



United States Department of the Interior
FISH AND WILDLIFE SERVICE
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DEC 16 2010

Memorandum

To: Coordination Committee, San Juan River Basin Recovery Implementation Program

From: Regional Director, Region 2 *Joy E. Nikolopoulos*

Subject: Service Review and Assessment of the San Juan River Basin Recovery Implementation Program

The U.S. Fish and Wildlife Service (Service) has completed a Review and Assessment of the San Juan River Basin Recovery Implementation Program (Program) as defined in the Program Document (September 23, 2010). Service responsibility number 21 requires that the Service prepare on a biennial basis a written "Sufficient Progress" assessment of the Program's progress towards recovery of the Colorado pikeminnow and razorback sucker, including the Program's ability to provide Endangered Species Act (ESA) compliance for water development and management activities in the San Juan River Basin. The report is also to include any corrective actions to ensure future ESA compliance in accordance with the *Principles for Conducting Endangered Species Act section 7 Consultations on Water Development and Water Management Activities Affecting Endangered Fish in the San Juan River Basin* (Principles).

Using the Principles, the Service determines whether progress by the Program is sufficient to provide a reasonable and prudent alternative or measure based on the following factors:

1. *Actions that will result in a measurable positive population response, a measurable improvement in habitat for the fishes, legal protection of flows needed for recovery, or a reduction in the threat of immediate extinction;*
2. *Status of fish populations;*
3. *Adequacy of flows; and*
4. *Magnitude of the impact of activities including, but not limited to, contaminant and fish migration impacts.*

The Principles, adopted by the Coordination Committee in 2002, constitute a guide to define how Program actions will be used to provide ESA compliance for water development and water

management activities. The Principles were reviewed by the Service and found to be consistent with the ESA and its implementing regulations (50 CFR Part 402). The Principles rely heavily on the Program's ability to implement the activities and actions found in the Program's Long Range Plan (LRP). Revisions to the LRP, including insertion of actions needed to achieve recovery, will normally occur during the annual review and update. All parties to the Program, including the Service, make recommendations to update the LRP. The Principles also state that if the Service concludes at any time, that the Program is not implementing actions on schedule, and that this impacts the ability of the Program to provide measures for compliance with the ESA, the Service will provide a written assessment to the Coordination Committee. The assessment will include the Service's recommendations for corrective actions. The Coordination Committee will have an opportunity to modify timing, funding, and/or priorities in the LRP to ensure that the Service can rely on the Program to provide reasonable and prudent alternatives and measures. For this Program assessment, the Service utilized the following sources of information: (1) the 2010 LRP; (2) the Program's annual, research, integration, and evaluation reports; (3) biological opinions including Navajo Reservoir Operations, Navajo Indian Irrigation Project, Animas-La Plata Project, and Navajo-Gallup Water Supply Project; and, (4) the population goals and management actions presented in the 2008 draft Recovery Goals for each species (USFWS 2008).

Service Determination

The Service considers the Program's overall progress toward recovery of Colorado pikeminnow and razorback sucker in the San Juan River to be sufficient for the Program to continue as the ESA compliance mechanism for water development and operations within the San Juan River Basin. The Program's actions and tasks described in the LRP and management activities in the Recovery Goals are being satisfactorily met, such that the Program will continue to serve as a foundation for reasonable and prudent alternatives in applicable section 7 consultations.

U.S. Fish and Wildlife Service Recommendations

The Program Assessment includes six specific recovery recommendations and actions (pages 23 and 24 of the attached document). These recommendations are activities that the Program needs to implement to benefit the recovery of the endangered fish in the San Juan River. Completing the recommendations will allow the Program to make significant progress toward recovery of the Colorado pikeminnow and razorback sucker within the San Juan River Basin. The Service requests that the Program develop appropriate tasks and timeframes for each action that will be incorporated into the LRP during the annual LRP update.

Attachment

cc: Field Supervisor, U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office, Albuquerque, NM
Field Supervisor, U.S. Fish and Wildlife Service, Colorado Ecological Services Field Office, Grand Junction, CO
Field Supervisor, U.S. Fish and Wildlife Service, Utah Ecological Services Field Office, Salt Lake City, UT



U.S. Fish and Wildlife Service

Review and Assessment

San Juan River Basin Recovery Implementation Program

December 2010

**U.S. Fish and Wildlife Service
Region 2**

INTRODUCTION

The San Juan River Recovery Implementation Program was formed to conserve the endangered Colorado pikeminnow and razorback sucker in the San Juan River while providing Endangered Species Act (ESA) compliance for water development and management activities. The Fish and Wildlife Service (Service) is required, every two years, to assess whether the San Juan River Basin Recovery Implementation Program's (Program) progress towards recovery of these species is sufficient for the Program to continue to serve as the reasonable and prudent alternative and reasonable and prudent measures for water development and management activities in the San Juan River Basin. Corrective actions are identified if needed, to assure the Program's continued compliance with the Endangered Species Act.

This review and assessment report relies on the "*Principles for Conducting Endangered Species Act section 7 Consultations on Water Development and Water Management Activities Affecting Endangered Fish in the San Juan River Basin*" (Principles; SJRIP 2002) and recovery management actions detailed in the 2008 draft recovery goals for razorback sucker (USFWS 2008a) and Colorado pikeminnow (USFWS 2008b). The Principles constitute a guide to define how Program actions will be implemented to provide ESA compliance for water development and water management activities. The Principles rely on the Program's ability to implement the activities and actions found in the Long Range Plan (LRP; SJRIP 2010). The LRP steps down recovery management actions from the Recovery Goals and describes site-specific management actions needed to minimize or remove threats and to support wild self-sustaining population of Colorado pikeminnow and razorback sucker (USFWS 2008a, 2008b). The Program uses the LRP to develop annual work plans that identify and describe specific activities and projects to be implemented in a given year.

For this Program assessment, the Service utilized the following sources of information: (1) the 2010 LRP; (2) Program annual, research, integration, and evaluation reports; (3) the 2008 draft Recovery Goals for each species; and (4) past biological opinions that have relied on the Program for ESA compliance. The management actions from the draft Recovery Goals relevant to the San Juan River Basin are listed below (USFWS 2008a, 2008b). The Service anticipates that the successful implementation of these management actions for both the Colorado pikeminnow and the razorback sucker will ultimately lead to a positive population

response by the endangered fish species that will result in achieving the recovery demographic criteria laid out in the Recovery Goals.

1. *Provide and legally protect habitat (including flow regimes necessary to restore and maintain required environmental conditions) necessary to provide adequate habitat and sufficient range for all life stages to support recovered populations*
2. *Provide passage over barriers within occupied habitat to allow adequate movement and, potentially, range expansion*
3. *Minimize entrainment of subadults and adults in diversion canals/out-take structures*
4. *Ensure adequate protection from diseases and parasites*
5. *Regulate nonnative fish releases and escapement into the San Juan River, floodplain, and tributaries*
6. *Control problematic nonnative fishes as needed*
7. *Minimize the risk of hazardous-materials spills in critical habitat*
8. *Remediate water-quality problems*
9. *Reestablish populations with hatchery-produced fish*
10. *Minimize the threat of hybridization with white sucker [only applicable to razorback sucker]*
11. *Provide for the long-term management conservation plans to protect populations and their habitats beyond delisting [Efforts to develop long-term species conservation plans are not a priority until the Program is closer to meeting downlisting and delisting objectives.]*

ASSESSMENT AND REVIEW OF PROGRESS TOWARD RECOVERY

The Service reviewed the Program's current and past activities to evaluate accomplishments and deficiencies in attaining the management actions identified in the LRP. These actions are considered necessary for the recovery of Colorado pikeminnow and razorback sucker. The Service's assessment of the Program is based on: (1) successful implementation of the management actions that are necessary to achieve species recovery; (2) the recovery demographic criteria in the Recovery Goals to downlist and delist Colorado pikeminnow and razorback sucker; and (3) and the positive population response criteria developed to document and gauge demographic improvements for both species. Any corrective actions or

demographic improvements for both species. Any corrective actions or recommendations to improve the Program's progress toward recovery are identified after each section.

IMPLEMENTATION OF RECOVERY ACTIONS FROM RECOVERY GOALS

- 1. Provide and legally protect habitat (including flow regimes necessary to restore and maintain required environmental conditions) necessary to provide adequate habitat and sufficient range for all life stages to support recovered populations.*

Flow Regime

The LRP calls for protection, management, and augmentation of habitat (Element 2). This includes implementing and revising flow recommendations which are intended to provide suitable habitat for native fish in the San Juan River. This LRP element also calls for identifying and implementing recovery actions other than flows to provide suitable habitat for the native fish community.

The Program developed flow recommendations for the operation of Navajo Dam on the San Juan River in 1999 (Holden 2000). The flow recommendations are intended to mimic a natural flow regime characterized by variability in flow, spring peak flow, and low base flows. These flows are necessary to develop and maintain the habitat and hydrologic conditions needed for all life stages of Colorado pikeminnow, razorback sucker, and other native fishes (Holden 2000). Miller (2006) suggested that achieving higher peak flows during runoff, along with changing the shape of the ascending and descending limb of the hydrograph may be a higher priority than meeting the 2,500 and 5,000 cfs flow recommendations. Flows of 2,500 cfs are not correlated with maintaining open interstitial space in cobble bars and flows of 5,000 cfs do not maintain backwater habitats as initially thought when the flow recommendations were developed (Miller 2006).

While the intent of the flow recommendations to develop and maintain the habitat and hydrologic conditions favorable to the native fish community, the flow recommendations should be periodically evaluated to determine: (1) habitat response to flow recommendations, (2) whether the habitat response achieved is consistent with the objectives of the flow recommendations, and (3) endangered fish (or suitable native fish surrogate if endangered fish numbers are too low) response to the flow recommendations. The Program has been collecting habitat and fish data since 2000 when the flow recommendations were developed. The Program

is currently in the process of developing the next generation of the San Juan River Basin Hydrology Model (SJRБ Hydrology Model). Upon completion of the model in mid-2011, the Program will begin the process of revising the flow recommendations with an expected completion date of December, 2013.

Habitat

The Service outlined reasonable and prudent measures in the Navajo-Gallup Water Supply Project Biological Opinion to minimize incidental take of razorback sucker and Colorado pikeminnow. These measures included (1) actions to create and maintain habitat complexity and to minimize the loss and degradation of habitat for the endangered fish in the San Juan River (Action 2.2.3) and (2) the maintenance and application of the SJRB Hydrology Model (Action 2.1.2). Consistent with the Section 7 Principles, these activities are included in the SJRIP Long Range Plan (San Juan Recovery Program, 2010). To create and maintain habitat complexity, the Program is currently investigating the use of mechanical habitat manipulation actions by partnering on a New Mexico Environment Department River Ecosystem Restoration Initiative (RERI) project that will restore secondary channels on the San Juan River.

Climate Change

The LRP includes recovery actions (Action 2.1.5) necessary to address the threat of climate change to razorback sucker and Colorado pikeminnow in the San Juan River. These include using the SJRB Hydrology Model to determine if the timing and magnitude of runoff change and whether these changes would limit BOR's ability to meet the flow recommendations. The SJRB Hydrology Model revisions and subsequent revisions to the flow recommendations will allow the Program to incorporate the possible effects of climate change.

Temperature

The hypolimnic release from Navajo Dam suppresses the temperature of the San Juan River. Lamarra (2007) reported that warmer summer temperatures in the San Juan River above the Animas River confluence would result in the upstream movement of fish, including Colorado pikeminnow that could potentially spawn in habitats that are currently unavailable due to the present thermal conditions. As identified in the Navajo Reservoir Operations Biological Opinion, Reclamation agreed to evaluate water temperature impacts of Navajo releases. Reclamation developed a model to investigate the effect of a temperature control device at Navajo Dam on water temperatures in the San Juan River downstream of the dam (Cutler 2005).

A temperature control device could increase the water temperature from May to October by as much as 8.4°C and 7.6°C in some years, but the average increase would only be 2°C and 1.4°C at Farmington and Shiprock, respectively (Cutler 2005). Cutler (2005) indicated that ideal temperatures of 20-25°C for Colorado pikeminnow and razorback sucker that occur in late June at Farmington could be achieved approximately two weeks earlier with a temperature control device. These temperatures are achieved in July at Shiprock without a temperature control device. The Biology Committee determined that a temperature control device (TCD) was not warranted on Navajo Dam because temperature impacts on spawning and rearing appear to be minimal. A TCD may provide seasonal range expansion above critical habitat but it is unknown if range expansion above critical habitat is necessary for recovery (SJRIP 2010).

Recovery Action 1, Summary and Recommendations:

The Program is making sufficient progress in providing for and protecting the habitat necessary to support recovery of all life stages of endangered fish.

The Service recommends that the Program: (1) continues to focus on LRP Action 2.2.3 to evaluate and implement habitat restoration strategies to augment the function of river flow to create and maintain suitable habitat; (2) ensures that habitat response to the flow recommendations is evaluated (Action 2.2.2); that flow recommendations are revised as appropriate (Action 2.2.1); and (3) evaluates the possible effects of climate change on the timing and magnitude of runoff as it relates to the ability to meet the flow recommendations from Navajo Dam (Action 2.1.5).

2. Provide passage over barriers within occupied habitat to allow adequate movement, and potentially, range expansion.

Action 2.3.1 of the LRP details the Program goal of providing and maintaining fish passage at diversion structures.

The Program Evaluation report (Holden 2000) identified five diversion structures between RM 180 and RM 140 as potential barriers to fish movement, particularly upstream movement, they are: Fruitland (RM 178.5), Cudei (RM 142.0), Arizona Public Service Company (APS or Four Corners Generating Station Weir; RM 163.3), Hogback (RM 158.6), and Public Service Company of New Mexico Weir (PNM or San Juan Generating Station Weir; RM

166.6). Ryden (2000) reported that Cudei Diversion, Hogback Diversion, and APS weir were passable by fish at some flows but upstream movement was more restricted by PNM Weir, especially for non-native fish. Davis and Coleman (2004) reported that at times the APS weir is not a barrier to fish passage. Fish passage at the APS weir was related to flow. Model results indicated that the structure was a barrier at low flows but not at high flows (Stamp et al. 2005).

Holden (2000) detailed a plan to combine Hogback and Cudei Diversions and provide for a nonselective fish passage at the Hogback Diversion to restore access to 36 miles of critical habitat. Cudei Diversion was removed in 2002 and replaced with a subsurface siphon that does not impact fish movement (Davis and Coleman 2004). A nonselective fish passage was constructed at Hogback Diversion in 2002.

A selective fish passage around the PNM weir was completed in 2003 that allows native fish to continue upstream and remove non-native fish from the San Juan River. Fish use of the PNM passage is monitored by the Navajo Nation Department of Fish and Wildlife and reported monthly. A total of 110,776 native and 3,060 non-native fish have used the PNM passage through 2009 (A. Lapahie personal communication 23 Mar 2010).

Passive integrated transponder (PIT) tag data is used to monitor endangered fish movement up and downstream of these diversions and to evaluate the number and frequency of fish that negotiate these barriers. Since 2003, a total of 48 Colorado pikeminnow and 27 razorback sucker have used the PNM fish passage (SJRIP unpublished data).

All identified impediments to fish movement have been removed with the exception of APS weir and Fruitland Diversion. The Program has requested that Reclamation develop appropriate design alternatives for review and consideration by the Program for APS weir and Fruitland Diversion (LRP Tasks 2.3.1.5 and 2.3.1.6, respectively).

Recovery Action 2, Summary and Recommendations:

The Program is making sufficient progress in providing fish passage over barriers in the San Juan River that allow for movement and range expansion by the endangered fish. The Program needs to continue pursuing fish passage at APS weir and Fruitland Diversion in accordance with the LRP.

3. Minimize entrainment of subadults and adults in diversion canals/out-take structures.

The Program uses Action 2.3.3 “Minimize fish entrainment at diversion structures” in the LRP to address this recovery activity.

In addition to blocking upstream movement of adult fish, diversion dams may also impact recruitment by entraining fish. In 2004 and 2005, numerous native and non-native fishes, including over 200 Colorado pikeminnow (up to 315 mm SL), were detected in irrigation canals along the San Juan River but were most numerous in the Hogback Canal (Renfro et al. 2006). The Program opted to construct a fish weir instead of a fish screen at the Hogback Canal. Construction is expected to start on the project in 2011. The Program should evaluate the need for fish screens or deflection weirs at other diversion and out-take structures along the San Juan River in accordance with the LRP.

Recovery Action 3, Summary and Recommendations

The Program is making sufficient progress in minimizing entrainment of fish in diversion canals and out-take structures. The Program needs to ensure tasks in the LRP to evaluate the need for screens or deflection structures at other diversions are completed.

4. Ensure adequate protection from diseases and parasites.

The Program uses LRP Task 1.3.2.2, “Survey health of fish in the San Juan River to ensure adequate protection from disease and parasites” to address this recovery management action.

Fish health studies were conducted from 1992 to 1997 using flannelmouth and bluehead sucker as a surrogate for the endangered fish in the San Juan River. These studies investigated lesions and other abnormalities (Landye et al. 1999). In most years less than 1% of fish exhibited abnormalities but during some sampling periods as many as 3.5% of non-endangered suckers had abnormalities, primarily lesions (Landye et al. 1999). Based on these studies there was no indication that fish health was a limiting factor for Colorado pikeminnow or razorback sucker in the San Juan River (Holden 2000). Visual inspections of general fish health and condition occur on an annual basis during fish handling and capture activities on the San Juan River.

Recovery Action 4, Summary and Recommendations:

The Program is making sufficient progress to ensure that endangered fish have adequate protection from disease and parasites. Visual inspections of endangered fish should continue as part of the monitoring program. Any indication of poor health of endangered fish should be logged and reported. If the Program finds that indications of poor health are a concern or an impediment to recovery, the Program should identify the causes and recommend corrective actions.

5. *Regulate non-native fish releases and escapement into the San Juan River, floodplain, and tributaries.*

The Program uses LRP Action 3.2.1, “Develop policies and agreements among affected stakeholders for non-native game fish management” to regulate non-native fish releases and escapement into the San Juan River. The action and tasks in the LRP associated with this recovery management action direct the Program to implement this policy through an agreement with relevant Federal, State, and Tribal agencies.

In February 2009, Chuck McCada (U.S. Fish and Wildlife Service, Region 6) distributed a draft “Cooperative Agreement for Implementation of Procedures for Stocking Nonnative Fish Species in the San Juan River Basin.” This document is similar to one developed for the Upper Basin Recovery Program. The Biology Committee has reviewed the draft cooperative agreement which is now being reviewed by the State of New Mexico. The cooperative agreement among Colorado Division of Wildlife, New Mexico Game and Fish Department, Utah Division of Wildlife Resources, Navajo Nation, Ute Mountain Ute Indian Tribe, Southern Ute Indian Tribe, and the U.S. Fish and Wildlife Service will require the signatures of all parties.

Recovery Action 5, Summary and Recommendations:

The Program is making sufficient progress in regulating non-native fish releases in the San Juan River Basin but the Program needs to pursue attaining the necessary signatures to the cooperative agreement to implement the non-native stocking procedure as soon as possible (Action 3.2.1).

6. Control problematic non-native fishes as needed.

Goal 3.1 in the LRP details the Program's actions and tasks to control problematic non-native fish in the San Juan River.

The introduction of non-native species has been a major factor contributing to the extinction of many North American freshwater fish (Miller et al. 1989). Holden (2000) summarized the impact of non-native fish predation, competition, and hybridization on the native fish community in the San Juan River and Brooks et al. (2000) detailed the results of non-native fish interactions during the 7-year research period.

Limited mechanical removal of non-native fish began in 1997 and intensive removal of non-native fish via raft electrofishing has occurred in the upper and lower portions of the San Juan River since 2001 and 2002, respectively (Davis et al. 2009, Elverud 2009). In 2006 the non-native fish removal program was extended to include the reach from Shiprock, NM to Mexican Hat, UT to remove non-native fish from a greater proportion of critical habitat. Non-native control efforts are focused on removing channel catfish and common carp. The selective fish passage at PNM weir also allows for the removal of non-native fish while allowing native fish to pass upstream.

River-wide Schnabel population estimates for channel catfish increased from almost 132,000 in 1992 to nearly 275,000 in 1995 and common carp increased from over 26,000 to more than 107,000 during the same time period (Brooks et al. 2000). The Lincoln-Peterson population estimate for channel catfish in the lower San Juan has remained around 18,000 for the five years (2004-2009; Elverud 2009). Continued channel catfish population estimates in the lower San Juan River allow for the calculation of exploitation rate and the evaluation of removal effectiveness.

Channel catfish capture rates have remained relatively constant in the lower river (Elverud 2009) while captures rates have decreased in the upper river (Davis et al. 2009). Although river wide capture rates of channel catfish have remained relatively constant following the initiation of intensive non-native removal efforts, catfish populations are responding to removal efforts by shifting their distribution to middle sections of the river that have not experienced this long-term removal effort (Ryden 2009).

Capture rates of common carp have declined through time over the entire river (Davis et al. 2009, Elverud 2009).

A waterfall between the San Juan River and Lake Powell currently serves as a barrier for non-native fish moving from the lake to the river. This barrier is expected to persist into the near future and creates an opportunity to maximize the removal of non-native fish without immigration from Lake Powell. Continued monitoring at the base of the waterfall could determine when problematic lake species like walleye and striped bass are poised to enter the San Juan River (Elverud 2009). When Lake Powell fills above elevation 3660 ft, the water fall will disappear. Non-native fish from Lake Powell will once again have access to critical habitat in the San Juan River.

With continued river-wide removal efforts, it is expected that numbers of non-native predators and competitors will decline. A positive endangered fish population response cannot yet be linked to non-native removal efforts. Measurable objectives and methods for assessing and maintaining effectiveness of removal efforts should be developed and implemented river-wide. Efforts to determine river-wide population estimates for problematic non-native fish would allow researchers and managers to evaluate an exploitation rate of these populations to assess the effectiveness of removal efforts.

It is expected that these efforts will promote the survival of native fish as the level of predation by non-natives and competition between native and non-native fish is reduced.

Electrofishing is the primary means of removing problematic non-native fish. As a result, endangered fish and other native fish are also captured during these efforts. Approximately 75% of Colorado pikeminnow and 71% of razorback sucker recaptures have occurred during non-native fish removal efforts, highlighting the importance of this management activity in providing information that can be used to evaluate the demographic status of endangered fish populations.

The Program held a technical workshop in May 2010 to review and assess the non-native fish control program and make recommendations on how the current control program could more effectively reduce the threat of non-native species. An outcome of the workshop was confirmation that the current level of effort should continue with some modifications. A number of recommendations were generated at the workshop including making adjustments to the

current methodology and developing a comprehensive non-native species management plan for the Program.

Recovery Action 6, Summary and Recommendations

The Program is making sufficient progress in controlling problematic non-native fishes. The Program needs to develop a comprehensive non-native species management plan. The plan should include measureable river-wide objectives to determine the effects of removal efforts on native and non-native fishes. This would allow better evaluation of this activity in the future. The Program should develop a plan to control non-native fish entering the San Juan River from Lake Powell when the lake refills and be prepared to implement that plan.

7. Minimize the risk of hazardous-materials spills in critical habitat.

The Program uses Goal 2.4 of the LRP to provide suitable water quality to support recovery of Colorado pikeminnow and razorback sucker populations.

Specific tasks outlined in the Recovery Goals to address the risk of hazardous spills within critical habitat were reiterated in the 2006 Service draft assessment of the Program (USFWS 2006). These tasks included: (1) review and recommend modifications to State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for razorback sucker and Colorado pikeminnow populations from hazardous-materials spills, including prevention and quick response to hazardous-materials spills; (2) implement State and Federal emergency-response plans that contain the necessary preventive measures for hazardous-materials spill; (3) identify the locations of all petroleum-product pipelines within the 100-year floodplain of critical habitat; and, (4) assess the need and install emergency shut-off valves on problematic petroleum-product pipelines within the 100-year floodplain of critical habitat to minimize the potential of spills. The Service recommended that the Program develop specific actions for implementation in 2007 to address minimizing the risks of hazardous material spills within critical habitat. To date these tasks have not been completed. However, a task to address this recovery action is included in the 2010 LRP (Task 2.4.3, Minimize the risk of hazardous material to areas of designated critical habitat) and the Program has initiated efforts to address this issue.

The Nature Conservancy, a Program participant, is conducting conservation planning activities that include evaluating the need for physical habitat enhancements and conducting an analysis of hazardous materials threats and impacts to the San Juan River ecosystems. The Program included funds in the 2009 and 2010 Annual Workplans to assist with this effort. The primary goal of this scope of work is to utilize existing data and analyses of essential habitats, flow-habitat relationships, and endangered fish distributions to identify locations for habitat improvement projects that will use mechanical means to assist flows in the creation or improvement of endangered fish habitats. A secondary goal is to analyze existing and proposed hazardous material threats to the San Juan River ecosystems, identify best management practices, and make recommendations to minimize the risks of hazardous material impacts on the San Juan River. Because this threats assessment is the first step to completing the tasks identified above, the Program needs to insure this work is accomplished in a timely manner and a plan is developed and implemented to accomplish the identified recovery action.

There are other groups within the San Juan River Basin, including the San Juan Watershed Group, Animas Watershed Partnership, and the New Mexico Environment Department that are involved with developing databases to track locations where potential hazardous spills could enter the San Juan River. The Program needs to improve coordination with these groups in order to share data to address this issue.

Recovery Action 7, Summary and Recommendations:

The Program is making progress in minimizing the risk of hazardous-material spills in critical habitat with the threats assessment being done by the Program, as a first step. The Program needs to ensure Tasks 1-4 above (USFWS, 2006) are accomplished to fully address this recovery action. This will require collaboration with other groups within the San Juan River Basin that are addressing the risk of hazardous-material within the Basin. Appropriate actions and tasks should be incorporated in the LRP with time frames for completion.

8. Remediate water-quality problems.

The LRP addresses water quality in the San Juan River under Goal 2.4 “Provide suitable water quality to support recovery of Colorado pikeminnow and razorback sucker populations” and Task 4.2.2.4 “Monitor water quality in the San Juan River.”

The Service has serious concerns with current levels of mercury and selenium found in the tissues of razorback sucker and Colorado pikeminnow in certain locations in the Upper Colorado River basin because mercury and selenium contamination may be causing reproductive impairment (Service 2009). At the same time, the Service recognizes that actual remediation is beyond the scope or capabilities of the Program, and will require regulatory action by other federal agencies. It is the recommendation of the Service that the Program Office take a lead role in: 1) developing a comprehensive contaminants monitoring plan for the San Juan River, 2) identifying the effects of contaminants on recovery of endangered fish, and 3) providing assistance in developing recommended water quality criteria for problematic contaminants for consideration by state and federal water quality regulatory agencies when adopting enforceable water quality standards. The Biology Committee, contaminant biologists, fish toxicologists, and management and policy expertise are needed to develop the monitoring plan. The plan will need to be closely coordinated between Region 2 and Region 6 of the Fish and Wildlife Service and with the Upper Colorado Recovery Implementation Program. The Program Office will be the lead for establishing a working group from Region 2 and 6 including expertise from both Recovery Programs to begin the process of addressing the contaminant issue and in developing the monitoring plan.

The Service continues to highlight the threat posed by contaminants to the Colorado pikeminnow and razorback sucker within the San Juan River Basin. The Service's 2009 draft biological opinion on the Desert Rock Energy Project (DREP) highlighted concerns of mercury accumulation in predatory fish like Colorado pikeminnow and selenium in razorback sucker. Mercury is a bioaccumulating neurotoxin that affects the reproductive health of fish (Crump and Trudeau 2009). Mercury levels in pikeminnow over 400 mm TL suggested likely reproduction impairment (Service unpublished data). Razorback sucker shed excess dietary selenium in their eggs that can cause high embryo mortality if selenium levels are sufficiently high (Lemly 2002). A comprehensive contaminants monitoring plan is needed for the San Juan River Basin and development should include participation by the appropriate entities. The plan should include a process for identifying contaminants and the impact of contaminants on endangered species. Specific actions and tasks from this plan that are appropriate for the Program should be reflected in the LRP.

Recovery Action 8, Summary and Recommendations:

Due to these contamination concerns and the potential impact on recovery efforts for Colorado pikeminnow and razorback sucker population, the Program needs to take immediate actions to address the issue of mercury and selenium contamination in the San Juan River Basin. In cooperation with other entities, the Program needs to ensure a comprehensive contaminants monitoring plan is developed to identify water quality threats to the endangered species. The Program also needs to include monitoring tasks in the LRP to address the water quality issues.

It is the recommendation of the Service that the Program Office take a lead role in 1) developing a comprehensive contaminants monitoring plan for the San Juan River, 2) identifying the effects of contaminants on recovery of endangered fish, and 3) providing assistance in developing recommended water quality criteria for problematic contaminants for consideration by state and federal water quality regulatory agencies when adopting enforceable water quality standards. The first step needs to be a definition of issues and the process for plan development. The role of the Program needs to be defined and agreed to by the Coordination Committee. Specific monitoring tasks for the Program need to be identified, approved by the Coordination Committee, and incorporated into the LRP. Development of that information will be coordinated with Program activities and the information developed will be reported to the Program.

9. Reestablish populations with hatchery-produced fish.

In Element 1 of the LRP “Management and augmentation of populations and protection of genetic integrity,” the Program identifies actions and tasks for stocking of hatchery-produced fish.

After experimental stocking of endangered fish during the 7-year research period, the Program developed an augmentation plan for razorback sucker (Ryden 1997). Originally, razorbacks were reared at Dexter National Fish Hatchery and Technology Center (Dexter NFH) and stocked into grow-out ponds at Navajo Agricultural Products Industry (NAPI) in the spring and harvested in the fall for stocking into the river. Between 1997 and 2001, only 8% of the total razorback sucker stocking goal of 73,482 fish was achieved (Furr and Davis 2009a). An addendum to the augmentation plan for razorback sucker was completed in 2003 to guide stocking efforts from 2004 to 2011 (Ryden 2003b). In 2004, only 2,989 razorback sucker were

stocked into the San Juan River, well below the stocking objective of 11,400 age-2 ($\geq 300\text{mm}$) fish. In May of 2005, a second addendum was proposed to change the starting date of the eight-year razorback sucker stocking plan until corrective measures to improve production were completed and in-place. To date, a new starting date has not been determined. Currently, razorbacks continue to be spawned at Dexter NFH but are now stocked into grow-out ponds at both Uvalde National Fish Hatchery (Uvalde NFH) and NAPI ponds. Fish produced and stocked from the NAPI ponds are supplemental to the 11,400 fish provided to the Program by Uvalde NFH (Furr and Davis 2009c). After corrective measures were taken, razorback sucker stocking goals have been attained in three of the last four years. A new plan or addendum will be needed prior to the start of the 2012 stocking season to guide razorback sucker stocking in the future.

In 2002, stocking of Colorado pikeminnow started under the direction of an augmentation plan developed by the Program (Ryden 2003a). Colorado pikeminnow are reared at Dexter NFH to satisfy the Program's annual stocking objectives of 300,000 age-0 and 3,000 age-1+ pikeminnow. From 2005 to 2009, the Program met or exceeded the total stocking goal. The Colorado pikeminnow stocking plan (Ryden 2003a) expired in 2009; however, the stocking goal from the Phase I stocking plan remains in effect through 2010. A Phase II stocking plan was developed (Furr and Davis 2009d) and is under review by the Program's Biology Committee. A review by Durst (2010) suggested that, while return rates (one year post release) of age-1 Colorado pikeminnow were almost 4 times greater than return rates of age-0 fish, the cost of the returned fish was 30 times greater for age-1 fish. As a result of this analysis the new stocking plan shifts all augmentation efforts to production and stocking of age-0 Colorado pikeminnow. With full utilization of available rearing space, production forecasts suggest $\geq 400,000$ age-0 Colorado pikeminnow can be produced annually.

Of all the management actions to recover Colorado pikeminnow and razorback sucker in the San Juan River, stocking/augmentation with hatchery produced fish has led to the largest population response of the endangered fish because of its direct impact on increasing endangered fish numbers. However, because both species are long-lived it will take many years to determine if the Program's stocking activities are successful. Annual monitoring of larval fish indicates that razorback sucker are reproducing but few larval Colorado pikeminnow have been captured. Recruitment of endangered fish into the adult population remains a concern for both species.

Recovery Action 9, Summary and Recommendations:

The Program is making sufficient progress in reestablishing populations of endangered fish within the San Juan River with hatchery-produced fish. In order to continue augmenting endangered fish populations with hatchery-produced fish, the Program needs to ensure augmentation plans for both Colorado pikeminnow and razorback sucker are updated as scheduled to guide stocking into the future and that stocking objectives are achieved annually. Additionally, the Program needs to continue to monitor reproduction and recruitment of both species.

10. Minimize the threat of hybridization with white sucker.

The Program uses Action 1.3.3 in the LRP to evaluate the risk of hybridization among sucker species.

The Program evaluated the degree of razorback sucker hybridization using DNA-based genetic markers on larval fish (Turner et al. 2002). Of 61 total fish screened, Turner et al. (2002) detected only two hybrids; both were flannelmouth-bluehead sucker crosses. All eight razorback suckers screened were pure razorbacks (Turner et al. 2002). Currently there is no evidence of white sucker-razorback sucker hybridization.

Although there is no regular genetic analysis of razorbacks in the San Juan River, morphological hybrids could be detected through other sampling activities. White suckers are removed during monitoring, non-native fish control, and other Program activities on the San Juan River. There are no other efforts in place to minimize the threat of potential razorback sucker hybridization with white sucker because the available data indicates that white sucker-razorback hybridization is not a problem at this time.

Recovery Action 10, Summary and Recommendations:

The Program is making sufficient progress in minimizing the threat of razorback sucker hybridization with white sucker; however, an out-year LRP objective should be established to periodically reconfirm that razorback sucker hybridization with white sucker is not a threat to the species.

RECOVERY DEMOGRAPHIC CRITERIA FOR DOWNLISTING AND DELISTING BOTH SPECIES

For the San Juan River Basin, the Colorado pikeminnow draft recovery goals (USFWS 2008b) state that a target of 1,000 age-5+ Colorado pikeminnow established through augmentation or natural reproduction is required for downlisting and a population of 800 self-sustaining adults maintained in the San Juan River is needed for delisting. These target numbers for Colorado pikeminnow are based on inferences about the carrying capacity of the San Juan River Basin (USFWS 2008b). The razorback sucker draft recovery goals (USFWS 2008a) target a population of 5,800 self-sustaining adults in the San Juan River. These targets highlight the need to regularly conduct population estimates in order to evaluate progress toward recovery for both endangered species.

During the seven-year research period (1991 to 1997), Ryden (2000) estimated that there were fewer than 50 adult Colorado pikeminnow in the San Juan River in any given year. In 2000, it was estimated that there were 19 wild adult pikeminnow in the San Juan River from RM 136.6 to RM 119.2 (95 % C.I. 10-42; Ryden 2000). No wild Colorado pikeminnow have been captured since 1999 (Ryden 2008, Davis and Furr 2008). A Schnabel multiple-census population model for stocked razorback sucker from RM 158.6 to RM 2.9 estimated that there were 268 razorbacks in October 2000 (Ryden 2001) and approximately 1,200 in October 2004 (Ryden 2005b). No wild razorback suckers were found during the seven-year research period (Holden 2000). Hatchery-reared razorback sucker, especially fish larger than 350 mm introduced into the San Juan River in the 1990s, have survived and reproduced, as evidenced by recapture data and collection of larval fish (Brandenburg and Farrington 2008).

The current monitoring protocol is not designed to determine population estimates and no estimates have been made in recent years; however, because recovery goals are based on target populations, regular population estimates are critical to evaluate progress toward recovery for both species.

Recovery Demographic Criteria, Summary and Recommendations:

In order to determine sufficient progress in achieving recovery demographic criteria for downlisting and delisting Colorado pikeminnow and razorback sucker, the Service recommends that the Program explore conducting population estimates for both species. The most recent

estimates for both species are over five years old and intensive stocking and other management activities have occurred during the intervening period. Initial population estimates should be conducted using existing data. In the future when sufficient numbers of fish are in the system, a specific effort designed to estimate population size will be needed. Population estimates should be conducted when monitoring results suggest that Colorado pikeminnow and razorback sucker populations are approaching recovery goal targets.

POSITIVE POPULATION RESPONSE CRITERIA

In the Final Biological Opinion for the Animas-La Plata Project (ALP), dated June 19, 2000 the U.S. Fish and Wildlife Service (Service) concluded " ... *that the Animas-La Plata Project, as described in this biological opinion, is not likely to jeopardize the continued existence of the Colorado pikeminnow or razorback sucker, and the proposed project is not likely to destroy or adversely modify designated critical habitat. ... This conclusion is based on the description of the proposed action contained in this biological opinion with full implementation of the conservation measures*"

The *conservation measures* referred to in the biological opinion are activities included as part of the proposed action that address a variety of issues related to conservation of endangered species. The Positive Population Criteria specifically addresses Conservation Measure 1 under which Reclamation committed to operate Navajo Reservoir in a manner that mimics the natural hydrograph of the San Juan River to benefit endangered fishes and their critical habitat.

In addition to mimicry of a natural hydrograph, Reclamation also committed to developing Positive Population Criteria under conservation Measure 1 to determine a positive population response for the endangered Colorado pikeminnow and razorback sucker. Conservation Measure 1 states that these criteria would be developed in consultation with the Biology Committee and submitted to the Service for concurrence within one year of the date of the ALP biological opinion.

The criteria were developed to determine the population response of Colorado pikeminnow and razorback sucker to the operation of Navajo Dam mimicking a natural hydrograph in the San Juan River. The Positive Population Criteria were developed in consultation with the Biology Committee and Reclamation received the Biology Committee's endorsement of the criteria during its May 15-16, 2001 meeting. The Positive Population

Criteria are divided into two parts Interim Response Criteria (2002-2006) and Positive Population Criteria (2007-2011) (Reclamation 2001).

The Interim Response Criteria developed for 2002-2006 have been met for both species. For the Colorado pikeminnow, these short-term criteria were: (1) collection of greater than 10 individuals larger than 350mm during a standardized monitoring trip; (2) presence of wild larvae or YOY individuals in standardized monitoring collections in 2 of 5 years; and (3) range expansion above Hogback Diversion. The Interim Response Criteria for razorback sucker for 2002-2006 were: (1) collection of greater than 20 individuals larger than 300 mm during the annual fall standardized monitoring trip; (2) collection of greater than 0.15 individuals per hour of electrofishing larger than 300 mm; and (3) evidence of reproduction in standardized monitoring in at least 2 of 5 years.

Part two of the Positive Population Response Criteria was developed for 2007-2011 to build on Interim Response Criteria developed for 2002-2006. These criteria establish expectations for improvements in Colorado pikeminnow and razorback sucker population demographics. Attainment of the population response criteria for 2007-2011 will depend on the successful implementation of various projects by the Program and will represent a significant step towards self-sustaining populations in the San Juan River. The criteria are intended to determine whether the stocked fish are capable of any of the following: (1) attaining adult size; (2) successfully reproducing; or (3) re-colonizing newly opened reaches of river. In addition, these response criteria will determine if reproduction is occurring in sufficient numbers and nursery habitats are adequate to yield naturally produced young-of-year (YOY).

Colorado pikeminnow positive response criteria 2007-2011.

- 1. Collection of 10 or more adult Colorado pikeminnow (≥ 450 mm TL) during a standardized monitoring trip.*

In 2007, standardized monitoring collected 167 Colorado pikeminnow but only one was larger than 450mm and of the 207 pikeminnow collected in 2008 none was larger than 450mm (Ryden 2008, 2009). While Colorado pikeminnow are being captured during standardized monitoring trips, large reproductive fish that could contribute to a self-sustaining Colorado pikeminnow population are rarely captured. Due to past stocking efforts and predictions based on models there should be Colorado pikeminnow larger than 450mm in the San Juan River.

These fish may be evading capture, they may be lost over the waterfall into Lake Powell, they could be in tributaries to the San Juan River, or they may have died due to various unknown causes. Investigations into these issues are planned. In 2010, the Coordination Committee authorized a survey of the San Juan Arm of Lake Powell in 2011 to determine the extent of fish lost over the waterfall. The feasibility of installing passive PIT tag readers in the river to detect fish movement and locations is also being investigated.

2. *A positive trend analysis of annual adult/sub-adult CPUE values from standardized monitoring that indicates increasing numbers of fish (regression analysis that results in a slope > 0 with a minimum of four data points), or a riverwide population estimate of adult (≥ 450 mm TL) that exceeds 400 individuals and is composed of multiple age classes.*

Because there have been no river-wide population estimates for Colorado pikeminnow since Ryden's (2000) estimate from the 7-year research period, CPUE values are being used. The scaled CPUE of Colorado pikeminnow that have been in the San Juan River for at least one overwinter period has not significantly changed in 4 of the last 5 years (Ryden 2009).

3. *Presence of larval or YOY pikeminnow in standardized monitoring collections in 3 of 5 years.*

Since 2003, there have been only two years when age-0 Colorado pikeminnow were detected (Brandenberg and Farrington 2009). There were 3 age-0 pikeminnow detected in 2007 and 2 in 2004 (Brandenberg and Farrington 2009). The lack of detectable Colorado pikeminnow reproduction may be due to the small number of reproducing adults in the San Juan River, high predation by non-native species on these fish, or a lack of suitable larval habitats to retain these larval fish, possibly resulting in the larvae drifting into to Lake Powell.

4. *A density of $0.67/1000m^3$ larval Colorado pikeminnow in standardized drift monitoring during years when monsoons do not have a negative effect on sampling efficiency. Or a density of $0.5/100m^2$ wild young-of-year Colorado pikeminnow in low velocity habitat as detected during standardized monitoring.*

In 2004 and 2007, a total of only 5 larval Colorado pikeminnow were collected (Brandenberg and Farrington 2009). The density of wild age-0 Colorado pikeminnow is much lower than the target goals, only 0.017 fish/ $100m^2$ in 2004 and 0.022 fish/ $100m^2$ in 2007 (Brandenberg and Farrington 2009). Both the larval and small-bodied monitoring program regularly capture YOY Colorado pikeminnow but these YOY fish are thought to be stocked

individuals (Brandenberg and Farrington 2009, Paroz et al. 2009). Drift netting is no longer used in the larval fish sampling protocol.

5. Range expansion above Hogback Diversion following removal of this and other fish barriers.

In 2008, 14 Colorado pikeminnow that did not have PIT tags were collected upstream of the Hogback Diversion (Ryden 2009) and 27 were collected in 2007 (Ryden 2008). A total of 48 Colorado pikeminnow have been detected at the PNM fish weir since 2003 (A. Lapahie personal communication). Therefore, Colorado pikeminnow have clearly expanded their range following the removal of these barriers to their migration, although some stocking of Colorado pikeminnow occurs upstream of these barriers.

Positive Population Criteria for Colorado pikeminnow, Summary and Recommendations:

As of 2009, the Program has not met the Colorado pikeminnow Positive Population Response Criteria for 2007-2011. While the Program is conducting management actions with the expectation of a positive population response by Colorado pikeminnow, the anticipated results are not being attained. When developing positive population response criteria for 2012 and beyond, the Service recommends that the Program evaluate past criteria to develop reasonable criteria for the future. Although the Program expects that management actions currently under way will lead to a positive population response, the Service recommends that the Program investigate why these criteria are not being met in order to be able to reach demographic criteria established in the Recovery Goals.

Razorback sucker positive response criteria 2007-2011.

- 1. Collection of 80 or more adult razorback sucker (> 400 mm) during a standardized monitoring program trip. Or an increase in the CPUE of adult razorback sucker (> 400 mm) to 0.6 fish/hour during a standardized monitoring program trip.*

In 2007, a total of 207 razorback sucker were collected ranging from 221-516mm in size and 69 were larger than 400mm. In 2008, a total of 78 razorback sucker were collected between 273-525mm in size and 62 were larger than 400mm (Ryden 2008, 2009). While numerous large stocked razorback suckers are being collected, the target number in the appropriate size class is not being reached. Razorback sucker CPUE for fish larger than 400mm was about 0.01 fish/hour in both 2007 and 2008 and the scaled CPUE for razorback sucker that have been in the river for

at least one overwinter period has not changed over the last six years (Ryden 2009). A recent study on the survival of hatchery reared razorback sucker stocked into the San Juan River (Bestgen et al. 2009) should be used to evaluate the stocking program to determine if stocking objectives are appropriate to reach these expectations for the number of larger size-class fish.

2. *A riverwide population estimate of adult razorback sucker of 2,900 or more fish.*

The most recent population estimate for razorback sucker was the Schnabel multiple-census population model for RM 158.6 to 2.9 in 2004 that indicated approximately 1,200 fish (Ryden 2005b). Regular population estimates are needed when fish populations begin to approach recovery demographic criteria.

3. *Evidence of increased reproduction in at least 3 of 5 years based on standardized monitoring.*

Razorback sucker larvae have been collected every year from 2003 to 2008 indicating that sufficient numbers of razorback suckers are spawning to produce larvae in detectable numbers (Brandenberg and Farrington 2009). Brandenberg and Farrington (2009) reported 463 larval razorback captured in 2003, 41 in 2004, 19 in 2005, 202 in 2006, 200 in 2007, and 126 in 2008.

4. *Range expansion above Hogback Diversion following removal and/or modification of fish barriers.*

Ryden (2008, 2009) collected 13 and 5 razorback sucker upstream of the Hogback Diversion in 2007 and 2008, respectively. A total of 27 razorback suckers have been detected using the PNM fish weir since 2003 (A. Lapahie personal communication). Thus, razorback suckers are able to utilize new areas of critical habitat that become available once barriers to movement are removed.

Positive Population Criteria for razorback sucker, Summary and Recommendations:

The Program is meeting most of the razorback sucker positive population response criteria for 2007-2011. Although not all criteria are being met for razorback sucker, the collection of the target number of fish over 400mm, regular reproduction, and range expansion are encouraging for the recovery of this species within the San Juan River Basin. The Service recommends that the Program evaluate past positive population response criteria to develop a new set of criteria for 2012 and beyond. The criteria should lead to achievement of demographic

criteria for down listing and delisting within the timeframe specified in the revised recovery goals.

CONCLUSION AND RECOMMENDATIONS

The Service considers the Program's overall progress toward recovery of Colorado pikeminnow and razorback sucker within the San Juan River Basin to be sufficient for the Program to continue as the ESA compliance mechanism for water development, management and operations within the San Juan River basin. The Program's actions and tasks described in the LRP and management activities in the draft Recovery Goals are being satisfactorily met, such that the Program will continue to serve as a foundation for reasonable and prudent alternatives and measures in applicable Section 7 consultations.

Proposed additions to the LRP:

The recommendations outlined below are activities that the Service believes the Program should implement to benefit the recovery of the endangered fish in the San Juan River. Completing the recommendations will allow the Program to make significant progress toward recovery of the Colorado pikeminnow and razorback sucker within the San Juan River Basin.

The Service requests that the Coordination Committee add these recommendations to the LRP and ensure appropriate tasks with timeframes are included in the LRP.

1. Develop a comprehensive contaminants monitoring plan to identify sources and magnitude of water quality threats that are adversely affecting the endangered species.
2. Investigate the use of habitat manipulations such as non-native vegetation removal to create and maintain habitat complexity in the San Juan River and monitor the response of any actions intended to create habitat.
3. Ensure the Bureau of Reclamation moves forward with the design studies for fish passage improvements at APS Weir and Fruitland Diversion and implementation of fish passage improvements as needed.
4. Evaluate the need for fish screens or deflection weirs at other diversion and out-take structures along the San Juan River.
5. Minimize the risks of spills of hazardous materials within critical habitat. To fully address this recovery action, the Service recommends that the Program Office develop specific actions for accomplishing each of the following tasks and include appropriate actions and tasks in the LRP with time frames for completion.

- a. Review and recommend modifications to State and Federal hazardous-materials spills emergency-response plans to ensure adequate protection for razorback sucker populations from hazardous-materials spills, including prevention and quick response to hazardous-materials spills.
 - b. Ensure implementation of State and Federal emergency-response plans that contain the necessary preventive measures for hazardous-materials spill.
 - c. Ensure identification of the locations of all petroleum-product pipelines within the 100-year floodplain of critical habitat and assess the need for emergency shut-off valves to minimize the potential for spills.
 - d. Ensure installation of emergency shut-off valves on problematic petroleum-product pipelines within the 100-year floodplain of critical habitat.
 - e. Develop Best Management Practices for heavy equipment use within the 100 year floodplain.
6. Develop a revised set of positive population response criteria for 2012 through 2016 that are structured to meet recovery demographic criteria for downlisting and delisting specified in recovery goals/plans adopted by the Service. This should include identifying any additional management actions necessary to attain those criteria that should be carried out by the Program. The criteria should be for a specified time frame and reevaluated and updated periodically.

LITERATURE CITED

- Abell, R. 1994. San Juan River Basin water quality and contaminants review. Museum of Southwestern Biology, Department of Biology, University of New Mexico, Albuquerque, NM.
- Bestgen, K.R., K.A. Zelasko, and G.C. White. 2009. Survival of hatchery-reared razorback suckers *Xyrauchen texanus* stocked in the San Juan River Basin, New Mexico, Colorado, and Utah. Larval Fish Laboratory, Department of Fish, Wildlife and Conservation Biology, Colorado State University, Fort Collins, CO.
- Brandenburg, W.H. and M.A. Farrington. 2008. Colorado pikeminnow and razorback sucker larval fish surveys in the San Juan River during 2007. San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.
- Bureau of Reclamation. 2007. Value Engineering Final Report on the Hogback Diversion Dam - Fish Screen Project. DOI Bureau of Reclamation. Upper Colorado Region, Grand Junction, CO.
- Brooks, J.E., M.J. Buntjer, and J.R. Smith. 2000. Non-native species interactions: management implications to aid in recovery of the Colorado pikeminnow (*Ptychocheilus lucius*) and razorback sucker (*Xyrauchen texanus*) in the San Juan River, Colorado, New Mexico, Utah. San Juan River Basin Recovery Implementation Program draft report, USFWS, Albuquerque, NM.
- Cutler, A. 2005. Navajo Reservoir and San Juan River temperature study. Bureau of Reclamation report to San Juan River Basin Recovery Implementation Program.
- Crump, K.L. and V.L. Trudeau. 2009. Critical review: mercury induced reproductive impairment in fish. *Environmental Toxicology and Chemistry* 28:895-907.
- Davis, J.E. and S.M. Coleman. 2004. Non-native species monitoring and control in the upper San Juan River 2002-2003 and Assessment of fish movement through the non-selective fish ladder at Hogback Diversion, New Mexico 2003. San Juan River Basin Recovery Implementation Program draft report, USFWS, Albuquerque, NM.
- Davis, J.E. and D.W. Furr. 2008. Non-native species monitoring and control in the Upper San Juan River, New Mexico 2007. Progress report for the San Juan River Recovery Implementation Program. U.S. Fish and Wildlife Service, New Mexico Fishery Resources Office. Albuquerque, New Mexico.
- Davis, J.E., D.W. Furr, and E. Teller. 2009. Nonnative species monitoring and control in the upper San Juan River: 2008. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.

- Elverud, D.S. 2009. Nonnative control in the lower San Juan River 2008. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.
- Furr, W.D. and J.E. Davis. 2009a. Augmentation of the San Juan River razorback sucker population 2008. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.
- Furr, W.D. and J.E. Davis. 2009b. Augmentation of Colorado pikeminnow (*Ptychocheilus lucius*) in the San Juan River: 2008. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.
- Furr, W.D. and J.E. Davis. 2009c. A stocking plan and production protocol for razorback sucker (*Xyrauchen texanus*) reared at NAPI ponds (draft). San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.
- Furr, W.D. and J.E. Davis. 2009d. Augmentation of Colorado pikeminnow (*Ptychocheilus lucius*) in the San Juan River: Phase II, 2010-2020 (draft). San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.
- Holden, P.B. (Ed.). 1999. Flow recommendations for the San Juan River. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.
- Holden, P.B. 2000. Program evaluation report for the 7-year research period (1991-1997). San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.
- Lamarra, V.A. 2007. San Juan River fishes response to thermal modification. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.
- Landye, J., B. McCasland, C. Hart, and K. Hayden. 1999. San Juan River fish health surveys 1992-1997. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.
- Lemly, A.D. 1993. Guidelines for evaluating selenium data from aquatic monitoring and assessment studies. *Environmental Monitoring and Assessment* 28:83-100.
- Lemly, A.D. 2002. Selenium assessment in aquatic ecosystems: a guide for hazard evaluation and water quality criteria. Springer-Verlag, New York, NY.
- Miller R.R., J.D. Williams, and J.E. Williams. 1989. Extinctions of North American fishes during the past century. *Fisheries* (14):22-38.
- Miller, W.J. 2006. San Juan River standardized monitoring program five year integration report. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.
- Paroz, Y.M., D.L. Propst, and S.M. Carman. 2009. Small-bodied fish monitoring, San Juan River, September –October 2008. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.

- Platania, S.P. 1990. Biological summary of the 1987 to 1989 New Mexico-Utah ichthyofaunal study of the San Juan River. Unpublished report to the New Mexico Department of Game and Fish, Santa Fe, and the U.S. Bureau of Reclamation, Salt Lake City, Utah, Cooperative Agreement 7-FC-40-05060.
- Propst, D.L. and K.B. Gido. 2004. Responses of native and nonnative fishes to natural flow regime mimicry in the San Juan River. *Transactions of the American Fisheries Society* 133:922-931.
- Renfro, L.E., S.P. Platania, and R.K. Dudley. 2006. An assessment of fish entrainment in the Hogback Diversion Canal, San Juan River, New Mexico, 2004 and 2005. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM.
- Ryden, D.W. 1997. Five-year augmentation plan for razorback sucker in the San Juan River. U.S. Fish and Wildlife Service, Grand Junction, CO.
- Ryden, D.W. 2000. Adult fish community monitoring on the San Juan River, 1991-1997. Final Report. U. S. Fish and Wildlife Service, Grand Junction, CO.
- Ryden, D.W. 2001. Monitoring of razorback sucker stocked into the San Juan River as part of a five-year augmentation effort: 2000 interim progress report. U.S. Fish and Wildlife Service, Grand Junction, CO.
- Ryden, D.W. 2003a. An augmentation plan for Colorado pikeminnow in the San Juan River. U.S. Fish and Wildlife Service, Grand Junction, CO.
- Ryden, D. W. 2003b. An augmentation plan for razorback sucker in the San Juan River: An addendum to the five-year augmentation plan for razorback sucker in the San Juan River (Ryden 1997). U.S. Fish and Wildlife Service, Grand Junction, CO.
- Ryden, D. W. 2005a. An augmentation plan for Colorado pikeminnow in the San Juan River: Addendum #1: Stocking of age-1 fish to supplement ongoing augmentation efforts. U.S. Fish and Wildlife Service, Albuquerque, NM.
- Ryden, D.W. 2005b. Augmentation and monitoring of the San Juan River razorback sucker population: 2004 interim progress report. U.S. Fish and Wildlife Service, Grand Junction, CO.
- Ryden, D.W. 2008. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 2007.
- Ryden, D.W. 2009. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 2008. San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.
- San Juan River Basin Recovery Implementation Program. 2006. Program document. San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM (under revision).

- San Juan River Basin Recovery Implementation Program. 2010. Long range plan. San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.
- Stamp, M., M. Golden, and R.C. Addley. 2005. Evaluation of the need for fish passage at the Arizona Public Service and Fruitland irrigation diversion structures. San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.
- Turner, T.F., M.V. McPhee, D. Alò, W.H. Brandenburg. 2002. Determination of occurrence of hybridization of San Juan River razorback sucker through genetic screening of larval fishes. Draft report prepared by the Museum of Southwest Biology, University of New Mexico, Albuquerque, NM.
- U.S. Bureau of Reclamation. 2001. Positive Population Response Criteria for Colorado Pikeminnow and Razorback Sucker in the San Juan River. Upper Colorado Region, Western Colorado Area Office.
- U.S. Fish and Wildlife Service. 2006. Annual Service review and assessment of the San Juan River Basin Recovery Implementation Program (draft). U.S. Fish and Wildlife Service, Southwest Region (2), Albuquerque, New Mexico.
- U.S. Fish and Wildlife Service. 2008a. Razorback sucker (*Xyrauchen texanus*) Recovery Goals: amendment and supplement to the Razorback Sucker Recovery Plan (2008 revisions). U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.
- U.S. Fish and Wildlife Service. 2008b. Colorado pikeminnow (*Ptychocheilus lucius*) Recovery Goals: amendment and supplement to the Colorado Squawfish Recovery Plan (2008 revisions). U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.