



Middle Rio Grande Endangered Species
Collaborative Program

Long-Term Plan for Science & Adaptive Management

Version 2.0

Approved by the Executive Committee

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Prepared for:

The Middle Rio Grande Endangered Species Collaborative Program

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FOREWORD

This Long-Term Plan for Science & Adaptive Management (Long-Term Plan) is a living document that will be updated regularly 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 approach to incorporating that knowledge into recommendations. This Long-Term Plan builds on past efforts to incorporate adaptive management into Collaborative Program operations. Modifications to this Long-Term Plan will serve to document iterative learning within the Collaborative Program.

The Collaborative Program's Executive Committee approved this Long-Term Plan at the March 23, 2022 meeting.

Cover photo credit: "Rio Grande cottonwood gallery during fall in the Bosque," Danielle Galloway, U.S. Army Corps of Engineers

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LIST OF ACRONYMS

ABCWUA	Albuquerque-Bernalillo County Water Utility Authority
Admin Ad Hoc	Administrative Ad Hoc Group
BDD	Buckman Direct Diversion
BEMP	Bosque Ecosystem Monitoring Program
BO	biological opinion
CEM	conceptual ecological model
CoA	City of Albuquerque
Collaborative Program	Middle Rio Grande Endangered Species Collaborative Program
EC	Executive Committee
ESA	Endangered Species Act
FPC	Fiscal Planning Committee
HR	habitat restoration
Long-Term Plan	Long-Term Plan for Science and Adaptive Management
MOA	memorandum of agreement
MRGCD	Middle Rio Grande Conservancy District
NMAG	N.M. Office of the Attorney General
NMDGF	N.M. Department of Game and Fish
NMISC	N.M. Interstate Stream Commission
PASS	Program and Science Support contract
PESU	Pecos sunflower
PST	Program Support Team
Reclamation	U.S. Bureau of Reclamation
RGSM	Rio Grande silvery minnow
RIO	River Integrated Operations
S&T Ad Hoc	Science & Technical Ad Hoc Group
SAMC	Science and Adaptive Management Committee
SAMIS	Science and Adaptive Management Information System
SWFL	southwestern willow flycatcher
UNM	University of New Mexico
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
YBCU	yellow-billed cuckoo

1.0 INTRODUCTION

The Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) uses a science and adaptive management process for its operations in support of its mission and goals, and to support greater adaptive management efforts within the Middle Rio Grande. The Long-Term Plan for Science & Adaptive Management (Long-Term Plan) defines this process, as well as the Collaborative Program's role in implementing it, by framing management questions, supporting research, sharing and evaluating findings, and generating recommendations.

1.1 Purpose of the Long-Term Plan for Science & Adaptive Management

Protecting and recovering listed species in the Middle Rio Grande has become increasingly difficult due to multiple environmental and administrative challenges, such as persistent drought and reduced or unpredictable funding. To meet these challenges and better utilize the available resources, signatories to the Collaborative Program have agreed to support and apply adaptive management within the Middle Rio Grande Basin. The Collaborative Program's primary role in adaptive management is weighing and contextualizing scientific evidence to inform decision-making. The Collaborative Program then formulates scientifically defensible recommendations to natural resource and water managers regarding actions that benefit the listed species in the Middle Rio Grande.

The Long-Term Plan guides Collaborative Program operations by organizing its structure and activities around the adaptive management cycle, and by serving as an evolving communication and planning tool for both short- and long-term efforts. It is structured to present the Collaborative Program's current focus and priorities and provide an administrative timeline for operations. Although signatories are not obligated to implement the activities specified in the Long-Term Plan, they may use the document to aid in their administrative out-year planning, and give scientific coverage for activities implanted under their individual authorities, under which they participate in the Collaborative Program.

How to Use the Long-Term Plan

The Long-Term Plan fulfills both administrative and scientific needs for the Collaborative Program and its signatories. As a living document that is regularly updated, the Long-Term Plan provides the most up-to-date information regarding the Guiding Principles, Collaborative Program structure and operations, and recommended activities.

The information in the Long-Term Plan also provides guidance on how to share information with the Collaborative Program, including different venues for information exchange, the types of information that would be relevant to the Collaborative Program, and the opportunities for information synthesis and recommendations from the Collaborative Program. Additionally, Appendix D serves as a guide to the Collaborative Program's current science strategies and peer review panel recommendations, which may be referenced by signatories when developing linkages between individual projects and Collaborative Program science priorities using the Science and Adaptive Management Information System (SAMIS; See Section 6.1).

1.2 Development and Structure

The Long-Term Plan was developed with the Collaborative Program's Guiding Principles (i.e., mission, goals, and Science Objectives) in mind. It describes the ways in which the Collaborative Program operates in service of the Guiding Principles, and recommends specific activities to address priority objectives and meet the goals of the Collaborative Program. The recommended activities list (Section 10.0) contains activities with the potential to address planning needs in the Middle Rio Grande. The list is a subset of the Project Bank contained within the SAMIS (Section 6.1), and is intended to help resource managers in their planning efforts by highlighting the projects and studies that advance our understanding of the system and species and support adaptive management. Additionally, the Long-Term Plan hosts an administrative timeline that facilitates tracking, coordination and timely completion of Collaborative Program efforts.

1.3 Updates

The Long-Term Plan is periodically updated in order to remain relevant to evolving management questions, and current scientific understanding. Some of these updates will be triggered by revisions to the Guiding Principles. Other updates will occur on a regular Biennial Schedule that documents and incorporates new findings and recommends appropriate adjustments to complete the adaptive management cycle. The Executive Committee (EC) must approve all updates to the Long-Term Plan.

Collaboratory and Science Evaluation

The Collaborative Program hosts a biennial "Collaboratory", a workshop to synthesize scientific learning from the past two years in the context of the Collaborative Program's Science Objectives and scientific uncertainties, and to strategically plan for future management needs. In order to identify opportunities for input and collaboration, Collaboratory participants learn about signatories' upcoming projects, and priority questions and management issues. Collaboratory participants discuss those issues, organize them by topic, and formulate one or more specific questions for each.

The results of the Collaboratory directly inform a biennial Science Evaluation, wherein the Collaborative Program's Science and Adaptive Management Committee (SAMC) recommends updates to the Science Objectives and Science Strategies (reprioritized and revised to better respond to management needs) and develops approaches to address questions identified by managers. The results of the Science Evaluation inform an update to the Long-Term Plan every two years that reflects changes to priorities, current scientific understanding, and new entries to the Project Bank. These updates, revisions, and realignments keep the Collaborative Program's efforts current, and connect the various steps of the adaptive management cycle.

Annual Program Evaluation

The Collaborative Program conducts an Annual Program Evaluation focusing on the continued relevance of the Collaborative Program's Guiding Principles and activities, operational effectiveness and efficiency, and signatory engagement. Based on the Annual Program

Evaluation results, the EC may decide to revise the Guiding Principles or the Collaborative Program's administrative structure or operations. These revisions will be reflected in updates to the Long-Term Plan.

2.0 OVERVIEW OF THE COLLABORATIVE PROGRAM

The Collaborative Program is a partnership of federal, state, and local governmental entities, Indian Tribes and Pueblos, and non-governmental organizations aiming to protect and recover federally listed species in the riparian corridor of the Middle Rio Grande, 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 of 1973 (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).

The Collaborative Program was formally established in 2003 with the signing of a Memorandum of Understanding, followed by a 2008 Memorandum of Agreement (MOA) and a 2022 MOA which reaffirmed the signatories' commitment to the Collaborative Program. Currently, sixteen signatories support the Collaborative Program's mission by performing scientific, technical, and administrative activities. The signatories fund and staff scientific studies, population management efforts, water operations, and habitat restoration to the benefit of the Middle Rio Grande's listed species, while also participating in Collaborative Program planning, administration, and technical support.

2.1 Collaborative Program Area

The geographic area of interest covered by the Collaborative Program follows the Rio Grande, including its tributaries, stretches from the New Mexico/Colorado border downstream to the elevation of the spillway crest of Elephant Butte Reservoir and excludes the land reserved for the full pool of Elephant Butte Reservoir. Under the Long-Term Plan, five reaches have been delineated within the Middle Rio Grande (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.

2.2 Stakeholders

A Collaborative Program stakeholder is an organization whose members have a vested interest in listed species recovery and protection of water uses in the Middle Rio Grande. Primarily, the Collaborative Program stakeholders are the sixteen signatories to the MOA that hold seats on the EC:

- Albuquerque Bernalillo County Water Utility Authority (ABCWUA)
- Audubon New Mexico
- Bosque Ecosystem Monitoring Program (BEMP)
- Buckman Direct Diversion (BDD)
- City of Albuquerque (CoA)
- Middle Rio Grande Conservancy District (MRGCD)
- New Mexico Office of the Attorney General (NMAG)
- 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, Middle Rio Grande 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.

2.3 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 adaptive management, including its opportunities and boundaries, and describes the administrative foundation for that role.

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 Middle Rio Grande. These assumptions are listed in Box 1.

Box 1. 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 Middle Rio Grande.
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 Middle Rio Grande.
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 Middle Rio Grande.
5. There is no central decision-making or funding authority in the Middle Rio Grande; the Collaborative Program does not have decision-making authority on any individual signatory's budget, contracts, or management actions.

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 water management obligations, Biological Opinions (BOs) and non-ESA obligations, other adaptive management-specific efforts in the Middle Rio Grande, and opportunities for Collaborative Program engagement in adaptive management.

Water Management Obligations

The Rio Grande supports numerous water uses in support of ecological, tribal, agricultural, municipal, and recreational purposes. Water allocation and delivery in the Middle Rio Grande is managed and regulated by multiple entities to achieve these purposes, including several

individual signatories that have water delivery obligations to users within and downstream of the Middle Rio Grande.

Biological Opinions

Several signatories operate within the Middle Rio Grande under programmatic and/or project specific BOs (Table 1). One of the more expansive BOs in the Middle Rio Grande is the 2016 Middle Rio Grande BO. Signatory partners to this BO include Reclamation, NMISC, and MRGCD. ABCWUA and BDD operate under separate programmatic BOs in the Middle Rio Grande (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 link to the USFWS website: <https://ecos.fws.gov/ecp/report/biological-opinion>.

Table 1. Current Middle Rio Grande Signatories' Biological Opinions (BOs).

Signatory Parties	Year Issued	Title
ABCWUA	2004	BO on the Effects of Actions Associated with the Programmatic Biological Assessment for the City of Albuquerque Drinking Water Project
BDD	2007	BO 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	BO 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 NMISC 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 Middle Rio Grande is highly managed and regulated by multiple entities. This includes several individual signatories that have water delivery obligations within the Middle Rio Grande and to downstream users.

Other Regulatory Adaptive Management Efforts

As part of the 2016 Middle Rio Grande BO, BO partners plan to implement River Integrated Operations (RIO), an adaptive management approach for river operations designed to address species and water management needs, while improving sustainable management of the Middle Rio Grande. 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 adaptive management in monitoring projects and evaluating their success in order to determine if mitigation actions are sufficient to avoid, minimize, or compensate for adverse impacts.

The Collaborative Program's efforts to provide science-based recommendations are expected to complement all adaptive management efforts in the Middle Rio Grande. By reducing uncertainty around the management of listed species and their habitats, the Collaborative Program intends to improve management of the Middle Rio Grande.

Opportunities for Science Support

The Collaborative Program as an entity does not have the authority to implement or direct river management actions – that authority lies within the jurisdiction of several participating signatories. This offers signatories and other stakeholders a unique setting to have an open inter-agency discourse to develop a shared vision towards addressing the most important ecosystem-level science questions, uncertainty, and habitat management considerations for species recovery and water delivery.

The Collaborative Program develops scientifically defensible solutions and recommends evidence-based best management alternatives for the recovery of listed species in the Middle Rio Grande. With a diverse group of collaboratively engaged signatory members, the Collaborative Program is distinctly positioned to support the work of its signatories and other Middle Rio Grande stakeholders. Furthermore, each signatory contributes individually to Collaborative Program operations, which collectively strengthens its work.

Given its unique strengths, the Collaborative Program has carved its own operational space in adaptive management of the Middle Rio Grande. 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 Middle Rio Grande and garner public and political support.

3.0 GUIDING PRINCIPLES

The Collaborative Program's mission, goals, and Science Objectives guide the direction of its science and adaptive management efforts. The Long-Term Plan describes their purpose and outlines the administrative process to update these Guiding Principles.

Mission

In 2019, the Collaborative Program adopted the mission statement in Box 2.

Box 2. 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.

Goals

The Collaborative Program's long-term species-specific goals (Box 3) are linked to the species recovery plans. They are meant to be aspirational and complementary to existing and future efforts in the Middle Rio Grande. The Collaborative Program assists its signatories and partners in pursuit of these goals by providing scientifically defensible recommendations for management actions benefitting the listed species. When the Collaborative Program activities and initiatives are kept in line with its Guiding Principles, they pave the way for a collaborative approach to future management of the Middle Rio Grande that benefits its listed species.

Box 3. Collaborative Program Goals.

- A) Establish and maintain a self-sustaining population of endangered Rio Grande Silvery Minnow distributed throughout the Middle Rio Grande.
- B) Maintain and protect the Middle Rio Grande recovery unit goals for endangered southwestern willow flycatcher.
- C) Maintain and protect suitable threatened yellow-billed cuckoo habitat in the Middle Rio Grande.
- D) Establish and maintain a self-sustaining endangered New Mexico meadow jumping mouse population in the Middle Rio Grande.
- E) Maintain and protect the threatened Pecos sunflower in the Middle Rio Grande.
- F) Avoid the future listing or up-listing of species in the Collaborative Program area.
- G) Manage available water to meet the needs of endangered species and their habitat.

Science Objectives

The Collaborative Program's Science Objectives (Box 4) support the goals by focusing the Collaborative Program's efforts on criteria within the species recovery plans for RGSM, SWFL, and PESU; the recovery outline for NMMJM; and the conservation strategy for YBCU. The strategies associated with each objective present the various approaches for achieving that objective, including methods, targets and timelines.

The Collaborative Program uses the species recovery plans, published literature, and input from scientific and technical experts to develop objectives and associated strategies. Initial objectives

were defined during a workshop in February 2021, subsequently reviewed by the SAMC and recommended to the EC, who ultimately approved them in July 2021. The management relevance and scientific justification of the Science Objectives will be formally reviewed every two years as part of the Science Evaluation by the SAMC.

Box 4. Collaborative Program Science Objectives.

Rio Grande Silvery Minnow (RGSM) Objectives

- A-1) Estimate the abundance of augmented and wild born RGSM populations in the Angostura, Isleta, and San Acacia reaches from year to year.
- A-2) Increase understanding of how the life history traits of the RGSM change over time and space, to better inform management of the species and increase the probability of recovery.
- A-3) Determine the relationships between base flow and survival and recruitment of RGSM in the Middle Rio Grande.
- A-4) Determine suitable environmental flow (i.e., timing, duration and magnitude of spring hydrograph) needed to cue spawning and recruitment for the RGSM population, given system constraints and opportunities.
- A-5.1) Refine existing research and modeling efforts to understand the quantity and quality of habitat available at different flow regimes.
- A-5.2) Develop a range of options for increasing habitat availability and refugia at life stage-limiting flow regimes for all life stages.
- A-6.1) Evaluate the effects of species management (i.e., propagation, augmentation, rescue/salvage) on RGSM genetic diversity.
- A-6.2) Evaluate the effects of species management (i.e., propagation, augmentation, rescue/salvage) on RGSM population viability.

Southwestern Willow Flycatcher (SWFL) Objectives

- B-1) Monitor for SWFL in the Middle Rio Grande management unit of the Rio Grande recovery unit.
- B-2) Determine habitat availability for SWFL within the Middle Rio Grande.
- B-3.1) Characterize optimal breeding habitat conditions in currently occupied SWFL locations to inform restoration.
- B-3.2) Manage successional processes that maintain existing SWFL breeding habitat in the Program Area.
- B-3.3) Expand SWFL breeding habitat through restoration efforts in the Program Area.

Yellow-Billed Cuckoo (YBCU) Objectives

- C-1.1) Characterize optimal habitat (i.e., foraging and nesting) conditions on landscape and microhabitat levels in currently occupied YBCU locations to inform habitat mapping and restoration efforts.

C-1.2) Determine successional processes that promote optimal YBCU habitat (i.e., foraging and nesting) in the Program Area.

C-1.3) Expand monitoring efforts for YBCU.

New Mexico Meadow Jumping Mouse (NMMJM) Objectives

D-1.1) Initiate and support NMMJM monitoring efforts to locate existing populations, identify relevant habitat features, and identify potentially suitable unoccupied habitat.

D-1.2) Contribute to efforts to expand habitat and preserve existing habitat in the Middle Rio Grande.

Pecos Sunflower (PESU) Objectives

E-1.1) Continue and expand monitoring and surveying for PESU stands in the West-Central New Mexico Recovery Region.

E-1.2) Preserve and expand existing habitat stands in the West-Central New Mexico Recovery Region.

Other Objectives

F-1) Monitor trends in ecosystem function in the Middle Rio Grande for indications of decline (e.g., changes in vegetation structure and composition, population trends in other special status species, etc.).

F-2) Determine the impacts from non-native vegetation on listed species' habitat availability and population dynamics.

G-1) Support efforts to enhance the operational flexibility of water managers to support species.

For each Science Objective, the SAMC develops Science Strategies detailing specific actions to address them, and to carry out the Science Strategies, projects are proposed to be included in the Project Bank and Long-term Plan. The Collaborative Program's recommended scientific activities and future direction, as outlined in this Long-Term Plan, are adaptive and determined by the Science Objectives. As such, changes to the Science Objectives and Science Strategies will trigger updates to the Long-Term Plan.

3.1 Using the Guiding Principles to Plan in the Face of Uncertainty

The different levels of the Guiding Principles are hierarchical with increasing level of specificity and, therefore, achievability (Figure 2). The mission statement and goals are meant to be aspirational, whereas the objectives and strategies provide more details on how to address the mission and goals. Strategies, in turn, inform the development of individual projects.

Each of the Guiding Principles adds detail to an idea from the layer above it. For example, each of the seven Collaborative Program goals can, and most do, have multiple associated Science Objectives. In turn, each of those Science Objectives may have multiple Science Strategies that provide more specificity, and each Science Strategy may inform the development of one or more projects.



Figure 2. Conceptual diagram of the Collaborative Program Guiding Principles.

The different levels of the hierarchy also inform strategic planning timelines. For example, because goals are inherently less specific than objectives, more time should be allowed for achieving goals. Similarly, the details provided in a strategy will enable the rapid design of a study to address it. This framework allows for general expectations regarding the timing of progress regarding the Guiding Principles (Figure 3).



Figure 3. Conceptual diagram of the approximate time periods and planning resolution for the different levels of the Collaborative Program's Guiding Principles.

The biennial Science Evaluation will ensure the application of adaptive learning within the Collaborative Program through the assessment of new scientific information, associated revisions to Science Objectives and Science Strategies, and regular updates to the recommended activities list of the Long-Term Plan. As part of the Science Evaluation, the Guiding Principles may be updated to respond to changes in management priorities or to incorporate a significant change in scientific understanding.

4.0 COLLABORATIVE PROGRAM ORGANIZATIONAL AND OPERATIONAL STRUCTURE

Scientific activities take time to move through the adaptive management cycle and require a structured, long-term planning approach. To meet the need for more intensive out-planning, the Collaborative Program's science and adaptive management process has undergone restructuring. The resulting Collaborative Program structure promotes proactive, thorough, and timely Collaborative Program efforts. The following outlines the Collaborative Program's operations and structure designed to facilitate the science and adaptive management process. Figure 4 illustrates the hierarchical organization of the Collaborative Program, and Figure 5 depicts organizational operations.

4.1 Organizational Structure

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

The EC forms Administrative (Admin) 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.

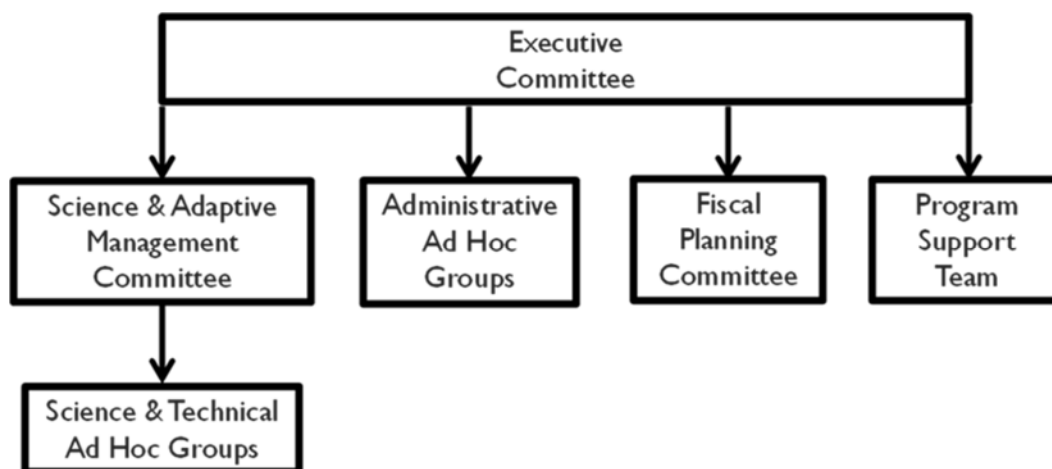


Figure 4. Collaborative Program hierarchical structure.

4.2 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 1 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 5 illustrates Collaborative Program communication and workflow.

Science and Technical Support

The Collaborative Program’s role in the Middle Rio Grande is that of a science-based program providing recommendations for scientific activities and best management alternatives. Scientific and technical support is key to the Collaborative Program’s success. The SAMC is responsible for implementation of the science and adaptive management program, 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;
- 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 Long-Term 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 Middle Rio Grande 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 5. 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 may prompt the SAMC to direct internal reviews or engage independent expert reviews, with approval from the EC (Section 6.3).

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 in Section 6.3.

Policy and Guidance

While the SAMC is responsible for implementation of the science and adaptive management program, the EC is the Collaborative Program's decision-making body. As such, the EC provides leadership, oversight, and approval for implementation of science and adaptive management activities and initiatives. EC representatives provide a collective knowledge of management regulations, policies, and operations related listed species in the Middle Rio Grande. As part of a science and adaptive management program, the EC is responsible for the following:

- 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 Admin 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

The EC relays recommendations for scientific activities and science-based best management alternatives to the appropriate resource managers. Recommended scientific activities are organized in Section 10.0 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 the Guiding Principles. The Guiding Principles include the Collaborative Program's mission, goals, and Science 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 Admin 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 Long-Term Plan and/or by-laws
- Re-scoping work plans as necessary

Administrative Support

Under the Collaborative Program's hierarchical structure (Figure 4), three administrative groups exist to support the Collaborative Program operations: Admin 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 Admin 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 Admin 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 Long-Term Plan. Admin 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, the FPC meets to coordinate the implementation of signatory activities of interest to the Collaborative Program, and identify and help fill resource gaps. 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's Annual Work Plan (Section 9.1); 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. The PST also coordinates overall Collaborative Program operations, as depicted in Figure 5.

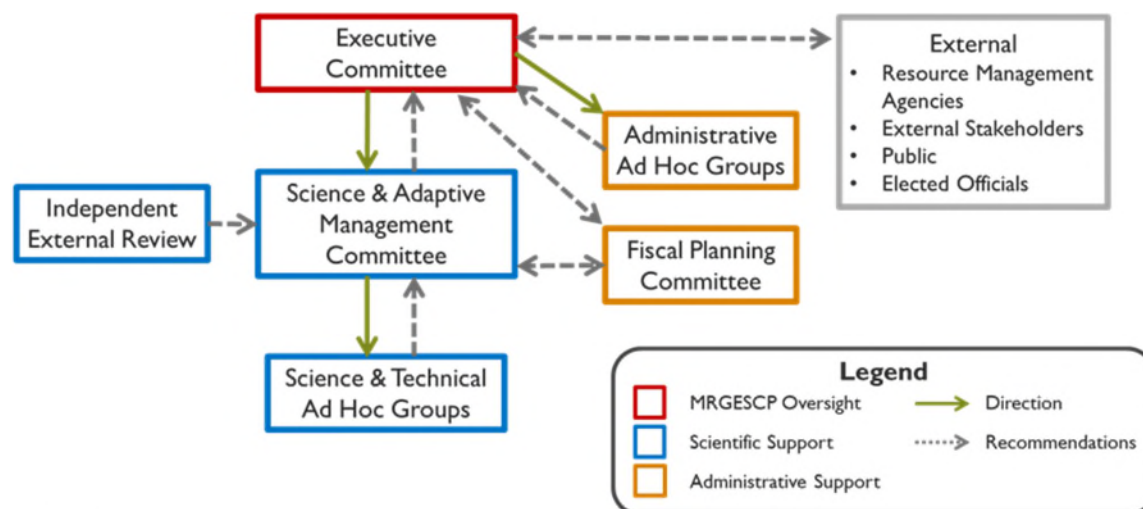


Figure 5. Communication and work flow for implementing the Long-Term Plan.

5.0 COMMUNICATION PRINCIPLES AND PLATFORMS

The Collaborative Program recognizes clear, transparent, consistent, complete, and regular communication is key to building trust and good relationships. The Collaborative Program strives to provide opportunities for information sharing, and to also continually increase the caliber of communication.

5.1 Communication Principles

At its April 2017 retreat, the EC agreed to a set of Communication Principles (Box 5) for the Collaborative Program to operate under. These principles are the foundation for how Collaborative Program operates administratively and as a science and adaptive management program.

Box 5. Collaborative Program Communication Principles.

- Clearly defined roles and responsibilities, for clarity on who has authority to make decisions or represent a signatory at a Collaborative Program meeting.
- Schedules and deadlines should be communicated as far in advance as practical to the appropriate individuals. In turn, those individuals should communicate information within their own organizations.
- Signatory representatives are responsible for keeping others in their respective organizations informed and up-to-date on relevant information, requests, and action items.
- An organization should, as much as possible, present a unified message on an issue. If there is disagreement, it should be made clear which viewpoints are individual opinions.
- Agreements that are made in meetings should be communicated within signatory organizations and to appropriate members of the public.
- Information and data that is used to inform decisions should be accessible to all parties in a transparent manner.
- Raise any issues with the Program Manager and/or Science Coordinator as soon as possible.
- The Program Manager and/or Science Coordinator should be copied on relevant communication.
- Provide opportunities for public comment and outreach.

New Mexico's climate is anticipated to trend towards a more arid climate over the next 50 years and this is expected to affect water resources throughout the State. As a result, effective partnering and leveraging of available resources will rely on effective communication to manage the expected increased tension between competing uses of water associated with the Middle Rio Grande.

The science and adaptive management framework described in the Long-Term Plan has been structured for signatories to adaptively orient communications, activities, and recommendations into a science, policy, and management context for the benefit of signatories and other stakeholders in New Mexico. Figure 6 is a conceptual diagram of the communication necessary for a science and adaptive management program. The Collaborative Program has implemented processes to ensure consistent, complete, and clear communication amongst the three different groups (executives, managers, and scientists) necessary for adaptive management, and to both learn from and disseminate information to those external to the Collaborative Program. The four foundational elements described in Section 7.4 (Table 2) serve as pillars upon which a shared understanding can be developed. This framework should guide the prioritization of scientific research, investments to meet end-user needs, and adaptive management as a whole. The Collaborative Program utilizes several forums to share information within the context of Collaborative Program activities. These forums are meant to establish consistent, transparent, and regular internal communications between the EC, SAMC, Admin and S&T Ad Hoc Groups, and FPC.

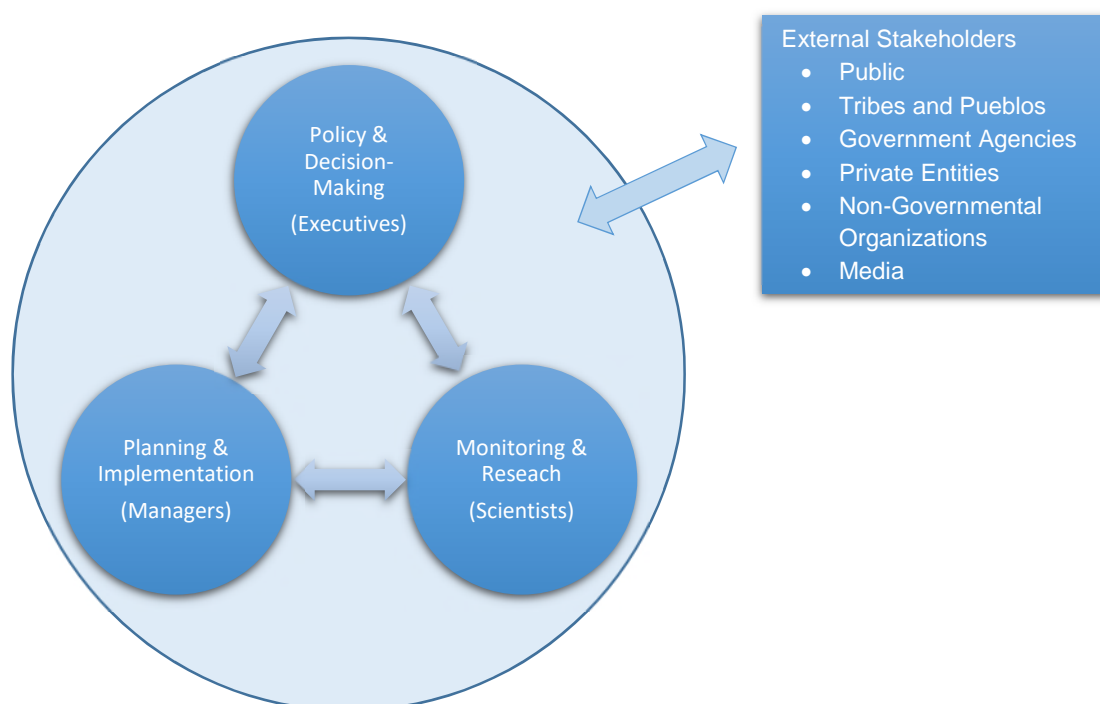


Figure 6. Lines of communication necessary for a successful science and adaptive management program.

5.2 Venues and Opportunities

The Collaborative Program utilizes several forums to share information, both technical and administrative, within the context of Collaborative Program activities. These are described below, and may be used by both Collaborative Program participants and outside entities who wish to share information.

Science Symposium

The Science Symposium is a biennial meeting for scientists and other technical experts to share relevant research and scientific findings to the larger Collaborative Program. Invited keynote speakers present insights on key topics for the Collaborative Program. The presentations and discussions from the Science Symposium contribute to adaptive learning and are later captured in updates to the CEMs.

Collaboratory

The Collaborative Program hosts a biennial “Collaboratory”, a workshop to synthesize scientific learning from the past two years in the context of the Science Objectives and uncertainties, and to strategically plan for future management needs. In order to identify opportunities for input and collaboration, workshop participants learn about signatories’ upcoming projects and priority management issues. Collaboratory participants discuss those issues, organize them by topic, and formulate one or more specific questions for each.

Workshops

The Collaborative Program hosts periodic workshops (at least one a year) for signatories and other interested parties to have conversations on a given topic that directly influences Collaborative Program operations and direction. Workshops can be convened around either scientific or programmatic topics and provides an opportunity for a larger audience to contribute to and guide initiatives of interest to the Collaborative Program.

Seminars

Seminars are public presentations hosted by the Collaborative Program and feature speakers both internal and external to the Collaborative Program. They serve as a forum for disseminating new and relevant information to the widest audience. Presentations occur on an as-needed basis and can feature topics related to signatory interests including scientific and policy-related issues. Following each seminar, the presenter hosts a question-and-answer session which allows for discussion and clarity on the topic.

Newsletters

Collaborative Program newsletters provide participants with relevant Collaborative Program information, engagement opportunities, and updates on operations and activities. Newsletters are distributed bi-monthly and highlight opportunities for coordination and collaboration, administrative deadlines, individual signatory updates, event announcements, and awards and recognitions.

6.0 TOOLS SUPPORTING THE LONG-TERM PLAN FOR SCIENCE & ADAPTIVE MANAGEMENT

The Collaborative Program employs the use of several administrative and planning tools to support decision making within the science and adaptive management framework. Below, these tools are described with regard to their relationships to the science and adaptive management process.

6.1 Science and Adaptive Management Information System (SAMIS)

The SAMIS is a tool for tracking activities, informing adaptive management recommendations by the Collaborative Program and documenting adaptive management actions by its signatories. The information system consists of a relational database, two user interfaces, a cloud server, authentication software, database managers, and end users.

The SAMIS integrates previously developed tools (e.g., conceptual ecological models) and recommendations (e.g., from independent science panels) with current scientific findings and priority questions, and links them in meaningful ways with proposed and ongoing signatory activities. These linkages organize the signatories' collective contributions within the complex management context of the Middle Rio Grande and its listed species. In other words, the SAMIS has been designed to characterize both the incremental value of individual activities and the accrued value of multiple activities over time in support of the goals of the Collaborative Program.

Utilizing a hub and spoke framework centered on a Project Bank (Figure 7; Section 6.1), the SAMIS links individual projects to strategic planning elements (Figure 7, orange pathway), recommendations from independent science panels (blue pathway), and critical uncertainties identified within conceptual ecological models (green pathway). The project findings, management recommendations and opportunities for adaptive management depicted in the purple pathway are SAMIS outputs that document the programmatic value of a project once it is completed. In this way, the SAMIS tracks a project from proposal to report, ensuring that all relevant findings are exploited for adaptive learning.

The Project Bank

The cornerstone of the SAMIS is the Project Bank: a list of past, current, and proposed activities that relate to water management and recovery of listed species in the Middle Rio Grande Basin. Items in the Project Bank (in various stages of development) are categorized and linked to scientific uncertainties, recommended actions, and planning strategies, and other projects in order to enable prioritization of activities that support decision-making.

This regularly maintained list of projects contains technical, logistical, and administrative details needed to categorize and sort projects to create customized summary reports for managers. These details also allow for the generation of metadata through linkages to other information in the SAMIS, which is helpful for evaluating the Collaborative Program's progress in science and adaptive management. These linkages also enable the organization of proposed activities based on scientific impact and relevance to Collaborative Program planning priorities.

Science & Adaptive Management Information System

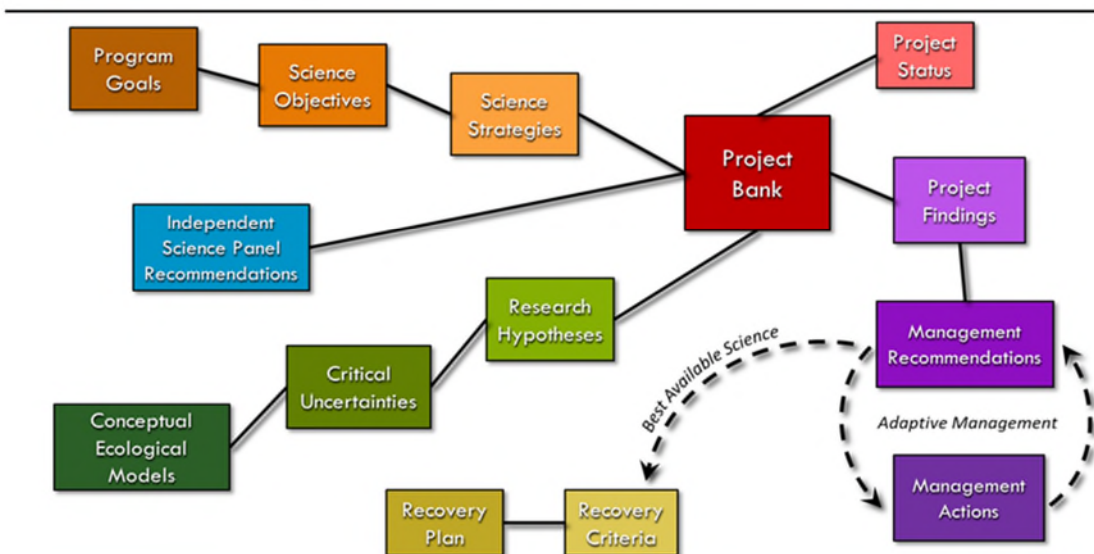


Figure 7. Conceptual diagram depicting the information inputs (orange, blue, and green pathways) to the Project Bank (red hub) and the outputs (purple pathway) of the SAMIS.

Using the SAMIS

Figure 7 above depicts the pathways between the Project Bank and other SAMIS structural elements, such as critical uncertainties, conceptual ecological models, and management recommendations. These relationships will enable users of the SAMIS to search, sort, filter and export subsets of projects with the characteristics they select. Example searches might include:

- List of ongoing projects that address critical uncertainties about a species of interest;
- List of completed projects funded by a particular agency within a specified date range; or
- List of all Collaborative Program Science Objectives, Science Strategies, recommendations and uncertainties addressed by a specified project.

In addition to customized searches and summaries, the SAMIS serves as a platform for impartial prioritization of proposed activities. By comparing the number and relative importance of connections to each project, for example, a user might rank a set of projects based on criteria selected to meet their agency's needs. This process can also be applied broadly to organize research studies and other activities along a timeline for long-term planning purposes.

Sorting studies by species, river reach, year, or type of activity facilitates collaboration among researchers and promotes leveraging of resources, such as data and personnel. Summarizing the estimated costs and programmatic contribution of a set of projects, as well as their collective value to a recovery plan or biological opinion, could help to justify research funds. On a larger scale, simple summary statistics could be calculated to examine the allocation of resources across the different focal species or across the geographic reaches for different fiscal years. These types of comparisons help the Collaborative Program track its progress and realign planned activities to its goals in the short and long term.

6.2 Program Portal

The Program Portal serves as a communication and administrative support tool. Administratively, the Program Portal houses the Collaborative Program's event calendar, which is regularly updated with upcoming Collaborative Program events and used to disseminate meeting agendas and read ahead materials. The Program Portal also contains the Collaborative Program's document library, geospatial mapper, and relevant datasets.

Document Library

The Portal hosts a document library that serves as a public resource for accessing Collaborative Program documents. It is a useful tool for filtering Collaborative Program materials by keyword, species, date, publishing organization, etc. The document library includes all Collaborative Program meeting minutes, agendas, and read-ahead materials; charters; newsletters; and group ad hoc charges. The document library also includes any publications linked to the Collaborative Program's species of interest that are provided by Collaborative Program participants, and these publications are included in a bibliography that is updated on a yearly basis and housed on the Portal. Any deliverables that come from the Collaborative Program, such as the Annual Report

and the Long-term Plan, are also included in the document library for easy reference and access to interested parties.

Geospatial Mapper

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 Middle Rio Grande. 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 adaptive management process by directly addressing the objectives and values of the stakeholders.

Datasets

Long-term datasets that cannot be readily found elsewhere, but are useful to Collaborative Program participants for their work in the Middle Rio Grande, are housed on the Portal. There are seven datasets providing geospatial information on the Portal, three of which cover general Middle Rio Grande characteristics, including River Miles, Vegetation, and River Reaches.

The Habitat Restoration dataset (RioRestore) was developed by GeoSystems Analysis under contract with NMISC to be a comprehensive geo-database that consolidates information from past habitat restoration efforts to develop a standard nomenclature to describe implementation activities and goals. The RiverEyes dataset was collected by the USACE to document Middle Rio Grande river drying, a critical element in managing RGSM populations during the irrigation season, and includes data and metadata from 1996 through 2019. The Portal also includes two datasets related to the RGSM, the USFWS RGSM Rescue Data and the RGSM Monitoring data. The USFWS RGSM Rescue Data provides documentation on the number and location of rescued RGSM during extreme low flows in the Middle Rio Grande from 2011-2018, while the RGSM Monitoring Data were collected by Reclamation from 1993-2019, and include information on mark-recapture, population estimation and occupancy monitoring of the RGSM in the Middle Rio Grande.

6.3 Peer Review

The Collaborative Program incorporates peer review into its internal processes to ensure robust and defensible administrative and scientific work products. Additionally, the Collaborative Program has procedures for seeking external reviews if an issue merits independent appraisal due to its importance for decision support or level of contention. The Collaborative Program delineates four categories of peer review:

- Internal peer review:
 - Internal Administrative Review
 - Internal Scientific Review
- External peer review:
 - External Expert Review
 - Independent Science Panel

A short description of each category is provided below. For more details, including standardized processes and codes of conduct related to peer review, see Appendix C.

Internal Review

Internal peer review is carried out within the Collaborative Program and administered by the PST at the direction of the EC, for Internal Administrative Reviews, or the SAMC, for Internal Scientific Reviews.

Internal Administrative Review

Internal administrative documents that are authored by the Collaborative Program and/or are essential to Collaborative Program governance and operations are reviewed by all the signatories. An internal administrative review is facilitated by the PST, which compiles individual signatory reviews, incorporates changes and, as appropriate, catalogs edits and responses to comments when finalizing a document for EC approval.

Internal Scientific Review

Internal technical reviews are delegated by the SAMC to one or more reviewers with appropriate qualifications and relevant subject matter expertise. This type of review may be applied to S&T Ad Hoc Group deliverables, technical reports, study designs, models, and other work products relating to the science program. A request for a review by the Collaborative Program by an organization (either a signatory or external to the Collaborative Program) may also be considered for internal scientific review.

External Review

External peer review is performed by individuals from outside the Collaborative Program. The review is administered by a third-party contractor to avoid bias.

External Expert Review

In the event that a work product has a large amount of influence on research direction, quality of management recommendations, or Collaborative Program operations, and involves a high degree of scientific uncertainty, the SAMC may recommend it for an external expert review. Individuals from outside the Collaborative Program are nominated to perform the review, and support is provided remotely via conference calls or web conference. Reviewer comments may be documented with individual comment forms or a consensus report. The work product under review should be complete enough to provide all necessary information to the reviewers without further need to interface with the Collaborative Program.

Independent Science Panel

The Collaborative Program has sponsored several Independent Science Panels. These tend to be costly and time-intensive for both the reviewers and Collaborative Program participants. Independent Science Panels are multi-day meetings with technical presentations from Collaborative Program scientists to the panel members, who should spend time prior to the meeting reviewing relevant scientific literature and other background materials. Given the resource-intensive nature of Independent Science Panels, these are reserved for broad, complex issues that are consequential to scientific understanding and trajectory of research, and have influence on management decisions.

6.4 Modelling Tools

A shared understanding of management actions, their intended effects, and associated uncertainties is critical to effective communication among decision makers, especially those tasked with managing a highly dynamic system, such as the Middle Rio Grande. Use of clear, common language and shared acknowledgment of key relationships, information gaps and assumptions helps to focus discussions among scientists, managers and other stakeholders. As adjustments in management are attempted, proper documentation of decision points and results is essential to adaptive learning and preservation of institutional knowledge.

One way to establish a centralized decision space in which to consider the effects of different management actions is with a model. The term “model” refers to anything that provides a reasonable representation of a system that is the setting for a natural resource management problem (Williams 2011). A model can be as basic as a verbal or written description, or as complex as a series of computer simulations.

In the framework of adaptive management, models connect management actions with stakeholder objectives (Conroy and Peterson 2013). Models applied to the adaptive management process should be viewed as useful, albeit imperfect, tools that are subject to continuous

refinement as new information becomes available. A model does not produce a decision but, instead, characterizes relationships and uncertainties useful for guiding the decision-making process.

Conceptual ecological models are useful for education and communication purposes, both internal and external to the Collaborative Program. The Collaborative Program has four primary applications for system-wide and species-specific CEM tools:

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

7.0 ADAPTIVE MANAGEMENT APPLICATION

The Collaborative Program uses a science and adaptive management process to determine how to best manage limited resources in the Middle Rio Grande to benefit listed species. Specifically, the Collaborative Program's science and adaptive management 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 adaptive management cycle, tailors each step of the adaptive management cycle to the Collaborative Program, and defines the role of adaptive management in the Collaborative Program.

7.1 The Adaptive Management Cycle

Adaptive management 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 adaptive management 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 8; Williams et al. 2009).

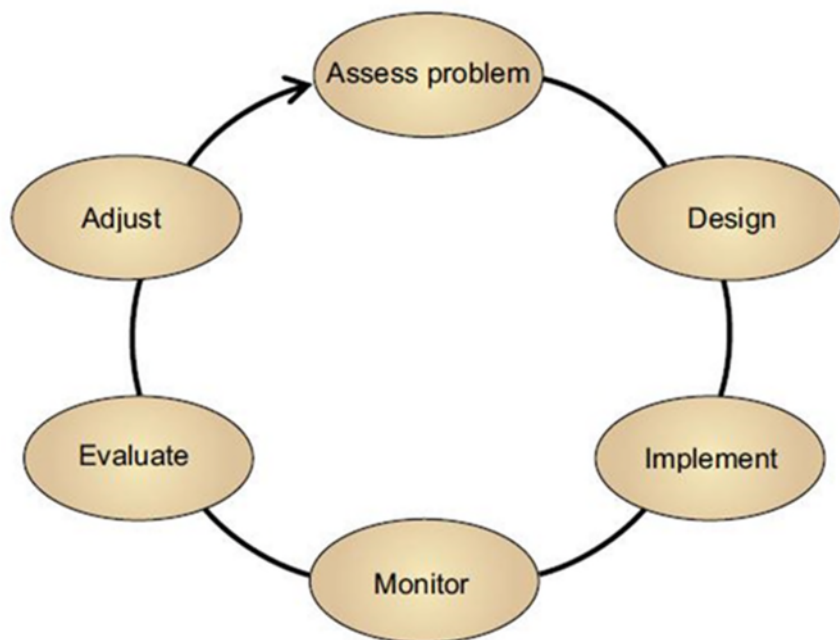


Figure 8. Adaptive management cycle.

Each step of the adaptive management 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 adaptive management cycle steps:

- **Assess Step:** Sets the foundation for the rest of the adaptive management 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 Middle Rio Grande 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 adaptive management decision tools (Section 6.0) 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 adaptive management 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 Middle Rio Grande. Documenting each iteration of the adaptive management 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, adaptive management 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 4.0), with the SAMC translating and communicating scientific evidence to the EC;
2. Continual updates to SAMIS (Section 6.1), which stores and link goals, Science Objectives, Science Strategies, metrics, uncertainties, and the Project Bank, to facilitate transparent prioritization of the Collaborative Program's scientific activities; and
3. Commitment to iterative learning through tracking (via SAMIS), evaluating, and incorporating scientific evidence into experimental designs, decision support tools (Section 6.0), and Collaborative Program objectives (Section 3.0) on at least an annual basis.

7.2 Defining Adaptive Management for the Collaborative Program

The Collaborative Program Long-Term Plan presents a science-based process aimed at reducing uncertainty within the Middle Rio Grande ecosystem relating to management of listed species. The Collaborative Program's definition of adaptive management, as approved by the EC, is stated in Box 6.

Box 6. 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 adaptive management 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 Middle Rio Grande.

7.3 Implementing Adaptive Management with the Collaborative Program

The Collaborative Program provides scientific and technical support to natural resource managers to inform the continual improvement of management actions for listed species. This process emphasizes learning from the results of scientific activities to inform management. As a science and adaptive management program, 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 adaptive management Database

As part of the science and adaptive management 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 Middle Rio Grande system, and include, but are not limited to, the list in Box 7.

Box 7. 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 adaptive management cycle (Figure 8).

7.4 Supporting Adaptive Management in the Middle Rio Grande

Over the past decade, the Collaborative Program's EC has reaffirmed its commitments to use science and adaptive management as the central tenets for its operations and decision-making processes, and to support a broader vision for the Middle Rio Grande. The Long-Term Plan codifies that commitment and lays out the policies, procedures, and structure required to

implement adaptive management within the context of the Middle Rio Grande by detailing how the Collaborative Program's organizational structure and operations can track progress, improve communication, and learn from and adjust for new information. Additionally, the Long-Term Plan describes activities that support adaptive management by addressing critical scientific uncertainties, integrating new information and forecasts, responding to management questions, and implementing adaptive management strategies.

Supporting Resiliency and Climate Change Planning

The 2009 U.S. Geological Survey (USGS)'s *Climate Change and Water Resources Management: A Federal Perspective* lists four elements of a collaborative process and sound science strategy (Table 2). These foundational elements are incorporated throughout the Collaborative Program's operations and processes, and are instrumental in ensuring the plan's value and utility to individual signatories and to adaptive management in the Middle Rio Grande.

Table 2. The Elements of a Collaborative Process and Sound Science Strategy

Element	Definition
Consolidate the Needs of the Natural Resource Management Community	Identify the common needs of the federal and non-federal natural resource management community for information and tools required to support adaptation as climate changes
Inform the Scientific Community	Guide and foster federal and non-federal research and technology investments toward meeting these "user-defined" needs
Teamwork and Participation	Generate collaborative efforts across the natural resource management and scientific communities to develop, test, and apply new methods, tools, and capabilities
Flexible and Inclusive	Issue periodic updates as new information and additional perspectives are obtained

The Collaborative Program embraces these elements throughout its administrative schedule (Section 8.0). Common needs across the natural resource management community of the Middle Rio Grande are assessed regularly via engagement with the SAMC. The SAMC considers the needs and challenges of each signatory organization, and uses scientific evidence to design management-relevant recommendations that meet the Collaborative Program's objectives. In addition, annual evaluation of the objectives ensures activities are aligned to address current management needs and changing hydrologic conditions, while the biennial science evaluation aligns the objectives with evolving critical scientific uncertainties. Impartial prioritization of research efforts is based on the level of scientific impact, timeliness, and relevance to management needs. This prioritization, along with tracking and synthesis of new findings, is carried out primarily through the use of the SAMIS, with input from the SAMC and approval by the EC.

Updates to the SAMIS, supported with scientific evidence, are documented to create a decision record that can be referenced, as needed, to support adaptive management. With a shared understanding of past decisions and the motivations behind them, scientists and managers will

be able to build forward-thinking and proactive contingencies into their decision-making processes. For future scenarios, the Long-Term Plan lays out a path along which the Collaborative Program can inform adaptive management and navigate uncertainties, such as those associated with climate change.

Appendix E provides a list of climate-planning tools and resources as a reference to aid in individual signatory planning efforts, and overall Collaborative Program activities involving climate change.

Incorporating Future Planning into the Long-Term Plan

USACE and Reclamation built upon the USGS foundational elements (2009) with a 2011 planning guide, *Addressing Climate Change in Long-Term Water Resources Planning and Management*, which details eight technical steps to categorize ways of incorporating climate trends and forecasts into long-term water resource planning. These are:

1. *Summarize Relevant Literature*
2. *Obtain Climate Change Information*
3. *Make Decisions about How to Use the Climate Change Information*
4. *Assess Natural Systems Response*
5. *Assess Socioeconomic and Institutional Response*
6. *Assess System Risks and Evaluate Alternatives*
7. *Assess and Characterize Uncertainties*
8. *Communicating Results and Uncertainties to Decision-Makers*

Similar steps can be used by the Collaborative Program to incorporate other future scenarios besides climate change into strategic planning. By integrating forecasts, model outputs, and condition-dependent alternatives, the Collaborative Program can make its recommended activities, such as habitat restoration, more resilient to changing environmental and operational conditions.

Socioeconomic factors, risk, and uncertainty are assessed at multiple levels of the planning process by engaging regularly with experts and stakeholders. To ensure that Collaborative Program activities remain relevant to management, individual signatories may participate in the Collaboratory by contributing their priority questions and issues for consideration during updates to the Long-Term Plan.

8.0 ADMINISTRATIVE SCHEDULE

Integrating an administrative schedule into the Collaborative Program's science and adaptive management framework is a critical component for providing timely recommendations of priority scientific activities to signatories and others working in the Middle Rio Grande. This section

provides details for tasks that should occur every year, but is not an exhaustive list. Additional tasks that are not mentioned may include external funding deadlines related to grants, Collaborative Program efforts related to specific requests or recommendations, or other activities that are not bounded by an annual schedule.

8.1 Committee Tasks and Coordination

Table 4 lists the annual tasks needed to carry out Collaborative Program operations, including committee meetings. The schedule does not exclude other activities or meetings, it is meant to provide a framework for activities that directly inform each other throughout the year, based on the responsibilities of each Collaborative Program committee.

Executive Committee Tasks and Coordination

The EC is responsible for ensuring that the Collaborative Program's administrative and governance activities are carried out, determining the Collaborative Program's direction and structure, and that work plans and schedules are met.

The EC directs an Admin Ad Hoc Group or the PST to carry out the annual Collaborative Program evaluation. By performing regular Collaborative Program-wide reviews of activities, the decision-makers (including EC members, Congressional and State representatives, and others) can be assured that Collaborative Program actions are accomplishing the Collaborative Program's mission and benefitting the listed species. Additionally, this effort provides evidence that federal and non-federal expenditures and efforts are producing tangible benefits for the listed species and their habitats.

Each year, the EC will either direct an Admin Ad Hoc Group or the PST to draft the Collaborative Program's Annual Work Plan, which the EC will approve in December of that year. This Annual Work Plan is informed by the activities carried out in the previous year, the scientific priorities set by the SAMC and EC, and the operational needs of the Collaborative Program. Drafting the Work Plan includes working with each committee to include their administrative tasks, deadlines, and reporting periods, as well as the tasks of the EC. The Annual Work Plan includes the activities to be carried out and the responsible Collaborative Program group(s).

Science and Adaptive Management Committee Tasks and Coordination

The SAMC appointments include up to eight positions that hold two-year staggered terms. Each year, the Collaborative Program's Science Coordinator works with the EC to administer a new member search.

The SAMC will update the conceptual ecological models (CEMs) annually based on the new scientific findings from completed signatory projects, new published literature, and information shared at the Science Symposium or the Collaboratory. The SAMC is also responsible forming and overseeing S&T Ad Hoc Groups. The SAMC may form S&T Ad Hoc Groups to develop project ideas to build off of scientific findings or to respond to new management questions. These project ideas are then entered into the Project Bank and used to update the Long-Term Plan. The SAMC

carries out the biennial Science Evaluation, from which it recommends to the EC any updates to the Science Objectives, Science Strategies, and the Long-Term Plan.

The SAMC will also work with the PST to hold workshops on a topic of timely relevance to the Collaborative Program. The SAMC decides on the topic based on scientific need, and coordinates with the PST to develop the agenda and determine desired outcomes. The Collaborative Program will host a topical workshop every fall, and may plan for more if there is a particular need.

Fiscal Planning Committee Tasks and Coordination

The FPC plays the central role of helping signatories coordinate the necessary resources (e.g., funding, staff, land access, laboratory space, etc.) to plan and implement projects that are relevant to the Collaborative Program. These projects do not necessarily have to be in the Long-Term Plan, but should pertain to the Collaborative Program's Guiding Principles. Part of the coordination should be working on developing appropriate monitoring plans to collect data on species response.

The FPC communicates to the SAMC on what recommended science activities in the Long-Term Plan are being implemented. Additionally, the FPC works with signatories to ensure signatory contributions are entered into SAMIS, activity statuses are updated, and findings from scientific activities are presented to the Collaborative Program.

The FPC also helps coordinates signatory habitat restoration projects, as necessary, that come out of the quarterly Habitat Restoration Coordination meetings. These meetings are an open forum for signatories to share their current and planned projects, and to identify areas for additional collaboration or need for FPC action in order to fill resource gaps.

8.2 Signatory Contributions

Signatory contributions are, as defined by the EC, signatory-implemented or –funded activities that either support the Collaborative Program administratively, or provide scientific findings and results that contribute to the Collaborative Program's understanding of the listed species and their habitats. Signatory contributions are tracked in SAMIS. Findings, data, and final reports are provided to the Collaborative Program for inclusion in science and adaptive management tools (e.g., CEMs, SAMIS, geospatial mapper). Collectively, the results of signatory contributions will inform recommendations on future science activities (via updates to the Long-Term Plan) and management activities. Signatory contributions fall into the following categories:

- *Program Management and Administration* – Non-research support of the Collaborative Program's Guiding Principles through administrative assistance, funding coordination, planning, coordination, and staffing of Collaborative Program activities. Examples include the Program and Science Support contract, the Program Portal, and public outreach initiatives.
- *Species Management and Recovery* – Non-research activities with influence on or relevance to recovery of one or more listed species within the Middle Rio Grande.

Examples include rescue operations, support of captive propagation facilities, and control of invasive species.

- *Population Monitoring and Modeling* – Descriptive empirical and/or mathematical investigations of population data for one or more listed species within the Middle Rio Grande. Examples include estimation of population size and trends over time, estimation of vital rates, and population viability forecasts.
- *Habitat Assessments and Modeling* – Descriptive empirical and/or mathematical investigations of physical environmental features at various spatial scales (e.g., site, reach, landscape) with influence on one or more listed species or the ecosystem of the Middle Rio Grande. Examples include hydrology and hydraulic modeling, mapping and geographic information systems, geomorphic studies, water quality studies, and climate change studies.
- *Field and Laboratory Experiments* – Any study designed to test a hypothesis about a listed species or other biotic response to a manipulation in a field or laboratory setting. Examples include habitat manipulations of flows or vegetation, before-after control-impact restoration designs, and laboratory studies of physiological responses.

The PST will work with the FPC to prepare a yearly report of each signatory's contributions based on information in SAMIS.

8.3 Collaborative Program Administrative Schedule

The schedule in Table 3 ensures the timely completion of annual and biennial administrative Collaborative Program activities supporting operations benefitting the listed species in the Middle Rio Grande. The activities in the schedule align with the steps of the adaptive management cycle, and the biennial nature ensures the periodic evaluation and documentation of new scientific, updates to adaptive management support tools, and continual improvement of Collaborative Program operations. IN this way, the Collaborative Program closes the adaptive management loop.

Activities that are in colored font denote agenda topics for the corresponding committee meeting (e.g., green for EC, yellow for SAMC, light blue for FPC).

Not all Collaborative Program activities are included in the Biennial Schedule. Some, such as drafting a new Memorandum of Agreement, has a timeframe longer than two years. Others are not beholden to any set schedule and may occur any time and as appropriate. These include:

- Science-based management recommendations from the EC
- Propose activity ideas for the Project Bank
- Public outreach and education
- Internal or external peer review

- Additional Admin or S&T Ad Hoc Groups
- Emergency or special EC meetings
- Holding seminars
- Holding additional topical workshops

The Biennial Schedule is subject to change based on Collaborative Program need, priorities, activities, direction, and any future changes to the Collaborative Program structure.

Table 3. Collaborative Program Biennial Administrative Schedule.

	MEETINGS	EVERY YEAR (YEARS A & B)		YEAR A	YEAR B
JANUARY	SAMC	Annual Program Evaluation SAMC new member search SAMC Search Admin Ad Hoc	Draft Annual Report		Science Evaluation Develop proposed projects from Collaboratory
FEBRUARY ^N	HR coord FPC				
MARCH	EC	Signatory Contributions report Results of Program Evaluation <ul style="list-style-type: none"> • Updates to charter * • Form By-Laws Admin Ad Hoc* 	Appoint new SAMC members Approve Annual Report Relate MAT/hydrology forecast to Collaborative Program		Approve updated Science Objectives Approve updated Long-Term Plan
APRIL ^N	SAMC	Updates to CEMs By-Laws Admin Ad Hoc* Ensure data on Portal is up-to-date		S&T Ad Hoc to work with contractor to update RioRestore	
MAY	HR coord FPC				
JUNE ^N	EC	Updates and recs from SAMC Work Plan update	Update By-Laws*		
JULY	SAMC				
AUGUST ^N	HR coord FPC				Funding check: RioRestore, Program Portal, PASS
SEPTEMBER	EC	Updates and recs from SAMC	Work Plan update		
OCTOBER ^N		Topical Workshop	Draft Annual Report		
NOVEMBER	SAMC HR coord FPC				
DECEMBER ^N	EC	Hydrology and species summary SAMC summary Next year's work plan Determine SAMC SME needs		Collaboratory (Go to Year B)	Science Symposium (Go to Year A)

* If needed; ^N Newsletter

HR coord = Habitat restoration coordination meeting; Long-Term Plan = Long-Term Plan for Science & Adaptive Management; MAT = Minnow Action Team; PASS = Program and Science Support contract; SAMC = Science and Adaptive Management Committee, SME = subject matter expert, S&T = Science & Technical, FPC = Fiscal Planning Committee, EC = Executive Committee

9.0 FUTURE DIRECTION

The recent progress and current momentum in the Collaborative Program have fostered an optimistic outlook among many participants. However, this optimism is tempered somewhat by a climate forecast for New Mexico which is likely to become more arid over the next 50 years. Observed increases in annual temperatures and aridity are causing a greater demand for groundwater resources in response to the decreases in surface water within the Middle Rio Grande. If the Collaborative Program is to realize its envisioned success of addressing the needs of both the species and the communities that depend upon the ‘ecological services’ of the Middle Rio Grande, then the signatory decision environment will likely need to explicitly consider a larger geo-political landscape in the future. This will ensure the deliberations and recommendations of the Collaborative Program directly support solutions aligned with the water crisis issues and strategies for resilience that encompass the Middle Rio Grande.

9.1 Work Plan Process

In order to operationalize the Long-Term Plan, the Collaborative Program adopts an annual work plan that details specific tasks to be carried out in a particular year. The PST develops the work plan with input from the EC Co-Chairs and ensures the inclusion of tasks necessary for Collaborative Program operations and activities in the context of the current scientific and administrative priorities.

The PST creates a work plan on a yearly basis that includes all contract deliverables and outlines other tasks identified by the Collaborative Program’s participants as critical to its success or further development (i.e., new ad hoc group charges, seminars, etc.). Once completed, the annual Work Plan is brought to the EC to be approved with the understanding that the timeline and deliverables can change with EC approval as priorities shift and the year progresses.

See Appendix A for the most recent Annual Work Plan.

9.3 Future Focus

While specific tasks in an annual work plan may change due to the current needs and priorities, the Collaborative Program has determined the general tasks to be focus areas for future work plans:

- Developing science-based management alternatives, comparing the strength of evidence for each alternative, and providing reasoning for associated management recommendations.
- Supporting the use of scientific findings and associated uncertainty to inform the design, implementation, and management of project.
- Planning for future management needs around climate change, including forecasting future conditions and formulating responses for likely scenarios.

- Providing and clarifying science-informed decision rationale in response to challenges to management recommendations within or external to the Collaborative Program
- Providing funding justifications to individual signatories by demonstrating the value of signatory activities.
- Help with public outreach and engagement, including providing common messaging.
- Documenting adaptive management learning and progress.

10.0 COLLABORATIVE PROGRAM RECOMMENDED ACTIVITIES

In addition to the administrative schedule listed in 8.0, the recommended activities for this Long-Term Plan are also listed below (Table 4). These activities fall into the same categories used to define signatory contributions (Section 8.2):

- *Program Management and Administration*
- *Species Management and Recovery*
- *Population Monitoring and Modeling*
- *Habitat Assessments and Modeling*
- *Field and Laboratory Experiments*

Table 4 lists the Collaborative Program recommended activities populated from the SAMIS Project Bank. It notes the Collaborative Program objective(s) it would address, the project category, and the species of interest. It also indicates the project status, as follows:

1. *Outlined*: Proposed project idea has been outlined, but lacks details needed for a scope of work.
2. *Scoped*: Scope of work has been developed, which includes research question/objective, study design, budget, timeline, etc.
3. *Submitted*: Project scope of work has been submitted to a potential funding agency.
4. *Approved*: Funding agency has agreed to fund the project, but work has not commenced.
5. *In-progress*: Project work is underway.

The associated spreadsheet of Collaborative Program recommended activities is the full report-out from the SAMIS Project Bank, and allows for individual signatories to create filters, queries, and pivot tables to aid in their own planning processes.

One of the future tasks is the development by the SAMC of a robust set of criteria for evaluating items in the SAMIS Project Bank. A preliminary set of suggested criteria includes three components:

1. The SAMIS *linkage* count, which appraises the intrinsic value of the project to the Collaborative Program by quantifying the direct connections to elements within the SAMIS;
2. A S.M.A.R.T. (Specific, Measurable, Achievable, Relevant, and Time-bound) score, which appraises the clarity and completeness of a project's scope of work, and;
3. An adaptive management score, which appraises the value of the project to planning and adaptive management.

Initial feedback on these scores has been mixed, so refinement and evaluation by the SAMC will continue. Future Long-Term Plan updates will incorporate the revised criteria into the Recommended Activities list.

Table 4: Recommended Activities Sorted by Project Name

Project Name	Program Objective	Project Status	Project Category	Focus/Species
Assess the Persistence of Stocked Silvery Minnow	Science Objective A-6.2	Outlined	Population Monitoring and Modeling	RGSM
Assessing temporal and spatial continuous water quality trends in the Angostura, Isleta, and San Acacia reaches of the Middle Rio Grande	Science Objective A-2, A-3, A-4	Approved	Habitat Assessments and Modeling	MRG Ecosystem
Assessing temporal and spatial continuous water quality trends in the Isleta and San Acacia reaches of the Middle Rio Grande	Science Objective A-3, G-1	Outlined	Habitat Assessments and Modeling	Other
Assessment and Monitoring of Rio Grande Silvery Minnow Genetics	NA	In-Progress	Population Monitoring and Modeling	RGSM
Assessment of Native and Non-native Fish Species in the Middle Rio Grande and their relation to Rio Grande Silvery Minnow	Science Objective A-2	Outlined	Field and Laboratory Experiments	RGSM
Bosque and Riverine Restoration Project and Fish Passage at Isleta Diversion Dam	NA	In-Progress	Field and Laboratory Experiments	RGSM
Candelaria Nature Preserve Risk Management Plan	NA	In-Progress	Program Management and Administration	MRG Ecosystem
Characterize the relationship between the annual CPUE index and true Rio Grande Silvery Minnow population size	Science Objective A-1	Outlined	Field and Laboratory Experiments	RGSM
Compare and contrast Yellow-billed Cuckoo and Southwestern Willow Flycatcher breeding habitat requirements within the Middle Rio Grande	Science Objective B-3.1, C-1.3	Outlined	Field and Laboratory Experiments	YBCU
Compare invasive survey methods (trapping, telemetry) to noninvasive methods (e.g., models, remote cameras, track plates) for risk, effectiveness and reliability regarding study of New Mexico meadow jumping mouse	Science Objective D-1.2	Outlined	Field and Laboratory Experiments	NMMJM

Project Name	Program Objective	Project Status	Project Category	Focus/Species
Comparison of Environmental Conditions Experienced by Rio Grande Silvery Minnow in Hatchery Facilities to those Experienced in the Middle Rio Grande	Science Objective A-2	Outlined	Field and Laboratory Experiments	RGSM
Conduct Rio Grande Silvery Minnow Monitoring at 10(j) Reintroduction Sites to Evaluate Stocked Populations	Science Objective A-1	In-Progress	Field and Laboratory Experiments	RGSM
Continue to Support the Development of Population Viability Analysis Models	Science Objective A-3	Outlined	Habitat Assessments and Modeling	RGSM
Data Collection and 2D Modeling of High-flow Channels	Science Objective A-3, A-4, A-5.1	Outlined	Habitat Assessments and Modeling	MRG Ecosystem
Decision Tree of Hydrologic Conditions	Science Objective A-3, A-4	Outlined	Program Management and Administration	Other
Describe metapopulation structure, dynamics and connectivity of Southwestern Willow Flycatcher populations in the Middle Rio Grande	Science Objective B-3.3	Outlined	Population Monitoring and Modeling	SWFL
Describe population dynamics of New Mexico meadow jumping mouse in the Middle Rio Grande	Science Objective D-1.1	Outlined	Field and Laboratory Experiments	NMMJM
Describe the impacts of the tamarisk beetle on Southwestern Willow Flycatchers and their breeding habitats in the Middle Rio Grande	Science Objective B-3.1, B-3.2	Outlined	Field and Laboratory Experiments	SWFL
Determine the amount of genetic variation within and between populations of New Mexico meadow jumping mouse	Science Objective D-1.1	Outlined	Field and Laboratory Experiments	NMMJM
Determine the rate of development and hatching success under various environmental conditions for Rio Grande Silvery Minnow	Science Objective A-2, A-3	Outlined	Field and Laboratory Experiments	RGSM

Project Name	Program Objective	Project Status	Project Category	Focus/Species
Determine the survival rates and estimate their natural (process) variability for different age classes of Rio Grande Silvery Minnow	Science Objective A-3	Outlined	Population Monitoring and Modeling	RGSM
Determine which site selection and prioritization procedures contribute to the successful restoration of Southwestern Willow Flycatcher breeding habitats along the Middle Rio Grande.	Science Objective B-3.1, B-3.2	Outlined	Field and Laboratory Experiments	SWFL
Develop and Utilize a Decision Tool to Test the Feasibility of Re-establishing Rio Grande Silvery Minnow Populations at Potential Reintroduction Locations	Science Objective A-3, A-4	Outlined	Field and Laboratory Experiments	RGSM
eDNA marker development for Rio Grande Silvery Minnow (<i>Hybognathus amarus</i>)	Science Objective A-1, A-2	Approved	Population Monitoring and Modeling	RGSM
Effects of Sediment Management to River Habitats	Science Objective A-2, A-4	Outlined	Habitat Assessments and Modeling	MRG Ecosystem; RGSM
Effects of Temperature Degree Days and Photoperiod on Rio Grande Silvery Minnow Spawning	Science Objective A-2	Approved	Field and Laboratory Experiments	RGSM
Efficacy of RGSM Egg Collection over Varying Temporal and Spatial Scales	Science Objective A-6.2	Outlined	Population Monitoring and Modeling	RGSM
Estimate the fecundity of Rio Grande Silvery Minnow and its variability with age or size	Science Objective A-2, A-3	Outlined	Population Monitoring and Modeling	RGSM
Evaluate and quantify in channel habitat diversity and utilization for all life stages of Rio Grande Silvery Minnow	Science Objective A-1, A-2, A-3, A-4, A-5.1	Scoped	Habitat Assessments and Modeling	RGSM
Evaluate the sizes, distributions, and status of Southwestern Willow Flycatcher populations along the Angostura Reach	Science Objective B-1	Outlined	Population Monitoring and Modeling	SWFL

Project Name	Program Objective	Project Status	Project Category	Focus/Species
Evaluate Water Quality in the Middle Rio Grande in Relation to the Rio Grande Silvery Minnow	Science Objective A-2, A-4, A-5.1	Outlined	Field and Laboratory Experiments	RGSM
Evaluation of Paired Spawning and Communal Spawning for Rio Grande Silvery Minnow	NA	Scoped	Field and Laboratory Experiments	RGSM
Evaluation of Rio Grande Silvery Minnow Population Model Alternatives	Science Objective A-3	In-Progress	Field and Laboratory Experiments	RGSM
Evaluation of Yellow-billed Cuckoo (Yellow-billed Cuckoo) Prey Base and Associated Host Plants	Science Objective C-1.3	Scoped	Population Monitoring and Modeling	YBCU
Fish Movement Study at the Constructed San Acacia Diversion Dam Fish Passage	Science Objective A-4	Outlined	Population Monitoring and Modeling	RGSM
Flow Frequency Analysis for Albuquerque South to Belen	Science Objective A-3, A-4	Approved	Habitat Assessments and Modeling	MRG Ecosystem; RGSM; SWFL; YBCU
Genetic Comparison of Rio Grande Silvery Minnow Eggs/Larvae Collected on the Floodplain to those Collected in the Main Channel	Science Objective A-2	Outlined	Field and Laboratory Experiments	RGSM
Genetically-Based Techniques to Measure Physiological Response to Drying in RGSM	Science Objective A-2	Outlined	Population Monitoring and Modeling	RGSM
Habitat Restoration Planning and Design	NA	Outlined	Field and Laboratory Experiments	Other
Habitat Restoration Projects Assessment	Science Objective F-1, G-1	Outlined	Field and Laboratory Experiments	MRG Ecosystem
Habitat Restoration Revegetation Techniques	Science Objective A-5.2, B-3.1, B-3.2, F-2	Outlined	Field and Laboratory Experiments	MRG Ecosystem

Project Name	Program Objective	Project Status	Project Category	Focus/Species
Hink and Ohmart Vegetation Mapping	Science Objective B-2, B-3.1, B-3.2, C-1.1, F-2	Approved	Habitat Assessments and Modeling	MRG Ecosystem
Historical evaluation of alluvial channel crossings	Science Objective A-4	Approved	Habitat Assessments and Modeling	MRG Ecosystem
Identification and Evaluation of Potential Sites for RGSM 10(j) Reintroduction	Science Objective A-3	Outlined	Habitat Assessments and Modeling	RGSM
Identify and Assess Habitat Needs, Management Activities, and Any Major Hurdles to Rio Grande Silvery Minnow Reintroduction into Upper and Lower Rio Grande and Pecos River Reaches	Science Objective A-2, A-3	Outlined	Field and Laboratory Experiments	RGSM
Identify Spatial Behavior Patterns and Drivers of Those Behaviors Within and Among Years for Yellow-billed Cuckoos that Breed in the Middle Rio Grande	Science Objective C-1.3	Outlined	Field and Laboratory Experiments	YBCU
Identify the abiotic and biotic variables that predict suitable Yellow-billed Cuckoo breeding habitats in the Middle Rio Grande across multiple spatial and temporal scales	Science Objective C-1.3	Outlined	Field and Laboratory Experiments	YBCU
Identify the key life-history sensitivities of Rio Grande Silvery Minnow and which age-specific survival and fecundity rates most affect the rate of population change	Science Objective A-2	Outlined	Population Monitoring and Modeling	RGSM
Identify the Yellow-billed Cuckoo breeding population sizes, distributions, and trends in the Middle Rio Grande	Science Objective C-1.3	Outlined	Field and Laboratory Experiments	YBCU
Impacts of Climate Change on Middle Rio Grande Water and Species Management	Science Objective A-3, A-4, G-1	Outlined	Habitat Assessments and Modeling	MRG Ecosystem

Project Name	Program Objective	Project Status	Project Category	Focus/Species
Implement the Strategy for Maintenance and Construction of Southwestern Willow Flycatcher Habitat	Science Objective B-3.3	Outlined	Field and Laboratory Experiments	SWFL
Improving Southwestern Willow Flycatcher and Yellow-billed Cuckoo Habitat Restoration Site Selection	Science Objective B-1, B-3.1, B-3.2, C-1.1, C-1.3	Scoped	Habitat Assessments and Modeling	SWFL; YBCU
Investigate the ways in which key Rio Grande Silvery Minnow vital rates vary as a function of hydrologic factors, abiotic environmental factors, and biotic factors	Science Objective A-2	Outlined	Field and Laboratory Experiments	RGSM
Locate potential Middle Rio Grande populations of New Mexico meadow jumping mouse	Science Objective D-1.1	Outlined	Field and Laboratory Experiments	NMMJM
Maximizing Success for Habitat Restoration Projects by Optimizing Alternatives for Active Re-vegetation, Supplemental Watering, and Other Management Activities	Science Objective F-2	Outlined	Field and Laboratory Experiments	MRG Ecosystem
Middle Rio Grande Habitat Restoration Fisheries Monitoring	Science Objective A-5.1, A-5.2	Outlined	Population Monitoring and Modeling	RGSM
Minimize the Adverse Effects to Rio Grande Silvery Minnow from Levee Project Construction and In-situ Monitoring	Science Objective A-2, A-3	Approved	Field and Laboratory Experiments	RGSM
Modeling of the future bosque ecosystem vegetative community under climate change	Science Objective F-2	Outlined	Habitat Assessments and Modeling	MRG Ecosystem; RGSM; SWFL; YBCU; PESU; NMMJM; Other
Monitor and Evaluate Southwestern Willow Flycatcher Habitat Restoration	Science Objective B-1, B-3.1	Outlined	Field and Laboratory Experiments	SWFL

Project Name	Program Objective	Project Status	Project Category	Focus/Species
Monitor Habitat Restoration Projects for Effectiveness	Science Objective B-3.1, C-1.1, F-1	Outlined	Field and Laboratory Experiments	MRG Ecosystem
MRG restoration sites WIFL/YBCU annual surveys	Science Objective B-1, B-3.2, C-1.3	Approved	Population Monitoring and Modeling	YBCU
Optimize Survivorship of Rio Grande Silvery Minnow During Transportation and Stocking For Post-Release Retention At Reintroduction and Augmentation Site	Science Objective A-6.2	Outlined	Field and Laboratory Experiments	RGSM
PIT Tagging and Genetic Characterization of Broodstock	NA	In-Progress	Population Monitoring and Modeling	RGSM
Portable bubble barrier development and testing	NA	Approved	Field and Laboratory Experiments	RGSM
Program and Science Support	Administrative Objective Admin-1	In-Progress	Program Management and Administration	Other
Program Portal	Administrative Objective Admin-1	In-Progress	Program Management and Administration	Other
Qualitative Assessment of the MRG from the perspective of geomorphology, hydraulics, and hydrology	Science Objective A-3, A-4, A 5.1	Approved	Habitat Assessments and Modeling	MRG Ecosystem
Quantify Middle Rio Grande Channel Habitat Diversity Analysis	Science Objective A-3, A-4	Approved	Habitat Assessments and Modeling	MRG Ecosystem; RGSM; SWFL; YBCU
Quantify Piscine Predators and Competitors	Science Objective A-2, F-1	Outlined	Field and Laboratory Experiments	RGSM
Raptor Nest Monitoring	NA	Approved	Population Monitoring and Modeling	Other
RGSM Larval Gut Analysis	Science Objective A-2	Outlined	Field and Laboratory Experiments	RGSM

Project Name	Program Objective	Project Status	Project Category	Focus/Species
Rio Grande Silvery Minnow Ecological Studies Evaluating Habitat Use and Recruitment	Science Objective A-2, A-3	Outlined	Field and Laboratory Experiments	RGSM
Rio Grande Silvery Minnow Genetics over Time in Hatchery Facilities	NA	Scoped	Field and Laboratory Experiments	RGSM
Rio Grande Silvery Minnow Population Estimation	Science Objective A-1, A-3	Outlined	Population Monitoring and Modeling	RGSM
Rio Grande Silvery Minnow Spawning and Recruitment Study at the Los Lunas Silvery Minnow Refugium	Science Objective A-4, A-5.2	Outlined	Field and Laboratory Experiments	RGSM
Sediment analysis for Middle Rio Grande	Science Objective A-3, A-4, A-5.1	Approved	Habitat Assessments and Modeling	MRG Ecosystem; RGSM
Short-Interval Assessment of Whole-Stream Rio Grande Metabolism	Science Objective A-3, F-1, G-1	Outlined	Habitat Assessments and Modeling	MRG Ecosystem
Size-Related PIT Tagging Mortality and Surgical Methods to Minimize Mortality in RGSM	Science Objective A-6.2	Outlined	Field and Laboratory Experiments	RGSM
Soil Moisture Holding Capacity Study	Science Objective B-3.2	Scoped	Field and Laboratory Experiments	MRG Ecosystem
Thermal and Dissolved Oxygen Tolerance of Rio Grande Silvery Minnow	Science Objective A-2, A-5.1	Scoped	Field and Laboratory Experiments	RGSM
Thermal Limits of RGSM Survivability	Science Objective A-2	Outlined	Field and Laboratory Experiments	RGSM
Use modeling tools (e.g., FLO-2D and HEC-RAS) to estimate frequency and extent of overbank inundation and in-channel habitat in the Middle Rio Grande	Science Objective A-3, A-5.1, B-3.3	Outlined	Field and Laboratory Experiments	RGSM; SWFL
USGS Groundwater/Surface Water Interaction	Science Objective A-4, A-5.1, B-3.3, G-1	Outlined	Habitat Assessments and Modeling	Other

Project Name	Program Objective	Project Status	Project Category	Focus/Species
Using URGWOM to Evaluate Future Water Management Strategies	Science Objective A-4, A-5.1, G-1	Outlined	Habitat Assessments and Modeling	MRG Ecosystem; RGSM; SWFL; YBCU; PESU; NMMJM
Water Requirements for Southwestern Willow Flycatcher and Yellow-billed Cuckoo Habitat and Nesting	Science Objective B-1, B-3.1, B-3.2, B-3.3, C-1.1	Outlined	Field and Laboratory Experiments	SWFL; YBCU
Yellow-billed Cuckoo Genetics/Genomics	Science Objective C-1.3	Scoped	Field and Laboratory Experiments	YBCU
Ground Water - Surface Water Interactions in the Riparian Zone	Science Objective B-3.3	Outlined	Habitat Assessments and Modeling	MRG Ecosystem

11.0 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.

Biennial Schedule: The Collaborative Program's administrative schedule of activities that support Collaborative Program operations and ensure the completion of the adaptive management cycle.

Collaboratory: A biennial workshop where the Collaborative Program synthesizes scientific learning within the context of applied learning and adaptive management, and identifies priority management questions for the next two years.

Guiding Principles: Collectively, the mission, goals, and objectives of the Collaborative Program.

Long-Term Plan for Science & Adaptive Management: The central planning document of the Collaborative Program which codifies Collaborative Program operations and activities within a science and adaptive management framework.

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 Middle Rio Grande 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.

Program Portal: The Collaborative Program's website.

Project Bank: The central component of the Science and Adaptive Management System (SAMIS). A repository of activities, both implemented and recommended, of interest to the Collaborative Program.

Science and Adaptive Management Information System (SAMIS): A relational database that serves as a planning and reporting tool for the Collaborative Program. It links implemented and proposed activities with Collaborative Program guiding principles, individual

signatory's planning priorities and authorities, scientific uncertainty, and panel recommendations.

Science Evaluation: A biennial process initiated by the Collaboratory where the Collaborative Program's scientific objectives and strategies are evaluated within the context adaptive management and learning, and revised as necessary to reflect current management priorities and scientific understanding.

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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13.0 APPENDICES

- A. 2022 Collaborative Program Work Plan
- B. Scientific Code of Conduct and Principles
- C. Peer review process
- D. SAMIS Reference Guide of Strategies and Independent Science Recommendations
- E. Climate-related tools and planning initiatives implemented by Collaborative Program signatories and research partners

Appendix A. 2022 Collaborative Program Work Plan

2022

Middle Rio Grande Endangered Species Collaborative Program (MRGESCP) Work Plan

Tasks

1

Administrative tasks

2

Task Science & Technical (S&T) Ad Hoc Groups

3

Building linkages and content for the Science and Adaptive Management Information System

4

Decision tools to facilitate adaptive learning

5

Information sharing and coordination

TASK	SUBTASK	EC	AAH	SAMC	S&T	FPC	PST	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Executive Committee (EC) meeting	X								X			X			X			X
	Science & Adaptive Management Committee (SAMC) meeting			X				X			X			X				X	
	Fiscal Planning Committee (FPC) meeting					X			X			X			X			X	
1a	Maintain and update documents and content on the Program Portal						X	X	X	X	X	X	X	X	X	X	X	X	X
1b	Maintain and update activities in the Science and Adaptive Management Information System (SAMIS)	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
1c	Hold trainings for SAMIS	X		X			X			X	X								
1d	Continue updating and approve the revised Science & Adaptive Management Plan	X		X			X	X	X	X									
1e	Complete and present results from the annual MRGESCP evaluation	X		X			X	X	X	X									
1g	Sign the new Memorandum of Agreement (MOA)	X						X	X	X	X	X							
1h	Continue drafting and approve the 2021 Annual Report	X					X	X	X	X									
1i	Implement agreed upon changes from the annual evaluation	X		X			X				X	X							
1j	Begin drafting 2022 Annual Report						X									X	X	X	X

1k	Begin developing 2022 signatory contributions reports					X												X	X
1l	Develop the SAMC annual summary report			X		X												X	X
1m	Develop and approve 2023 Annual Work Plan	X		X		X											X	X	X
2a	Continue the RGSM Integrated Population Model S&T Ad Hoc Group				X		X	X											
2b	Continue the revision of the revised Rio Grande Silvery Minnow (RGSM) Conceptual Ecological Model (CEM)				X		X	X	X										
	Initiate an Internal Science Review of the draft revised RGSM CEM			X	X	X					X	X							
2c	Convene the RGSM Hypothesis Development S&T Ad Hoc Group				X				X	X	X	X	X						
2d	Convene Habitat Restoration (HR) Guidance S&T Ad Hoc Groups to develop species-specific restoration goals, monitoring considerations, and metrics to document success				X				X	X	X	X	X	X	X				
2e	Organize and convene a Scenario Planning S&T Ad Hoc Group to synthesize climate change planning efforts, and identify the elements necessary to include in Collaborative Program operations in order to inform adaptive management				X				X	X	X	X	X	X	X	X			
2f	Organize and convene a New Mexico Meadow Jumping Mouse CEM Development S&T Ad Hoc Group				X								X	X	X	X	X	X	X
2g	Organize and convene a Pecos Sunflower CEM Development S&T Ad Hoc Group				X								X	X	X	X	X	X	X
3a	Populate the Project Bank with past and current projects. Specify research hypotheses, where appropriate			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
3b	Populate the Project Bank with potential projects and hypotheses			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3c	Develop strategies from the Science Objectives.			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3d	Strategically identify uncertainties in the CEMs and link them to the appropriate elements in SAMIS				X	X	X	X	X	X	X	X							

3e	Assess status of identified critical uncertainties			X	X					X	X	X	X	X	X			
4a	Convene a Peer Review Administrative Ad Hoc Group to revise the draft MRGESCP peer review process		X					X	X	X	X	X						
4b	SAMC review and EC approve the revised MRGESCP peer review process	X		X						X	X	X						
4c	Conduct a survey of management needs regarding Rio Grande silvery minnow population monitoring			X			X			X	X	X	X					
4d	Evaluate and refine Project Bank scoring elements to align with management needs			X			X				TBD based on SAMC feedback							
4e	Plan for and host the Collaboratory	X		X			X									X	X	X
5a	Send out regular MRGESCP newsletters						X		X		X		X		X		X	X
5b	Host quarterly HR coordination meetings					X	X		X			X			X		X	
5c	Coordinate on fulfilling project needs that were identified at the HR coordination meetings					X			X			X			X		X	
5d	Host regular collaborative seminars			X			X			X			X			X		X
5e	Host a topical workshop (topic: TBD)			X												X		

Appendix B. Scientific Code of Conduct and Principles

Scientific Code of Conduct for the Middle Rio Grande Endangered Species Collaborative Program* Adopted April 15, 2010

Purpose

To establish a standard code of professional conduct among the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) signatories and participants with respect to all scientific activities.

Scope

- The professional conduct and management of scientific activities by and on behalf of the Collaborative Program signatories and
- All Collaborative Program participants including, but not limited to: committee members, work group members, ad hoc work group members and contractors and their representatives, when they conduct Collaborative Program-related studies, review reports, engage in discussions, and present, manage or apply information resulting from scientific activities.

Objectives

- To ensure that the information generated through scientific activities is as reliable, objective, repeatable, and as available to Collaborative Program participants and the public as possible.
- To convey the importance of scientific information
 - by recognizing the importance of science in furtherance of accomplishing Collaborative Program goals.
 - by using scientific information in establishing credibility and value of the Collaborative Program with the public.
- To assist Collaborative Program participants in performing their duties with the utmost professionalism and quality.

Code of Conduct

To the best of their ability, all Collaborative Program participants performing or managing scientific activities, or applying resulting information, shall:

- Be guided by the scientific method.
- Strive to advance science and produce scientific information that is of the highest quality and most reliable.
- Understand and adhere to the standards of reporting the results of scientific activities (e.g., employment of the scientific method), distinguishing when conclusions are based on documented, reproducible analysis of data.

- Be accountable for the quality of any data collected, the interpretations of that data, the integrity of conclusions drawn from scientific activities and provide access to data (and metadata) where appropriate, including documentation of analyses based on those data.
- Be conscientious in the collection, use, documentation and maintenance of data.
- Review, report and apply the results of scientific activities with honesty, thoroughness, objectivity and without conflict of interest.
- Communicate information to the scientific community and the public in order to promote understanding of the work of the Collaborative Program, including activities related to water management, water use, fish and wildlife, and their habitat needs.
- Acknowledge that uncertainty is inherent in science and in using scientific information to manage listed species, their habitats and water use in the Collaborative Program area.
- Recognize that decision making will need to be accomplished despite this uncertainty, but that decision making will be performed using the best available scientific information at the time and adapted as better information is made available.
- Place reliability and objectivity of scientific activities and results ahead of personal gain and/or allegiance to individuals and organizations.
- Be respectful in the treatment of colleagues, other scientists, professional contacts and the public.
- Recognize the ideas and work of others and be mindful in acknowledging those contributions.
- Avoid hindering the scientific activities of others and engaging in dishonesty, fraud, deceit, misrepresentation, coercive manipulation or other misconduct.
- Present professional opinions and advice only in Program areas for which you are qualified (professional education, training or experience) and for which you are informed.
- Accept constructive criticism of scientific activities and critique others' work in a respectful and objective manner.

*Adapted from the U.S. Fish & Wildlife Service's "Scientific Code of Professional Conduct for the Service" (212 FW 7)

Scientific Principles

Adopted September 2018

Purpose

To establish guidelines for professional scientific behavior among the Collaborative Program signatories and participants that signatories and participants are expected to adhere to.

These scientific guidelines will apply to the conduct and management of scientific activities by and on behalf of the Collaborative Program signatories. All Collaborative Program participants—including, but not limited to, committee members, work group members, contractors, and signatory representatives—are expected to adhere to these guidelines when they: conduct Collaborative Program-related studies; review reports and scientific findings; engage in discussions; and present, manage, or utilize information resulting from scientific activities.

A rigorous scientific process leads to better data, better analysis, and ultimately, better decisions. A process for pursuit of scientific knowledge that does not incorporate standards of conduct results in misunderstanding, poor analysis, and decisions based on faulty science. The scientific method by definition is a systematic set of principles and procedures that involves careful observation, rigorous skepticism, formulating and testing hypotheses (assumptions), and the development of information (data) that can be used to assess responses to various actions. It is a counter approach to embracing decisions based on intuition, beliefs or assumptions. Our goal is to create a state of learning through the collection of data to assist in developing facts and ultimately improved information to assist in decision-making. Utilizing the scientific method in a process of systematically developing knowledge based on the collection of observations, research, and experimentation carried on in order to determine the nature or principles of the area of study is critical.

This document serves to supplement, not replace, the 2010 Collaborative Program Scientific Code of Conduct. This document is meant to detail the discussions of the Collaborative Program's Executive Committee in September 2018, and their agreement to work towards a better culture for objective science.

Scientific Process Principles

The Collaborative Program science program should be:

- Interdisciplinary
- Interagency
- Collaborative
- Evidence-based
- Transparent and open
- Management-relevant

To the best of their ability, all Collaborative Program participants performing or managing scientific activities, or applying resulting information, shall foster an environment of sound scientific process. Elements of such an environment include:

- Following the communication principles adopted by the Executive Committee at the April 2017 retreat.
- Being open-minded, skeptical, and without preconceptions in the spirit of scientific inquiry.
- Having honest conversations around scientific studies and results.
- Creating a forum for civil discourse about the development, acquisition, and use of data and knowledge gained from applied and research science.
- Disagreeing in a professional manner, and when providing and receiving feedback, be mindful that critiques are not personal attacks.
- Being open to and participating in evaluation of one's work, including peer reviews.
- Questioning and understanding the assumptions underlying scientific opinions.
- Encouragement to publish in reputable scientific peer-reviewed journals.
- A common set of guidelines for all scientists in the Program.
- Transparency and openness in sharing data, results, and methodologies.
- Accountability to these principles, the Scientific Code of Conduct, and administrative deadlines and processes.

Appendix C. Peer Review Process

Note: The draft peer review process is currently in development and review. Following EC approval and adoption (scheduled for June 2022), the final peer review process will be included as Appendix C of the Long-Term Plan.

Appendix D. Science Objectives, Strategies, and Panel Recommendations

RGSM Objectives

A-1) Estimate the abundance of augmented and wild born RGSM populations in the Angostura, Isleta, and San Acacia reaches from year to year.

Strategy A-1a: Evaluate CPUE as an estimator of abundance (i.e., the assumption that number of fish caught per unit effort is proportional to stock size).

Strategy A-1b: Design a study to determine effect(s) of discharge on mesohabitat availability.

A-2) Increase understanding of how the life history traits of the RGSM change over time and space, to better inform management of the species and increase the probability of recovery.

Strategy A-2a: Compare the RGSM life history traits by reach, where appropriate, and identify differences that can be affected by management actions to improve recovery.

Strategy A-2b: Identify factors that influence life history traits (e.g., water availability, food resources, water temperature). Seven life history traits: size at birth; growth pattern; age and size at maturity; number, size and sex ratio of offspring; age- and size-specific reproductive investments; age- and size-specific mortality schedules; length of life.

A-3) Determine the relationships between base flow and survival and recruitment of RGSM in the MRG.

Strategy A-3a: Review current research publications and develop hypotheses to determine the relationship between base flow (outside of spring runoff) and habitat quality (suitability) and availability. (1 year)

Strategy A-3b: Support development of models, such as integrated population models, habitat suitability models, and hydrologic models, to analyze seasonal and minimal habitat availability during base flow periods by reach, in consideration of variable annual water supply. (1-3 years, depending on model)

Strategy A-3c: Collect field measurements of habitat, flow, and population data to validate and refine modeling efforts, including routine monitoring and experimental manipulations. (ongoing with annual evaluation, following the AM cycle)

Strategy A-3d: Clearly define assumptions and uncertainties involving minimum base flow, habitat quality and availability, and a self-sustaining population (including survival rate, recruitment, etc.) as defined by the USFWS in the RGSM Recovery Plan. (ongoing with annual evaluation, following the AM cycle)

A-4) Evaluate suitable environmental flow (i.e., timing, duration and magnitude of spring hydrograph), given system constraints and opportunities, needed to cue spawning and recruitment for the RGSM population.

Strategy A-4a: Determine thresholds for each component of the hydrograph based on river conditions (previous, current, forecast).

Strategy A-4b: Apply findings from A-2 and A-5

Strategy A-4c: Relate system constraints and opportunities to river conditions.

Strategy A-4d: Describe management and river conditions by reach.

Strategy A-4e: Determine magnitude threshold (lower) for recommending allocation of resources based on severity of river condition.

Strategy A-4f: Design a study to evaluate the success of the “jiggle.”

A-5.1) Refine existing research and modeling efforts to understand the quantity and quality of habitat available at different flow regimes by 2030.

Strategy A-5.1a: Support ongoing hydraulic modeling efforts to quantify available habitat.

Strategy A-5.1b: Obtain remote sensing data to add to modeling efforts (especially at low flows), including coordinated ground truthing.

Strategy A-5.1c: Include ground truthing of x sites to measure depth, velocity, river width, and transects to measure flow, (potentially adding to existing effort).

A-5.2) Develop a range of options for increasing habitat availability and refugia at life stage limiting flow regimes for all life stages by 2030.

Strategy A-5.2a: Investigate potential strategies for returning agricultural water to increase habitat refugia.

Strategy A-5.2b: Investigate strategies to create floodplain structures that increase habitat complexity.

Strategy A-5.2c: Support projects (ISARO) to combine low flow conveyance channels to maintain summer flows.

A-6.1) Evaluate the effects of species management (i.e., propagation, augmentation, rescue/salvage) on RGSM genetic diversity.

A-6.2) Evaluate the effects of species management (i.e., propagation, augmentation, rescue/salvage) on RGSM population viability.

SWFL Objectives

B-1) Monitor for SWFL in the MRG management unit of the Rio Grande recovery unit.

Strategy B-1a: Conduct annual SWFL surveys in designated critical habitat areas to track territories in the MRG management unit.

Strategy B-1b: Conduct annual SWFL nest monitoring in designated critical habitat areas to track population dynamics in the MRG management unit.

Strategy B-1c: Develop a tiered strategy for surveys at varying levels of effort to account for years when the full effort cannot be implemented, to prioritize “core” populations and ensure that every site in the MRG is surveyed at least once every three years. (within a year).

Strategy B-1d: Analyze available survey 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.

Strategy B-1e: Analyze available nest monitoring data annually to determine limiting factors to SWFL population growth and sustainability.

B-2) Determine SWFL habitat availability within the MRG.

Strategy B-2a: Every 3-4 years, determine the availability of suitable, moderately suitable, and unsuitable SWFL habitat patches in the MRG management unit.

Strategy B-2b: Every 3-4 years, ground truth vegetation remote sensing models and refine models.

Strategy B-2c: Maintain and update Hink & Ohmart maps on the Program Portal as new data is acquired.

B-3.1) Characterize optimal breeding habitat conditions in currently occupied SWFL locations to inform restoration.

Strategy B-3.1a: Incorporate existing data on breeding habitat into restoration designs.

Strategy B-3.1b: Identify data gaps regarding optimal breeding habitat.

B-3.2) Manage successional processes that maintain existing SWFL breeding habitat in the Program Area.

Strategy B-3.2a: Determine factors that cause habitat loss, accounting for successional processes.

Strategy B-3.2b: Develop record of past activities and findings for reference (success vs. failure) and planning (modeling).

B-3.3) Expand SWFL breeding habitat through restoration efforts in the Program Area.

Strategy B-3.3a: Investigate opportunities to expand spatial scale for study/recovery.

Strategy B-3.3b: Invite San Juan Conservation District and others to present brown bags seminars on SWFL conservation for information exchange.

Strategy B-3.3c: Identify water availability and resources for creating SWFL habitat.

YBCU Objectives

C-1.1) Characterize optimal habitat (i.e., foraging and nesting) conditions on landscape and microhabitat levels in currently occupied YBCU locations to inform habitat mapping and restoration efforts.

Strategy C-1.1a: Strengthen understanding of effects from stressors and drivers (e.g., anthropogenic activities, vegetation structure/species, patch size, and prey abundance) on all life stages.

C-1.2) Determine successional processes that promote optimal YBCU habitat (i.e., foraging and nesting) in the Program Area.

Strategy C-1.2a: Design outreach to protect existing habitat through promotion of recommended land-use practices (e.g., no-till, organic, noise reduction, host plants for prey).

C-1.3) Expand monitoring efforts for YBCU.

Strategy C-1.3a: Increase use of tracking technology.

Strategy C-1.3b: Determine YBCU habitat use outside of areas used by SWFL.

NMMJM Objectives

D-1.1) Initiate and support NMMJM monitoring efforts to locate existing populations, identify relevant habitat features, and identify potentially suitable unoccupied habitat.

Strategy D-1.1a: Expand on existing vegetation/habitat monitoring efforts to include vegetation characteristics relevant to NMMJM (e.g. herbaceous vegetation).

Strategy D-1.1b: Analyze monitoring data to determine potential habitat.

Strategy D-1.1c: Identify and survey potential NMMJM habitat in the MRG.

D-1.2) Contribute to efforts to expand habitat and preserve existing habitat in the MRG.

Strategy D-1.2a: Explore potential options for NMMJM reintroduction if suitable habitat is found.

Strategy D-1.2b: Evaluate the efficacy of non-invasive survey methodologies.

PESU Objectives

E-1.1) Continue and expand monitoring and surveying for PESU stands in the West-Central New Mexico Recovery Region.

Strategy E-1.1a: Coordinate existing monitoring and surveying efforts through data sharing efforts.

Strategy E-1.1b: Expand on existing monitoring efforts to determine PESU habitat indicators/requirements.

E-1.2) Preserve and expand existing habitat stands in the West-Central New Mexico Recovery Region.

Strategy E-1.2a: Collect seeds from appropriate existing populations to establish a seedbank.

Other Objectives

F-1) Monitor trends in ecosystem function in the MRG for indications of decline (e.g., changes in vegetation structure and composition, population trends in other special status species, etc.).

Strategy F-1a: Review the biennial assessment from the NMDGF for status of various species in the MRGESCP area. Consider including protection measures for applicable species in restoration efforts, where possible.

Strategy F-1b: Include other monitoring efforts of (i.e. monitoring migratory bird trends, habitat monitoring) in the MRGESCP database.

Strategy F-1c: Compile a database of habitat and biological surveys within the MRG and update annually.

F-2) Determine the impacts from non-native vegetation on listed species' habitat availability and population dynamics.

Strategy F-2a: Maintain and update Hink & Ohmart maps on the Program Portal as new data is acquired.

Strategy F-2b: Research the relationship of non-native vegetation on listed species' habitat availability.

Strategy F-2c: Research the relationship of non-native vegetation on listed species' population dynamics.

Strategy F-2d: Make management recommendations to minimize and mitigate negative impacts from non-native species to the listed species in the MRG.

G-1) Support efforts to enhance the operational flexibility of water managers to support species.

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.

Strategy G-1c: Compile/present monitoring data for various species/habitat uses to advise on annual storage volumes.

*Independent Science Panel Recommendations***Amec Foster Wheeler Environment & Infrastructure, Inc. 2016. Expert Peer Review of the Middle Rio Grande Endangered Species Collaborative Program's Rio Grande Silvery Minnow Genetics Project**

Reporting Rec. 1	Sometimes it is not clear how Ne estimators relate to purpose. The reports could improve the explanations for why certain approaches were adopted.
Reporting Rec. 2	Develop a biological relevant and realistic benchmark for critically low levels of genetic diversity. One possible way to set a benchmark would be to estimate the 95% confidence interval (CI) for genetic diversity (expected heterozygosity [He] and number of alleles [Na]) using all samples across time and space. If the diversity falls below the CI, then more aggressive management actions may be warranted.
Reporting Rec. 3	There needs to be a clear statement of the hypothesis and predictions being tested. For example, a simple hypothesis is whether there is a difference in estimates of genetic diversity between the pre- and post-augmentation periods. If this is the case, one approach would be to use a linear model to compare the estimates pre- and post- augmentation. Although time should be included as a co-variate, there is no effect of augmentation on observed heterozygosity corrected for sample size (Hoc) ($t = 1.95$, $p = 0.071$).
Reporting Rec. 4	The authors need to redefine pre-augmentation (1987, 1999) and augmentation periods (post 1999) given the augmentation that took place in 2000 and 2001. They may not be able to conclude strongly whether genetic diversity of the natural spawning population has changed. However, the authors can say that augmentation has maintained genetic diversity throughout the augmentation period, with the provision that this conclusion is based on the nine microsatellite loci evaluated, which might not reflect genome-wide variation.
Reporting Rec. 5	Microsatellite loci may no longer be the most effective markers for the purpose as the cost of newer, genotyping-by-sequencing (GBS) approaches has become more affordable for largescale throughput of many individuals. The limitations of microsatellites relative to other genetic markers such as single nucleotide polymorphisms (SNPs), and trade-offs associated with different genetic markers in relation to RGSM genetic monitoring goals, are discussed in detail under Questions 2, 8, 9, 10, and 13 (particularly 13).
Reporting Rec. 6	The Genetic Project PIs may also wish to examine genetic diversity / Ne variation over time using a piecewise regression as these can be used to find any breakpoints in the data; also referred to as segmented regression. If a breakpoint is identified say for pre- versus post-augmentation, then separate regressions can be run for each section. This approach can also identify points in time where there are temporal changes in genetic diversity.

Question 13 Rec. 1a	The panel therefore recommends that both neutral and adaptive genetic variation be monitored over time in RGSM in the future using a larger, more diverse set of genetic markers. Genotyping-by-sequencing (GBS) or related equivalent would provide more confident estimates of genome-wide neutral genetic variation (N_{ac} , H_o) in RGSM because it would more likely represent the entire genome (for more information on GBS and related NGS approaches and their practical benefits for conservation genetics monitoring, see the review of Allendorf et al. 2010)...thus we recommend examining phenotypic variation for important life history traits (size/age maturity, growth rate), behavioral traits (anti-predator behavior, risk taking behavioral syndromes) and morphology (body shape as it relates to flow regime).
Question 13 Rec. 1b	Sampling of floodplains should be considered and included where feasible to ensure that the genetic characteristics of RGSM are adequately represented in egg collection samples.
Question 13 Rec. 2a	Conduct random sampling of annual egg collections from nature, to include not only the main channel but also the floodplains, for subsequent hatchery rearing (e.g., current collections only come from the main channel of the Rio Grande River, not on floodplains).
Question 13 Rec. 2b	Rear RGSM in environmental conditions that resemble natural environmental conditions as much as possible. This will reduce relaxation of selection or non-random survival at egg/early life stages in relation to habitat selection/settlement, behavioral/physiological characteristics, anti-predator responses etc. Specific recommendations for RGSM hatcheries include: (i) early juvenile environmental enrichment that resembles critical floodplain habitat (temperature, substrate, flow, turbidity, pH, conductivity, food sources, natural daylight); and (ii) some exposure to natural predators, or at the very least, mimicking of predators to stimulate anti-predator conditioning.
Question 13 Rec. 2c	RGSM live longer in captivity and the breeding program uses 4-year old fish as brood stock. By contrast, in the wild the breeding population is comprised largely of 1-year old fish. Thus, it will be prudent to evaluate the phenotypic effects of older brood-stock. Also, because larger fish have about 4x as many eggs as younger adults (10,000 vs. 2,500), and there is also likely higher variance in egg production among 4-year old fish compared to the variation in egg production among 1-year old fish. This could undermine efforts to equalize family sizes. Thus, using younger fish as brood stock will reduce the likelihood of un-intentional domestication selection, and also result in higher effective population sizes (due to reduced variance in egg production among females).
Question 13 Rec. 2d	Equalize contributions of different adults in the captive broodstock to new broods/lots as much as possible.
Question 13 Rec. 2e	Rear RGSM so as to maintain the growth trajectories typical of wild-raised fish (i.e., Age 1 fish in captivity should exhibit the same range of sizes of Age 1 fish

	in the wild). At present, either faster growing individuals may be unintentionally selected for, or other fish phenotypes (e.g., size, condition, body shape) may not match natural sizes upon release.
Question 13 Rec. 2f	Rear RGSM on natural diet if possible; diet appears natural at early life stages, but diet appears supplemented in later life stages (pellet feed).
Question 13 Rec. 2g	Minimize the duration in captivity as much as possible before release; domestication selection is reduced with less captive exposure (see Frankham 2008 and Fraser 2008).
Question 13 Rec. 3a	Maximize the information gained from re-stocking efforts of hatchery-raised fish back into the river in order to test particular scientific hypotheses and inform adaptive management.
Question 13 Rec. 3b	In addition (or alternatively if resources are limited), the genetics survey could focus on characterizing whether the year classes maintained in the hatcheries change over time in their genetic constitution as a consequence of differential mortality.
Question 13 Rec. 3c	Monitoring of domestication selection could include DNA fingerprinting (GBS) of wild-caught egg collections. An investigation into whether non-random changes to genome-wide variation were occurring at successive early life stages relative to the same stages in the wild would provide evidence that the hatchery environment is resulting in domestication selection.
Recommendation 1	A flow chart should be constructed for each year that gives detailed numbers for: eggs and dates taken, disposition of eggs/larvae to specific rearing sites, broodstock maintained, actual breeding strategy, disposition of eggs/larvae to specific rearing sites, pooling of larvae prior to stocking, stocking sites, source of juveniles, and dates. These data should be standardized and collected for each hatchery engaged in fish production and the data should be made available electronically to all interested parties. Deviations from planned methodologies (such as the inclusion of approximately 10,000 eggs from unplanned spawning in a broodstock tank) should be noted in the flow chart.
Recommendation 2	When deviations from planned methodologies result in the production of offspring, those offspring should not be released into the wild. Release of these offspring into the river could have a negative effect on the overall genetic diversity of the population. Providing flexibility in the next recovery permit should allow such surplus fish to be properly handled, whether used for research or held until natural death in the hatchery.
Recommendation 3	All broodstock and sufficient subset of the pre-release juveniles should be genotyped and the contribution of each broodstock individual determined. These results can be used to gain a more accurate, precise and biologically relevant estimate of N_e for each year class. This approach avoids the inherent assumptions and excessive variance associated with the N_e estimators

	currently employed. This should be done every year. Developing a high throughput method would facilitate more rapid genotyping.
Recommendation 4	The Genetics Management and Propagation Plan and/or the Augmentation Plan should have a detailed methodology as to what will be done should a drought lasting more than three/four years occurs or all four year classes of broodstock are lost to a major hatchery accident.
Recommendation 5	The Science Workgroup (led by the Program) and the Genetics Workgroup (led by the USFWS) should integrate the genetics data and the decision-making more carefully. Specifically, there should be more translation of the genetics research into the adaptive management process, hatchery broodstock practices, and the integration of the past 15 years of research (genetics and ecology combined).
Recommendation 6	A more stable, consistent funding stream for the genetics research (e.g. an extended funding cycle) would ensure that all critical, temporally important genetic studies are accomplished each year (e.g., broodstock genotyping, pre-release juvenile genotyping). Cost will vary depending on the analysis and goal. At the time of writing this report, the RGSM program can expect to require approximately \$50-150/individual for GBS or RAD-seq if outsourced to a genomics facility (including individual sample preparation, but not including salary for a research associate for sample preparation, data filtering and data analysis); a minimum of 30-40 individuals per year is recommended. Other genetic assessments do not require the amount of genetic data generated from GBS; any parentage assignments of offspring generating from mixed matings in the hatchery, for example, would be expected to cost approximately \$5-10/individual (not including personnel salaries), and so could be (and should be) conducted on larger numbers of individuals (1000s).
Recommendation 7	The use of only four year fish as broodstock may compromise the maintenance of genetic diversity because of the possibility of non-random, differential survival of individuals in the hatchery. Crosses should include younger fish. As a consequence of using younger fish as broodstock with lower fecundity, more fish will be needed to produce the quota of eggs and this will increase the effective number of breeders.
Recommendation 8	It will be useful to conduct an evaluation of whether domestication selection is occurring in the hatcheries. This could be done using an appropriate genetic analysis and/or measuring quantitative traits to assess phenotypic variation of each captive cohort during each year in captivity.

Recommendation 9	We recommend the use of the term “naturally spawned” in place of the term “wild” to refer to fish captured in the river that do not have an elastomeric tag; this assumes that all augmentation fish received a tag. It is likely that all fish captured in the wild have experienced some hatchery influence in their ancestry.
Recommendation 10	If possible, the augmentation team should consider artificially spawning broodstock in a one female by one male mating scheme, all the while maintaining the same total number of broodstock adults spawned (or increasing this number). This would allow equalizing family size as families are combined.
Recommendation 11	Relatedness should be calculated for broodstock prior to use to choose specific crosses that avoid inbreeding. If group spawning continues, relatedness estimates could be used to ensure that potential spawners in a group have low kinship.
Recommendation 12	To facilitate adaptive management, experimental studies comparing the survival and reproductive success of subsets of RGSM from different stocking strategies and hatchery facilities in nature would also shed light on the extent to which domestication selection is a concern in the recovery program.
Recommendation 13	A study using next-generation sequencing technology (e.g., GBS, RAD-seq) should be done with pre-augmentation samples and post-augmentation year classes to determine how the genome as a whole has changed over time. At the time of writing this report, the RGSM program can expect to require approximately \$50-150/individual for such an assessment (more for RAD-seq) if outsourced to a genomics facility (including individual sample preparation, but not including salary for a research associate for sample preparation, data filtering and data analysis); a minimum of 30-40 individuals per year is recommended.

Hubert, Wayne et al. 2016. Summary of Findings by the External Expert Panelists: Rio Grande Silvery Minnow Population Monitoring Workshop

1	Separate the catch and effort data from the small-mesh seine and the fine-mesh seine into two data sets and compute separate CPUE indices for each gear type, as well as for individual age classes captured in each gear type.
2	The CPUE from the small-mesh seine is primarily an index of the relative abundance of a single cohort of RGSM (i.e., the most recent cohort) that is recruited into the gear late in the summer and captured into the summer of the following year. The precision of the index can be improved by exclusion of older cohorts. A separate CPUE index can be computed for older cohorts. Consider the use of length-at-age data and frequency histograms to identify cohorts.

3	Only larval fish should be included in the computation of CPUE indices from the fine-mesh seine because of this gear's selectivity for this life stage.
4	An aspect of the CPUE data that warrants attention is the treatment of zero catches in data analyses. Inclusion of dry sample sites as zero CPUE values when analyzing CPUE data for RGSM in the MRG should be avoided. Field data records and the database in which the RGSM CPUE data are stored allow dry sampling sites to be distinguished from sites that were sampled and no RGSM were caught. The problem arises during statistical analyses because the naughty naughts (observations of zeros at dry sampling sites) are treated in the same manner as the zero catches at fished sites where no RGSM are caught.
5	Survey designs should strive to minimize false zeros resulting from: (1) an inappropriate sampling design (e.g., sampling in mesohabitats avoided by RGSM) and (2) ineffective survey methods (e.g., insufficient sampling effort to detect an organism when it is present).
6	The proportions of various mesohabitat types sampled are likely to bias CPUE indices because the catchability coefficient probably differs among mesohabitat types and RGSM are likely to be selective for specific mesohabitat types. We recommend that better understanding of the influence of mesohabitat type on CPUE be developed and used to account for variability in CPUE indices. Further, we recommend that estimation of mean site-specific CPUE be improved by addressing the variable number of mesohabitats that are sampled at any given site and the amount of sampling in each mesohabitat type. We recommend estimation of mean site-specific CPUE from individual seine hauls (which are distinguishable in the database as of 2006); mean CPUE at each site is then computed from the individual CPUEs at each of the 18-20 mesohabitat units sampled per site.
7	Environmental factors (e.g., turbidity, water temperature, substrate size, depth, current velocity, and discharge) during sampling are likely to bias CPUE indices because of their influence on catchability. We recommend that better understanding of the influence of measurable environmental factors on the catchability of each seine type be developed and used to account for variability in CPUE indices.
8	Factors influencing detection and catchability of RGSM in seines need to be determined and incorporated into the sampling design to permit more robust estimation of CPUE.
9	Measures of CPUE for RGSM from the MRG are currently identified as recovery standards for the species. We recommend modification of recovery standards to be explicit regarding the gear, sampling design, sampling techniques, data analysis, and life stage, as well as protocols used to compute the CPUE index.

10	We recommend depiction of the relationship of hydrological covariates and estimates of the mean annual CPUE for RGSM derived from the mixture model. Those relationships should use the October data from 1993 to 2014. Further, we recommend that such analyses be repeated for catch data collected in 2006 to the present, but using the individual seine-haul approach to estimate CPUE.
11	We recommend that the assumptions of the mixture models be fully defined and that the results of analyses be interpreted with consideration of the assumptions and the effects of the potential violation of assumptions.
12	A greater number of sampling sites would improve the accuracy and precision of status assessments and improve estimates of RGSM CPUE and spatial distribution, especially at the reach scale. A greater number of sampling sites in each of the three reaches would facilitate status and trend estimates at the reach scale. To make statistically rigorous reach-scale CPUE estimates, 20-50 sites per reach are recommended. A design with substantially more sites and longer site lengths should be more effective at detecting RGSM when they are at low densities or demonstrating patchy distributions.
13	When river flows decline so that dry sampling sites occur among the 20 fixed sites sampled by the Monitoring Program, the ability to make inference regarding CPUE of RGSM over the MRG is impaired. The current 20-fixed-site sampling is not adequate when dry sampling sites occur. An ancillary randomized sampling design is recommended at such times to be able to make inferences about RGSM abundance and distribution throughout the entire MRG. Such a random sampling design would entail sampling at many more sites over the length of the MRG. An ancillary design of this type would enhance the feasibility of assessing the abundance and distribution of RGSM in the MRG during years of low flows and when the species is likely to occur in low abundance.
14	Consider using key drivers of mesohabitat variability, such as current velocity, substrate size, and water depth at specific locations where seines are deployed, to replace the mesohabitat factor in the mixture models.
16	Examine the historical availability of mesohabitats in the MRG relative to discharge. If these two measures can be linked, then annual or monthly discharge may provide a good surrogate of mesohabitat availability.
17	Evaluate alternatives to the parametric mixture model, in particular, Bayesian hierarchical models, for estimating annual CPUEs.
18	Use classification and regression trees, boosted regression trees, or random forests to examine relationships between hydrologic variables and CPUE for identifying thresholds above or below which CPUE exhibits changes.

19	Implement directed studies using different sampling designs, such as multi-year, multi-site, before-after-control-impact (BACI) designs to enhance understanding of the response of the population to changes in river discharge, habitat rehabilitation projects, and availability of mesohabitats.
21	Conduct stock-recruitment studies to determine how the abundance of fall recruits relates to the abundance of spring spawners. Investigate the effects of spring and summer discharges on the stock recruitment relationship to enhance understanding of the dynamics of RGSM. Implement a spring sampling protocol at spawning sites to estimate the number of spring spawners, and compare with October results for several years; such studies may provide useful data on RGSM population dynamics and limiting factors.
22	Complete a study of age-specific fecundity and survival rates based on pre-breeding (fall) population estimates, spring spawners, and hatchery supplementation. Results from this study could be used to estimate population recovery and extirpation potentials as a function of altered flow regimes and stocking.
23	Consider genetic fingerprinting and epigenetic studies, including bar-coding and gene-expression, of presumed wild and hatchery fish to help determine hatchery contributions to the spring spawners and the long-term risks to the wild population.
24	Expand the analyses in Dudley et al. (2015) to assess flow regime and habitat fragmentation effects on RGSM occurrence and abundance and suggest preliminary flow regimes for rehabilitating the wild RGSM population.
Observation Beyond the Scope 1	Attention to long-term climate-change issues and integration with climate-change planning efforts was not evident to the expert panelists (from the readings or from discussions at the December workshop) regarding how the Cooperative Program and Monitoring Program plan to address markedly lower flows and higher water temperatures.
Observation Beyond the Scope 2	The MRG lacks minimum instream flow requirements to assure recovery. A major element of discussion by program scientists and interested parties during the workshop focused on low-flow periods and the potential for survival of RGSM during those periods when portions of the MRG have no observed surface flows or when there is no measurable discharge at gaging stations. It became evident to the external panelists that there are no specified minimum instream flow requirements or guidelines for the MRG . Minimum instream flow requirements or guidelines would not only enhance the potential for recovery of the RGSM in the MRG, but they would enable the current 20-site design of the Monitoring Program to be used to assess continuously status and trends of the RGSM stock in the MRG.

Observation Beyond the Scope 3	<p>The Monitoring Program assesses relative abundance of the RGSM in October; the young-of-year fish encountered at this time are likely to include the progeny of hatchery fish that were stocked the previous year (in November), survived the winter, and successfully reproduced. As such, the Monitoring Program is measuring the ability of hatchery stocking to contribute to or maintain a population in the MRG. Understanding of the dynamics of the RGSM population and the effects of changes in water resources in the MRG is hindered by confounding of environmental and hatchery-fish effects. There is a need for Monitoring Program scientists to effectively disentangle the source of new recruits (Creel et al. 2015), in particular the relative contribution of hatchery-origin fish and naturally spawned wild fish. One suggestion is to apply individual-based models (IBMs) to simulate changes in the system (e.g., cessation of stocking, decreased discharge rates) and assess those effects on RGSM populations (see e.g., Rose et al. 2013a and b). IBMs are used to describe population outcomes by tracking the fate of the individual fish that compose the population. As such, these models allow individual fish to exhibit unique combinations of growth, survival, fecundity, and movement probabilities. Although this is a powerful approach for the study of animal populations, IBMs require large amounts of data. Thus, the feasibility of this approach will depend on the depth of knowledge of basic biological processes for RGSM in the 1186 MRG.</p>
Observation Beyond the Scope 4	<p>In recent years, low RGSM abundance has led to salvaging fish from residual pools and the introduction of hatchery reared fish to supplement the RGSM population. This creates a dilemma of providing fish to preclude RGSM extinction versus creating a domesticated hatchery-dominated population ill equipped to survive the rigors of a highly stressed environment. Therefore, additional genetic fingerprinting and epigenetic studies of presumed wild, hatchery, and hatchery-originated progeny are needed to determine hatchery contributions to the spring spawners and the risks thereof to the wild population (Quinones et al. 2014; Trushenski et al. 2015; Carmichael et al. 2015)...The question of greatest concern here is the degree to which the population has become, or is becoming, a largely hatchery-derived population with reduced survivability in the face of climate change and other physical and chemical habitat alterations. This becomes of greatest concern when wild populations are naturally and anthropogenically constricted in numbers relative to the numbers of hatchery-origin fish added to the population. Because of such natural and anthropogenic pressures, the highly variable RGSM population likely will continue to be reduced and the wild population may be extirpated (Lawson 1993; Cowley 2006). Continuation of current hatchery augmentation practices should include a rigorous risk/benefit analysis.</p>

Observation Beyond the Scope 5	Although not explicitly discussed during the December workshop, the current recovery plan and criteria for the RGSM (USFWS 2010) are based on the 20-fixed-site sampling protocol. Recovery criteria for the MRG include presence of unmarked and age-0 RGSM at 75% of all sites per reach in October; an October CPUE of >5 RGSM/100 m ² in all sites in a reach for five consecutive years; and age-0 RGSM in 75% of all sites in a reach for five consecutive years. To the degree that insufficient October flows limit sampling of all 20 sites, those recovery criteria cannot be met. In addition, the recovery plan implicitly assumes that genetic exchange is generally in a downstream direction, that the wild RGSM genetic composition has been preserved, and that unmarked fish have a wild genotype. However, those assumptions may be negated by ongoing hatchery practices as discussed above in Observation 4.
Observation Beyond the Scope 6	The analyses in Dudley et al. (2015) could lead to quantitative instream flow and habitat studies and be used to assess flow regime and habitat fragmentation effects on RGSM occurrence and abundance and then used to set preliminary system-wide instream flow criteria for rehabilitating RGSM. This is because current rehabilitation actions such as salvage, stocking of hatchery fish, and local flow and physical habitat manipulations have only local or temporary effects compared with the system-wide effects of major diversion dams and basin-scale land use (e.g., Wang et al. 2003; Hughes et al. 2005, 2014). Normalizing flow regimes, improving fish passage, and extensively lowering floodplains would help rehabilitate a species such as the RGSM (Williams et al. 1999; Tockner et al. 2000; Dudley et al. 2015; Novak et al. 2015); admittedly, such rehabilitation measures may be costly. Although portions of the MRG have experienced periods of natural drying and flooding historically, anthropogenic increases in the frequency or extent of drying and anthropogenic decreases in the frequency and extent of flooding, together with passage barriers, likely reduce the potential of wild RGSM to persist and flourish in the MRG (Hughes et al. 2005; Novak et al. 2015).
Observation Beyond the Scope 7	During the workshop, the panelists noted that a number of organizations and agencies were engaged in research on RGSM in the MRG (i.e., US Fish & Wildlife Service, Bureau of Reclamation, and Army Corps of Engineers). However, the expert panelists did not identify whether formal procedures for sharing outcomes and results from these studies are in place, for example, via annual multi-day research review and discussion meetings with all Cooperative Program and Monitoring Program partners. In addition, models to describe the hydrodynamics of the MRG have been developed, but fish population studies do not appear to make use of these models. The water resource problems in the MRG are complex and water management actions affecting discharge and flow in the river affect the population of RGSM. An annual research review or similar activity may help to strengthen information exchange and advance scientific understanding of the issues in the MRG.
Observation Beyond the Scope 8	An adaptive management program may help to improve understanding of the relationship between management actions in the MRG and the status of the RGSM population. We understand that such an approach will soon be implemented for the

	<p>MRG and encourage the Collaborative Program to pursue a rigorous adaptive management program. Adaptive management is typically viewed as a partnership between management agencies and agencies engaged in research to address critical uncertainties in the system. Partnerships are key because new knowledge about the system will be obtained only when research and management work hand-in-hand. In adaptive management, (1) the science problems must be defined in a clear manner that permits design of targeted investigations; (2) conceptual and simulation models are then used to investigate responses of the system to potential management interventions; (3) direct, purposeful manipulations are implemented and the response of the system measured in a statistically reliable manner; and (4) analyses and synthesis of outcomes are completed in a timely manner to support robust decision-making. Adaptive management in the MRG would benefit from a conceptual model of the system that integrates water use, hydrodynamics, and fish population responses. It is unclear if such a model exists, but it is imperative to develop such models to ensure that management manipulations will provide sufficient contrast and ensure a measurable result.</p>
Observation Beyond the Scope 9	<p>In addition to adaptive management, Collaborative Program partners and collaborators may wish to consider other tools such as scenario planning (Baker et al. 2004; Hulse et al. 2004; Allen and Gunderson 2011; Rowland et al. 2014) and resilience building (NYC 2013; Norfolk 2014). Scenario planning may be an effective management approach when uncertainty about the system is high and factors that affect the system are not readily controlled (e.g., amount of snow pack available for replenishment of rivers). In this approach, alternative futures are explored with the goal of identifying improvements to current management actions. This may be a good strategy to pursue now, perhaps together with adaptive management. As uncertainty about the system declines (through learning derived from targeted research studies and adaptive management), we suggest implementing a resilience building approach. The approach is effective when driving factors remain uncontrollable and system uncertainty is low. Many coastal cities have adopted this approach in the face of rising sea levels (e.g., New York City [NYC 2013] and Norfolk, VA [Norfolk 2014]).</p>
Observation Beyond the Scope 10	<p>The research done on the RGSM warrants publication in high-level peer reviewed journals. The Expert Panel was provided 14 documents to help it prepare for the December workshop. Of those 14, only 2 were published in, or submitted to, a peer-reviewed journal by a member of the Program; however, the results and interpretations included in the annual reports should be published in journals. Similarly, the Expert Panelists were shown agency reports at the Workshop that were not included in the preselected workshop reading materials that likely had received thorough agency review, but apparently had not yet been submitted for journal publication. In the scientific world, peer-reviewed journal publication is the standard by which research is judged. Publishing in such journals would add increased scientific credibility to the Collaborative Program, and funding the time needed to prepare and revise journal manuscripts should be included in the research grants of the Monitoring Program.</p>

Noon, Barry et al. 2017. Independent Science Panel Findings Report: Rio Grande Silvery Minnow Key Scientific Uncertainties and Study Recommendations

A1	Clarify the relationship between the annual catch-per-unit-effort and true population size by estimating catchability.
A2	Determine the key, age-specific, life history sensitivities of the RGSM (that is, use sensitivity analysis methods to determine which vital rates [survival and/or reproduction] most affect rates of population change.
A3	Estimate age-specific survival rates
A4	Estimate age-specific fecundities of wild fish.
A5	Using statistical modeling, estimate the relationships between RGSM demographic rates and A.) hydrological factors (flow magnitude and duration, summer drying of the channel); and B.) abiotic environmental factors (temperature, turbidity, salinity); and C.) biotic factors (predation, competition, prey availability).
A6	Evaluate the existence and strength of any density-dependent factors that may be limiting population growth.
A7	Model the potential effects of hatchery augmentation on population dynamics and the significance of hatchery fish to achieving recovery objectives.
A8	Determine if the collection and translocation of salvage fish during summer drying periods contributes significantly to population dynamics.
B1	Development and deployment of "vertically-integrating" Moore egg collectors
B2	Improved assessments of relations between possible environmental cues that trigger spawning activity.
B3	Establish size-specific fecundities of natural-spawning RGSM.
C	Clarify the detail of annular mark formation on otoliths and firmly establish the longevity of RGSM.
D1	Estimate the spatial extent and hydraulic quality used by RGSM for key life-stages (spawning, larval rearing, juvenile and adult survival). Estimate how these habitats are distributed in the river channel and floodplain in each MRG reach under a range of discharges and seasonal flow regimes.
D2	Establish the proximate trigger(s) for spawning by evaluating the effects of flow velocity, temperature, rate of increase in flow velocity, or some combination of these factors.
D3	Determine the roles and relative contributions to fish production (age 0 recruitment and survival of all age-classes) of channel and floodplain habitat in a reach of channel and floodplain typical of the MRG.
D4	What is the management potential for fish production (recruitment and survival of age 0 fish) in each reach of the MRG if the annual peak flow, and thus the nature and range of available habitats, is permanently limited below historic levels of availability.
E1	Establish the age composition of the RGSM population, including A.) application of distribution separation methods to estimate age composition, and B.) gear selection study.

E2	Determine how the vertical and horizontal distribution of RGSM eggs in the MRG mainstream channel varies as a function of flow and location?
E3	Calculate revised CPUE values as mesohabitat-specific levels and do not combine across mesohabitat types. The meso-habitat specific CPUE calculated for the most abundant high density mesohabitat type should be used for assessment of trend in abundance of the RGSM population at the October sampling date.

Appendix E. Climate-related tools and planning initiatives implemented by Collaborative Program signatories and research partners

LAST UPDATED: DECEMBER 23, 2021

This list is provided as a reference for Collaborative Program signatories and partners, and is not comprehensive.

Organization	Title	Link
ABCWUA	Water 2120: Securing our Water Future - Water Resources Management Strategy	https://www.abcwua.org/wp-content/uploads/Your_Drinking_Water-PDFs/Water_2120_Volume_I.pdf
ABCWUA	Water Conservation Plan and Rebate Programs	https://www.abcwua.org/wp-content/uploads/Conservation_Rebates/2037_Water_Conservation_Plan.pdf
BEMP	Long-Term Monitoring Data	https://bemp.org/data-sets/
COA	Climate Action Plan	https://www.cabq.gov/sustainability/documents/2021-climate-action-plan.pdf
National Audubon Society	Birds and Climate Visualizer	https://www.audubon.org/climate/survivalbydegrees
NMDGF / Natural Heritage New Mexico	New Mexico Conservation Information System (NMCIS)	https://www.wildlife.state.nm.us/conservation/
NMISC	50-Year Water Plan	https://www.ose.state.nm.us/Planning/50YWP/index.php
USACE	Defense Climate Assessment Tool (DCAT)	https://www.repi.mil/Portals/44/Documents/Resilience/Webinars/REPIWebinar_ResilienceToolsTechnology_30JUN21.pdf
Reclamation	2021 Rio Grande Basin SECURE Report	https://www.usbr.gov/climate/secure/docs/2021secure/basinreports/RioGrandeBasin.pdf
Reclamation	2021 West-Wide Climate and Hydrology Assessment	https://www.usbr.gov/climate/secure/docs/2021secure/westwidesecurereport1-2.pdf
Reclamation	West-Wide Climate Risk Assessment: Upper Rio Grande Impact Assessment	https://www.usbr.gov/watersmart/baseline/docs/urgja/URGIAMainReport.pdf
U.S. Department of Agriculture / UNM	Northern New Mexico Climate Change Project	https://reeis.usda.gov/web/crisprojectpages/1003701-northern-new-mexico-climate-change-project.html

Organization	Title	Link
U.S. Department of Agriculture / New Mexico State University	Southwest Regional Climate Hub	https://jornada.nmsu.edu/sw-climate-hub
U.S. Department of Agriculture – Natural Resources Conservation Service	Snow Telemetry (SNOTEL)	https://www.wcc.nrcs.usda.gov/snow/
U.S. Department of the Interior - Indian Affairs	Tribal Climate Resilience Program	https://www.bia.gov/bia/ots/tribal-climate-resilience-program
Multiple	Middle Rio Grande/Albuquerque Urban Waters Federal Partnership	https://www.epa.gov/urbanwaterspartners/urban-waters-and-middle-rio-grandealbuquerque-new-mexico
Multiple	National Drought Resilience Partnership (NDRP)	https://www.drought.gov/about/partners
Multiple	Native Nations Climate Adaptation Program (NNCAP)	https://www.nncap.arizona.edu/
Multiple	OpenET (satellite-based estimates of evapotranspiration for improved water management across the western U. S.)	https://openetdata.org/
Multiple	Rio Grande Water Fund	https://www.nature.org/en-us/about-us/where-we-work/united-states/new-mexico/stories-in-new-mexico/new-mexico-rio-grande-water-fund/
Multiple	Southwest Climate Adaptation Science Center	https://www.swcasc.arizona.edu/
Union of Concerned Scientists	Confronting Climate Change in New Mexico	https://www.ucsusa.org/sites/default/files/attach/2016/04/Climate-Change-New-Mexico-fact-sheet.pdf