible uncertainties | | X | | | X | |
| *1.3k.* Develop executive summaries for uncertainties for which there is non-consensus about hypotheses. Executive summaries should do the following:<br>• Summarize the available literature<br>• Note areas of agreement<br>• Provide alternative hypotheses<br>• Identify knowledge gaps | | | | | X | |
| *1.3l.* Link hypotheses to Collaborative Program objectives, management alternatives, and recovery goals | | X | | | | |

**Table A1. Science & Adaptive Management (S&AM) Plan Implementation Task List.**

| Tasks | Responsible Group(s) | | | | | |
|---|---|---|---|---|---|---|
| | EC | SAMC | AAH | FPC | S&T | SIG |
| *1.3m.* Identify limiting factors for addressing a hypothesis, for example: • Preliminary studies • Necessary river conditions • Documented presence of species • Technology/equipment needs • Financial resources • Regulatory or political constraints | | X | | X | | |
| **D. Scientific Activities** | | | | | | |
| *1.3n.* Compile existing scientific activities (e.g., project ideas list, annual reports), assign a status, and link to hypotheses (i.e., Project Bank) | | | | | X | |
| *1.3o.* Develop new scopes of work to address the alternate hypotheses and knowledge gaps for inclusion into the Project Bank | | | | | X | |
| **1.4 Operationalize the AM Database** | | | | | | |
| *1.4a* Provide training on use of the AM Database | | X | | X | X | X |
| **1.5 Develop an administrative schedule with the following:** • Signatory funding deadlines • Administrative deadlines • Recovery plan five-year reviews | | | | X | | X |
| **1.6 Populate the Long-Term Plan using the AM Database and the Project Bank** | | | | | | |
| *1.6a* Use the AM Database to rank scientific activities based on relevance to management alternatives and Collaborative Program objectives, and feasibility | | X | | | | |
| *1.6b* Deliberate on incorporation of scientific activities recommended by the SAMC into the Long-Term Plan | X | | | | | |
| *1.6c* Review the Long-Term Plan and incorporate recommendations into individual signatory out-planning | | | | | | X |
| **1.7 Reevaluate Collaborative Program objectives and tools, in light of scientific findings** | | | | | | |
| *1.7a* Synthesize analyses and conclusions into evidence-based recommendations for management alternatives | | X | | | | |
| *1.7b* Review the Long-Term Plan and incorporate recommendations into individual signatory out-planning | | | | | | X |
| *1.7c* Update tools with new scientific findings, as necessary | | | | | X | |
| **1.8 Provide regular progress reports to the EC** | | | | | | |
| *1.8a* Provide quarterly progress reports | | X | | | | |
| *1.8b* Provide an annual science and AM report | | X | | | | |
| **2. DEVELOP AND AGREE ON PROCESSES TO SUPPORT THE IMPLENTATION OF THE S&AM PLAN AND THE LONG-TERM PLAN** | | | | | | |
| **2.1 Revise the scope of work process to incorporate elements from the S&AM Plan** | | X | | | | |
| **2.2 Refine the peer review process, including both internal and external review** | | | X | | | |
| **2.3 Refine the topical executive summary process** | | X | | | | |

**Table A1. Science & Adaptive Management (S&AM) Plan Implementation Task List.**

| Tasks | Responsible Group(s) EC | SAMC | AAH | FPC | S&T | SIG |
|---|---|---|---|---|---|---|
| **2.4 Develop a process for supporting signatory resources and efforts (e.g., lobbying, funding, letters of support)** | | | X | | | |
| **3. IMPLEMENT THE NEW ORGANIZATIONAL STRUCTURE** | | | | | | |
| **3.1 Clarify signatory expectations under the Collaborative Program's science and AM process with the following:** • Annual report • Cost share | X | | | | | X |
| **3.2 Sunset all existing work groups and incorporate any ongoing work into the charges and charters of new ad hoc groups and committees under the new structure** | X | | | | | |
| **3.3 Identify the tasks to be completed under the science and AM process, and draft S&T charges to complete those tasks** | | X | | | | |
| **3.4 Convene S&Ts to complete charges** | | | | | X | |
| **3.5 Update the By-Laws to reflect the new organizational structure and governance** | X | | X | | | |
| **3.6 Draft and adopt a new Memorandum of Agreement** | X | | X | | | |
| **4. COMMUNICATION** | | | | | | |
| **4.1 Science** | | | | | | |
| *4.1a* Hold Brown Bags | | | | | | X |
| *4.1b* Host Science Symposium | | X | | | | |
| *4.1c* Complete topical executive summaries | | | | | X | |
| *4.1d* Publish peer-reviewed works | | | | | | X |
| **4.2 Recommendations to resource managers** | | | | | | |
| *4.2a* Deliberate on SAMC findings and make final evidence-based recommendations on best management alternatives | X | | | | | |
| *4.2b* Make recommendations on scientific activities for implementation | X | X | | | | |
| **4.3 Collaborative Program communication** | | | | | | |
| *4.3a* Update and maintain the Program Portal | Program Support Team, in coordination with the Collaborative Program | | | | | |
| *4.3b* Distribute bi-monthly Collaborative Program newsletter | | | | | | |
| *4.3c* Participate in community outreach | | | | | | |

EC = Executive Committee; SAMC = Science and Adaptive Management Committee; AAH = Administrative Ad Hoc Groups; FPC = Fiscal Planning Committee; S&T = Science and Technical Ad Hoc Groups; SIG = signatories; RGSM = Rio Grande silvery minnow; SWFL = southwestern willow flycatcher; YBCU = yellow-billed cuckoo; NMMJM = New Mexico meadow jumping mouse; PESU = Pecos sunflower; Collaborative Program = Middle Rio Grande Endangered Species Collaborative Program.

# Appendix B. Rio Grande Silvery Minnow Conceptual Ecological Model

## LIST OF BOXES



## LIST OF TABLES



## LIST OF FIGURES

## RIO GRANDE SILVERY MINNOW LIFE HISTORY

The Rio Grande Silvery Minnow (*Hybognathus amarus*, RGSM) is a small-bodied member of the Cyprinid family, native to the Rio Grande basin. The RGSM once occurred throughout the Rio Grande Basin, from the MRG (Middle Rio Grande) all the way to the Gulf of Mexico. Historically, it was also found in important tributaries such as the Rio Chama, Jemez River, and Pecos River (Sublette et al. 1990, Bestgen and Platania 1991, Horwitz et al. 2018).

Currently, the RGSM occupies approximately seven percent of its historic range (U.S. Fish and Wildlife Service [USFWS] 2010, Mortensen et al. 2019). The majority of the population is found in the 280-kilometer reach of the MRG between Cochiti Dam and Elephant Butte Reservoir. Additionally, a much smaller, experimental population was introduced into a small portion of the Rio Grande, near Big Bend, Texas, in 2008. Although limited natural reproduction occurs within the MRG population, the Big Bend population is not believed to be self-sustaining at this time (USFWS 2008, Edwards 2017). The contraction of the RGSM's range is mostly attributed to modifications in hydrology resulting from anthropogenic changes in water use and storage in the basin (USFWS 2016, 2018). Historical loss of RGSM habitat, and an overall decline in RGSM abundance, resulted in the species being listed as endangered under the Endangered Species Act in 1994.

The life history of the RGSM is typical of similar small-bodied, riverine cyprinids that occupy lowland floodplain rivers of western North America (Platania et al. 2020). Spawning begins in the spring during the freshet, just prior to and during peak flows (typically mid-April to mid-May). The exact mechanism that initiates spawning is still unknown, but is likely related to hydrologic and temperature cues (Dudley et al. 2018, USFWS 2018). RGSM are broadcast spawners and highly fecund; a single female may produce anywhere from 2,000 to 10,000 eggs (Caldwell et al. 2019). Eggs become semi-buoyant after fertilization and drift downstream while they incubate. Egg incubation typically lasts for 24–48 hours and is highly temperature dependent (Platania 2000). The spawning strategy of the RGSM depends on reliable flows that are able to disperse eggs and larvae into slower moving, overbank and floodplain nursery habitats (Gonzales et al. 2014). Larvae hatch from their eggs at 4 millimeters (mm) standard length (SL), and, on average, become free swimming four days later, once they reach 5–10 mm SL. Larvae are gape limited and known to eat algae, diatoms, small invertebrates, cyanobacteria, detritus, periphyton, seeds, and pine pollen (Shirey et al. 2008, Magana 2009, Watson et al. 2009, Bixby and Burdett 2014). The larval life stage lasts until mid-July, when larvae transition to juveniles and reach 13–64 mm SL.

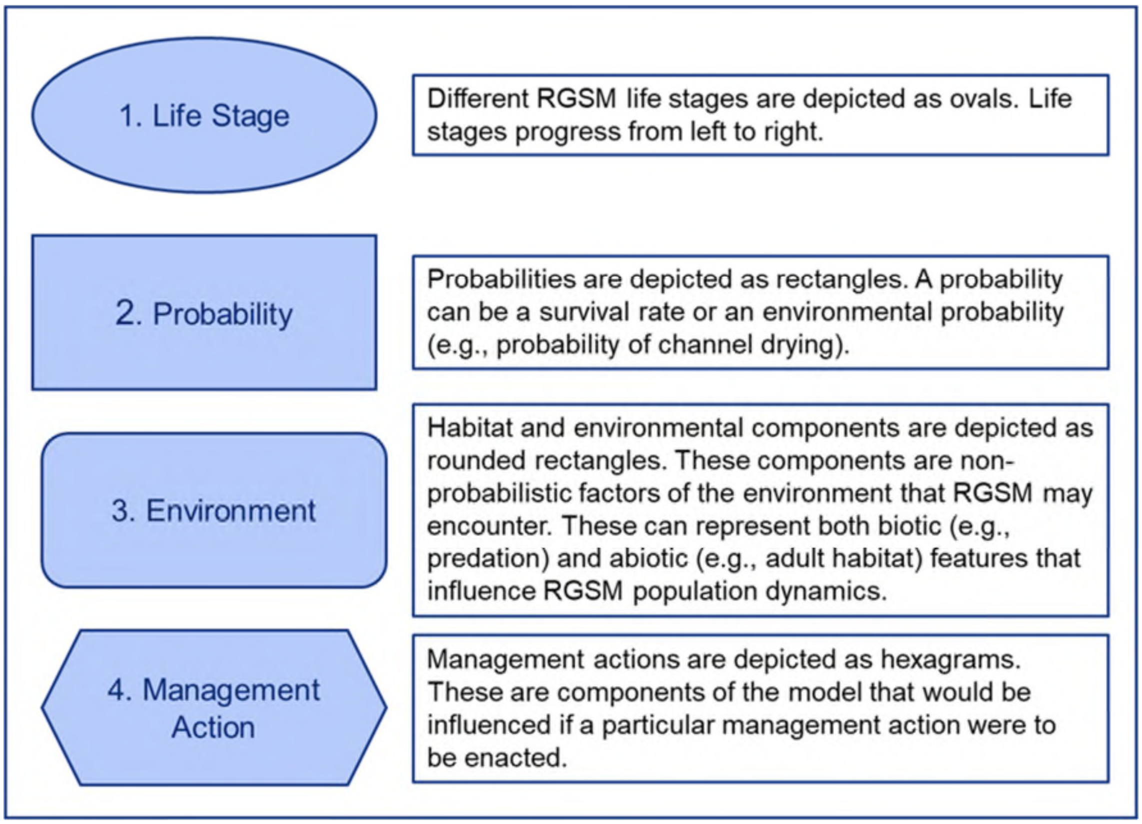
Juveniles primarily occupy in-channel habitats, as declining freshet flows have receded floodplain habitats. Juvenile habitats are notably deeper and in faster moving water than larval habitats. Juvenile RGSM have similar diets to larvae, as RGSM tend to be generalists. Juveniles grow through the summer and fall, before transitioning into adults and reaching 35–90 mm SL, beginning in December. During the summer, it is common for portions of the MRG to dry, leading to fragmentation of suitable RGSM habitats. When drying occurs, the lack of suitable habitat leads to stranding and high mortality for RGSM.

Adult RGSM have almost identical habitat use and diets to juveniles. During the winter, RGSM occupy deeper, slower habitats with adequate cover, which allows them to conserve energy (Platania and Dudley 2003). Sexual maturity is often achieved in less than 12 months, thus fish hatched the previous spring are able to contribute to the population the following spawning season. The typical life span of RGSM in the MRG is two years; however, individuals as old as five years have been observed (Dudley et al. 2018, Horwitz et al. 2018).

## CONCEPTUAL ECOLOGICAL MODEL DESCRIPTION

The RGSM conceptual ecological model (CEM) describes and depicts the life history of RGSM and all related biotic and abiotic factors of the MRG. With that in mind, transition schematics were developed for five RGSM life stages: adult egg production, egg to larvae, larvae to juvenile, juvenile to adult, adult to adult age 2+ (Figures B1–B5). A graphical RGSM CEM was developed from these schematics (Figure B6). The CEM is a variation of an influence diagram, which documents relationships between model components using arrows. There are four types of model components in the RGSM CEM, each one represented by a unique shape, as depicted in Box B1.

**Box B1. Rio Grande Silvery Minnow (RGSM) Conceptual Ecological Model (CEM) Components.**




Each CEM component is connected to at least one other component by an arrow. The direction of the arrow indicates the direction of influence and flow of information. All arrows are unidirectional, meaning a single arrow can only represent a single relationship. The thickness of the arrow represents the importance that the parent component has on the child component (destination; Table B1, Figure B6). The color of the arrow indicates the current level of understanding of the relationship between the components (Table B1). Black arrows indicate life stage transitions.

**Table B1. Relational Arrow Key for the Rio Grande Silvery Minnow Conceptual Ecological Model.**

| Level | Importance of Parent Component to Child Component | Understanding of Relationship |
|---|---|---|
| High | | |
| Medium | | |
| Low | | |

## COMPONENT GROUPS

All model components fall under one of ten categories, which are distinguished by different colors in the graphical model (Figure B6). The ten categories are defined in Table B2 and each one is a factor that influences RGSM. Determining general patterns in the relationships between these factors increases understanding of the RGSM life history. The ten categories also provide specific areas of focus for future studies.

In general, the CEM follows the life history of RGSM from adults in time step *t* to adults in time step *t+1*. The CEM moves chronologically left to right, beginning when adults in time step *t* spawn to create eggs, and progressing as the eggs become larvae, then juveniles, and finally adults in time step *t+1.* Mortality is represented between each time step by survival probabilities. Survival probabilities are informed by various components in the lower portion of the model (Figure B6). A full description of each model component can be found on Table B3.

**Table B2. Rio Grande Silvery Minnow (RGSM) Conceptual Ecological Model Component Categories.**

| Component Category | Definition |
|---|---|
| 1. Life History | Life history components are either RGSM life stages or population vital rates. These components comprise the RGSM life cycle, and are the end points of most other components in the model. |
| 2. Food Availability | Food availability components represent food availability at three different RGSM life stages: larval, juvenile, and adult. Food availability directly influences age-specific survival rates. |
| 3. Predation | Predation components represent the three most common predator categories: fish, avian, and invertebrate. RGSM are prey to a variety of other species in the Middle Rio Grande (MRG), and predation rates directly influence RGSM age-specific survival. |
| 4. Hydrology | Hydrology is a large component because of its influence on and interconnectedness with the system; it influences the RGSM life cycle through temperature, flow, and floodplain inundation. Most hydrologic components are related to flow ($Q$). |
| 5. Geomorphology | Geomorphic components represent the processes that affect the physical shape and environment of the river. These processes determine sediment scouring/deposition, overall river geometry, and other river hydraulics. |
| 6. Habitat | The three types of habitat occupied by RGSM are larval, juvenile, and adult. In general, RGSM use a wider range of stream velocities and depths as they grow from larvae to adults. Habitat availability may directly influence age-specific survival rates. |
| 7. Vegetation | Vegetation components refer to the diversity and density of vegetation that exists in the floodplains and main channel of the MRG. Vegetation helps determine floodplain inundation and overall river geometry. |
| 8. Disease and Parasites | The prevalence of disease and parasites that can adversely affect survival rates of RGSM. |
| 9. Genetics | Genetic diversity is the only component in the genetics category. Genetic diversity is informed by the density of adults present in the system, and influences overall fecundity. |
| 10. Photoperiod | Photoperiod is the change in the amount of daylight throughout the year. The photoperiod component may be a spawning cue, and may only influence fecundity. |

## CONCEPTUAL ECOLOGICAL MODEL SCALE

The RGSM CEM assumes specific spatial and temporal scales. Spatially, the extent of the model includes four reaches of the MRG (Cochiti Reach, Angostura (or Albuquerque) Reach, Isleta Reach, San Acacia Reach). Due to this scale, the model is spatially implicit at resolutions finer than the listed reaches. For example, fish occupying different parts of the same reach are assumed to experience the same mortality rates, and have the same access to habitat. The Northern Reach was excluded from the spatial scale of the RGSM CEM, as RGSM do not exist there. The five MRG reaches are defined in Section 1.3 of the *Science & Adaptive Management Plan*.

The current format of the RGSM CEM depicts the direction, importance, and current level of understanding of the relationships between model components. At this time, it is not possible to identify specific mechanisms for each relationship depicted in the RGSM CEM. However, this model is a tool intended to help managers and stakeholders identify the components and relationships that are most influential to management of RGSM.

Temporally, the RGSM CEM operates on an annual time step. Although much of the biology of RGSM occurs on finer spatial and temporal scales, little monitoring has been done to build a useful system-wide model that can operate at finer resolutions (e.g., 10-km reaches, or on a daily time step). The temporal scale of the RGSM CEM was chosen to reflect the current monitoring methods and population dynamics modeling efforts.

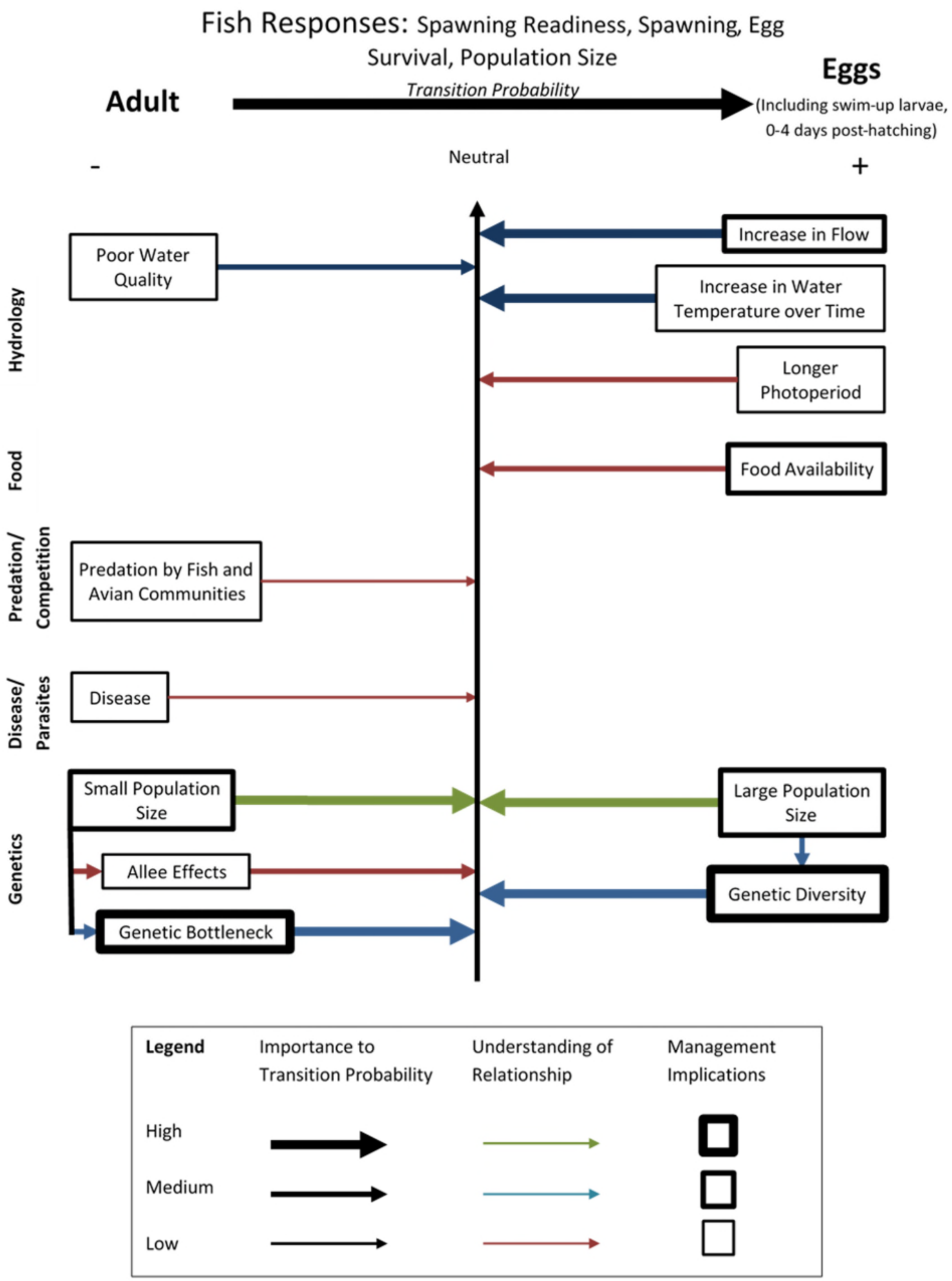



**Figure B1. Rio Grande Silvery Minnow Adult Egg Production Transition Schematic.**

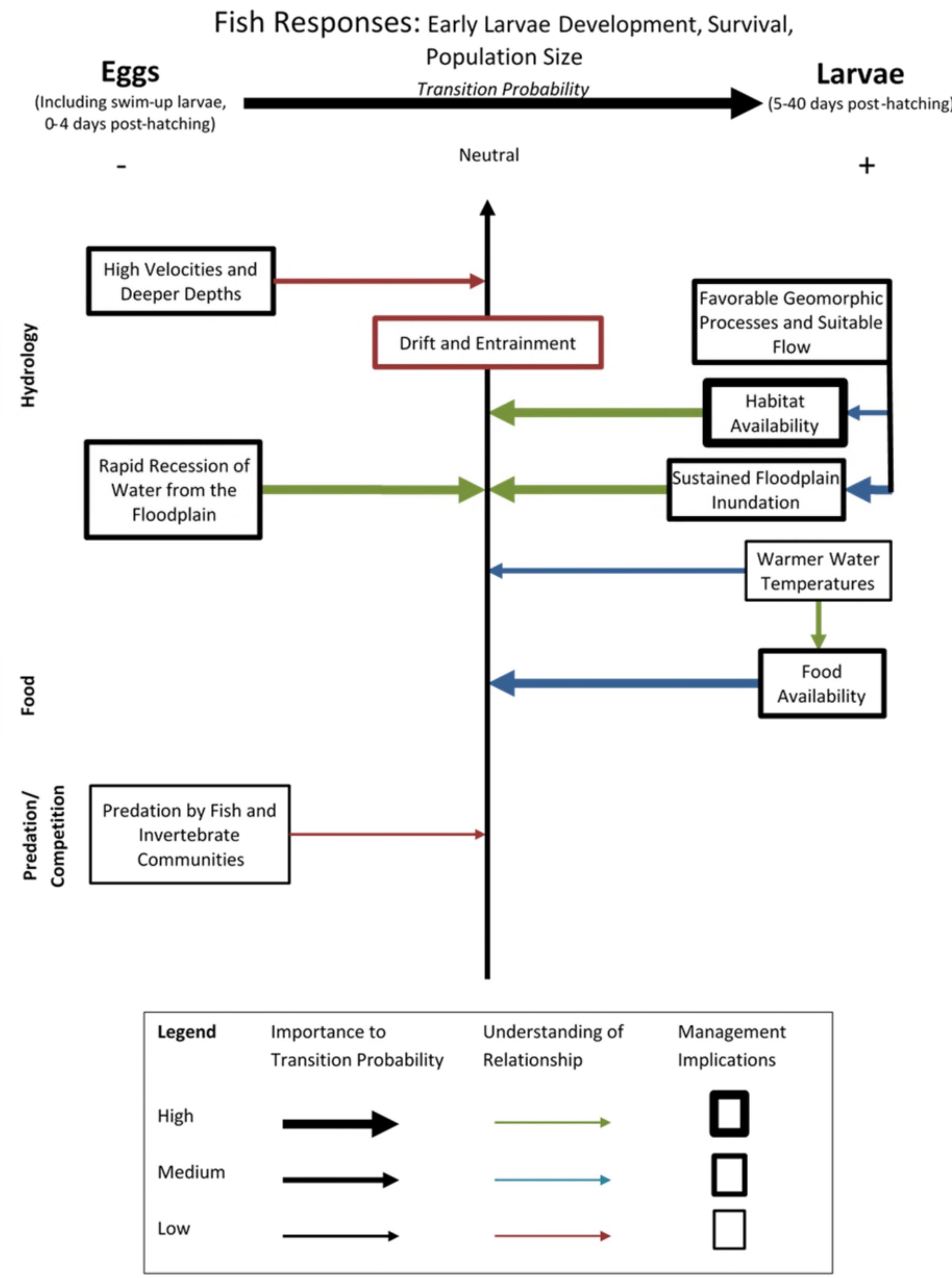



**Figure B2. Rio Grande Silvery Minnow Egg to Larvae Transition Schematic.**

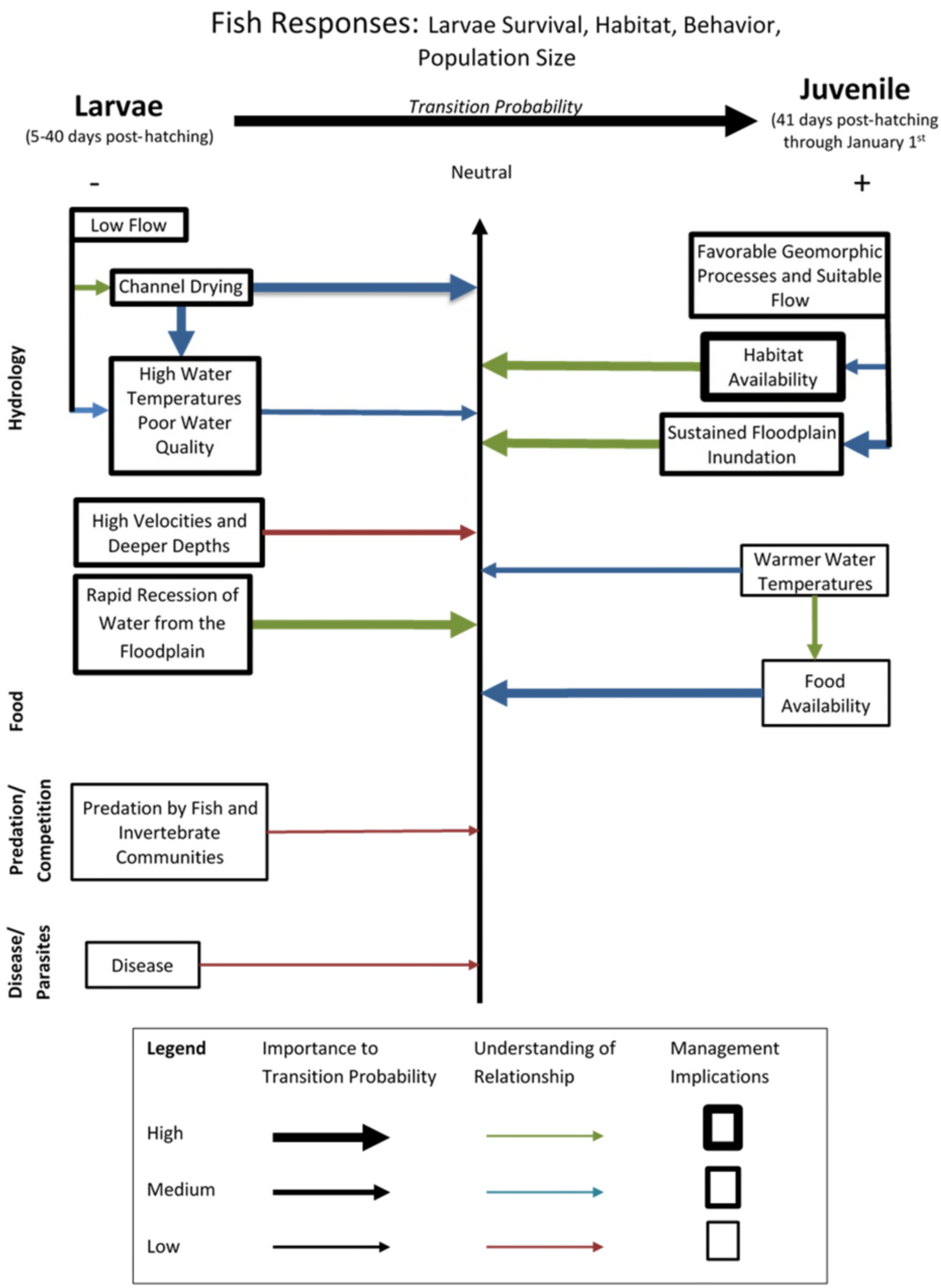



**Figure B3. Rio Grande Silvery Minnow Larvae to Juvenile Transition Schematic.**

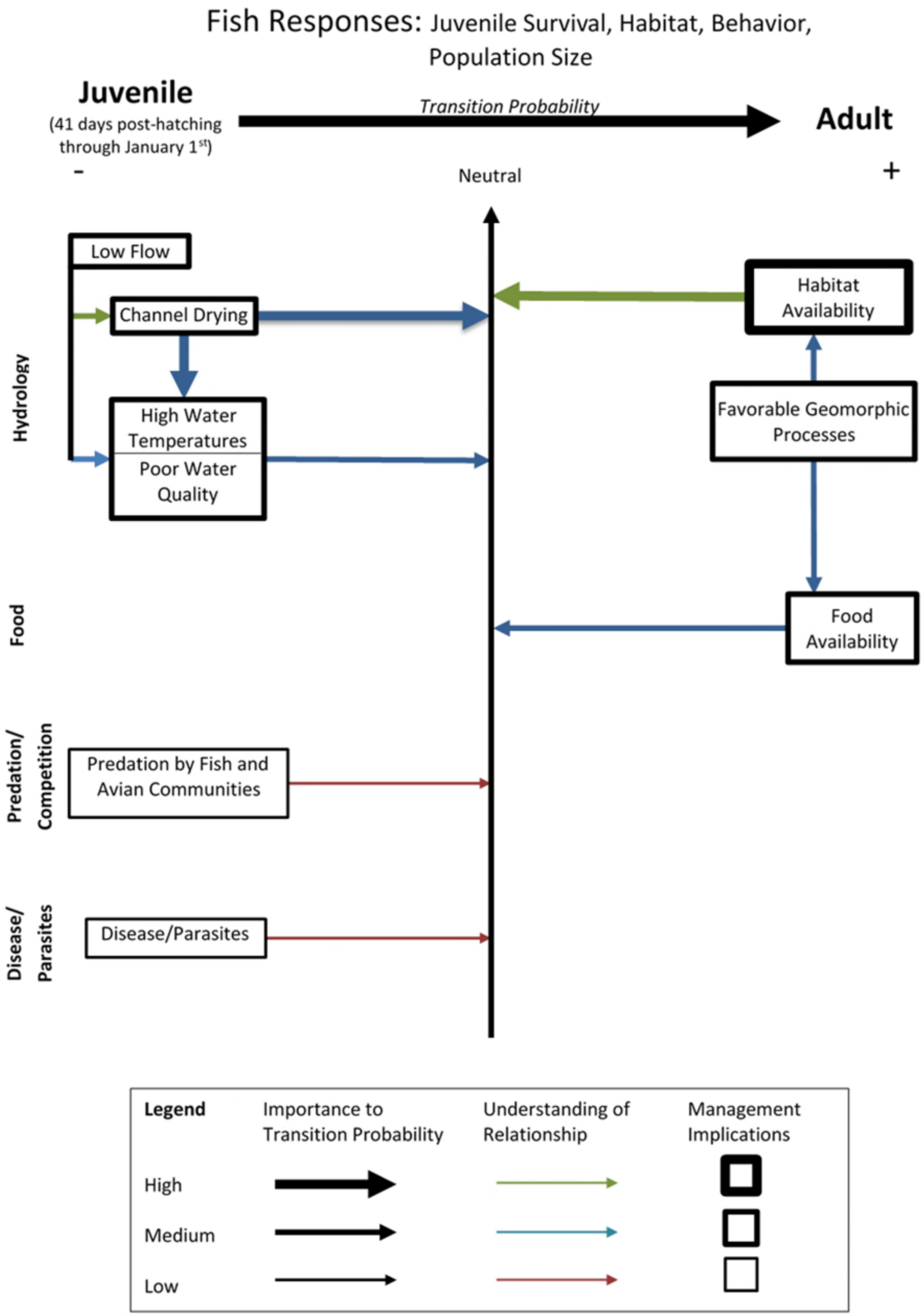



**Figure B4. Rio Grande Silvery Minnow Juvenile to Adult Transition Schematic.**

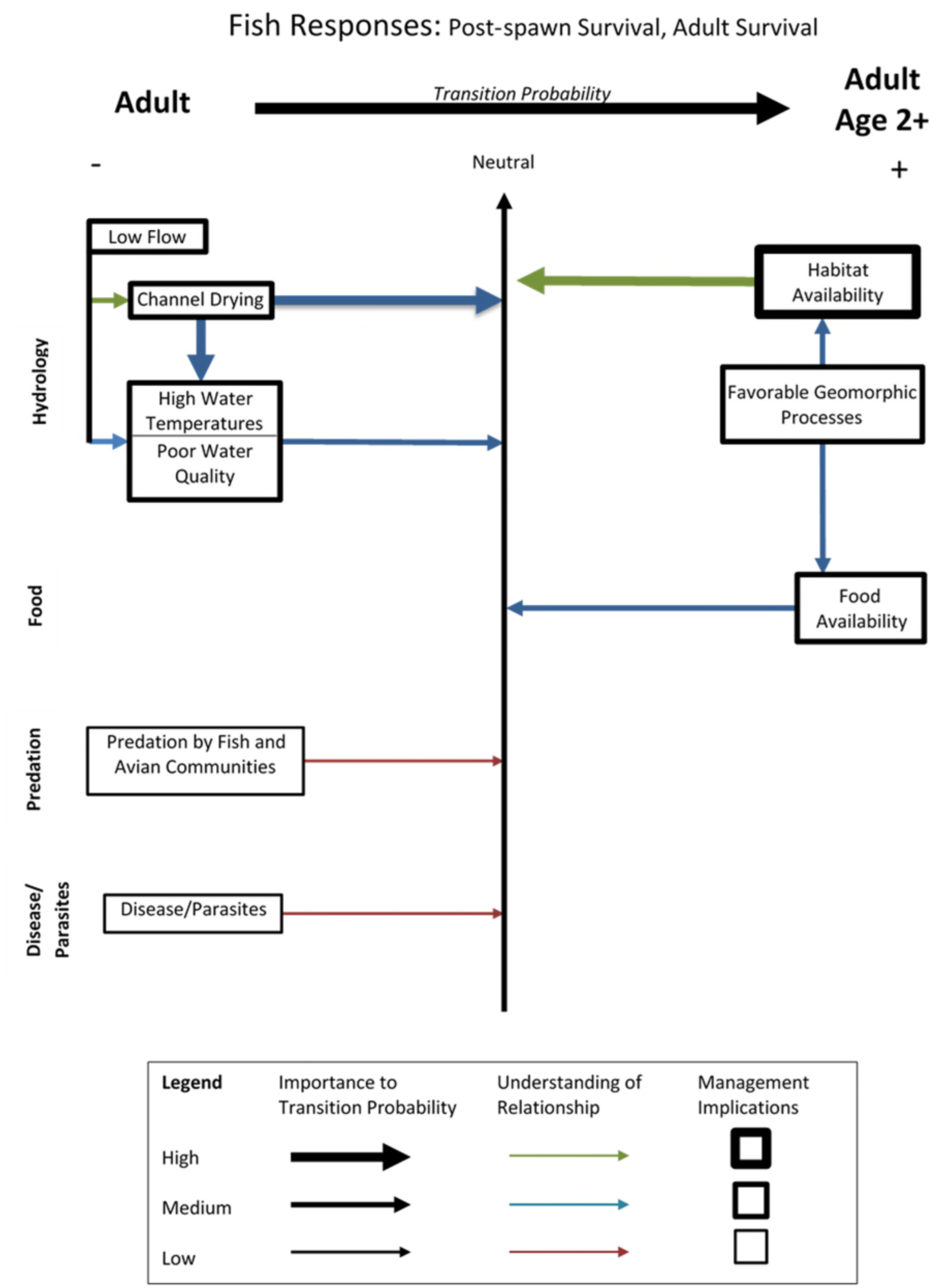



**Figure B5. Rio Grande Silvery Minnow Adult to Adult Age 2+ Transition Schematic.**

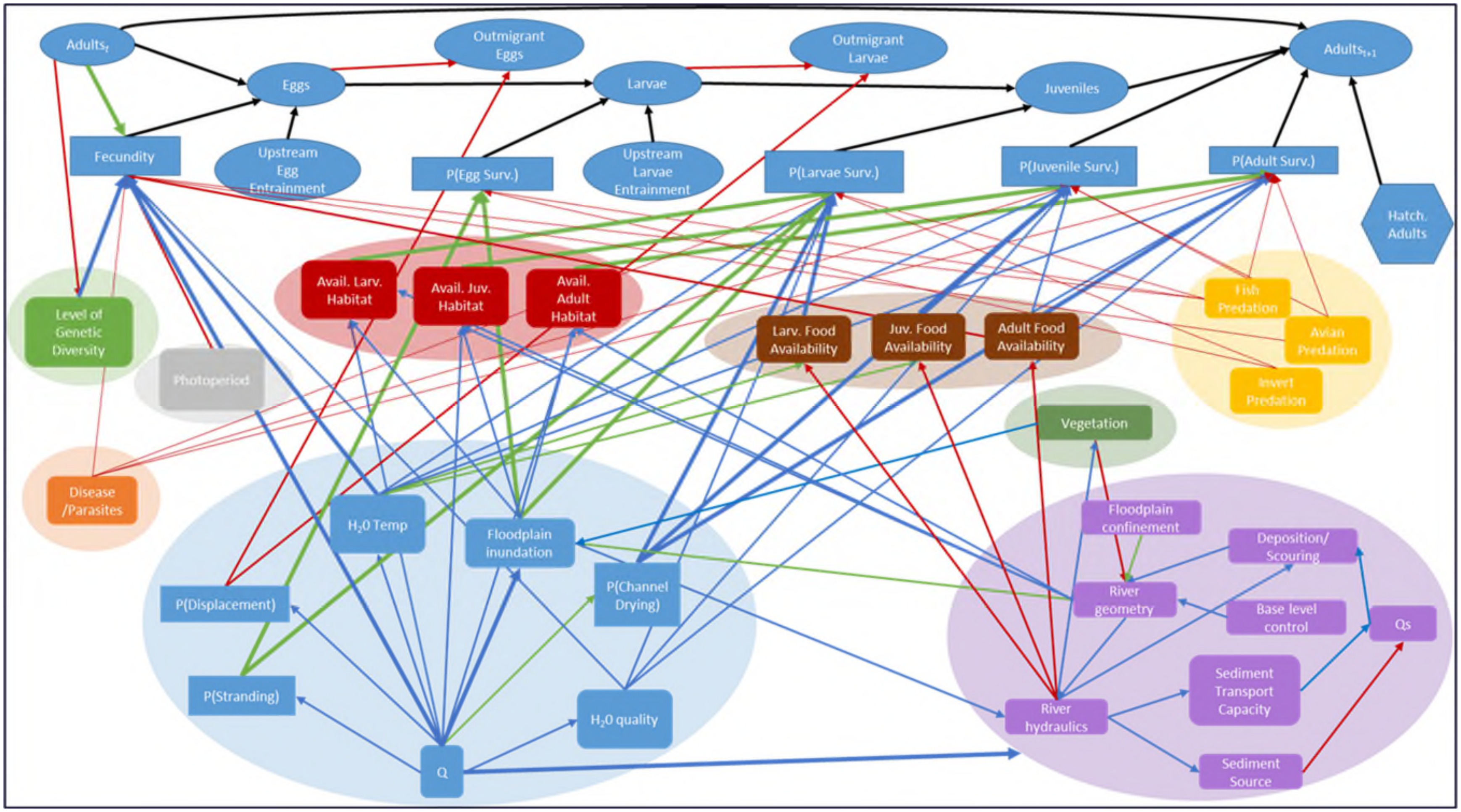



**Figure B6. Graphical conceptual ecological model for the Rio Grande silvery minnow.**

Each model component is connected to at least one other component with an arrow. The direction of the arrow indicates the direction of influence in the relationship and flow of information. The thickness of the arrow represents the importance that the parent component has on the child component. The color of the arrow indicates the current level of understanding of that relationship (red=low, blue=medium, green=high). Black arrows indicate life stage transitions.

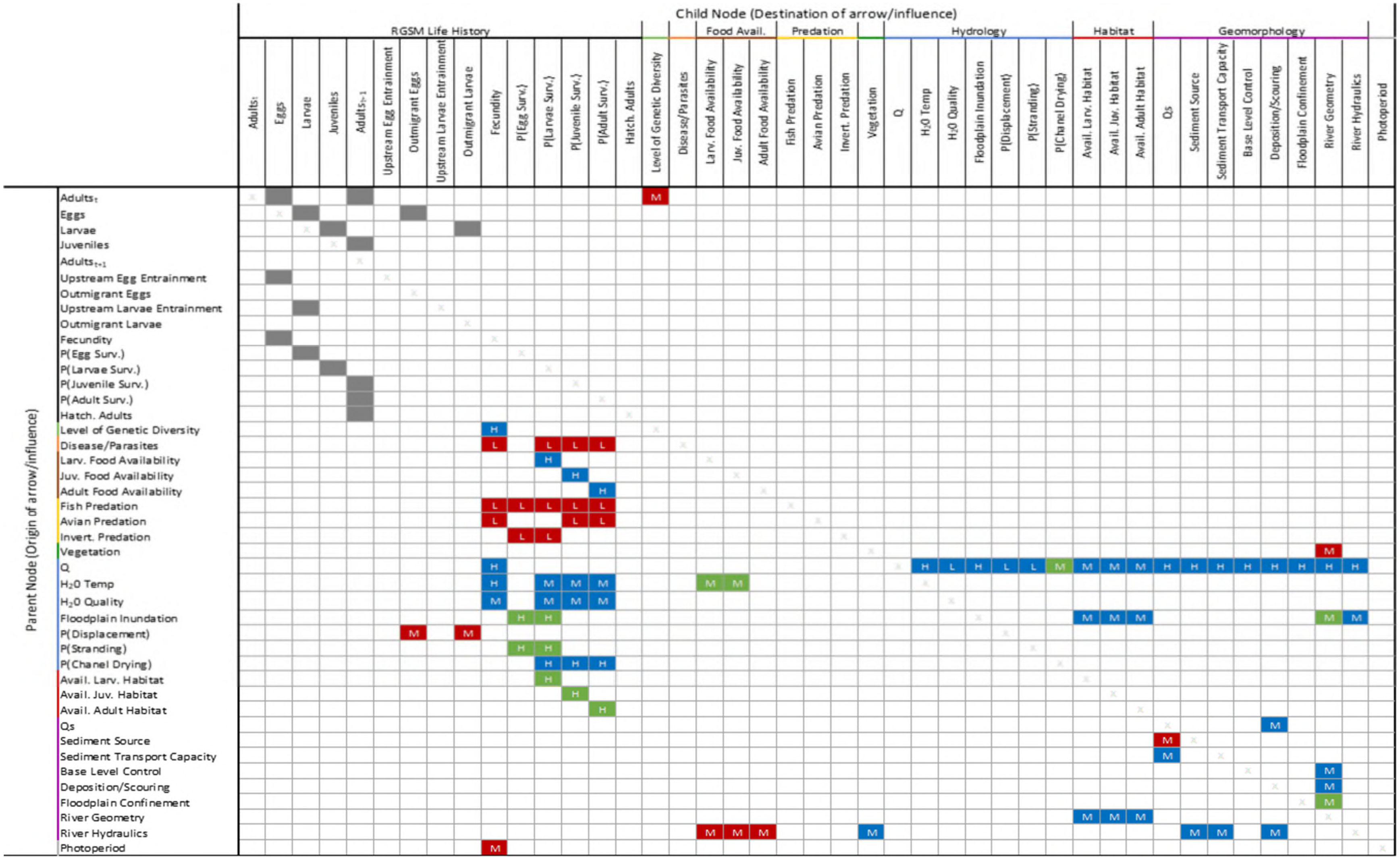



**Figure B7. Rio Grande silvery minnow (RGSM) conceptual ecological model (CEM) relationship matrix.**

The matrix describes every relationship (arrow) in the graphical RGSM CEM. Each row contains the component where a relationship originates (parent), and each column contains the component where that relationship ends (child). The color of the cell at the intersection of a parent and child component indicates the level of understanding of the relationship between them (red=low, blue=medium, green=high), and the letter in each cell indicates the importance the parent component has on the child component (L=low, M=medium, H=high). Grey boxes indicate life history transitions, and blank cells indicate no relationship.

**Table B3. Conceptual Ecological Model Component Descriptions.**

| Component | Category | Description |
|---|---|---|
| $Adults_t$ | Life History | Adult abundance at time step *t*. Adults are present year round in the Middle Rio Grande (MRG), and are classified as individuals >35 millimeters (mm). Adult age Rio Grande silvery minnow (RGSM) are predominately made up of one- and two-year-old fish; however, a small segment of fish can live up to five years. All adults are considered sexually mature and available to spawn. |
| Eggs | Life History | Total number of eggs produced during spawning during time step *t*, calculated by applying the spawning success rate (P(Spawning Success)) to $Adults_t$. |
| Larvae | Life History | The number of larvae produced during time step *t*, calculated by applying the egg survival rate (P(Egg Survival)) to Eggs. Larvae are classified as individuals between 4–13 mm standard length (SL), and can be found in the MRG between mid-April to mid-July. |
| Juveniles | Life History | The number of juveniles produced during time step *t*, calculated by applying larval survival rate (P(Larvae Survival)) to Larvae. Juveniles are classified as individuals between 13–64 mm SL, and can be found in the MRG between mid-July to December. |
| $Adults_{t+1}$ | Life History | Adult abundance at time step *t+1*. $Adults_{t+1}$ are comprised of both Juveniles that survive into adulthood as well as Adults from the previous time step *t*. |
| Upstream Egg Entrainment | Life History | The total number of eggs that are entrained from upstream reaches. |
| Out-migrant Eggs | Life History | The total number of eggs that disperse downstream out of the system/reach. |
| Upstream Larvae Entrainment | Life History | The total number of larvae that are entrained from upstream reaches. |
| Out-migrant Larvae | Life History | The total number of larvae that disperse downstream out of the system/reach. |
| Fecundity | Life History | The mean number of eggs produced by an individual RGSM. |
| P(Egg Survival) | Life History | The mean probability that an individual egg will survive to hatching during time step *t.* |
| P(Larvae Survival) | Life History | The mean probability that an individual larvae will survive to transition into the juvenile life stage during time step *t*. |
| P(Juvenile Survival) | Life History | The mean probability that an individual juvenile will survive to transition into the adult life stage during time step *t*. |
| P(Adult Survival) | Life History | The mean probability that an individual adult will survive to the next time step *t*. |
| Hatch. Adults | Life History | The number of hatchery origin adults stocked in the reach. |
| Level of Genetic Diversity | Genetics | The total amount of RGSM genetic diversity present in the MRG. |
| Disease/Parasites | Disease/Parasites | The prevalence of disease and parasites that can adversely affect survival rates of RGSM. |
| Larval Food Availability | Food Availability | The density of suitable diet items available for consumption by larval RGSM. |
| Juv. Food Availability | Food Availability | The density of suitable diet items available for consumption by juvenile RGSM. |
| Adult Food Availability | Food Availability | The density of suitable diet items available for consumption by Adult RGSM. |

| | | |
|---|---|---|
| Fish Predation | Predation | The prevalence of fish that prey on RGSM. |
| Avian Predation | Predation | The prevalence of birds that prey on RGSM. |
| Invert. Predation | Predation | The prevalence of invertebrates that prey on RGSM. |
| Vegetation | Vegetation | The diversity and density of vegetation that can influence the geomorphic processes in the MRG. |
| Q | Hydrology | Discharge, referring to the magnitude (in terms of peak discharge or volume of water), duration (how long discharge events last), frequency (how often they occur, what time of year they occur), and time sequence (the occurrence of discharge events within a year or over multiple years/decades) |
| $H_20$ Temp | Hydrology | In-stream temperature. |
| $H_20$ Quality | Hydrology | General water quality. |
| Floodplain Inundation | Hydrology | The amount of floodplain habitat created during spring runoff or during other water management activities. |
| P(Displacement) | Hydrology | The probability high flows may displace and disperse eggs and larvae out of the system. |
| P(Stranding) | Hydrology | The probability high flows that create floodplain habitat may recede too quickly and strand RGSM eggs and larvae in disconnected floodplains |
| P(Channel Drying) | Hydrology | The probability low flows may cause portions of the main channel to dry and fragment RGSM habitats. |
| Available Larval Habitat | Habitat | The total amount of RGSM larval habitat available to larval RGSM. |
| Available Juvenile Habitat | Habitat | The total amount of RGSM juvenile habitat available to juvenile RGSM. |
| Available Adult Habitat | Habitat | The total amount of RGSM adult habitat available to adult RGSM. |
| Qs | Geomorphology | Sediment load, referring to the magnitude (peak concentration or load or volume of sediment), gradation of sediment, portion of sediment size class moving in suspension or as bedload (or in-between), etc. |
| Sediment Source | Geomorphology | Where the transported sediment comes from (banks or beds of rivers, uniform or concentrated deposition sources from tributary inputs, e.g., fines from a tributary may coat a large section of a river, whereas coarser material deposits on the alluvial fan at the tributary confluence). The sources may be recent deposits, older deposits that have consolidated, or erosion of the bed or bank. |
| Sediment Transport Capacity | Geomorphology | The theoretical ability of the channel to move sediment of a given size class. |
| Base Level Control | Geomorphology | The influence of reservoir or in-stream channel features to cause backwater effects influencing river geometry and river hydraulics |
| Deposition/ Scouring | Geomorphology | The process of sediment being added or subtracted to a given cross section. This is dependent on grain size, and both addition and subtraction may occur at a given location, e.g., a bank could be eroding, while at the same time deposition is occurring on a bar opposite the erosion. |
| Floodplain Confinement | Geomorphology | The lateral constraint of the river from local geology or placement of engineered/spoil levees. |
| River Geometry | Geomorphology | The slope, width, mean depth, channel sinuosity, channel planform, cross section shape, wetted perimeter, XS area |

| | | |
|---|---|---|
| River Hydraulics | Geomorphology | How fast the water is moving (velocity), depth of the water, force the water applies at interfaces (shear stress, drag, water buoyancy, etc.) |
| Photoperiod | Photoperiod | The changes in daylight duration during the spring time, which may act as a spawning cue. |

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# Appendix C. Southwestern Willow Flycatcher and Yellow-Billed Cuckoo Conceptual Ecological Models

## LIST OF FIGURES

## AVIAN SPECIES CONCEPTUAL ECOLOGICAL MODELS

The conceptual ecological models (CEMs) for the southwestern willow flycatcher (*Empidonax traillii extimus*; SWFL) and yellow-billed cuckoo (*Coccyzus americanus*; YBCU) were developed in tandem, and are very similar. The SWFL and YBCU CEMs were developed around each species' life cycle. As both species are neo-tropical migratory songbirds, their basic life stages are the same (Figure C1). With the exception of Migration Southbound, Overwinter, and Migration Northbound, all other life stages are applicable to the Middle Rio Grande (MRG).

The avian species CEMs do not show relationships between variables in the way the RGSM CEM does (Appendix B). Much uncertainty exists in both the SWFL and YBCU basic life histories. These knowledge gaps must be addressed before building relational CEMs, like that of the RGSM.

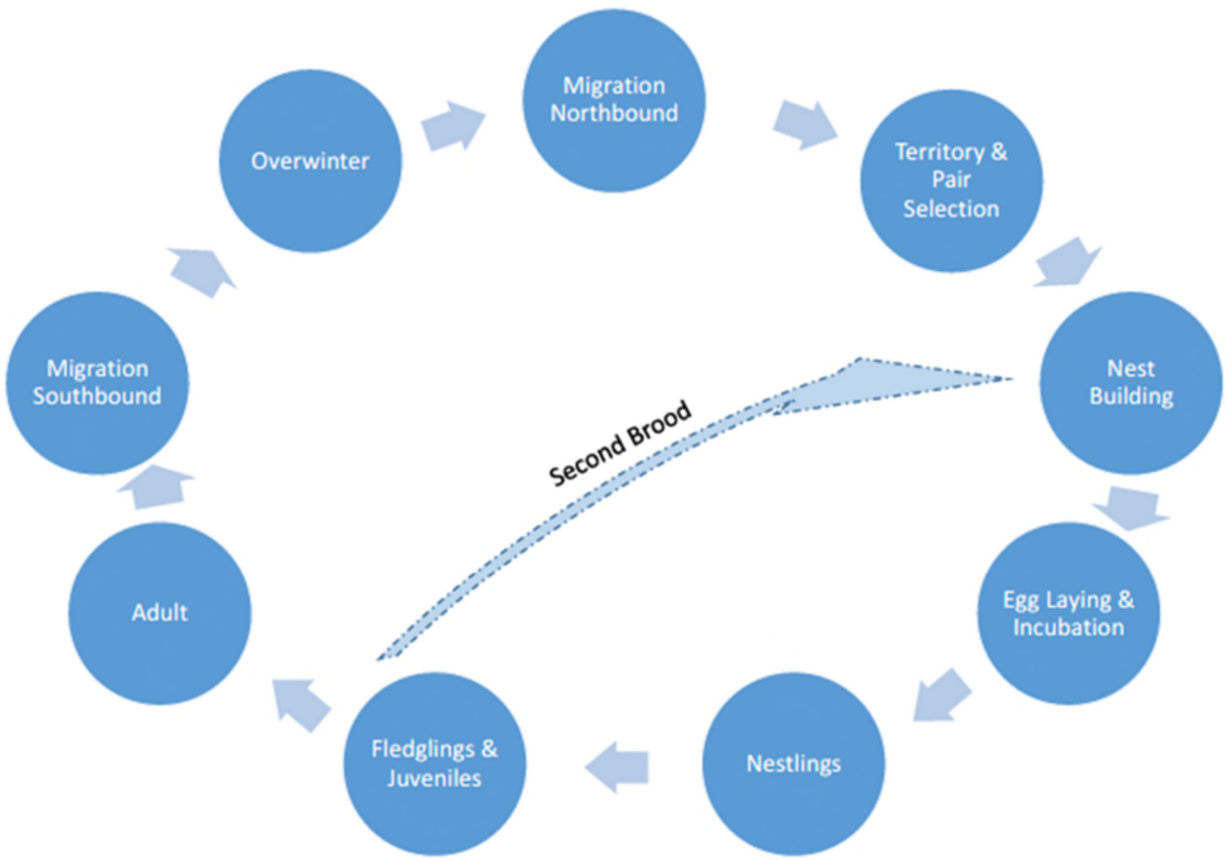


**Figure C1. Basic Life Cycle for the Southwestern Willow Flycatcher and Yellow-Billed Cuckoo.**

### Southwestern Willow Flycatcher Life History

The SWFL is a small perching bird less than 15 centimeters long, from bill to tail. It was listed as endangered in 1995 (Sogge et al. 2010). A primary reason for the species decline is the loss and degradation of its dense, native riparian habitat due to the anthropogenic modification of waterways through channelization and damming, water diversions and groundwater pumping, and alterations to the riparian zone. The SWFL is one of four recognized subspecies of willow flycatcher. SWFL overwinter in Mexico, Central America, and northern South America. They migrate north to breed in dense riparian habitats in the Southwest, including in the MRG (U.S. Fish and Wildlife Service [USFWS] 2002).

USFWS revised critical habitat for the YBCU in January 2013 to follow Recovery Plan goals, and identified 1,975 stream kilometers in Arizona, New Mexico, southern California, Nevada, Utah, and Colorado as breeding habitat (USFWS 2013). The current range of the YBCU is similar to their historic range, but population numbers have declined due to loss of suitable riparian habitat.

Northbound migrating SWFL arrive in the MRG in early May, and select territories and mating pairs through the spring (USFWS 2002; Sogge 2010). Little information exists on SWFL pair selection. The female of the breeding pair ultimately selects the nest site, choosing territory that can provide food, water, and shelter. SWFL breeding pairs prefer dense riparian habitat near or adjacent to surface water, or with saturated soil, which are both important for creating a microclimate at the nest site and habitat for the SWFL prey base of flying insects, such as mosquitoes (Sedgwick 2000; USFWS 2002; Sogge 2010). Generally, SWFL nesting sites are characterized by multi-age vegetation stands with 50–75 percent mid-story cover and dense cover that is 3–6 meters high (USFWS 2002). This dense vegetation provides protection from predators, and contributes to the cooler microclimate of the nest site (Sedgwick 2000). The species also exhibits site fidelity, and breeding pairs have been observed returning to the same nesting site in subsequent years, even if the quality of the site has degraded.

Within two weeks of pair selection, the female builds a cup-shaped nest over the course of 5–7 days, without help from the male (USFWS 2002; Sedgwick 2020). Egg laying generally occurs from mid-May through mid-June. SWFL lay 3–4 eggs per clutch over a span of 4–5 days. Eggs hatch in 12–14 days. Once hatched, the nestlings remain in the nest for 14–15 days before they fledge (leave the nest but are not fully independent). SWFL fledglings are capable of short flights (approximately 30 meters), and after leaving the nest, will remain in their parents' nesting territory for about 14 days before dispersing (Sedgwick 2020).

There is very little information on SWFL young-of-year once they have fledged and become juveniles, as surveys stop at that life stage. The life history of SWFL between the fledging life stage and leaving for the southern migration is a large data gap. Broods likely break up once the SWFL become juveniles, as there have been no reports of flocking immature SWFL.

SWFL sometimes have a second brood within a single breeding season. The likelihood of a second brood increases when the offspring from the first clutch fledge by late June or very early July. Re-nesting is common if the first nest is lost or abandoned. Clutch size decreases with each nest attempt. The proximity of the second nest to the first varies greatly, and could be on the same plant or up to several kilometers away (USFWS 2002; Sedgwick 2020).

The migration of SWFL south to their overwinter grounds is believed to begin sometime in mid-August through September, though there is uncertainty around the exact timing of migration, and the factors that influence that timing, as survey efforts have been focused around the breeding season (USFWS 2002).

### Yellow-Billed Cuckoo Life History

The Western U.S. Distinct Population Segment (DPS) of the YBCU was listed as threatened under the ESA on October 3, 2014 (USFWS 2014). YBCU are medium-sized birds about 30 centimeters in length. The YBCU's historic range was west of the Continental Divide, stretching from British Columbia down to northern Mexico. Today, the breeding habitat of the Western DPS of the YBCU population is along rivers in Arizona, California, and New Mexico (USFWS 2014; Hughes 2020). YBCU are riparian species, and require large expanses of riparian habitat at the landscape level with a mosaic of different vegetation (Johnson 2009; Hughes 2020).

YBCU arrive at their breeding grounds in mid- to late May to mid-June (Sechrist et al 2012; Hughes 2020). Little is known about YBCU pair selection (Johnson 2009). YBCU require a nest patch size of about five hectares with 50–75 percent mid-story cover that is 3–10 meters high. YBCU foraging territory is even larger, and individuals have been observed to have territories of 75–100 hectares (Johnson 2009; Dillon and Moore 2020).

At the nest patch scale, canopy cover is critical for providing the protection and microhabitat necessary for nest success. YBCU also prefer nest habitat in close proximity to water, especially if there is a low velocity flow of shallow depth underneath the nest. Nearby water contributes to the nest microclimate, and provides habitat for the YBCU's insect prey base. Both the male and female in a pair build the nest on a horizontal branch or fork of a tree over the course of several days (Hughes 2020).

While females can lay between 1–5 eggs per clutch, clutch size is usually 2–3 eggs. One egg is usually laid every other day, but females may wait up to five days between eggs. Eggs are incubated over 9–11 days. The duration of the egg laying and incubation period varies between 13–20 days total. Both parents help with incubation (Hughes 2020). Additionally, pairs may have younger males that assist with incubation (USFWS 2014; Hughes 2020). The degree of contribution from colony incubation is a knowledge gap, in terms of both level of effort, and genetics. There are data showing that different males and females may genetically contribute to eggs in the same brood (McNeil 2015).

YBCU are opportunistic feeders; they mainly eat large insects, but also prey on small lizards and amphibians. YBCU require a large amount of food, especially as nestlings. Both parents feed and brood the young equally, and nestlings transition to the fledgling stage by day 7–9. Once YBCU fledglings become juveniles, they (along with their parents) leave the nest patch after a day. Adult YBCU may lay second, and even third, clutches, sometimes with different partners (USFWS 2014).

As with the SWFL, little is known about YBCU life history once the young reach the juvenile stage. YBCU leave for their fall migration beginning in early to late August, with most birds departing by mid-September (Sechrist 2012; Hughes 2020).

## AVIAN SPECIES CONCEPTUAL ECOLOGICAL MODELS DESCRIPTION

The avian CEMs were developed in tandem, and are very similar. Both CEMs focus on life stages, with each life stage depicted as a bulls-eye graphic divided into wedges. Each wedge represents a driver or stressor at a particular life stage. A driver is a variable that is beneficial to the species at a specific life stage, and contributes to species success. A stressor is a variable that negatively affects the species at a specific life stage, and contributes to species failure, including mortality. The bulls-eye models also depict the level of importance of each variable, the ability to manage each variable, and if there are high level uncertainties related to each variable. The relative size of each variable wedge has no significance Figure C2 provides a legend for the avian CEMs.

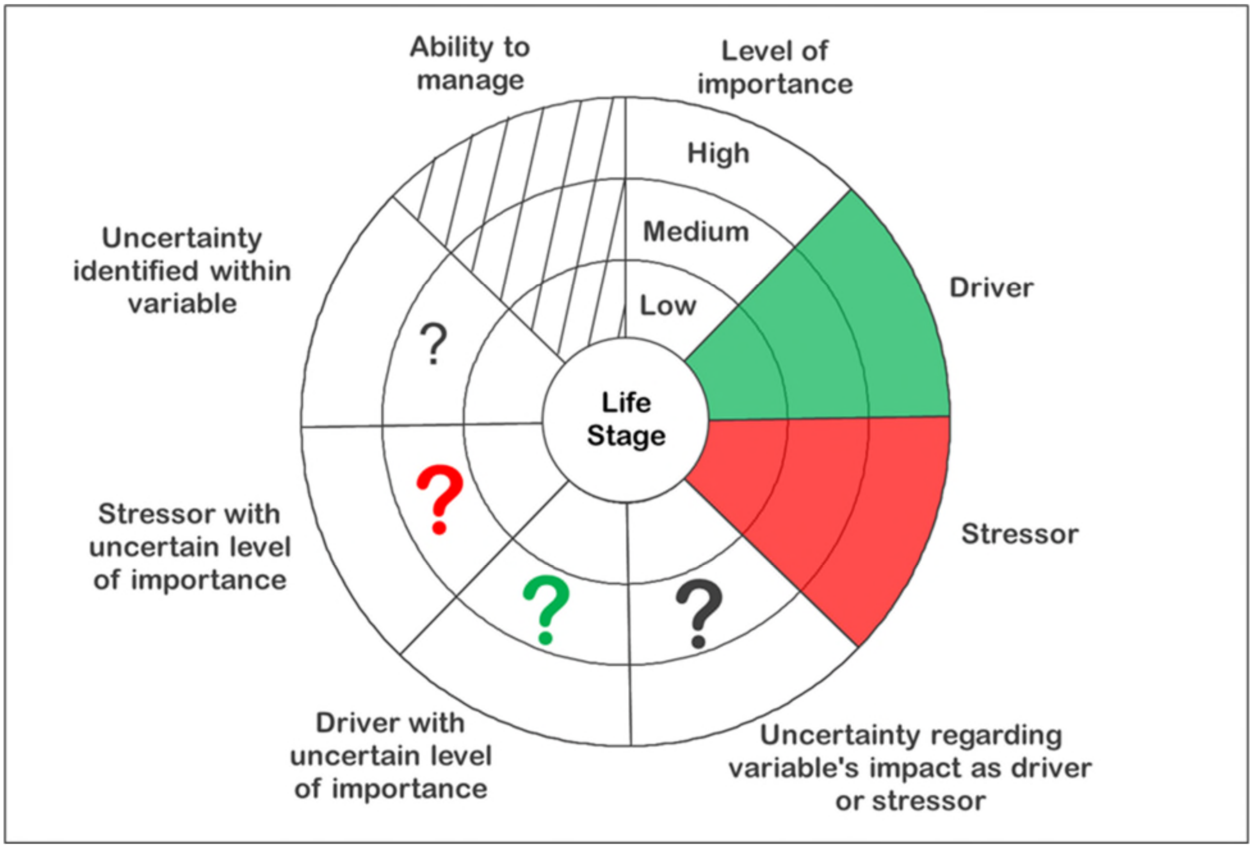


**Figure C2. Avian Conceptual Ecological Model Legend.**

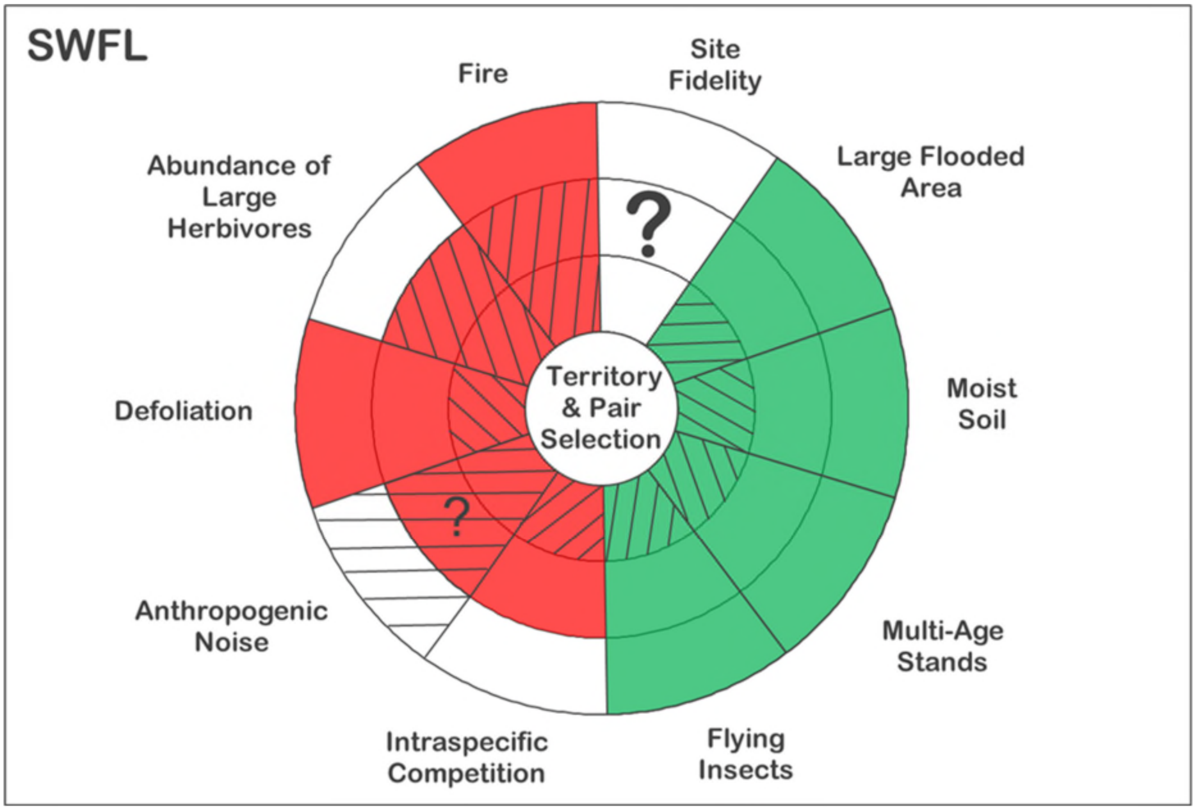

Figure C3. Southwestern Willow Flycatcher Territory and Pair Selection Life Stage.

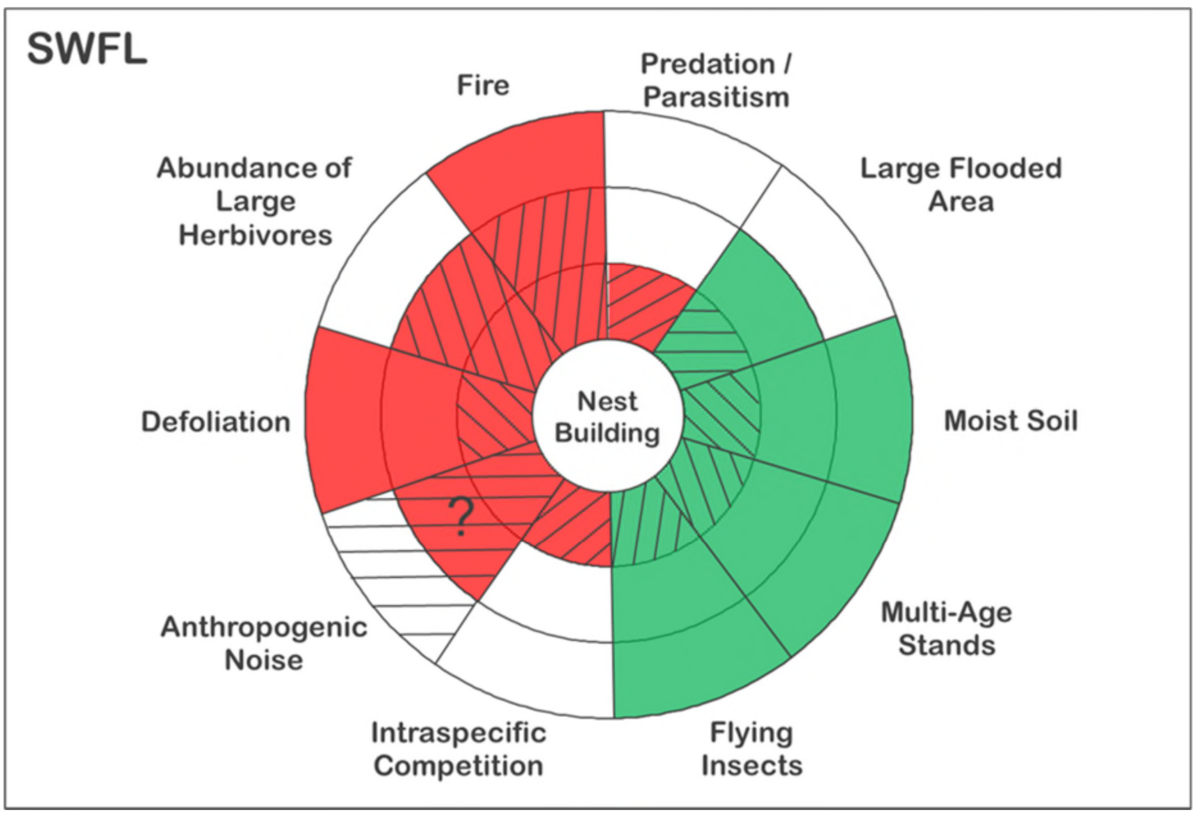

Figure C4. Southwestern Willow Flycatcher Nest Building Life Stage.

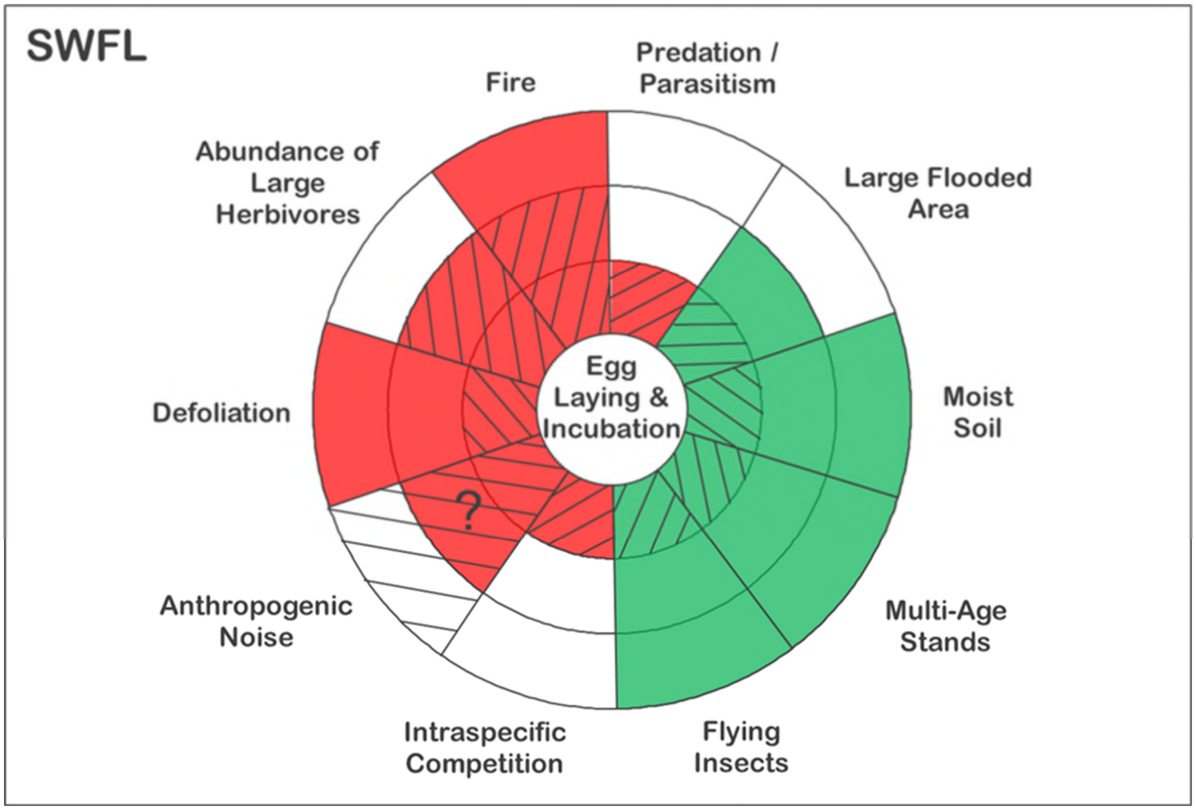


**Figure C5. Southwestern Willow Flycatcher Egg Laying and Incubation Life Stage.**

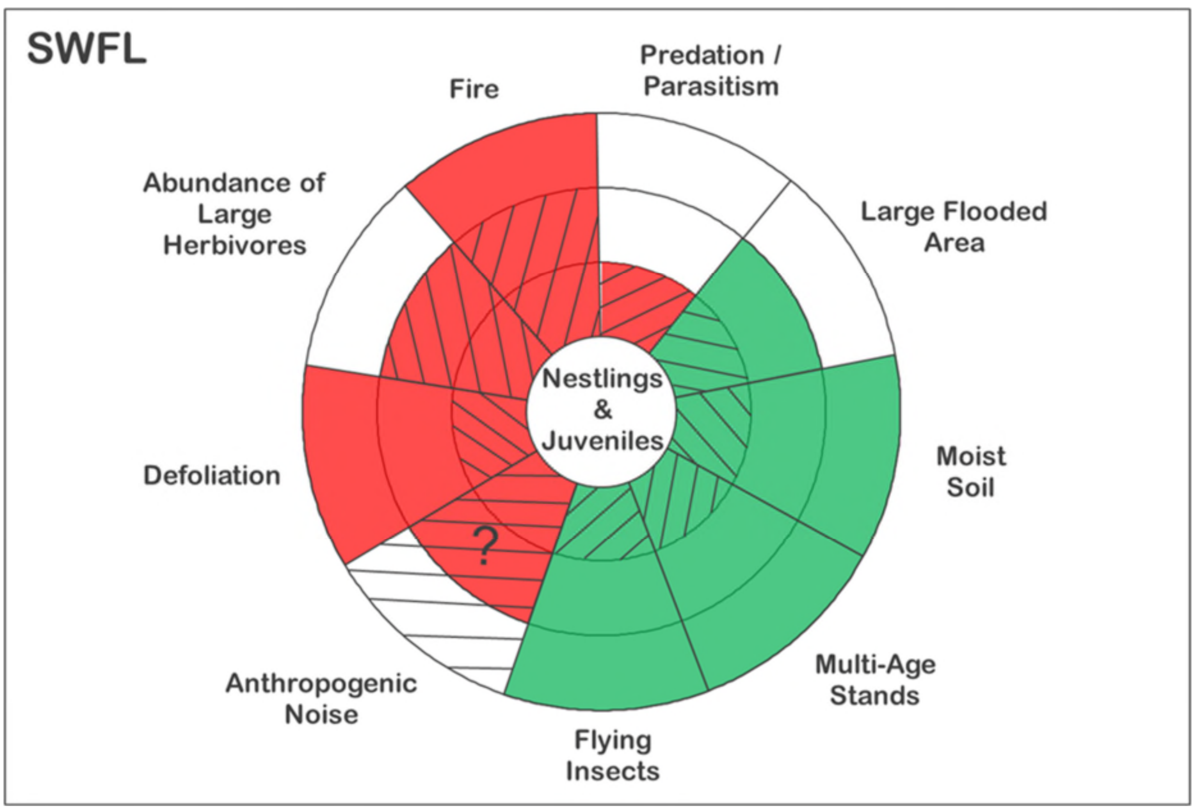


**Figure C6. Southwestern Willow Flycatcher Nestlings and Juveniles Life Stage.**

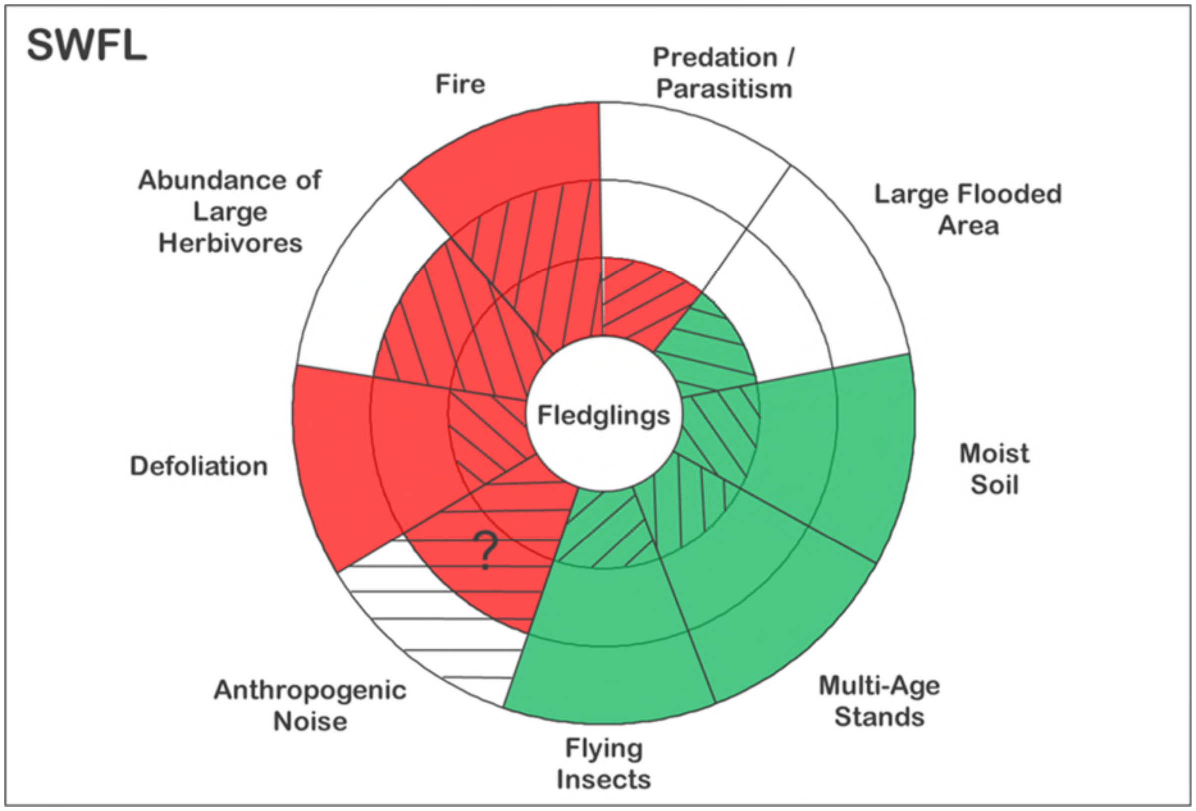


**Figure C7. Southwestern Willow Flycatcher Fledglings Life Stage.**

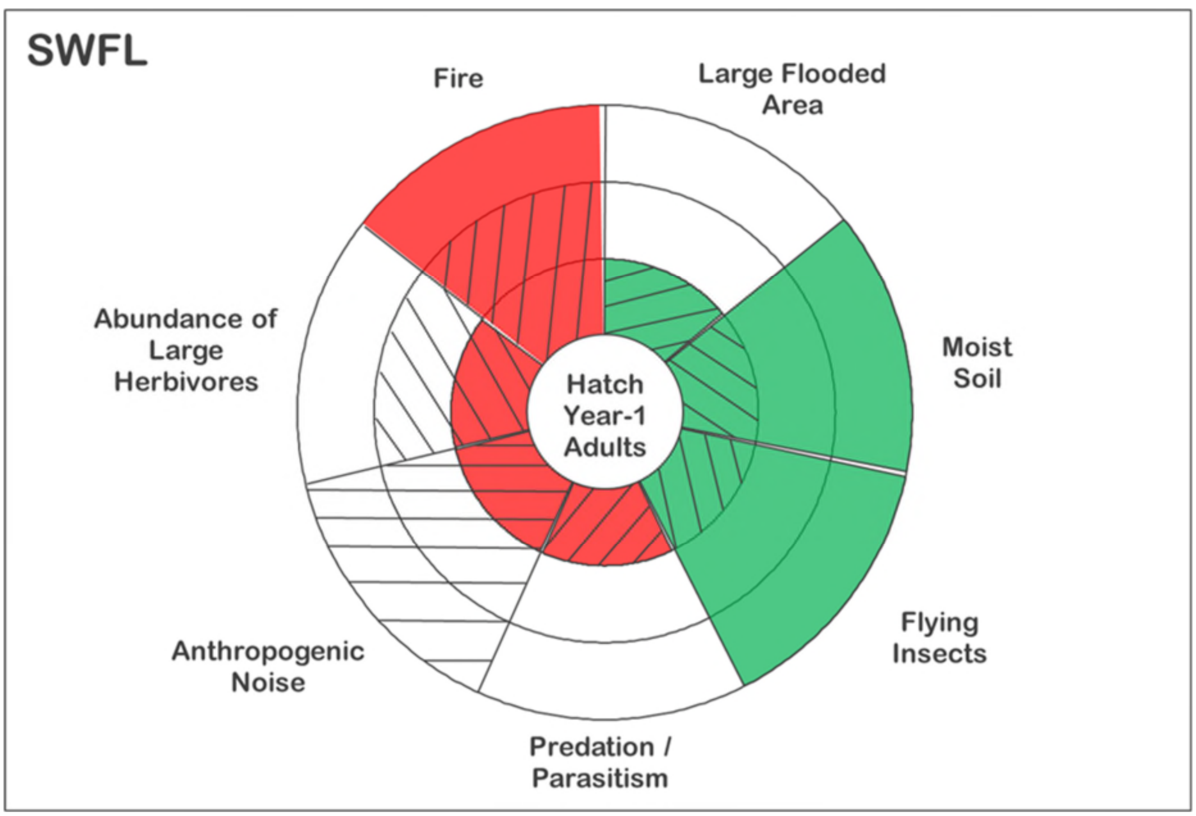


**Figure C8. Southwestern Willow Flycatcher Hatch Year-1 Adults Life Stage.**

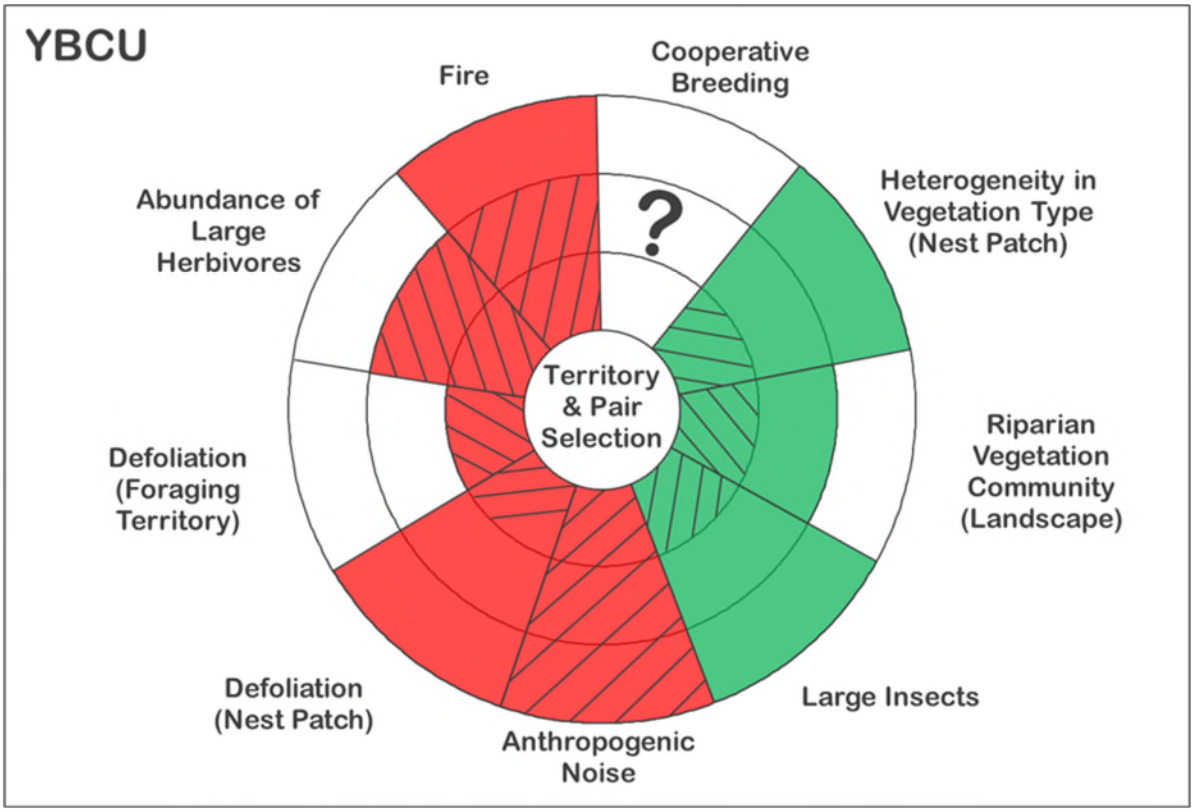


**Figure C9. Yellow-Billed Cuckoo Territory and Pair Selection Life Stage.**

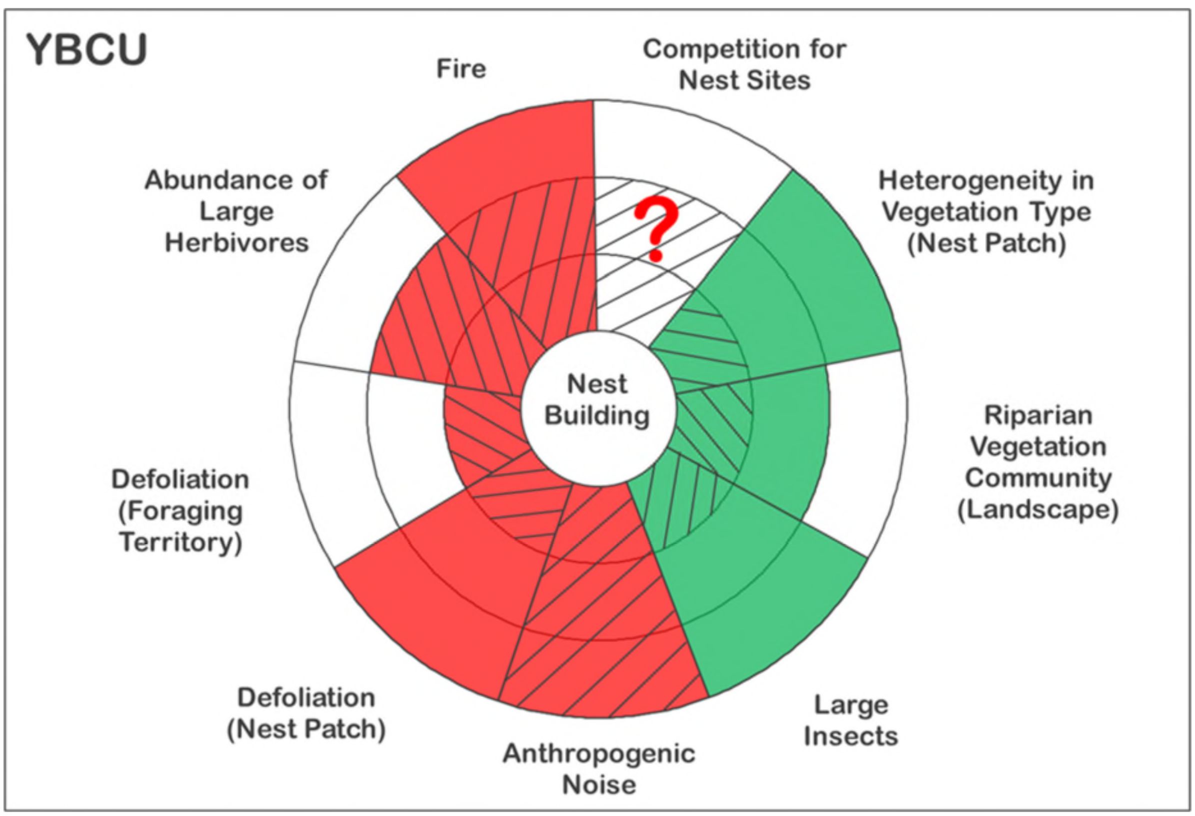


**Figure C10. Yellow-Billed Cuckoo Nest Building Life Stage.**

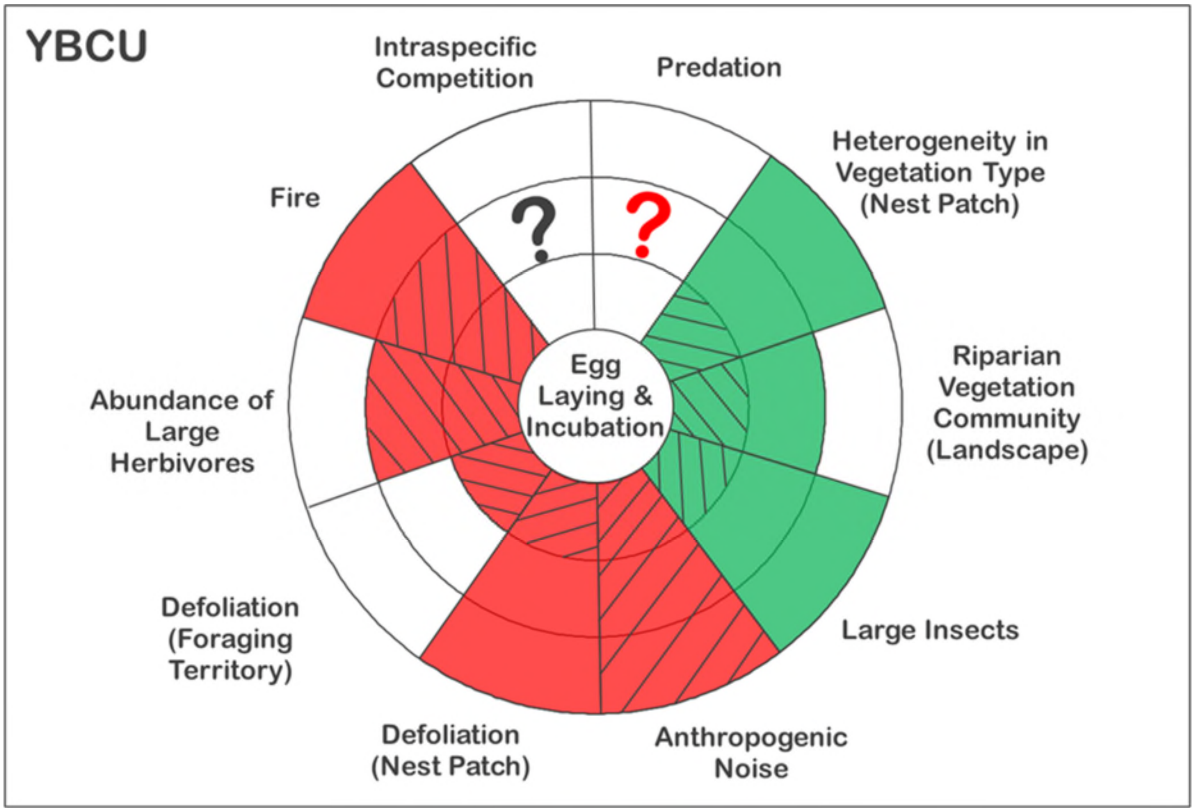


**Figure C11. Yellow-Billed Cuckoo Egg Laying and Incubation Life Stage.**

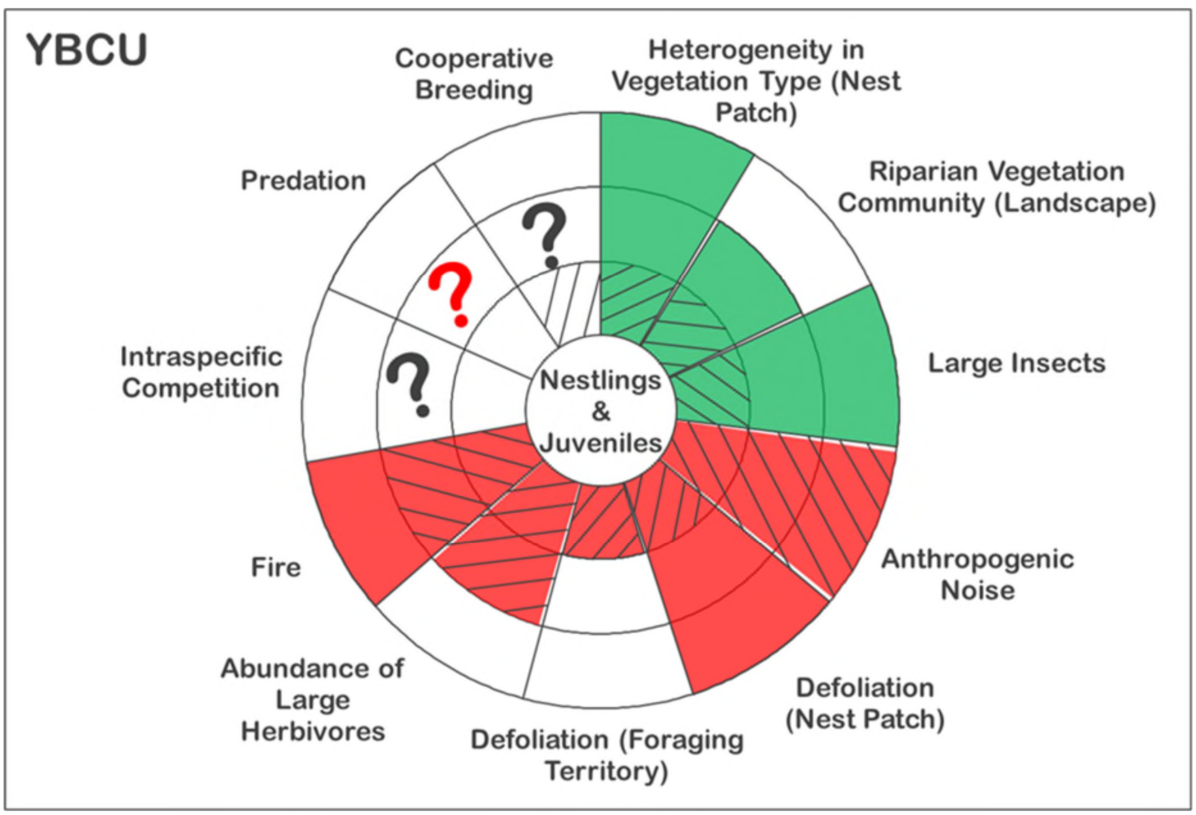


**Figure C12. Yellow-Billed Cuckoo Nestlings and Juveniles Life Stage.**

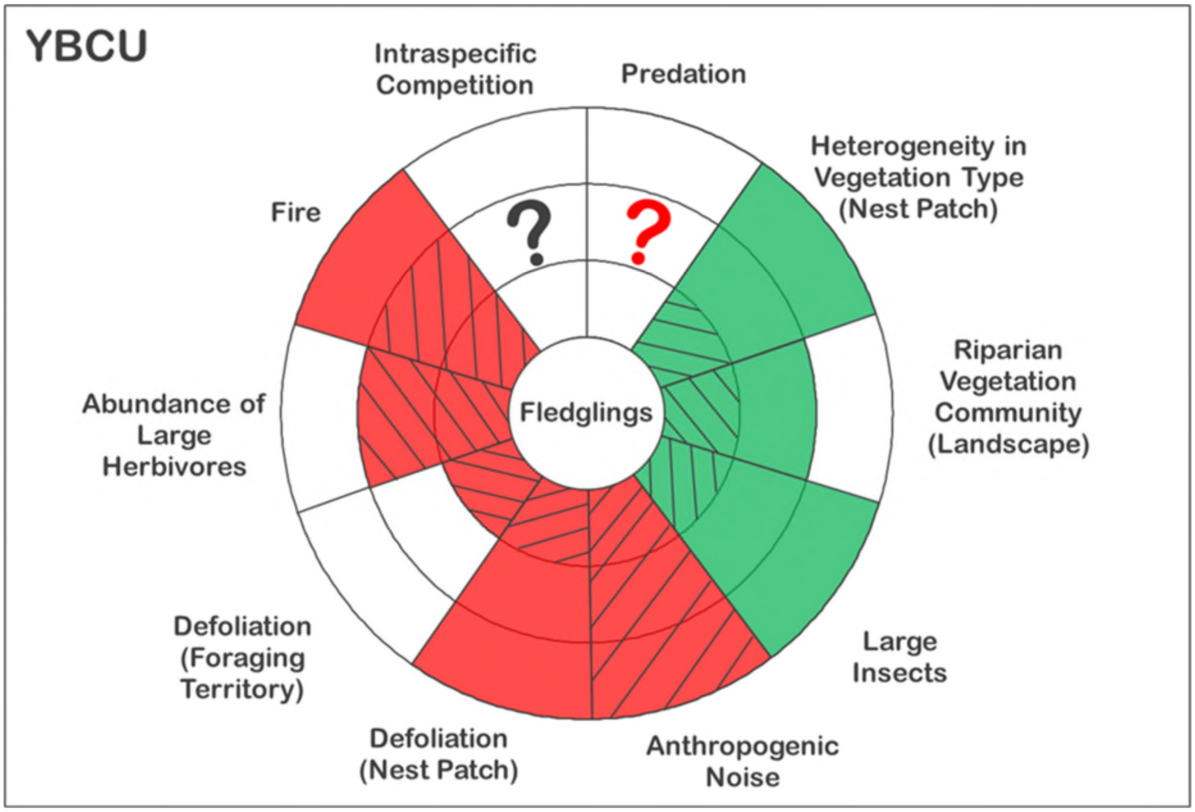


**Figure C13. Yellow-Billed Cuckoo Fledglings Life Stage.**

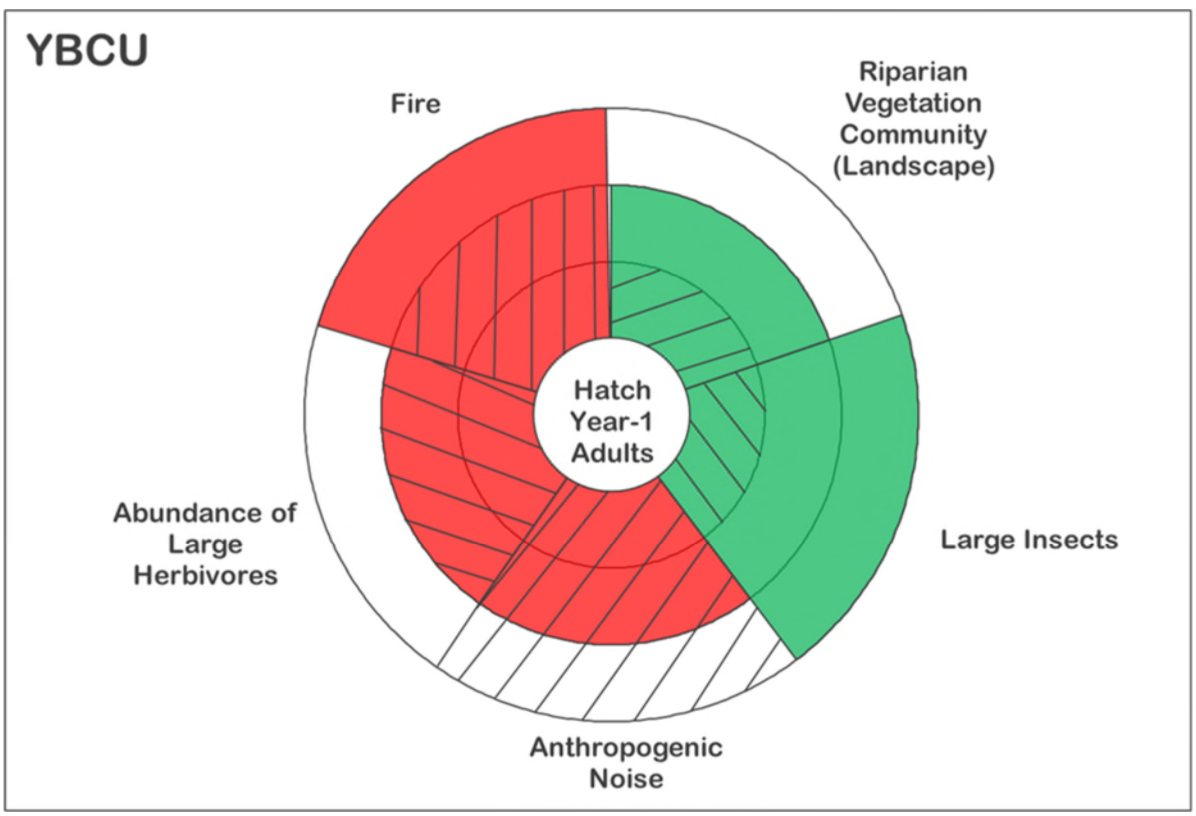


**Figure C14. Yellow-Billed Cuckoo Hatch Year-1 Adults Life Stage.**

# AVIAN CONCEPTUAL ECOLOGICAL MODELS LIFE STAGES DEFINITIONS

## Migration and Overwintering

### *SWFL*

Northbound Migration: SWFL are late spring migrants with arrival dates as early as May in Arizona (Phillips et al. 1964), and from the second week of May to mid-June in California (Small 1994). Captures recorded in 1994 and 1995 during spring migration occurred in the central Rio Grande valley of New Mexico between May 13 and June 8, with a peak in the first week of June, but varied by site and year (Yong and Finch 1997). Habitat used during spring migration is likely similar to that described for fall. In New Mexico, the SWFL is known to migrate regularly along the Rio Grande (Yong and Finch 1997) and the Pecos River (Hubbard 1987), and occurs regularly as a migrant in the southwestern-most desert region and the eastern-most plains region of the state (Hubbard 1987). Migration requires high-energy expenditures and successful foraging in unfamiliar areas, and exposes SWFL to predators. As a result, migration is the period of highest mortality within the annual cycle of the SWFL (Paxton et al. 2007). Willow flycatchers of all subspecies sing during northbound migration, perhaps to establish temporary territories for short-term defense of food resources.

Southbound Migration: Fall migration begins when adult birds depart from their breeding territories, generally in early to mid-August, but some birds may stay until mid-September if they fledged young late in the season (Phillips et al. 1964, Yong and Finch 1997). Unpaired males that fail to attract a mate, and pairs that repeatedly lose nests to nest parasitism or predation, may leave territories by early July. Fledglings leave the breeding areas a week or two after adults, likely because young birds undergo pre-basic molt on breeding grounds (adding to the length of their stay), while adults delay pre-basic molt until they reach wintering grounds (Unitt 1987, Yong and Finch 1997). Habitat use during migration is similar to breeding habitat, including riparian woodlands with open overstory and dense mid- and low-stories, and adjacent agricultural fields with close proximity to water. The highest capture rates in one study along the Middle Rio Grande occurred within willow habitat, followed by dense young cottonwood-Russian olive stands. The affinity for willow habitat and higher body mass recorded for SWFL in this habitat is likely due to higher densities of arthropods (McCabe 1991, Yong and Finch 1997). The mass gained by recaptured YBCU suggests stopover to replenish fat stores during migration is necessary for the species (Yong and Finch 1997). In New Mexico, birds are known to migrate regularly along the Rio Grande (Yong and Finch 1997).

Overwinter: The Pacific lowlands of Costa Rica, as well as other regions of Central America, seem to be the most important wintering grounds for the *extimus* subspecies based on genetic data (Paxton et al. 2011). On the wintering grounds, flycatchers use habitat with standing or slow-moving water and/or saturated soils, patches of trees, woody shrubs, seasonally inundated floodplains with emergent vegetation, pastures, and open areas, often within agricultural landscapes (Lynn et al. 2003, Schuetz et al. 2007). The presence of water or saturated soils seems to be more important than vegetative structure (Schuetz et al. 2007). Individuals defend territories throughout the winter and show high fidelity to wintering territories (Koronkiewcz et al. 2006, Sogge et al. 2007). Survivorship is thought to be high over the wintering period (Koronkiewcz et al. 2006). Threats on the wintering grounds include human-driven disturbance, such as mining and logging, as well as grazing by domestic livestock (Schuetz et al. 2007).

### *YBCU*

Migratory routes of western YBCU are not well known because few YBCU specimens collected on wintering grounds have been assigned to western or eastern populations. Western YBCU depart 2–3 weeks earlier than eastern cuckoos (Hughes 2020). Departures begin in early to late August, with most birds gone by mid-September, though some may depart later (Hughes 2020, McNeil et al, 2011).

Most information on migratory routes is based on two birds fitted with geolocators. Both birds suggested a loop migration route, with distances between 9,500–9,900 kilometers. The first recaptured bird migrated south, through Central America, to winter in portions of Bolivia, Brazil, Paraguay, and Argentina (Sechrist et al. 2012). The second bird passed through the Caribbean region, and wintered from mid-November to late April in the Gran Chaco of central South America, near the borders of Paraguay, Bolivia, and Argentina (McNeil et al. 2015).

Spring migration routes differed for both birds; the first bird migrated north through the Caribbean, and moved between New Mexico and Mexico at the end of summer in 2009, and again in 2010, before being recaptured at its breeding site. The second bird passed through Peru and Central America on its way north (McNeil et al. 2015). This bird also appeared to pause in southern Arizona or Sonora before and after migration, paralleling the first tracked bird. Data from these two birds show dynamic migration strategies, and suggest the monsoonal region may be important to the western YBCU population during the migratory stage of its life cycle.

Western YBCU arrive on breeding grounds starting mid- to late May, 4–8 weeks later than eastern YBCU occurring at the same latitude (Franzreb and Laymon 1993). Considerable numbers of Western YBCU are usually not present until early to mid-June, and transients continue to travel through late June to mid-July (Hughes 2020).

Little information exists for habitat use during migration. Western YBCU may migrate north, along greening riparian corridors and surrounding landscapes, following monsoon precipitation (Wallace et al. 2013).

## Territory and Mate Selection

This life cycle stage occurs upon arrival of adult birds to the breeding ground, where they must choose a mate and select a breeding territory. Birds choose territories that can provide food, water, shelter, and nesting sites.

### *SWFL*

Little information exists on SWFL pair selection. Studies on other *Empidonax* species indicate that pairs form using coordinated movements and sounds (Tarof and Ratcliffe 2000). Female SWFL ultimately select their nest sites.

### *YBCU*

There is even less information on YBCU pair selection. Pairs may visit potential nest sites together frequently prior to building nests.

## Nest Building

Nest building occurs when a bird or mated pair is actively building a nest before egg-laying begins. Nest building within a territory usually begins within a week or two of pair formation. Nest building is an energetically expensive activity for birds (Mainwaring and Hartley 2013).

### *SWFL*

The female SWFL builds a nest over the course of 5–7 days without help from the male. The nest begins with a platform of grass or strips of vegetation, and, using her beak and body, the female weaves grass through the platform vegetation to form a cup.

### *YBCU*

Together, a male and female YBCU build a nest over the course of several days. The nest is placed on a horizontal branch or fork of a tree, and is constructed from small twigs, pine needles, and similar material.

## Egg-Laying and Incubation

Egg laying generally begins between mid-May and mid-June, depending on the geographic area and elevation. This life cycle stage begins when females are actively laying eggs and continues through incubation until all eggs hatch. The energetic cost of egg production and incubation for female birds is poorly understood.

### *SWFL*

SWFL lay 3–4 eggs per clutch. Generally, one egg is laid per day, with one day skipped, so the egg-laying period takes between 4–5 days. SWFL eggs hatch in 12–14 days, thus the entire egg-laying and incubation period is between 16–20 days, on average. Males do not assist with incubation.

### *YBCU*

YBCU females can lay between 1–5 eggs in a clutch, but usually lay 2–3. Usually, YBCU lay one egg every other day, but females may wait up to five days between laying eggs. Eggs hatch in 9–11 days, and male and female YBCU share incubation duties. Helper males may assist with incubation. YBCU start incubation as soon as the first egg is laid, often resulting in nestlings of different ages in the same nest. The YBCU egg-laying and incubation period can be quite variable, lasting between 13–20 days.

Knowledge Gap: There is uncertainty around YBCU colony incubation and colony helping. Who contributes to eggs? Who contributes to incubation?

## Nestlings

The nestling life cycle stage occurs from the time the first egg hatches until the young leave the nest. During this life stage, nestlings and their adult parents are very vulnerable; nestlings are susceptible to predation, while adult parents expend a lot of energy foraging and protecting the nest.

*SWFL*

The nestling life cycle stage is very energetically costly for SWFL parents, as they bring food to their nestlings up to 22 times per hour. Female SWFL do the majority of brooding and feeding the young, but males do play a role in food provisioning. The nestling period lasts around 14–15 days.

*YBCU*

Growth is extremely rapid for YBCU nestlings; the YBCU nestling life stage can be as short as 17 days from the start of incubation, which is among the shortest of any bird species. Both parents brood and feed the young equally. Occasionally, a nonparent adult, or "helper" bird, will assist with caring for nestlings. Most YBCU nestlings have fledged and started to venture away from the nest by day eight.

### Fledglings

The fledgling life cycle stage occurs after young birds leave the nest, but before they are fully independent from their parents. Studies on fledgling survival for most bird species are lacking.

*SWFL*

SWFL young are capable of short (30 meter) flights at the time they leave the nest. SWFL young huddle together for 3–4 days after leaving the nest, and remain in adult SWFL territory for around 14 days before dispersing.

*YBCU*

YBCU young leave the nest at 7–9 days, and both parents and young leave the vicinity of the nest after one day.

*Knowledge Gap*

The uncertainty around what happens between the SWFL and YBCU fledgling life cycle stage and when they leave for full migration. There is some indication that the species may be vulnerable once they fledge, but there is no monitoring data.

### Juveniles

The juvenile life cycle stage occurs after young birds leave parent territory, and no longer depend on their parents for food.

*SWFL*

SWFL broods likely break up once the young enter the juvenile life cycle stage, as the flocking of immature SWFL has not been reported.

*YBCU*

There is little information for YBCU in the juvenile life cycle stage.

## SOUTHWESTERN WILLOW FLYCATCHER AND YELLOW-BILLED CUCKOO CONCEPTUAL ECOLOGICAL MODEL GLOSSARY

As noted previously, the size of the wedges on the life stage charts of the conceptual ecological models do not hold any significance. They are simply a product of the number of variables included in each life stage.

### Abundance of Large Herbivores

This variable includes both domesticated animals, such as cattle, and wild animals, such as elk, beavers, and feral hogs. Grazing and browsing from domesticated and wild herbivores can negatively impact the success of restoration sites and SWFL and YBCU nesting sites by stripping trees, knocking down vegetation, compacting soil, and causing erosion. Additionally, a growing herbivore population can also attract more predators, which increases trails that negatively impact SWFL and YBCU habitat.

Stressful environmental conditions, such as drought, exacerbate the negative impact of grazing, even when there is no increase in the herbivore population.

Properly managed herbivore populations could provide some benefit by increasing soil nutrients. In the short term, the large herbivore population could negatively impact water quality by trampling vegetation at the water's edge, which often contains riparian plant species that are important for SWFL nesting habitat.

#### *YBCU*

Because YBCU have long-distance vision and large home ranges, they may benefit from edge effects near agricultural areas, which may have greater food availability.

### Anthropogenic Noise

Anthropogenic noise can negatively affect SWFL and YBCU communication and nest success. This could hinder pair selection and, if the noise impact is too great, lead to nest abandonment. There are uncertainties related to how the timing, duration, and constancy of noise, as well as distance from the noise source, affect the degree of impact. Introduced noise may be less critical once nestlings have fledged; however, the lack of monitoring after fledging has led to uncertainties around this.

#### *SWFL*

There is an unpublished study at the Bosque del Apache National Wildlife Refuge on the impact mowing has on nests. Observations revealed that SWFL adults were initially defensive but began following the mowers due to the increase in insect activity.

#### *YBCU*

YBCU have large territories, which may indicate that they communicate over long distances. If so, YBCU may be greatly impacted by noise.

There is published literature that indicates YBCU vocalization frequency overlaps with the frequency of constant traffic, which leads to communication interference. YBCU have been observed to avoid high-traffic areas, and may even select lower quality habitat in order to avoid traffic noise. (Goodwin and Shriver 2011)

### Cooperative Breeding

YBCU are known to form colonies. Young juvenile males will act as “helper males” within a nest and help with feeding and incubation. A genetic study in Arizona found that eggs in the same nest had varied genetic parentage (McNiel 2015). There are many uncertainties around the degree to which colony size and cooperation contribute to nest success and to the genetic success of the population as a whole. Researchers may be overestimating the number of YBCU territories as a result of the colony nature of these birds.

### Defoliation

Defoliation increases the risk of predation and negatively impacts the microclimate needed for nest success. Causes of defoliation include the tamarisk leaf beetle, drought, fire, and tree senescence.

Defoliation that occurs during the breeding season will have different impacts than defoliation that occurs between seasons. During the breeding season, defoliation may cause the failure of existing nests. Defoliation that occurs before territory selection decreases habitat availability, as, SWFL and YBCU pairs are less likely to build nests in affected areas.

#### *YBCU*

Given the larger range of YBCU, defoliation effects on the species will be different at the nest patch scale compared to the larger foraging territory scale. Defoliation away from the nest patch, and in the foraging territory, will affect food availability. However, as the foraging territory of the YBCU is so large, impact may be minimal unless there is widespread defoliation. Widespread defoliation can be caused by the tamarisk leaf beetle, high intensity fire, drought, tree over-maturity, or overgrazing. If defoliation is localized, YBCU can forage in other areas.

### Fire

Depending on the intensity, fire can negatively affect riparian habitat, as it reduces short-term and long-term habitat availability. In the case of a catastrophic fire, sterilized soil may limit vegetation regrowth. In areas where the water table has been lowered due to water diversions, the historic riparian plant community may be unable to recover after a catastrophic fire and will transition to an upland or shrubland state. However, prescribed burns have been used to spur native plant rejuvenation and can produce post-fire soil benefits. Increase in leaf litter following defoliation can increase fire intensity. Non-native species and altered hydrology also alter fire behavior. More fire studies in riparian areas are needed.

### Flying Insects

SWFL mainly prey on flying insects, such as mosquitoes. These insects require slow-moving and/or standing water. Thus, abundant standing water is required to provide adequate insect prey for SWFL. Pesticide use, defoliation, drought, and other factors that dry out soil, negatively impact insect populations.

### Heterogeneity in Vegetation Type (Nest Patch)

YBCU require a nest patch size of over five hectares with 50–75 percent mid-story cover that is 3–10 meters high. Canopy cover is critical at the nest patch scale. (USFWS 2014; Johnson 2020)

### Intraspecific Competition

There are many uncertainties around how much intraspecific competition affects SWFL and YBCU breeding success. A site's ecological carrying capacity may be dependent on food availability.

#### *SWFL*

SWFL generally have a 20- to 40- meter foraging patch size. However, multiple SWFL may use high quality habitat patches, creating a high population density. SWFL pairs tend to spread out when adequate habitat is available, or when new habitat patches become available on the landscape; possibly as a result of lower food availability during early patch establishment.

#### *YBCU*

YBCU may compete amongst each other for nest sites and food sources, although the degree of competitive interactions is unknown. Competition may include intraspecific nest parasitism, which may be common for YBCU (McNiel 2015).

### Proximity to Water

Large flooded areas result in low velocity flows of shallow depths underneath nests. These areas contribute to the insect populations that make up the prey base for SWFL and YBCU, are beneficial for plant health, and facilitate the cooler microclimate needed for nest success.

Moist soil underneath the nest is vital for maintaining the microclimate needed for nest success. Additionally, moist soil boosts insect populations, plant health, and seed establishment.

#### *SWFL*

During migration, SWFL have been observed to be attracted to large flooded areas.

### Large Insects

YBCU are opportunistic feeders that feed on large insects and small lizards. They require a large amount of food, especially when they are young. YBCU young grow rapidly and fledge in seven days. YBCU may choose territory based on insect outbreaks. Pesticide use, drought, and defoliation negatively affect their prey base.

### Multi-Age Stands

SWFL breeding pairs prefer multi-age vegetation stands with 50–75 percent mid-story cover and dense cover that is 3–6 meters high. Dense vegetation provides protection from predators and contributes to the cooler microclimate of the nest site.

### Nest Parasitism and Nest Predation

SWFL and YBCU nest predators include snakes, raccoons, skunks, rodents, and other birds. Loss of vegetative cover, drought, and other stressors can lead to predation and parasitism. There are uncertainties around how much edge effects impact parasitism and predation.

#### *SWFL*

Cowbirds are known to parasitize SWFL nests. Cowbird abundance, and therefore parasitism, tends to be a function of habitat type and quality, and the availability of suitable hosts, therefore not specific to the SWFL. Data show that predation and parasitism balance out to about the same total combined level every year.

#### *YBCU*

YBCU tend to be quiet around their nests, so as not to attract predators. Loss of canopy cover, drought, and other stressors can increase the risk of predation.

### Riparian Vegetation Community (Landscape)

YBCU require large expanses of riparian habitat at the landscape level with a mosaic of different vegetation types for both the nest patch and foraging areas. The estimated home-range size of the YBCU is between 62–91 hectares (Sechrist et al. 2013; Dillon and Moore 2020).

### Site Fidelity

SWFL site fidelity can negatively or positively influence reproductive success, depending on site health and other characteristics. There is uncertainty around the degree of SWFL site fidelity, and what might influence dispersal to another site.

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# Appendix D. Middle Rio Grande Endangered Species Collaborative Program Objectives and Strategies

## PRELIMINARY COLLABORATIVE PROGRAM OBJECTIVES

These preliminary objectives are the starting point for conversation at the Objectives Workshop, described in Section 3.2, Task A of the *Science & Adaptive Management (S&AM) Plan*. These objectives are not final and will be revised prior to adoption by the Science and Adaptive Management Committee (SAMC). The objectives and strategies adopted by the SAMC will help the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) achieve its goals in addressing species needs. The preliminary objectives are primarily split between these five species: Rio Grande silvery minnow (*Hybognathus amarus*; RGSM), southwestern willow flycatcher (*Empidonax traillii extimus*; SWFL, yellow-billed cuckoo (*Coccyzus americanus*; YBCU), New Mexico meadow jumping mouse (*Zapus hudsonius luteus*; NMMJM), and Pecos sunflower (*Helianthus paradoxus*; PESU). A list of other objectives and strategies follow those related to each species. A revised Section 4.1 in the *S&AM Plan* will incorporate the adopted objectives and supersede Appendix D.

### Rio Grande Silvery Minnow

*Objective A-1: Analyze available monitoring data for the RGSM from Cochiti Reservoir to Elephant Butte Reservoir to track population trends in the Middle Rio Grande (MRG).*

Reclamation sponsors a long-term population monitoring program, which samples a minimum of 20 sites per year to document the presence or absence of marked and unmarked RGSM. This supports the recovery goals and Criteria 1.A.1, 1.A.2, 2.A.1, and 2.A.2 (Appendix E) in the *2010 U.S. Fish and Wildlife Service (USFWS) RGSM Recovery Plan* (USFWS 2010). This long-term monitoring effort provides indispensable data for evaluating the status of RGSM in the MRG.

Strategy A-1a:

Continue to support the monitoring effort and keep it as a high-priority for the Collaborative Program. Explore additional applications of the data, if possible.

Strategy A-1b:

Evaluate (temporarily) increasing the sample size and adding targeted sites to facilitate a statistically robust experimental design that addresses habitat use and informs habitat restoration efforts.

*Objective A-2: Continue to support research into the life history of the RGSM to inform management of the species.*

Contributing to ongoing research of the life history of the RGSM will help inform management decisions that benefit or reduce impacts to the species. The Collaborative Program has developed a RGSM conceptual ecological model (CEM) that is useful for deriving questions about the species' life history. This supports Recovery Goals 1, 2, and 3 (Appendix E) in the *2010 USFWS RGSM Recovery Plan* (USFWS 2010).

Strategy A-2a:

Generate research proposals to address previous panel recommendations (Noon et al. 2016, Fraser et al. 2013, etc.) and uncertainties identified with the RGSM CEM to better understand the life history of the RGSM.

Strategy A-2b:

Track life history research using the Adaptive Management (AM) Database to generate more timely management and study recommendations.

*Objective A-3: Support research and modeling efforts to determine how much base flow is needed to produce sufficient habitat to support species survival rates necessary to achieve a self-sustaining population in each reach.*

Base flows are important in maintaining wetted habitat; this habitat represents the overall carrying capacity for RGSM in any given area of the MRG. The following strategies support Recovery Criteria 2.B.1 and 3.B.1 (Appendix E) from the *2010 USFWS RGSM Recovery Plan* (USFWS 2010).

Strategy A-3a:

Review current research publications and develop hypotheses to address habitat availability during base flow periods (outside of spring runoff).

Strategy A-3b:

Support development of models, such as a population viability analysis, to analyze habitat availability during base flow periods.

Strategy A-3c:

Clearly define assumptions/uncertainties involving minimum base flow, sufficient habitat, and survival rates.

*Objective A-4: Support research and modeling efforts to determine the timing, duration, and magnitude of flows needed to produce sufficient habitat in support of species recruitment rates for a self-sustaining population in each reach.*

The timing, duration and magnitude of spring runoff are important to RGSM reproduction and have been demonstrated to have a significantly positive correlation with the October population density. The following strategies support Recovery Criteria 2.B.2, 2.B.3, 3.B.2, and 3.B.3 (Appendix E) from the *2010 USFWS RGSM Recovery Plan* (USFWS 2010).

Strategy A-4a:

Review current research publications and develop hypotheses to address nursery habitat availability during spring runoff.

Strategy A-4b:

Support development of models to analyze habitat availability during spring runoff.

Strategy A-4c:

Clearly define assumptions/uncertainties involving flow characteristics, sufficient habitat, and recruitment rates.

*Objective A-5: Contribute to research and modeling efforts to better understand the quantity and quality of habitat needed at different flow regimes to support recruitment and survival of RGSM.*

Habitat availability varies by reach and flow regime in the MRG, and more research and modeling efforts are needed to help determine the best balance between water management and habitat restoration to support species recruitment and survival. The following strategies support Recovery Criteria 2.B.3, 2.B.4, 3.B.3, and 3.B.4 (Appendix E) of the *2010 USFWS RGSM Recovery Plan* (USFWS 2010).

Strategy A-5a:

Perform modeling to determine the amount of habitat needed to support a self-sustaining population in each reach during 1) spring runoff, 2) summer low flow periods, and 3) fall and winter base flow periods needed.

Strategy A-5b:

Identify uncertainties related to recruitment of RGSM and perform literature reviews to develop research hypotheses on this topic.

Strategy A-5c:

Identify uncertainties related to survival of RGSM and perform literature reviews to develop research hypotheses on this topic.

Strategy A-5d:

Review new and existing research to identify specific metrics to measure habitat quality in support of recruitment and survival of RGSM for a self-sustaining population in each reach. Recommend a habitat monitoring protocol to provide empirical data.

**Southwestern Willow Flycatcher**

*Objective B-1: Continue monitoring for SWFL in designated critical habitat areas to track territories in the MRG management unit of the Rio Grande recovery unit.*

SWFL territories and nests have been consistently found in the MRG management unit and the number of territories have increased in the last ten years. Continued contributions to monitoring in the MRG will help track species recovery. The following strategies support all recovery criteria (Appendix E) listed in the *2002 USFWS Final Recovery Plan SWFL* (USFWS 2002).

Strategy B-1a:

Ensure designated critical habitat areas in the MRG are monitored annually for SWFL territories to contribute to understanding species recovery.

Strategy B-1b:

Analyze available monitoring data annually to ensure SWFL territories are not decreasing in the MRG management unit. If the number of territories are decreasing, review habitat areas where territories have decreased to make recommendations for improving habitat to increase SWFL territories.

*Objective B-2: Continue monitoring critical SWFL habitat and contribute to research on the impacts from non-native and exotic species on SWFL recovery.*

Habitat requirements for the SWFL have been well documented, but impacts from the management of the non-native and exotic tamarisk on SWFL recovery are poorly understood. The following strategy supports recovery Criterion 2.B (Appendix E) from the *2002 USFWS Final Recovery Plan SWFL* (USFWS 2002).

Strategy B-2a:

Perform literature reviews and recommend best management alternatives regarding non-native and exotic species to support SWFL and their habitat.

*Objective B-3: Support large-scale restoration efforts to protect and expand SWFL habitat in the MRG.*

Strategy B-3a:

Annually map or update maps of SWFL habitat in the MRG management unit.

Strategy B-3b:

Review habitat areas biennially and identify sites that can be expanded based on occupied territories to prioritize restoration efforts.

**Yellow-Billed Cuckoo**

*Objective C-1: Contribute to research and understanding of habitat needs for the YBCU.*

Critical habitat areas were proposed and revised by USFWS in 2020. The area includes much of the MRG, with the exception of the Albuquerque reach. More research is needed to determine habitat features needed to help prevent the up-listing of the YBCU. There is not currently a recovery plan for this species.

Strategy C-1a:

Perform literature reviews and make recommendations for research to better understand the habitat needs to support the YBCU.

Strategy C-1b:

Annually map or update maps of YBCU habitat in the MRG. Make recommendations to support expansion of habitat to support the species.

**New Mexico Meadow Jumping Mouse**

*Objective D-1: Contribute to efforts to expand habitat and preserve existing NMMJM habitat in the MRG.*

There is currently one known population of NMMJM in the Collaborative Program area, located at the Bosque del Apache National Wildlife Refuge. The biggest stressor to the species is habitat loss, typically a result of grazing, water management practices, drought, wildfire and other pressures. The following strategies support the findings in the *2014 USFWS Recovery Outline NMMJM* (USFWS 2014).

Strategy D-1a:

Provide a biennial assessment of opportunities to expand NMMJM habitat in the MRG to achieve a self-sustaining population.

Strategy D-1b:

Perform literature reviews and pursue opportunities to support research to better understand the life history of the NMMJM, including movement behavior, to support habitat recommendations.

### Pecos Sunflower

*Objective E-1: Continue monitoring for PESU stands in the West-Central New Mexico Recovery Region and preserve habitat.*

In the *2005 USFWS PESU Species Recovery Pla*n (USFWS 2005), the USFWS listed at least one potential core conservation area for an existing population of PESU within the West-Central New Mexico Recovery Region in the Collaborative Program area—the La Joya State Waterfowl Management Area. The area around the La Joya Drain is of particular interest. Monitoring and maintenance in that area should consider how to improve habitat for PESU.

Strategy E-1a:

Monitor one new area per year for PESU to see if the species is present. Monitoring could occur simultaneously with other monitoring occurring for habitat restoration sites or site maintenance monitoring. Consider monitoring in newly restored habitat areas in the Lower Reach Plan, where habitat for PESU may be suitable.

Strategy E-1b:

Devise a list of potential ways to keep the La Joya Drain area perennial to continue to provide suitable habitat for PESU.

### Other Objectives and Strategies

*Objective F-1: Monitor the status of other threatened species in the MRG.*

The Collaborative Program will track the status of other species of concern in the MRG to prevent future listings or up-listings within the Collaborative Program area.

Strategy F-1a:

Review the biennial assessment from the New Mexico Department of Game and Fish for status of various species in the Collaborative Program area. Consider including protection measures for applicable threatened species in restoration efforts, where possible.

Strategy F-1b:

Include an update on status of other threatened and endangered species at Collaborative Program science symposia.

*Objective G-1: Support the establishment and maintenance of a conservation storage pool in Abiquiu Reservoir.*

Efforts are underway to change authorizations at Abiquiu Reservoir, so native Rio Grande water can be stored in addition to the already authorized San Juan-Chama water storage. The flexibility to store both San Juan-Chama and native Rio Grande water will provide options for managing water resources on the MRG.

Strategy G-1a:

Provide monitoring data to support the environmental assessment process to establish the conservation storage pool.

Strategy G-1b:

When possible, find available water to support the conservation storage pool to benefit species and habitat.

# Appendix E. Consolidated Recovery Goals, Criteria, and Actions

## RIO GRANDE SILVERY MINNOW RECOVERY PLAN, FIRST REVISION (USFWS 2010)

### Recovery Goals

1. Prevent the extinction of the Rio Grande silvery minnow (*Hybognathus amarus*; RGSM) in the Middle Rio Grande (MRG) in New Mexico.
2. Recover the RGSM to an extent sufficient to change its status on the List of Endangered and Threatened Wildlife from endangered to threatened (downlisting).
3. Recover the RGSM to an extent sufficient to remove it from the List of Endangered and Threatened Wildlife (delisting).

### Recovery Criteria

1.A.1. Using the standard sampling protocol (Appendix E, USFWS 2010), and sampling at a minimum of 20 sites distributed throughout the MRG in New Mexico, document the presence of RGSM (all unmarked fish) at ¾ of all sites, per reach, sampled during October.

1.A.2. Annual reproduction in the MRG below Cochiti Reservoir, as indicated by the presence of young-of-year at ¾ of all sites, per reach, sampled during October.

1.B.1. A captive population of 50,000 to 100,000 fish with a composition and distribution (among facilities) consistent with the recommendations of the *RGSM Genetics Management and Propagation Plan* (USFWS 2007).

2.A.1. Using the standard sampling protocol (Appendix E, USFWS 2010), and sampling at a minimum of 20 sites distributed throughout the MRG in New Mexico, document for at least five consecutive years, an October catch-per-unit-effort from all monitoring sites within each reach of > 5 fish/100 $m^2$.

2.A.2. Annual reproduction in the MRG below Cochiti Reservoir, as indicated by the presence of young-of-year from ¾ of the monitoring sites, per reach, for at least five consecutive years.

2.A.3. Two additional populations of RGSM, in the historical range of the species but outside the MRG of New Mexico, that each demonstrate (by quantitative analysis) a probability of extinction in the wild of less than 10 percent within 50 years.

2.B.1. Base flow within occupied habitat sufficient to generate survival rates necessary to achieve Criterion 2.A.1. Wetted habitat represents the overall carrying capacity of a particular area for RGSM and influences survival rates for the population. The amount and distribution of base flows necessary for recovery can be informed by a population viability analysis.

2.B.2. Recruitment flows that generate population growth rates necessary to achieve Criterion 2.A.1.

2.B.3. Habitat of sufficient quantity and quality to generate recruitment and survival rates that meet Criterion 2.A.1. Quantity and quality will vary by site but each location is likely to need increased nursery habitat and overall channel complexity. These increases can be achieved through restoration, flow management, and removing impediments to river migration, such as giant cane (*Arundo donax*) in the Big Bend area.

2.B.4. Improve water quality within occupied areas and reintroduction sites to support recruitment and survival rates necessary to achieve Criterion 2.A.1.

3.A.1. Three populations of RGSM, in the historical range of the species, each of which demonstrate (using quantitative analysis) a probability of extinction in the wild of less than 10 percent within 100 years.

3.B.1. Base flows within occupied habitat sufficient to generate survival rates necessary to achieve Criterion 3.A.1.

3.B.2. Recruitment flows that generate population growth rates necessary to achieve Criterion 3.A.1.

3.B.3. Habitat of sufficient quantity and quality to generate recruitment and survival rates that meet Criterion 3.A.1.

3.B.4. Water quality within occupied areas and reintroduction sites to support survival rates of RGSM necessary to achieve Criterion 3.A.1.

### Recovery Actions

1. Develop a thorough knowledge of RGSM life history, ecology, and behavior, and the current status of its habitat.
2. Restore, protect, and alter habitats as necessary to alleviate threats to the RGSM.
3. Ensure the survival of the RGSM in its current habitat and reestablish the species in suitable habitats within its historical range.
4. Implement and maintain an adaptive management program so that appropriate research and management activities are implemented in a timely manner to achieve recovery of the RGSM.
5. Design and implement a public awareness and education program.

## FINAL RECOVERY PLAN SOUTHWESTERN WILLOW FLYCATCHER (USFWS 2002)

### Recovery Goals

1. Recover the southwestern willow flycatcher (*Empidonax traillii extimus*; SWFL) to an extent sufficient to change its status on the List of Endangered and Threatened Wildlife from endangered to threatened (downlisting).
2. Recover the SWFL to an extent sufficient to remove it from the List of Endangered and Threatened Wildlife (delisting).

### Recovery Criteria

1.A. Increase the total known population to a minimum of 1,950 territories (equating to approximately 3,900 individuals), geographically distributed to allow proper functioning as metapopulations, so that the SWFL is no longer in danger of extinction. *For reclassification to threatened status, these prescribed numbers and distributions must be reached as a minimum, and maintained over a five-year period*.

1.B. Increase the total known population to a minimum of 1,500 territories (equating to approximately 3,000 individuals), geographically distributed among Management Units and Recovery Units, so that the SWFL is no longer in danger of extinction. *For reclassification to threatened status, these prescribed numbers and distributions must be reached as a minimum, and maintained over a three-year period, and the habitats supporting these SWFL must be protected from threats and loss.*

2.A. Meet and maintain, at a minimum, the population levels and geographic distribution specified under reclassification to threatened Criterion 1.A.

2.B. Provide protection from threats and create/secure sufficient habitat to assure maintenance of these populations and/or habitats over time.

### Recovery Actions

1. Increase and improve occupied, suitable, and potential breeding habitat;
2. Increase metapopulation stability;
3. Improve demographic parameters;
4. Minimize threats to wintering and migration habitat;
5. Survey and monitor;
6. Conduct research;
7. Provide public education and outreach;
8. Assure implementation of laws, policies, and agreements that benefit the SWFL;
9. Track recovery progress.

## RECOVERY OUTLINE NEW MEXICO MEADOW JUMPING MOUSE (USFWS 2014)

Note: The goals and criteria are inferred from the Preliminary Recovery Strategy, and are not explicitly listed as such.

### Recovery Goal

Establish the number and distribution of resilient populations to provide the needed levels of representation and redundancy (genetic and ecological diversity) for the New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*; NMMJM) species to demonstrate viability.

### Recovery Criteria

To ensure viability, establish at least two resilient populations (where at least two existed historically) within each of eight identified geographic conservation areas.

### Recovery Actions

1. Establish partnerships to design and install effective barriers or exclosures or change livestock management techniques (e.g., fencing, reconfiguration of grazing units, off-site water development, or changing the timing or duration of livestock use) to limit ungulate grazing and protect riparian habitats from damage.

2. Work cooperatively with stakeholders to maintain the required microhabitat components or modify or limit actions (e.g., bridge and road realignment projects, water use and management, stream restoration, and vegetation management) that preclude their development and restoration, in order to stabilize and expand current NMMJM populations.
3. Identify priority areas to reduce fuels to minimize the risk of severe wildland fire and identify techniques for post-fire stabilization in areas that burn.
4. Modify off-road vehicle use and manage dispersed recreation through fencing, signage, education, and timing of use.
5. Facilitate the natural expansion of NMMJM habitat through the management and restoration of beaver. In New Mexico, beaver can no longer be relocated or transplanted without written consent from all property owners, land management agencies, or other affected parties (e.g., irrigation districts) within an 8-kilometer (5-mile) radius of the proposed release site or connective waters (New Mexico Department of Game and Fish 2009, entire).
6. Complete an emergency contingency and salvage plan to capture NMMJM and bring individuals into captivity in the event of severe wildland fire, post-fire flooding, or severe drought.
7. Establish a monitoring protocol to determine presence/absence or estimate the abundance of NMMJM populations.
8. Investigate the genetic diversity of populations to identify and address where long term management strategies may be needed to enhance their genetic integrity.
9. Formally evaluate whether assisted translocation or a captive breeding program for NMMJM would be beneficial as a recovery option.
10. Conduct research on the critical aspects of NMMJM life history (e.g., reproduction, abundance, survival, movement behavior).

## PECOS SUNFLOWER RECOVERY PLAN (USFWS 2005)

### Recovery Goal

Removal from the Federal list of threatened and endangered species (delisting). Protect and manage in perpetuity significant, sustainable populations of Pecos sunflower (*Helianthus paradoxus*; PESU) and habitat within its native range so that the protection of the Endangered Species Act is no longer required for the conservation and survival of the species.

### Recovery Criteria

1.A. Identify and establish at least one core conservation area for PESU in each of four distinct recovery regions that would collectively, if protected, ensure the long-term survival of the species. Each core habitat must occur on wetlands that are not threatened by depletion of the contributing aquifer and have demonstrated a self-perpetuating stand of PESU of greater than 5,000 individuals for a minimum of seven out of ten years. In addition to the core conservation area, each region should have at minimum one additional isolated stand of protected PESU with greater than 1,600 individuals for at least seven out of ten years to protect against catastrophic loss of the regional population.

1.B. Assure long-term protection of designated core conservation areas and designated isolated stands in perpetuity through the implementation of appropriate management plans, conservation easements, or land acquisition.

### Recovery Actions

1. Identify and establish core conservation areas and isolated stands.
2. Identify and address information gaps, compatible uses, and management actions regarding Pecos sunflower distribution, biology and aquifer stability.
3. Protect core conservation areas and isolated stands through landowner education, implementation of management plans, conservation easements, and land acquisition.
4. Monitor PESU conservation areas and management actions as needed to satisfy delisting criteria.

## WESTERN YELLOW-BILLED CUCKOO CONSERVATION STRATEGY (USFWS 2020)

Note: This information is based off the latest proposal for revised critical habitat designation in the Federal Register (Feb. 2020, Vol. 85, No. 39)

### Recovery Goal

The goal of our conservation strategy for the western yellow-billed cuckoo (*Coccyzus americanus*: YBCU) is to recover the species to the point where the protections of the Endangered Species Act are no longer necessary.

### Recovery Criteria

1.A. Identify the specific areas within the western YBCU's range that provide essential physical and biological features (e.g., breeding habitat), without which range-wide resiliency, redundancy, and representation could not be achieved.

1.B. Identify the fundamental parameters of the species' biology and ecology based on well-accepted conservation-biology and ecological principles for conserving species and their habitats and more general riparian and avian conservation management prescriptions.

### Recovery Actions

1. Designate critical habitat, focused on breeding habitat, which includes areas for nesting and foraging and also provides for dispersal habitat when breeding or food resources may not be optimal.
2. Include breeding habitat within three general habitat settings to allow for within-year and year-to-year movements to take advantage of any spatial and temporal changes in habitat resources and food abundance.
    a. Large river systems (mainstem rivers and their tributaries) in the southern and central portions of New Mexico, Arizona, and along the California border with Arizona (generally referred to as the Southwest);

b. Locations within southern Arizona not associated with major river systems or their tributaries;

c. Large river systems outside the Southwest (as identified in [a.] above) that occur in different ecological settings that are being consistently used as breeding areas by western YBCU (such as areas in parts of California, Utah, Idaho, or Colorado).

3. Monitor population potential for:

   a. Maintaining its existing distribution;

   b. Moving between areas depending on food, resource, and habitat availability;

   c. Increasing the size of the population to a level where it can withstand potentially negative genetic or demographic impacts;

   d. Maintaining its ability to withstand local- or unit-level environmental fluctuations or catastrophes.

## References


U.S. Fish and Wildlife Service 2002. Southwestern Willow Flycatcher (*Empidonax traillii extimus*) Recovery Plan. Albuquerque, New Mexico.

U.S. Fish and Wildlife Service 2010. Rio Grande Silvery Minnow (*Hybognathus amarus*) Recovery Plan, First Revision. Albuquerque, New Mexico.

U.S. Fish and Wildlife Service 2005. Pecos Sunflower (*Helianthus paradoxus*) Recovery Plan.

U.S. Fish and Wildlife Service 2014. New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*) Recovery Outline. Albuquerque, New Mexico.

U.S. Fish and Wildlife Service 2020. Western Yellow-Billed Cuckoo (*Coccyzus americanus*) Conservation Strategy. Federal Register (Feb. 2020, Vol. 85, No. 39).