United States Department of the Interior

FISH AND WILDLIFE SERVICE

New Mexico Ecological Services Field Office
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August 21, 2014

Cons. #22420-2011-F-0024-R001

Claudia V. Hosch, Associate Director
Water Quality Division, NPDES Permits and TMDLs Branch
U.S. Environmental Protection Agency, Region VI,
1445 Ross Avenue, Suite 1200,
Dallas, Texas 75202-2733

Dear Ms. Hosch:

This letter transmits the U.S. Fish and Wildlife Service's (Service) biological opinion (BO) on effects of the proposed action by U.S. Environmental Protection Agency (EPA) to authorize pollutants in stormwater discharges from Municipal Separate Storm Sewer Systems (MS4s) in the Middle Rio Grande (MRG) Watershed (Figure 1). The permit authorization would be in effect for a period of five years (2014-2019). The proposed action was described in EPA's Biological Evaluation (BE) and subsequent amendments (EPA 2010a, b; 2013a) and in the draft "Authorization to Discharge under the National Pollutant Discharge Elimination System (NPDES) for NPDES Permit No. NMR04A000" (EPA 2013b) and accompanying Factsheet (EPA 2013c). The Service refers to EPA's proposed action as the MRG Watershed MS4 Permit.

The EPA's request for consultation, in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 United States Code [USC] 1531 et seq.; ESA), was initially received on July 16, 2010, and subsequently amended in August 2013, and formal consultation was mutually extended in December 2013, February 2014, and June 2014. The Service considers the MRG Watershed MS4 Permit (EPA 2013a,b,c) to generally be a proposal to continue action previously authorized by EPA in the Albuquerque MS4 Permit (EPA 2010a,b,c; USFWS 2011) with some expansion of the available applicants. Therefore, formal consultation number, 22420-2011-F-0024, has been revised to 22420-2011-F-0024-R001A, to reflect the currently proposed action of EPA's MRG Watershed MS4 Permit. The consultation history associated with the Albuquerque MS4 Permit and EPA's proposed MRG Watershed MS4 Permit action is provided below.

The BO is based upon information submitted in the BE and amendments (EPA 2010a, 2013a); communications among EPA, AMAFCA, the U.S. Geological Survey (USGS), Pueblo of Sandia, and the Service; and other sources of information available to the Service. Records for this consultation are available at the Service's New Mexico Ecological Services Field Office.

Southwestern Willow Flycatcher

The EPA has determined the proposed project "may affect, but is not likely to adversely affect," flycatcher or its designated critical habitat. The Service concurs with this determination based on the rationale below.

The flycatcher is a migrant through the MRG, and may be present seasonally from April through August. No flycatcher breeding habitat or occupied nesting territories are known to occur within the MRG Watershed MS4 Permit action area. The closest known flycatcher breeding territories in or adjacent to the action area are located near Isleta, New Mexico, below the Isleta Diversion Dam. Evidence of these territories was observed in 2013, but this site is outside the action area and has recently been burned. Given there are no known nesting flycatchers in the action area, the Service does not anticipate any adverse effects to flycatchers would occur, including exposure to potential contaminants, such as PCBs, in the stormwater discharges authorized by the proposed action. In the future, if any nesting flycatchers are reported in the action area, the Service will inform EPA, so that EPA can reassess its findings for flycatcher and determine if reinitiating consultation with the Service would be necessary.

The action area, including any activities, stormwater, or non-stormwater discharges authorized by the MRG Watershed MS4 Permit, does not occur within designated flycatcher critical habitat (USFWS 2013a). The Service does not anticipate the proposed action will result in adverse effects to the Primary Constituent Elements (PCEs) of designated critical habitat. Because flycatcher critical habitat is downstream of the action area (78 FR 334; USFWS 2013a) and the abundance of their insect prey will not likely be adversely affected by any PCBs (Mayer et al. 1977) in authorized stormwater discharges, although bioaccumulation of PCBs in insects might be expected (Neigh et al. 2009). However, quality of insect prey is not a PCE, and therefore, we do not expect the proposed action will appreciably alter the PCEs of flycatcher designated critical habitat in the action area. Since breeding flycatchers are not found nesting in the action area where PCB contamination has been documented, the effects were considered discountable.

Rio Grande Silvery Minnow

Initially, EPA determined that its proposed MRG Watershed MS4 Permit Action "may affect, is not likely to adversely affect" the Rio Grande silvery minnow and its designated critical habitat. After informal consultation with the Service, EPA agreed that its proposed action might have adverse effects that could lead to incidental take of silvery minnows. In August 2013, EPA determined that the proposed MRG Watershed MS4 Permit Action "may affect, is likely to adversely affect," Rio Grande silvery minnow and its designated critical habitat. The Service has evaluated effects of the proposed action on the silvery minnow and its designated critical habitat and prepared the attached BO to quantify and identify management necessary to reduce effects.

Consultation History on EPA (Albuquerque and MRG Watershed) MS4 Permits

June 26-28, 2004. The USGS (Buhl 2005) conducted toxicity testing of stormwater and sediment collected from AMAFCA North Diversion Channel, Pilot Canal Embayment (Embayment) (Figure 1). During this testing, an extensive fish kill occurred in the Embayment (Lusk

2004). Low oxygen concentration in the stormwater was a determined to be major cause of the observed mortality of both Rio Grande silvery minnow in ongoing laboratory testing tests and of the native fish that died in the Embayment (Buhl 2005). The Service informed EPA of the fish kill, observed toxicity, and low oxygen condition by email and telephone.

June 30, 2004. After review of draft reports by the New Mexico Environmental Department (NMED) on PCBs in the action area, the Service informs EPA by email of the PCB contamination reported in stormwater collected from the San Jose Drain, which is a conveyance channel authorized for stormwater discharged by EPA's Albuquerque MS4 and subsequent MRG Watershed MS4 Permit.

November 29, 2006. The Service provides a presentation to potential Applicants, EPA, and the public, which guides EPA and Applicants on data needed to conduct ESA consultations with the Service, provides examples of how stormwater can adversely affect endangered species in New Mexico, and provides recommendations for conserving endangered species while implementing stormwater best management practices (BMPs) (USFWS 2006a).

June 1, 2007. The Service provides a letter informing EPA that formal consultation is required on the Albuquerque MS4 Permit based on new information that revealed stormwater may adversely affect federally listed species.

May 5, 2008. A Service-sponsored study conducted by UNM provides information that identifies low oxygen concentrations in MRG that are linked with stormwater discharges from the North Diversion Channel (Van Horn 2008).

August 5, 2009. AMAFCA provides a report that reviewed oxygen concentrations in the North Diversion Channel upstream, in the Embayment, and in the MRG nearby (Daniel B. Stevens and Associates, Inc. (DBSA) (2009). This report identified that as long as the Embayment remains in place, oxygen-depleted water from the Embayment will continue to cause short-term decreases in oxygen concentrations in the MRG and recommended a number of possible solutions to the low oxygen problem.

August 14, 2009. The EPA provides the Service a revised BE finding that the proposed action will not adversely affect the silvery minnow.

September 1, 2009. The Service sent EPA a letter indicating that it did not concur with the "may affect, but is not likely to adversely affect" determination for the silvery minnow, and the BE did not include adequate information to begin formal consultation.

March 22, 2010. The Service sent a letter to EPA stating that due to other EPA consultation priorities, it was unable to complete consultations on stormwater permits for the remainder of federal fiscal year 2010.

July 16, 2010. The EPA provides the Service a revised BE and letter affirming that issuance of the MRG Watershed MS4 Permit "may affect, but is not likely to adversely affect" the flycatcher, silvery minnow, or their designated critical habitat.

September 9 to October 15, 2010. The EPA and the Service exchanged information about proposed MS4 permit action and how exactly those actions adversely affect silvery minnow.

October 22 to October 27, 2010. The EPA and Service discuss the potential for interim adverse effects to endangered species through issuance of the Albuquerque MS4 Permit, and discuss the need to proceed with a formal consultation.

December 2010. EPA requests formal consultation on the Albuquerque MS4 Permit.

January 4, 2011. The Service requests a meeting with AMAFCA to obtain oxygen data, mixing calculations, and discharge statistics for the North Diversion Channel.

January 31, 2011. The Service informed EPA by letter of this date that sufficient information for formal consultation was provided by AMAFCA and formal consultation was initiated.

March 7–9, 2011. The Service AMAFCA, EPA, and Corps discuss mixing zone size calculations and a potential remedy for the low oxygen conditions found in the North Diversion Channel.

March 9, 2011. AMAFCA provides additional information on oxygen concentrations in the North Diversion Channel and the MRG upstream and downstream of the NDC outfall.

March 24, 2011. The Corps provides information on a proposed fill project by AMAFCA to reconfigure the North Diversion Channel to reduce the magnitude of low oxygen events.

April 28, 2011. The Service requests of EPA a two-week extension for preparing the draft BO.

May 18, 2011. The Service provides a draft BO to EPA for review. The Service provided a copy of the draft BO to Pueblo of Sandia, Pueblo of Isleta, and Bureau of Indian Affairs for review pursuant to Secretarial Order 3206 (U.S. Department of the Interior 1997).

September 11, 2011. The Service (2011a) issues final BO on the Albuquerque MS4 permit.

November 9, 2011. Corps provides Service with Biological Assessment (BA) to discharge fill material, widen, re-grade, and stabilize the AMAFCA North Diversion Channel.

January 3, 2012. The Service issues a final BO to Corps on the modification of the AMAFCA North Diversion Channel (USFWS 2012a).

March 2013. The Service and EPA coordinate on additional measures necessary to conserve endangered species through the proposed MRG Watershed MS4 Permit and staff attends EPA’s public meetings.

August 15, 2013. AMAFCA proactively takes remedial action to reduce the magnitude and frequency of low oxygen events in North Diversion Channel by installing windmill-powered air diffusion in the Embayment. EPA supplements the BE (EPA 2013a) and formal consultation is initiated.

October 2013. The Service provides a preliminary, rough draft BO to EPA for review.

December 2013. The Service discusses with EPA the use of the frequency of qualifying stormwater events conveyed through AMAFCA North Diversion Channel and use of oxygen saturation monitoring to estimate incidental take of silvery minnow in emails and requests an extension of formal consultation until February 17, 2014, to collect additional oxygen saturation data from AMAFCA.

February 2014. EPA grants the Service additional time to finalize the draft BO.

March 2014. The Service provides EPA another preliminary draft BO for review.

June 2014. The Service, EPA, AMAFCA, and City staffs discuss the use of the frequency of qualifying stormwater events conveyed through AMAFCA North Diversion Channel and options for management of low oxygen events associated with stormwater discharges.

July 2014. The Service provides EPA the draft BO for review and requests EPA's provision of the draft BO to affected Applicants or Tribes.

August 2014. EPA provides copies of the draft BO to potentially affected Applicants and Tribes.

Critical Habitat

This BO does not rely on the regulatory definition of "destruction or adverse modification" of designated critical habitat at Title 50 Code of Federal Regulations (CFR) Section 402.02. Instead, we have relied upon the Endangered Species Act statute and the August 6, 2004, Ninth Circuit Court of Appeals decision in Gifford Pinchot Task Force versus U.S. Fish and Wildlife Service (CIV No. 03-35279) to complete the following analysis with respect to designated critical habitat. This consultation analyzes the effects of the action and its relationship to the function and conservation role of silvery minnow designated critical habitat to determine whether the current proposal destroys or adversely modifies designated critical habitat.

Summary of the Biological Opinion Findings

In this biological opinion, the Service concludes that issuance of the MRG Watershed MS4 Permit is not likely to jeopardize the continued existence of the silvery minnow and is not likely to destroy or adversely modify designated critical habitat. Adverse effects to silvery minnow and its critical habitat will result from discharge of stormwater pulses that create low oxygen conditions in the North Diversion Channel Embayment and that subsequently convey that low oxygen water and any oxygen demanding pollutants into the MRG. The direct and indirect effects of the proposed action are not expected to reduce appreciably the likelihood of both the survival and recovery of the silvery minnow or diminish conservation value of its critical habitat for the following reasons: 1) the duration and intensity of events causing adverse effects are short-term; 2) only a portion of critical habitat is affected; 3) silvery minnows that are harassed are expected to later resume their normal feeding, breeding and sheltering behaviors, and; 4) ongoing silvery minnow population management programs will supplement the MRG with captive-reared silvery minnows for the duration of the proposed action. An Incidental Take Statement (ITS) is provided for the harm and harassment expected from authorized stormwater discharges. If actual incidental take levels exceed the estimated levels (ITS), or if any other re-initiation conditions are met, then EPA should reinitiate consultation.

Thank you for your concern for endangered species and New Mexico's wildlife habitats. If you have any questions regarding this BO or if we can be of further assistance, please contact Joel D. Lusk of my staff at the letterhead address, by email at joel_lusk@fws.gov, or telephone at (505) 761-4709.

Sincerely,

Wally Murphy
Field Supervisor

Enclosure

cc: (w/Encl)

Executive Engineer, AMAFCA, Albuquerque, New Mexico (Attn. J. Lovato and K. Stearns)
Stormwater Section Manager, City of Albuquerque, Municipal Development, Engineering Division, Stormwater Management Section, Albuquerque, New Mexico (Attn. K. Daggett)
Governor, Pueblo of Sandia, Bernalillo, New Mexico (Attn. F. Chavez and S. Bulgrin)
Governor, Pueblo of Isleta, Isleta, New Mexico (Attn. C. Walker)
Director, New Mexico Department of Game and Fish, Santa Fe, New Mexico
Chief, New Mexico Environment Department, Surface Water Quality Bureau, Santa Fe, New Mexico
District Three Engineer, NMDOT, Albuquerque, New Mexico (Attn. T. Parker)
Office of the Superintendent, Bureau of Indian Affairs, Southern Pueblos Agency, Albuquerque, New Mexico.
Assistant Regional Director, Ecological Services, Region 2, Albuquerque, New Mexico (Attn. J. Bair, Room 6034)
Chief, Division of Environmental Review, Region 2, Albuquerque, New Mexico (Attn. Environmental Contaminants Program Lead, L. Wellman and D. Baker, Room 6034)

ENDANGERED SPECIES ACT – SECTION 7(A)(2) FORMAL CONSULTATION

BIOLOGICAL OPINION

U.S. ENVIRONMENTAL PROTECTION AGENCY
GENERAL NPDES PERMIT NO. NMR04A000
(MRG WATERSHED MS4 PERMIT)

CONSULTATION NUMBER:
02ENNM00-2011-F-0024-R001

U.S. FISH AND WILDLIFE SERVICE
NEW MEXICO ECOLOGICAL SERVICES FIELD OFFICE
MIDDLE RIO GRANDE BRANCH
ALBUQUERQUE, NEW MEXICO

AUGUST 2014

WALLY MURPHY
FIELD OFFICE SUPERVISOR

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I. DESCRIPTION OF THE PROPOSED ACTION

MRG Watershed MS4 Permit Area and Facilities

In this BO, the Service refers to EPA's proposed action as the MRG Watershed MS4 Permit. Potential applicants seeking EPA's authority to discharge polluted stormwater under the MRG Watershed MS4 Permit might include City of Albuquerque (City), Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA), New Mexico Department of Transportation District III, University of New Mexico, Bernalillo County, Sandoval County, City of Rio Rancho, Village of Corrales, Pueblo of Sandia, Pueblo of Isleta, and others (EPA 2013b).

The EPA's MRG Watershed MS4 Permit (NMR04A000) will authorize its applicants to discharge polluted stormwater through a series of conveyance systems in cities, villages, towns, facilities, and other urbanized areas in MRG Watershed. The proposed action is the EPA's five-year authorization (2014-2019) of the MRG Watershed MS4 Permit, which allows operators of stormwater sewer systems to discharge stormwater and its pollutants into Waters of the United States, if certain conditions described by EPA are met. The EPA will issue the MRG Watershed MS4 Permit under the authority of the Clean Water Act (CWA), as amended (33 USC 26 1251–1387). The regulatory definition of an MS4 is provided in Part 40 of the Code of Federal Regulation (CFR) in subsections 122.26 (b)(4) and (b)(7). The MRG Watershed MS4 Permit is applicable to the operators of large and medium municipal stormwater sewer systems within the MRG watershed in New Mexico.

In the MRG Watershed, various stormwater collection and distribution systems were designed and constructed to intercept stormwater runoff from the nearby mountains, mesas, and from urban areas and convey it to the MRG. These stormwater conveyance systems are complex and consist of underground storm sewers and inlets, lined and unlined open channels, natural arroyos, detention basins, and flood control dams. The majority of the larger stormwater conveyance systems in the MRG Watershed are owned or operated by the City and/or AMAFCA (see https://206.25.254.11/, accessed December 2013). The UNM operates several storm sewer systems on each of its three college campuses. The NMDOT owns, operates, and maintains the storm sewer system that conveys runoff from roads and right-of-ways along highways and roads within the MRG Watershed. Medium-sized MS4s occur in the remainder of Bernalillo and Sandoval Counties, as well as other stormwater and agricultural drainages, may be included in the proposed action.

The stormwater sewer system in Albuquerque is vast and complex and contains approximately 1,161 km (722 mi) of storm pipes, 53 km (33 mi) of lined channels, 29 km (18 mi) of unlined arroyos, 12,300 storm manholes, and 16,100 storm inlets. These stormwater sewer systems are often delineated by the large collection basins that include a single collection channel that connects to the MRG, for example, the North Diversion Channel, South Diversion Channel, and San José Drain basins (see AMAFCA Map at https://206.25.254.11/). Some of the major arroyo collection channels in the MRG Watershed include Bear Canyon, Hahn, Embudo, Piedra Lisa, Calabacitas, Ladera, La Cueva, and San Antonio. In its entirety, the stormwater sewer system in the MRG Watershed is comprised of an immense series of conveyance structures including a watershed containing streets, highway and road drainages, curbs, gutters, ditches and man-made

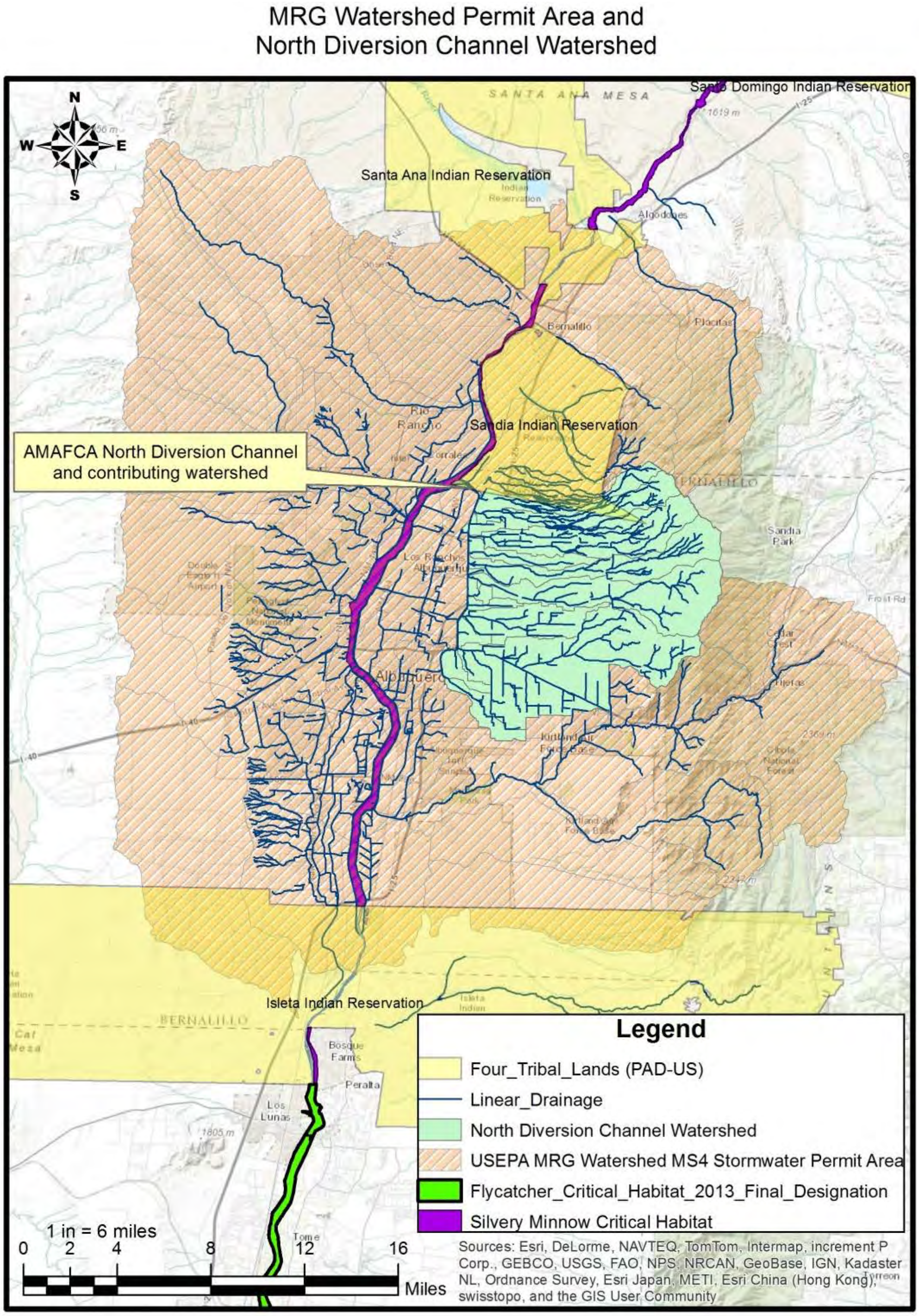


Figure 1. Approximate location of EPA's MRG Watershed MS4 Stormwater Permit action area, AMAFCA North Diversion Channel, critical habitats, and selected Tribal lands in New Mexico.

channels, underground storm sewers, pipes and inlets, man-hole covers, lined and unlined open channels, natural arroyos, detention basins and flood control dams, and a variety of other physical locations that interconnect these structures and convey stormwater to channels that then discharge into the MRG (Hoover 2010; Shoemaker et al 2012).

The North Diversion Channel drains the largest basin in the stormwater sewer system, approximately 238 square kilometers (km^2) (92 square miles [mi^2]), of which 142 km^2 (55 mi^2) is in the MRG Watershed MS4 Permit area (Figure 1). The basin extends on the east side of the City, from the Sandia Pueblo on the north, to Gibson Boulevard on the south, and from Interstate 25 on the west to the Sandia Mountain foothills on the east (SWCA 2004; Bennett 2013). The channel is concrete lined, except for 0.8 km (0.5 mi) from the outfall where it is a wide, unlined area with a combination of upland, riparian and wetland vegetation (SWCA 2004; Figure 2). The North Diversion Channel drains onto Pueblo of Sandia lands and into the MRG. At the end of the North Diversion Channel is the Pilot Channel Embayment, an area between an earthen retaining feature known as the equipment crossing and the MRG) (Figure 2).

Figure 2. Location of North Diversion Channel and Pilot Channel Embayment and Rio Grande near Alameda, New Mexico (Source: Eagle's Eye Photo Imaging, 2013, used with permission).

Stormwater pollutants controls under the MRG Watershed MS4 Permit

The proposed action would authorize pollutants in stormwater contained or discharged from all stormwater systems owned or operated by potential Applicants in the MRG Watershed MS4 Permit area (Figure 1). The MRG Watershed MS4 Permit also authorizes the temperature of the discharged stormwater and the placement of the outfalls of those discharges into the MRG. The MRG Watershed MS4 Permit also authorizes certain non-stormwater discharges such as potable water from drinking water facilities, lawn and landscape irrigation waters, rising groundwater, air conditioning unit condensates, residential or charity car wash runoff, wetland flows, flows from fire-fighting activities, and other similar, but occasional and incidental discharges unless determined by EPA or NMED to be significant contributors of pollutants (EPA 2013b).

The proposed MRG Watershed MS4 Permit identifies requirements necessary to minimize the type and amount of pollutants in urban stormwater discharges. For example, the MRG Watershed MS4 Permit would require that the Applicants implement a comprehensive Stormwater Management Program (SWMP) including pollution prevention measures, treatment or removal techniques, stormwater monitoring, use of legal authorities, and other appropriate means (that is, best management practices (BMPs)) to control pollutants entering the stormwater that is discharged from the MS4 *to the maximum extent practicable*. Commonly used BMPs include:

- Identifying major outfalls and pollutant loadings to focus on larger risks
- Detecting and eliminating non-stormwater discharges to the system
- Reducing pollutants in runoff from industrial, commercial, and residential areas
- Controlling stormwater discharges from new development and redevelopment areas

The draft MRG Watershed MS4 Permit requires implementation of BMPs to reduce the discharge of pollutants to the Maximum Extent Practicable (MEP), effectively prohibit non-storm water discharges into the MS4, an ensure that discharges do not cause or contribute to exceedances of State of New Mexico or Tribal water quality standards (including numeric or narrative criteria). In determining whether the SWMP is effective at meeting these requirements, the Applicants consider the most recent available stormwater quality monitoring data, a visual assessment, or any site inspection reports. Of these, the ambient stormwater quality monitoring data is most critical to identify the efficacy of BMPs for treating stormwater that may contain potentially toxic chemicals (e.g., pesticides, heavy metals, nutrients, PCBs) or other pollutants (e.g., oxygen demanding substances, suspended sediment concentrations). In the event that EPA receives Discharge Monitoring Reports from the potential Applicants (or other credible scientific information) identifying a discharge(s) that causes or contributes to an exceedance of water quality standards, EPA will notify the Applicant, and the Applicant shall submit to EPA, NMED, and others, a report that describes controls currently being implemented, additional controls that will be implemented to sufficiently prevent pollutants, and ensure that the discharge will no longer cause or contribute to an exceedance of any applicable water quality standards.

The draft MRG Watershed MS4 Permit (EPA 2013b) seeks to address concerns raised by various individuals and agencies (Lusk 2004; Yanick 2006; USFWS 2007a; Van Horn 2008; DBSA 2009; NMED 2010; USFWS 2011) regarding low oxygen discharges occurring in or traveling through the North Diversion Channel. EPA provides for the protection of threatened and endangered species by requiring a Sediment Pollutant Load Reduction Strategy applicable to all applicants. Applicants are required to conduct a sediment assessment, estimate baseline loading, and target controls to reduce sediment pollutant loads to the MRG over the next ten years.

Additionally, stormwater BMPS are to be evaluated so as not to adversely affect federally listed species critical habitats during their installation.

The draft MRG Watershed MS4 Permit (EPA 2013b) includes a Sediment Load Reduction Strategy that may help address such concerns as PCBs in the San José Drain or other sediment-adhered pollutants, such as Chemical Oxygen Demand, when implemented over time. Carbonaceous or Chemical Oxygen Demand (COD) refers to environmental tests used to determine the mass of oxygen gas consumed per liter of solution (Veenstra and Nolen 1991). Primary sources of COD are often recalcitrant compounds (e.g., organic matter, iron, ammonia, sulfides, etc.) usually on sediment. The Service was unable to quantify the reduction in sediment-adhered pollutants associated with the Sediment Load Reduction Strategy for the duration of the MRG Watershed MS4 Permit.

The MRG Watershed MS4 Permit also seeks to address PCBs in discharges from the San José Drain and the North Diversion Channel. The relevant Applicants are required to identify and evaluating controllable sources of PCBs in these two drainage basins within 3 months of the issuance date; to design and implement a monitoring study to evaluate presence and magnitude of PCB levels in stormwater discharges in the North Diversion Channel and San José drainage basins within 6 months; eliminate controllable sources of PCBs that cause or contribute to exceedances of State or Tribal water quality standards in waters of the United States within 1 year in the Annual Report; and report annually on PCB-related activities.

The MRG Watershed MS4 Permit (EPA 2013b, page 18 of Part I) describes the compliance with water quality standards requirement for oxygen. According to the draft MRG Watershed MS4 permit (EPA 2013b, page 18 of Part I, Endangered Species Act (ESA) Requirements):

3) To ensure actions required by this permit are not likely to jeopardize the continued existence of any currently listed as endangered or threatened species or adversely affect its critical habitat, permittees shall meet the following requirements and include them in the SWMP:

   a) Dissolved Oxygen Strategy in the Receiving Waters of the Rio Grande: The permittees must identify (or continue identifying if previously covered under permit NMS000101) structural controls, natural or man-made topographical and geographical formations, MS4 operations, or oxygen demanding pollutants contributing to reduced dissolved oxygen in the receiving waters of the Rio Grande. The permittees shall implement controls, and update/revise as necessary, to eliminate discharge of pollutants at levels that cause or contribute to exceedances of applicable water quality standards for dissolved oxygen in waters of the Rio Grande. The permittees shall submit a summary of findings and a summary of activities undertaken under Part I.C.3.a.(i) with each Annual Report. The SWMP submitted with the first and fourth annual reports must include a detailed description of controls implemented (or/and proposed control to be implemented) along with corresponding measurable goals. (Applicable to all permittees).

   b) As required in Part I.C.1.d, the COA and AMAFCA shall revise the May 1, 2012 Strategy for dissolved oxygen to address dissolved oxygen at the North Diversion Channel Embayment and/or other MS4 locations. The permittees shall submit the revised strategy to FWS and EPA for approval within a year of permit issuance and progress reports with the subsequent Annual Reports (see also Part I.C.1.d.(iv)). The revised Strategy for Dissolved Oxygen and progress reports can be submitted to FWS via e-mail nmesfo@fws.gov or by mail to the New Mexico Ecological Services field office, 2105 Osuna Road NE, Albuquerque, New Mexico 87113. (Only Applicable to the COA and AMAFCA)

c) The COA and AMAFCA permittees must continue conducting continuous monitoring of dissolved oxygen (DO) and temperature in the North Diversion Channel Embayment and at one (1) location in the Rio Grande downstream of the mouth of the North Diversion Channel within the action area (e.g., near Central Bridge). Submit summary of data and findings with each Annual Report. (Only Applicable to the COA and AMAFCA)

The Service interpreted 3(b) as to require the relevant Applicants (City and AMAFCA) to revise their “Strategy for Dissolved Oxygen” to address the frequency or magnitude of low oxygen events occurring in the North Diversion Channel Embayment and in the MRG downstream of the stormwater discharges through the North Diversion Channel Embayment. EPA states that the permittees shall submit the revised strategy to FWS and EPA for approval within a year of permit issuance as well as any progress reports with the subsequent Annual Reports (see also Part I.C.1.d.(iv)) due by December 1. The Service noted that implementation of the Strategy for Dissolved Oxygen and its performance criteria were not explicitly stated in EPA’s initial MRG Watershed MS4 Permit, and therefore, have identified criteria for performance in this BO that are or will be adopted into the final proposed action.

The MRG Watershed MS4 Permit also requires a variety of activities that would potentially improve the quality of stormwater discharges including:

- Implementation of measures necessary to bring stormwater discharges into compliance with the MRG Total Maximum Daily Load for bacteria.
- Addition of control measures of construction site stormwater runoff.
- Addition of post-construction stormwater management in planned development and redeveloped areas.
- Addition of pollution prevention requirements and procedures to ensure that new flood management projects are assessed for impacts on water quality.
- Addition of procedures to ensure existing flood management projects are reassessed for incorporation of additional water quality protection devices or practices.
- Addition of procedures to control the discharge of pollutants related to the storage and application of pesticides, herbicides, and fertilizers applied, to public right-of-ways, parks, and other municipal property; and to commercial application and distribution of pesticides, herbicides, and fertilizers where Applicants hold jurisdiction over the landscape.
- Addition of requirements to identify and control pollutants in stormwater discharges from municipal landfills; other treatment, storage, or disposal facilities for municipal waste (e.g., transfer stations, incinerators, etc.); hazardous waste treatment, storage, disposal and recovery facilities; and any other industrial or commercial discharges that the Applicants determines are contributing a substantial pollutant loading.

- Addition of a requirement that the Applicants implement and enforce an Illicit Discharge Detection and Elimination program to systematically detect and eliminate illicit discharges entering the MS4, and to implement defined procedures to prevent illicit connections and illegal dumping into the MS4.
- Requires control of floatables (e.g., litter and other human-generated solid waste) that describes controls and, where necessary, includes structural controls.
- Requires waste collection programs to collect used motor vehicle fluids (at a minimum, oil and antifreeze), and to collect household hazardous waste materials (including paint, solvents, fertilizers, pesticides, herbicides, and other hazardous materials) for recycle, reuse, or proper disposal.
- Requires spill prevention planning and spill response to prevent, contain, and respond to spills that may discharge into the MS4.
- Requires public education and outreach on stormwater impacts and an assessment of the overall success of the program, including such activities that:
  - increases public awareness about the causes and effects of stormwater pollution;
  - identifies actions that citizens, commercial, industrial, and institutional entities may take to control the impact of stormwater pollution on water quality;
  - promotes, publicizes, and facilitates the various elements of the SWMP through varied public education and outreach methods including public websites;
  - disseminates information to the general public regarding the proper handling, disposal and recycling of used motor vehicle fluids, household hazardous waste, grass clippings, car wash waters, and proper use of fertilizers, pesticides, and herbicides, and oil and toxic chemicals used on roadways, including information on the steps to report illicit discharges, or improper disposal of materials;
  - educates pet owners about proper disposal of pet waste, and;
  - educates owners and operators of commercial, industrial, and institutional facilities regarding their responsibility to control pollutants in stormwater discharges from their property to the MS4.

The EPA (2013c) describes the draft MRG Watershed MS4 Permit as an improvement over previously issued EPA permits by including additional conditions that address concerns about PCBs, low oxygen, and other stormwater water quality issues including bacteria, heavy metals, sediment pollutant loads, and temperature (EPA 2013c).

MRG Watershed MS4 Permit Action Area

This BO uses the term “Middle Rio Grande” (MRG) to refer to the river channel and its floodplain (within the levees) in the Rio Grande-Albuquerque Watershed (USGS Hydrologic Cataloging Unit 13020203; Seaber et al. 1987) in central New Mexico. The MRG is often divided into river reaches identified by an upstream diversion dam (e.g., Crawford et al. 1993; Dudley and Platania 1997) (Figure 3). Therefore, we refer to the Angostura Reach as that portion of the MRG below the Angostura Diversion Dam and above the Isleta Diversion Dam.

The action area includes all areas to be affected directly or indirectly by the proposed action (50 CFR 402.02). The action area is identified as occurring in the MRG Watershed (EPA 2013b, in Appendix A) and includes portions of Bernalillo, Sandoval, and Valencia Counties, New Mexico

(Figure 1). The action area includes the MRG Watershed MS4 Permit area; the locations of all authorized stormwater discharges and their mixing zones within in the MRG. The EPA (2010b; 2013b) generally describes discharges from the MRG Watershed MS4 Permit area as flowing downstream into waters of the State of New Mexico, Pueblo of Santa Ana, Pueblo of Sandia, and Pueblo of Isleta. Therefore, we defined the action area as the MRG Watershed MS4 Permit area, the MRG, any areas of mixing, and included the North Diversion Channel Embayment. Exact mixing zone sizes of stormwater discharges with the MRG were not described by EPA (2013a).

Langman (2007) identified travel times of MRG streamflow from the North Diversion Channel input to locations downstream. The travel time curves can be used to describe the time and distance that pulse inputs (such as stormwater runoff) from the North Diversion Channel can travel down the MRG. Pulse event travel times in the MRG measured at the Albuquerque Gage ranged from 13 to 25 hours, and would travel from less than 40 km (25 mi) to less than 80 km (50 mi) (Langman 2007). However, Langman (2007) evaluated pulse events ranging in duration from 1 to 11 days, whereas stormwater runoff events discharging from the North Diversion Channel associated with low oxygen are of short duration (usually less than 1 hr (DBSA 2009)). In addition, Langman (2007) provided no indication of concentrations within a potential plume, only how long it might take a plume to travel. Pulse events are likely to disperse from streamflow interaction with the bed, banks, and broader channel in the MRG because of available in-channel area for braiding, meandering, filling, which create longer flow paths and increase dispersion because of larger wetted perimeters that increase interaction with the channel substrate (Langman 2007). However, empirical mixing models have not been fully developed.

In the Angostura Reach, the City's Southside Water Reclamation Plant, as well as tributaries, provides dilution water. In addition, changes in flow occur at the Isleta Diversion Dam that affect stormwater discharge plume dispersion in the MRG. As a check to determine if our mixing zone size was appropriate, we compared these data to Van Horn (2008) who identified stormwater from the North Diversion Channel mixing with the MRG approximately 33 km (20 mi) downstream, and that increased approximately 3 mg/L in that distance. The mixing zone associated with low oxygen events discharged from the North Diversion Channel is likely dispersed within 50 km (31 mi), and the size of this estimated mixing zone is concordant with estimates by Van Horn (2008) and Langman (2007). Therefore, this BO will analyze the effects of the low oxygen events within this mixing zone as it occurs in the 50 km (31 mi) Angostura Reach of the MRG from the confluence of the North Diversion Channel downstream to the Isleta Diversion Dam (Figure 3). The Service has further characterized the mixing zone in the action area as an impact area and a zone of lethality using the rationale for effects analysis, below.

II. STATUS OF THE SPECIES

The proposed action considered in this BO may affect silvery minnows (and critical habitat) that are provided protection as an endangered species under the ESA. A description of this species, its status, and its habitat, are provided below and were used to inform our effects analysis.

Rio Grande Silvery Minnow

Legal status

The silvery minnow was federally listed as endangered under the ESA on July 20, 1994 (58 FR 36988; see U.S. Fish and Wildlife Service (1994). The species is also listed as an endangered species by the state of New Mexico (19 NMAC 33.1) (New Mexico Department of Game and Fish 1988), the state of Texas (sections 65.171 – 65.184 of Title 31 T.A.C) (Texas Parks and Wildlife Department 2003), and the Republic of Mexico (Secretaria de Desarrollo Social 1994).

Throughout much of its historic range, the decline of the silvery minnow is attributed primarily to destruction and modification of its habitat due to dewatering and diversion of water, water impoundment, and modification of the river (channelization, fragmentation, and hydro-modification). Competition and predation by introduced non-native species, water quality degradation, and other factors also have contributed to its decline. Climate change is an additional threat to the species, as increased temperatures may be associated with decreased spring snowmelt runoff or timing considered necessary for spawning and larval nursery habitat.

The Service designated critical habitat for the silvery minnow on February 19, 2003 (68 FR 8088; USFWS 2003c). The critical habitat designation extends approximately 252 km (157 mi) from Cochiti Dam in Sandoval County, New Mexico, downstream to the utility line crossing the MRG, a permanent identified landmark in Socorro County, New Mexico, just north of Elephant Butte Reservoir and at River Mile 62.1. The critical habitat designation defines the lateral extent (width) as those areas bounded by existing levees or, in areas without levees, 91.4 m (300 ft) of riparian zone adjacent to each side of the bank full stage of the MRG. Some developed lands within the 91.4 m lateral extent are not considered critical habitat because they do not contain the primary constituent elements (PCEs) of critical habitat and are not essential to the conservation of the silvery minnow. However, when flooded, floodplain areas may provide important habitat.

Lands located within the lateral boundaries of the critical habitat designation, but not considered critical habitat include: developed flood control facilities, existing paved roads, bridges, parking lots, dikes, levees, diversion structures, railroad tracks, railroad trestles, water diversion and irrigation canals outside of natural stream channels, the LFCC, active gravel pits, cultivated agricultural land, and residential, commercial, and industrial developments (USFWS 2003c). The Pueblo lands of Santo Domingo, Santa Ana, Sandia, and Isleta within this area are also not included in the critical habitat designation because specific management plans for the silvery minnow were developed by these Pueblos prior to critical habitat designation (68 FR 8088). Except for these Pueblo lands and those areas excluded, the remaining portion of the silvery minnow's occupied range in the MRG in New Mexico is designated as critical habitat.

The Service determined the PCEs of silvery minnow critical habitat based on studies on silvery minnow habitat and population biology (USFWS 2010a). These PCEs include:

Figure 3. Depiction of the MRG, its division into four river reaches, and Rio Grande silvery minnow designated critical habitat.

- A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats, such as, but not limited to the following: backwaters (a body of water connected to the main channel, but with no appreciable flow), shallow side channels, pools (that portion of the river that is deep with relatively little velocity compared to the rest of the channel), and runs (flowing water in the river channel without obstructions) of varying depth and velocity – all of which are necessary for each of the particular silvery minnow life history stages in appropriate seasons (e.g., the silvery minnow requires habitat with sufficient flows from early spring (March) to early summer (June) to trigger spawning, flows in the summer (June) and fall (October) that do not increase prolonged periods of low-or no-flow, and relatively constant winter flow (November through February));
- The presence of eddies created by debris piles, pools, or backwaters, or other refuge habitat within unimpounded stretches of flowing water of sufficient length (i.e., river miles) that provide a variation of habitats with a wide range of depth and velocities;
- Substrates of predominantly sand or silt; and
- Water of sufficient quality to maintain natural, daily, and seasonally variable water temperatures in the approximate range of greater than 1ºC (35ºF) and less than 30ºC (85ºF) and reduce degraded conditions (e.g., decreased dissolved oxygen, increased pH).

These PCEs provide for the physiological, behavioral, and ecological requirements essential to the conservation of the silvery minnow. While all of these PCEs are found in each of the four sub-reaches within the MRG, it does not imply that optimal conditions for or presence of silvery minnow occurs equally throughout this designated critical habitat.

General information

Rio Grande Silvery Minnow (silvery minnow) is one of seven species in the genus *Hybognathus* found in the United States (Pflieger 1980). The silvery minnow is a stout minnow, with moderately small eyes, a small, sub-terminal mouth, and a pointed snout that projects beyond the upper lip (Sublette et al. 1990) (Figure 4). Live specimens are light greenish-yellow dorsally and light cream to white ventrally. The fins are moderate in length and variable in shape, with the dorsal and pectoral fins rounded at the tips. The body is fully scaled, with some scales slightly embedded and smaller. The scales about the lateral line are sometimes outlined by dark spots (i.e., melanophores), suggesting a diamond grid pattern. Their eye is moderately small and orbit diameter is much less than gape width or snout length (Bestgen and Propst 1996). Maximum length attained is about 90 mm (3.5 in) in standard length (SL). (Standard length, or SL, is measured from the tip of the snout to the base of the tail whereas total length or TL, is measured from the tip of the snout to the end of the tail). The only readily apparent sexual dimorphism is the expanded body cavity of ripe females during spawning (Bestgen and Propst 1994); however, there are some notable differences. The pectoral fins of males flare broadly from their base to a triangular fan shape, while those of females are shorter, narrower, and oval shaped. The pectoral rays of breeding males are thickened, while those of females are slender, and the pectoral fin length in males is significantly greater (Bestgen and Propst 1994).

In the past, the silvery minnow was included with other species in the genus *Hybognathus* due to morphological similarities. Phenetic and phylogenetic analyses corroborated the hypothesis that it is a valid taxon, distinct from other species of *Hybognathus* (Cook et al. 1992, Bestgen and Propst 1994, Bestgen and Propst 1996). It is now recognized as one of seven species in the genus *Hybognathus* in the United States and was formerly one of the most widespread and abundant minnow species in the Rio Grande basin of New Mexico, Texas, and Mexico (Pflieger 1980) (Bestgen and Platania 1991).

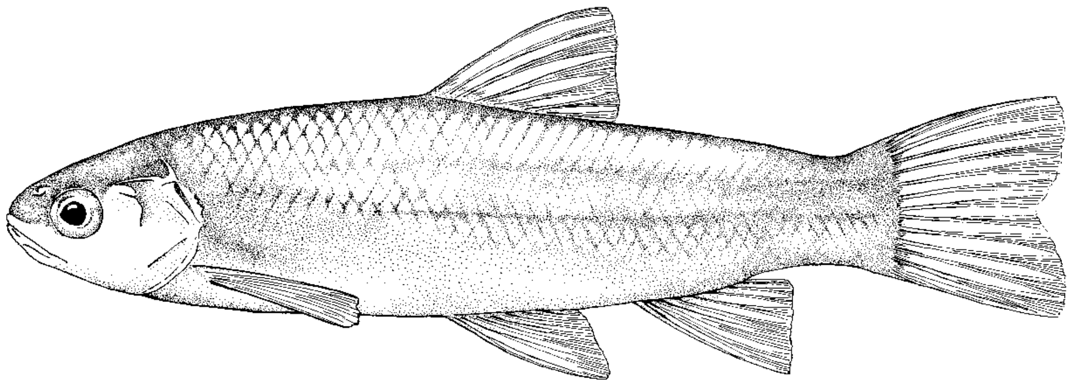


Figure 4. Depiction of a Rio Grande Silvery Minnow (U.S. Fish and Wildlife Service 2010)

Distribution

The silvery minnow currently occupies a 280 km (174 mi) stretch of the MRG, New Mexico, from Cochiti Dam in Sandoval County, to the headwaters of Elephant Butte Reservoir in Socorro County (U.S. Fish and Wildlife Service 1994). This includes a small section of the lower Jemez River, a tributary to the MRG north of Albuquerque. The species has not been found upstream of Cochiti Dam to Embudo, New Mexico, or in the Rio Chama downstream of Abiquiu Dam during numerous surveys since 1983. Therefore, it is presumed extirpated from the Rio Grande drainage upstream of Cochiti Dam (Platania and Dudley 2003, Buntjer and Remshardt 2005). The silvery minnow's current habitat is limited to approximately seven percent of its former range, and is split into four discrete reaches by three river-wide dams (Figures 3, 5). Current occupancy of the first reach, from Cochiti Dam to Angostura Diversion Dam, is uncertain. Most of this reach is within sovereign tribal jurisdictions of the Kewa Pueblo (formerly Santo Domingo), Cochiti Pueblo, and San Felipe Pueblo, and formal reports of silvery minnow monitoring results have not occurred since 1996. Silvery minnows were last collected in the Cochiti Reach within the San Felipe and Kewa (Santo Domingo) Pueblos during 1994 (Platania 1995a). Limited surveys since 1994 suggest that the species is no longer present in the reach or occurs in very low densities (U.S. Fish and Wildlife Service 2010a, Torres et al. 2008). Survey information for the other three reaches of the Rio Grande is presented below.

Silvery minnows were reintroduced into the Rio Grande near Big Bend, Texas, beginning in December 2008, as an experimental, non-essential population under section 10(j) of the ESA. This effort is still ongoing, and monitoring has confirmed survival, breeding, and movement both upstream and downstream of release sites (Edwards and Garrett 2013).

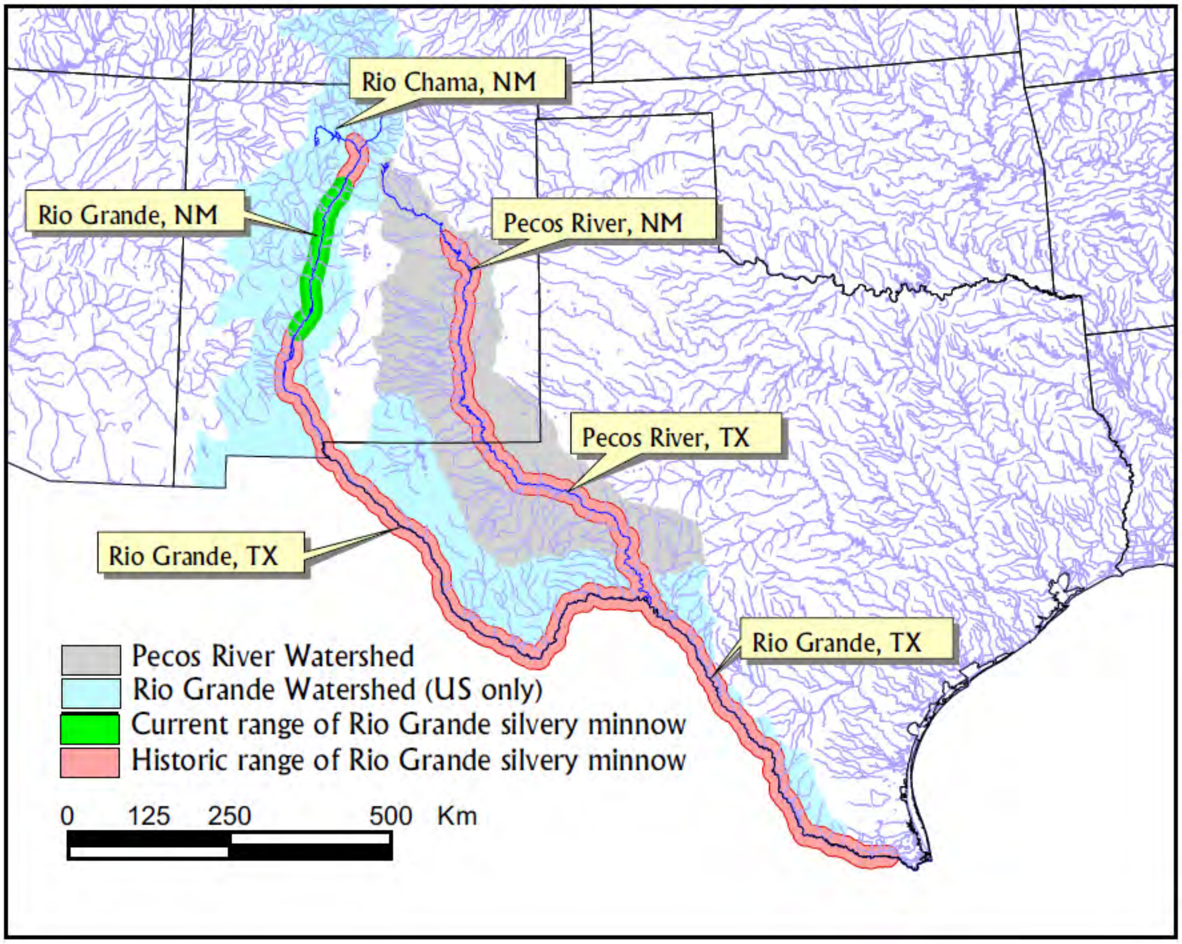


Figure 5. Approximate historical and current distribution of Rio Grande Silvery Minnow (Source Dudley and Platania 2003).

Life history

Prior to Federal listing little was known of the life history and ecology of the silvery minnow (Sublette et al. 1990). Most of the following information has been derived from studies undertaken since the mid-1990s in the MRG where the species persists.

The silvery minnow has a pelagic broadcast spawning strategy, producing semi-buoyant, non-adhesive eggs that passively drift while developing (Platania 1995b, Platania and Altenbach 1998). During a single spawning event, a female in captivity can broadcast as many as 3,000 eggs in eight hours, and females in captivity can produce 3 to 18 clutches of eggs in a 12-hour period, with the mean number of eggs in a clutch approximately 270 (Platania and Altenbach 1998). Platania (2000a) found that eggs were approximately 1.53 mm in size upon fertilization, but quickly swell to 3.06 mm. The development and hatching of eggs was correlated with water temperature, with eggs raised in 30ºC water beginning to hatch in approximately 24 hours while eggs reared in 20ºC (68˚F) water began hatching within approximately 42 hours. Upon hatching, larval fish are about 3.8 mm (SL) and grow about 0.13 mm per day during their larval stages depending on water temperature.

In the wild, the timing of spawning in relation to the hydrograph is an important factor in egg and larvae retention. The majority of adults in the wild spawn during an approximate one-month period in late spring to early summer (May to June) in association with spring runoff and when average mainstream water temperatures are between 18-22˚C (64-72˚F) (Dudley and Platania 2013a). The highest collections of silvery minnow eggs in the MRG have occurred during mid- to late May, with lower frequencies of eggs being collected in late May and June (Smith 1999, Platania and Dudley 2000; 2001). These data suggest there may be multiple silvery minnow spawning events during the spring and summer, perhaps concurrent with multiple flow spikes.

Spring flows allow inundation of adjacent floodplains what provide low-velocity, shallow-water nursery habitats that may retain eggs and provide larvae nutrition and cover (Hoagstrom and Turner 2013). Spawning on the descending limb of a hydrograph has resulted in poorer egg retention, whether inundated habitat is available at that time or not (Widmer et al. 2010). Conversely, higher egg retention has been measured when spawning occurs on the ascending limb during high flows, and when there is substantial inundated floodplain habitat available in the MRG. When not retained, eggs and larvae have been estimated to remain in the drift for three to five days, and could be transported as far as 250 mi downstream depending on river flows and availability of nursery habitat (Platania 2000a; Dudley and Platania 2008). Actual flow rates can vary within each reach to achieve shorter drift time or greater retention. These rates would correlate to the length and channel morphology of each reach, relative to when overbank flooding would occur at a given flow rate (Widmer et al. 2010). Depending on water temperatures, approximately three days after hatching the larvae move to low velocity habitats where food (mainly phytoplankton and perhaps zooplankton) is abundant and predation from other fish species may be scarce. Colder water temperatures, however, result in reduced hatch and longer larval development times (Platania 2000a). This could result in longer time in the drift before the larval minnows would be self-mobile and able to move out of the deeper channel into nursery habitat (Platania 2000a).

Age classes, longevity, and population dynamics

Based on length-frequency data collected from 2002 through 2006, there appears to be a minimum of two age classes at any one time, primarily of Age-0 and Age-1 fish are observed between June and December, and Age-1 and Age-2 fish are observed between January and June (Remshardt 2007, 2008a). This is based upon a minimum criterion of 35 mm SL to differentiate Age-1 from Age-0 fish. Based on length, some individuals are apparently Age-3, although estimated Age-2 and Age-3 individuals appear to comprise a very small proportion of the total population (<5%) in any given year (U.S. Fish and Wildlife Service 2010a). Young of the year (YOY) attain lengths of 38 to 41 mm SL by late autumn (U.S. Fish and Wildlife Service 2010a). The majority of Age-0 YOY fish reach sufficient size during this time to be considered Age-1 adults going into the winter. Age-1 fish are 46 to 48 mm SL by the start of the spawning season. Most growth occurs between June (post spawning) and October, but there is some growth in the winter months.

In the wild, the maximum longevity documented is about 30 months, but very few survive more than 13 months (U.S. Fish and Wildlife Service 2010a). The maximum longevity expected for hatchery-released fish is 36 months (U.S. Fish and Wildlife Service 2010a). However, the U.S.

Geological Survey's (USGS) Columbia Environmental Research Center in Yankton, South Dakota has reared several silvery minnows in captivity with a maximum age of 11 years, ranging in size from 46 to 73 mm SL, and in conditions designed to optimize their health (Buhl 2009).

Other recent investigations indicated the possibility of more than four age classes present at the same time in wild populations. Cowley et al. (2006) analyzed scales from the 1874 collection of minnows preserved at the University of New Mexico and concluded that up to five age classes existed in the population from this collection. However, a subsequent re-analysis by Horwitz et al. (2011) of scales from this 1874 collection and from more recent collections, as well as otoliths from more recent collections, only found three age classes (Age 0, 1, and 2). It is therefore prudent to base the determination of age class distribution on length-frequency data as corroborated by the results of hard tissue analyses, given these considerations. This translates into the current understanding that silvery minnows in the MRG primarily live a maximum of 3 years, with 82% of the fish being Age-0 and Age-1 in the fall (95% C.I. of 72-90%), and 96% of the fish being Age-1 and Age-2 in the spring (95% C.I. of 89-99%) (Horwitz et al. 2011).

As noted above, the vast majority of spawning silvery minnows in the MRG are Age-1, with older silvery minnows (Age-2 or older) estimated to comprise less than 5% of the spawning population (Remshardt 2007, 2008b, a, U.S. Fish and Wildlife Service 2010a). This is likely due to high levels of post-spawning mortality in adult fish that has also been documented in other cyprinid riverine fish (Meffe et al. 1988). High silvery minnow mortality occurs during or subsequent to spawning. This determination is based upon monitoring results, wherein larger adult fish are found prior to spawning but very few adult-sized fish are found in late summer (U.S. Fish and Wildlife Service 2010a). By December, the majority (greater than 98 percent) of individuals are YOY some of which due to size (> 35 mm) are considered Age-1 (Dudley and Platania (2007a, 2008a, 2009c); Remshardt (2007, 2008a, b). This population ratio does not change appreciably between January and June, as Age-1 fish usually constitute over 95 percent of the population prior to spawning.

In captivity, silvery minnows have been induced to spawn as many as four times in a year (C. Altenbach, City of Albuquerque, personal communication 2000). The high reproductive potential of silvery minnows appears to be one of the primary reasons that it has not been extirpated from the MRG. However, the short life span of the silvery minnow increases their population instability. When two below-average flow years occur consecutively, a short-lived species such as the silvery minnow can be impacted, if not eliminated from dry reaches of the river (U.S. Fish and Wildlife Service 2010a).

Habitat

The silvery minnow travels in shoals and tolerates a wide range of habitats (Sublette et al. 1990), yet generally prefers low velocity (< 0.33 $ft \cdot s^{-1}$ or 10 $cm \cdot s^{-1}$) areas over silt or sand substrate that are associated with shallow (< 40 cm, 15.8 in) braided runs, backwaters, embayments, eddies formed by debris piles, or pools (Dudley and Platania 1997, Watts et al. 2002, Remshardt 2007). A study conducted between 1994 and 1996 characterized habitat availability and use at two sites in the MRG, at Rio Rancho and Socorro. From this study, Dudley and Platania (1997) reported that the silvery minnow was most commonly found in habitats with depths less than 50 cm (19.7

in). Over 85 percent were collected from low-velocity habitats (<10 cm·s^{-1} or 0.33 ft·s^{-1}) (see also Watts et al. 2002; Bovee et al. 2008). Habitat for the silvery minnow includes stream margins, side channels, and off-channel pools where water velocities are low or reduced from main-channel velocities. Habitat use also varies seasonally, with preferred summer habitat including pools and backwaters, while preferred winter habitat is found in or adjacent to instream debris piles and associated with deeper water (Dudley and Platania 1996) (Dudley and Platania 1997). Stream reaches dominated by straight, narrow, incised channels with rapid flows are not typically occupied by the silvery minnow (Sublette et al. 1990) (Bestgen and Platania 1991). This preference for low velocity habitat, especially for survival and recruitment of larval and juvenile minnows, exemplifies the habitat preferences and recruitment requirements of most common native Rio Grande fishes (Pease et al. 2006).

Passively drifting eggs and larvae are found throughout all habitat types, whereas adult silvery minnows are most commonly found in backwaters, pools, and habitats associated with debris piles, and YOY fish occupy shallow, low velocity backwaters with silt substrates (Dudley and Platania 1997). Egg and larval minnow retention within reaches may be critical to population stability. Dudley and Platania (2007a, 2008) examined how flows moved egg surrogates and determined that silvery minnows require reaches greater than 100 km in length to retain sufficient eggs and larval fish for maintaining a self-sustaining population. Another recent study however, demonstrated the ability for drifting eggs to reach shallow nursery habitat in inundated floodplains in reaches less than 100 km. This was only possible under hydrological conditions requiring very specific water management actions during spawning that resulted in high flows on the ascending limb when eggs are released (Widmer et al. 2010).

Geomorphological characteristics are also an important component of effective silvery minnow habitat requirements. Silvery minnow have been shown to prefer silt and sand substrates over coarser substrates throughout all size classes (Dudley and Platania 1997). This preference has been linked to feeding requirements for benthic grazing of phytoplankton (Platania and Dudley 2003) (see also section 2.1.6) and possibly swimming efficiency as a function of surface velocity (Bestgen et al. 2003, Bestgen et al. 2010).

Feeding preference

Adult and larval silvery minnows are primarily herbivorous, feeding mainly on algae, which is inferred indirectly by the elongated and coiled gastrointestinal tract (Sublette et al. 1990) and that they have unique pharyngeal structures for filtering and masticating small food items (Watson et al. 2009). The majority of the algae consumed are in the form of phytoplankton, mainly diatoms. Diatoms are considered especially nutritious and are a preferred food of silvery minnows (Magaña 2009). Laboratory tests indicated that silvery minnows also prefer certain species of diatoms to others (Magaña 2009). Silvery minnows are opportunistic benthic feeders, pecking or filtering detritus and benthic algae from the substrate, primarily over sand and silt (Sublette et al. 1990, Magaña 2007; U.S. Fish and Wildlife Service 2010a). The presence of sand and silt in the gut of wild-captured minnows suggest that epipelic (growing on clay/silt) and epipsammic (growing on the surface of sand) algae are important foods (Shirey et al. 2008). Silvery minnow reared in the laboratory have also been directly observed to graze on algae in aquaria (Platania 1995b, Magaña 2007).

Some researchers have found a preponderance of certain zooplankton in silvery minnow diets during high flows (Magaña 2007), concluding that silvery minnow were thus omnivorous in response to varying hydrological conditions or the timing of food availability (Alo and Turner 2005). Watson et al. (2009) noted that hatchery fish raised in outdoor ponds ate a high proportion of insects and zooplankton, with up to 98% of gut contents comprised of insects in juvenile fish. They concluded, however, that this high proportion of insects might be an artifact of captive breeding conditions and not dietary preferences in the wild, although other research has indicated some degree of omnivory in wild fish (Magaña 2007; Blanchette et al. 2014).

Numerous other studies have also investigated the relationship of food availability for silvery minnow to habitat conditions and seasonality. Valdez et al. (*In Review*) found that macro-invertebrate and aufwuchs (a plant or animal organism that attaches or clings to surfaces of leaves or stems of rooted plants or on substrates) diversity varies with mesohabitat features. Shallow, low velocity habitats provide increased food availability for the silvery minnow. In the MRG, Valdez et al. (*In Review*) found that mesohabitats supporting local production and the greatest food sources for fish comprised relatively small wetted areas of the channel, which contained the majority of primary and secondary producers and coincided with low-velocity mesohabitats used by silvery minnows. Water velocity was significantly lower in mesohabitats with high densities of algae and diatoms except for woody debris, generally associated with high surrounding velocity. Drift macroinvertebrates were also found to be strongly associated with season, having higher abundances in May/June than in August, October, or December. As previously discussed, these invertebrates are thought by some researchers to compromise an alternate food source when algal food sources are eliminated or reduced by hydrodynamic scouring (Magaña 2007).

Bixby and Burdett (2009) evaluated algal communities in the MRG and found that their distribution is highly influenced by variation in turbidity and nutrients. In summer months, high turbidity from tributaries creates a light-limited environment that limits primary production to a shallow, littoral marginal zone ("bathtub ring"). Additionally, as the river flows through urban landscapes, there is a gradient of nutrient inputs as concentrations of phosphate and nitrates vary (Bixby and Burdett 2009). This combined effect of different abiotic factors, including local substrate and flow characteristics, can result in patchiness of food availability throughout the MRG (Bixby and Burdett 2009).

Swimming performance and movement

Silvery minnows are capable of moving long distances upstream as part of their life history. Bestgen et al. (2003) demonstrated in laboratory tests that silvery minnow are motivated upstream swimmers capable of swimming rather remarkable distances in a relatively short time, especially given their small size. Silvery minnows were routinely capable of swimming 50 km (31 mi) or more in about 48 hours. The maximum distance traveled was one individual swimming the equivalent of 125 km (77 mi) in about 73 hours at moderate water velocities of 35-50 cm/s. What is noteworthy about this distance is that it is greater than the distance of any individual reach of the MRG (Angostura, 65 km/40.4 mi, Isleta, 85.5 km/53.1 mi, San Acacia, 93.7 km/58.2 mi) (Bestgen et al. 2003). Temperature also plays a role in swimming performance.

Recent research (Bestgen et al. 2010) has focused on silvery minnow response to a simulated fish passage run, by testing both field-caught and hatchery silvery minnows. In a flume test at moderately warm temperatures, they found that the great majority of silvery minnows showed an immediate attraction to incoming flows and moved upstream to the top of the flume. They found that field-captured silvery minnows were capable of relatively high-speed and long-distance swimming. The mean critical swimming speed for silvery minnows was 51.5 cm/s, with faster sustained swimming speeds recorded for larger fish. Silvery minnows were capable of swimming for longer durations at lower water velocities and warmer water temperatures. Endurance was a function of significant synergistic effects of water velocity, water temperature, and fish total length. There were also varied responses to different substrates used in various runs of the flume test. This was also compounded by the type of substrate encountered, which will factor into surface velocity and ability to rest during prolonged long distance upstream movement (Bestgen et al. 2010). Those tests also showed that silvery minnows are able to swim several kilometers in just a few hours and up to 125 km. Overall, performance of field-captured silvery minnows exceeded that of hatchery-raised silvery minnows (Bestgen et al. 2010).

The ecological aspects of silvery minnow movements are not fully understood. Fausch et al. (2002) discussed the need to understand how and why stream fish species move within the available length of the stream in relation to a variety of physical features of the stream itself. These features are reflected in the spatial heterogeneity of habitats that support spawning, nursery, feeding, and seasonal sheltering functions across the landscape. The spatial heterogeneity of fish distribution may be affected by the availability of habitats by both location and season. Understanding these phenomena is essential to understanding movement of individual fish throughout or within portions of the river system (Fausch et al. 2002). The ability to understand the ecological aspects of silvery minnow movements is also limited by changes to the MRG that have emplaced barriers to free movement between river reaches. Information presented on movement studies are often considered in light of these limitations.

Various outcomes to movement studies have occurred and various conclusions made regarding the function of movement, but all seem to indicate at least some degree of upstream movement after release of fish into the river at a particular location. Early investigations by Platania et al. (2003) indicated through VIE tag studies that upstream movement they measured was dispersal and not migratory movement. Perkin et al. (2010a) noted “stockpiling” of reproductive adults below barriers. Dudley et al. (2005b) also noted that the highest catch rates for silvery minnows during annual monitoring activity were encountered immediately below diversion dams. Perkin et al. (2010b) suggest that this is indicative of migratory behavior as a reproductive strategy allowing colonization of upstream reaches following downstream drift of eggs and larvae. Some movement studies in the wild have relied on hatchery-raised fish, which may not behave identically to wild silvery minnows. In a 2001-2002, in a mark-recapture study of hatchery fish reared from wild caught eggs, 51 of the 66 (77%) marked fish recaptured from a cohort released in January 2002 were collected either at or downstream of the release site within 48 hours of release. The distance traveled ranged from 0.26 km (0.16 mi) to more than 25 km (15.5 mi). Of those remaining fish recaptured, 11 individuals were recaptured during or after April 2002, and 10 of those individuals had moved upstream (Platania et al. 2003).

Since 2006, the Service's New Mexico Fish and Wildlife Conservation Office (NMFWCO) has been conducting an experimental study of stocking success for silvery minnows reared in captive propagation facilities and released throughout their current range . The 2006 recapture data indicated that movement was generally downstream, with the majority of recaptures within approximately 16 to 24 km (10 to 15 mi) downstream of the release site. The maximum distance traveled from release to recapture was 59.4 km (36.9 mi) downstream, 300 days following release. Upstream movement was minimal; only about 5% of the 53 recaptured fish were collected upstream from their release sites. The maximum upstream distance traveled was 48.3 km (30.2 mi), 304 days following release (Remshardt 2008a). Subsequent monitoring in 2008 found one individual had moved 62 km (38.7 mi) upstream, and it was collected just below Isleta Diversion Dam, where its upstream movement may have been blocked (Remshardt 2010).

Research near Alameda, New Mexico, indicated that a significant number of hatchery raised PIT-tagged adults (>50 mm SL) moved upstream from their point of release and apparently used the nearby fish passage structure (Remshardt and Archdeacon 2011a). Between 2.2-4.5% of minnows released at three locations above and three locations below the Alameda fish passage structure were recorded upstream of their release site, while only 0.2-1.3% were detected downstream of their release site. Of the silvery minnows detected, 26.7% of those initially detected at the downstream end of the fish passage structure were later detected upstream of the passage structure. Silvery minnows using the fish passage structure moved as many as 13.5 mi upstream and 19.7 mi downstream from their release sites (Remshardt and Archdeacon 2011a).

Genetics

Evaluations of genetic data collected on silvery minnows indicated that overall, mitochondrial (mt) DNA and microsatellite diversity had declined between 1987 and 2005. This decline was greatest between 1987 and 2000, when mtDNA haplotype diversity declined 48 percent, prior to the beginning of population augmentation efforts in the MRG (Osborne et al. 2012). There have been two sharp declines in mt DNA diversity in the "wild" silvery minnow population. The first occurred in 1999, the second in 2001 (Turner and Osborne 2004, Alò and Turner 2005, Turner et al. 2005, Turner and Osborne 2007). The losses of diversity followed a sharp decline in abundance of silvery minnow between 1995 and 1997, and again between 1999 and 2000, as catch rates declined by an order of magnitude (Dudley et al. 2004). These declines in diversity coincided with extensive drying in the San Acacia Reach of the MRG. Mitochondrial DNA diversity continued to decline between 2004 and 2007 (Turner and Osborne 2007). An increase in inbreeding was also noted in 2007 as well, with fewer heterozygous fish sampled than would be expected (Turner and Osborne 2007).

While declines in genetic heterozygosity were recorded for silvery minnows collected from 1987 to 1999 and from 2000 and 2002, there were increases in those collected from 2002 and 2005. Stocking with captive-reared silvery minnows (from wild-caught eggs) between 2001 and 2003 was thought to have temporarily alleviated the loss of alleles and heterozygosity observed in wild silvery minnows during this period (Turner and Osborne 2004), effectively substituting for the effects of migration (Osborne and Turner 2010a). Heterozygosity again declined in silvery minnows collected in 2007 (Turner and Osborne 2007). This decline was also noted in fish collected in 2008 and 2009, with but a slight increase in those silvery minnows collected in 2010 (Osborne and Turner 2010a).

The silvery minnow genetically effective population size (N_e), which is generally equivalent to the number of individuals that contribute genes to subsequent generations, is a fraction of its population size (*N*) (Alò and Turner 2005), which is the actual number of individuals that can be counted (Frankham 1995b). In natural populations (of most species), the effective population size is generally about half the census population size, but may be lower for species that have high fecundity but also high early life stage mortality (such as the silvery minnow) (Turner et al. 2006). Much of the loss in silvery minnow effective population size is caused by a high variance in reproductive success resulting from the failure of breeding adults to match their reproductive efforts to the available and appropriate resources that allow for successful development and recruitment. Since silvery minnows may aggregate for breeding and spawning, high mortality of these early life stages can result if spawning occurs in a location with unfavorable environmental conditions and inadequate resources (Osborne et al. 2005).

Population monitoring

Long-term population monitoring of silvery minnow began in 1993 and has continued annually, with the exception of 1998 and the majority of 2009 (Dudley et al. 2012). The area monitored for silvery minnows is the MRG from Angostura Dam downstream to Elephant Butte Reservoir. Currently, 20 sites are sampled 9 times annually: 5 sites in the Angostura Reach, 6 sites in the Isleta Reach, and 9 sites in the San Acacia Reach (Figure 6). With the exception of the Cochiti Reach, 15 of these monitoring sites have been consistently used since 1993. Five additional sites were added in 2001 to increase the spatial extent of monitoring (Platania and Dudley 2001b; U.S. Fish and Wildlife Service 2010a). A detailed description of monitoring protocol used is given in Appendix E of the Recovery Plan (U.S. Fish and Wildlife Service 2010a).

Monitoring is conducted by seine netting in all apparent mesohabitat types at each monitoring site. Efforts are standardized to reflect catch-per-unit-effort (CPUE) (Figure 7). CPUE is considered to be one of the most widely used and established methods for measuring abundance of fish and has undergone extensive experimental and statistical testing and research to validate its use in fish population monitoring (Dudley and Platania 2012). In addition to CPUE, other estimates of the silvery minnow population size have been developed, such as site occupancy rates and other methods of population abundance that have been deployed or may be deployed.

The silvery minnow population has undergone fluctuations in abundance, which is highly correlated with hydrologic conditions (Dudley and Platania 2008b). Silvery minnow catch rates declined two to three orders of magnitude between 1993 and 2004, but then increased three to four orders of magnitude in 2005. Catch rates in recent years have approached levels similar to those observed at the time of listing in the mid 1990's. Specifically, the October 2010 catch rate declined approximately 14 times compared to October 2009, with a catch rate of 1.13/100m² in 2010, compared to 16.2/100 m² in 2009 (Dudley and Platania 2009b, 2010). A similar depressed trend was seen in October 2011, with a catch rate of 1.3/100 m². In October 2012, catch rates were at 0 silvery minnows/100 m², and increased slightly by October 2013 to 0.3 RGSM/100 m².

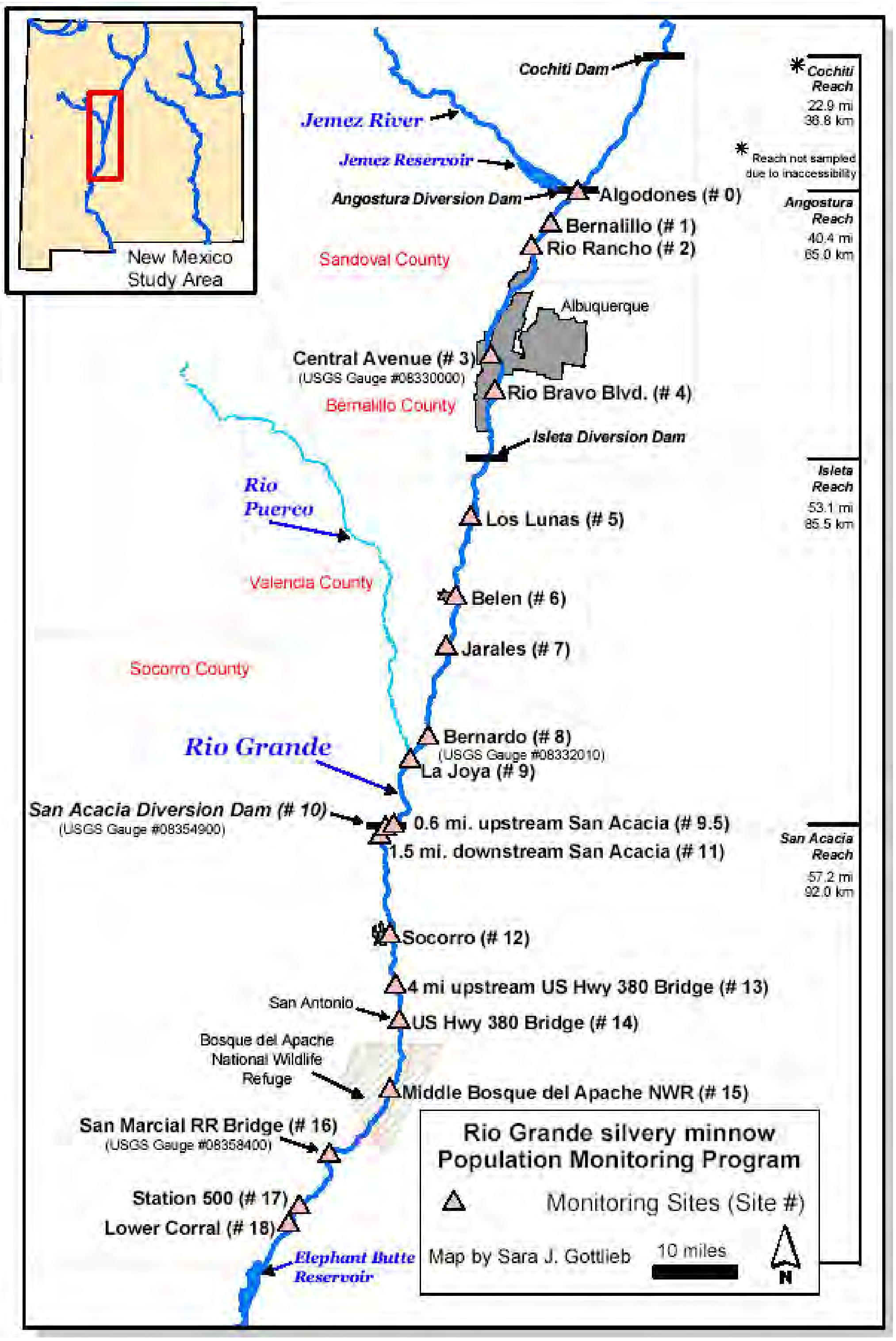


Figure 6. Sampling location of Rio Grande silvery minnow population monitoring.

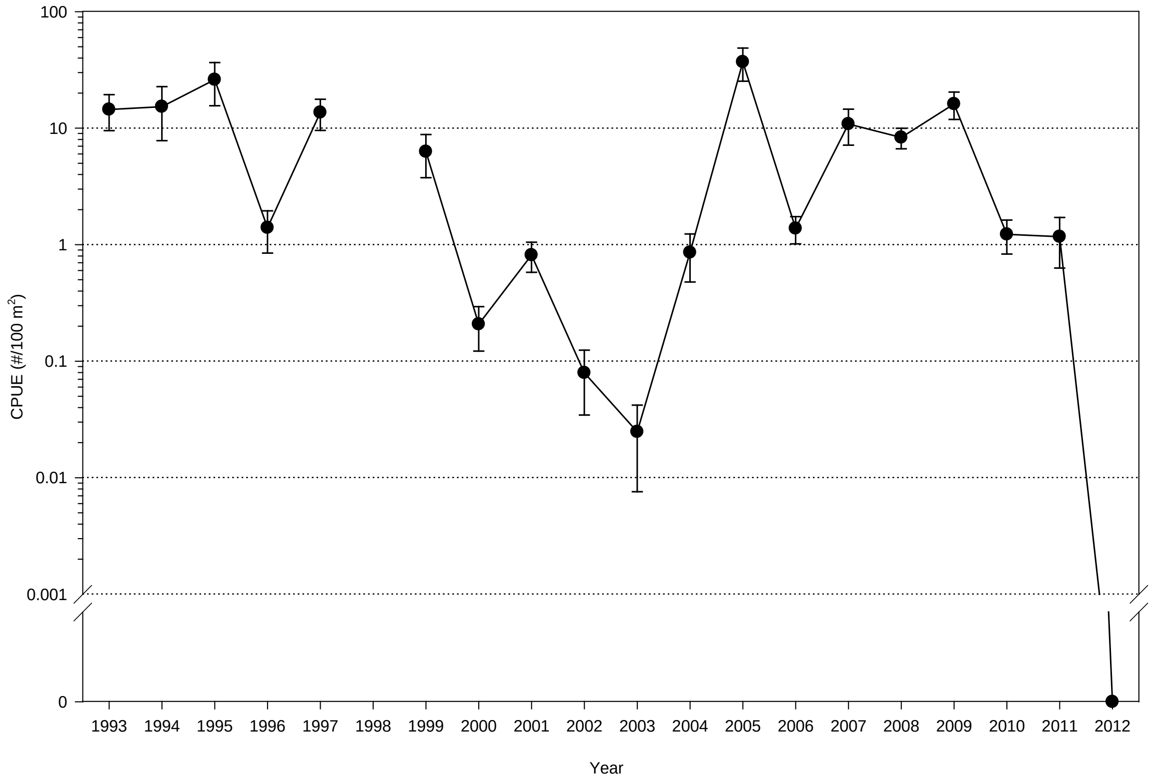


Figure 7. Rio Grande silvery minnow density data (silvery minnows per $100m^2$) from October 1993 to October 2012 population monitoring (Dudley et al 2013).

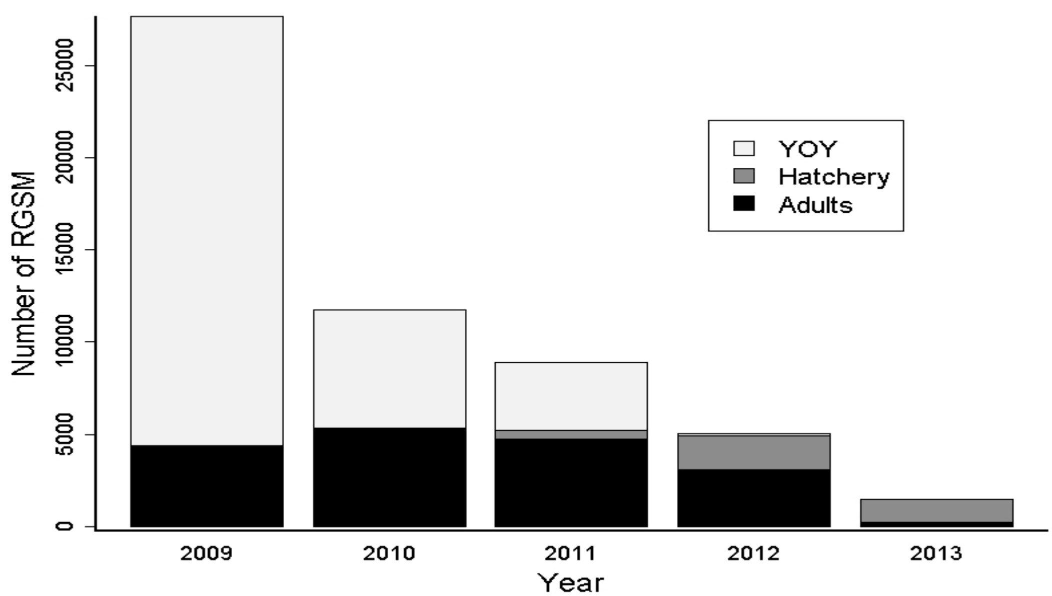


Figure 8. Rio Grande silvery minnows (young of year (YOY), hatchery-raised, or wild adults) caught during salvage activities conducted during 2009-2013 (Archdeacon 2013).

For the past 11 years, population monitoring during summer (post-spawn) showed increases in silvery minnow densities during 7 of the last 10 years (no summer data was collected in 2009) but no increase in 2002, 2006, 2012, and 2013, indicating that fall recruitment occurred in those years (Dudley et al. 2004, 2005a, 2006a, 2013; Dudley and Platania 2007b, 2008b, 2009a, 2011a, 2012). Decreases in the October silvery minnow densities from 2001 to 2002, 2005 to 2006, and 2011 to 2012 substantiate the lack of successful spawning and reduced fall recruitment. During standard population monitoring conducted in October 2012, no silvery minnow were detected; none (Dudley et al. 2012a). This is the lowest October result since comprehensive monitoring began (Figure 7). Dudley et al. (2009) describe how low spring flows have negative effects on abundance in all three reaches during subsequent October monitoring, while late season low flows could also negatively affect downstream reach abundance measurements, depending upon how early or late in the season these decreased flows occurred.

High spring runoff (>3,000 cfs for 7-10 days) (Dudley and Platania 2008a, U.S. Fish and Wildlife Service 2010a) and perennial flow will generally result in an increased availability of nursery habitat and increased survivorship of silvery minnows in the MRG. Routine augmentation of silvery minnows may also affect their spatial occupancy and distribution.

Table 1. Population monitoring data from October 2011 to September 2013 in all MRG river reaches and percent VIE-marked (hatchery-raised) silvery minnows (see Dudley et al. reports)

Sample Date	Presence at sites	CPUE All Reaches	CPUE Angostura	CPUE Isleta	CPUE San Acacia	% VIE marked
October 2011	8 of 20 sites	1.3	0.3	0.9	2.0	0%
December 2011	15 of 20 sites	4.1	0.3	5.1	5.6	0%
February 2012	14 of 20 sites	1.9	0	2.1	2.8	44%
April 2012	12 of 20 sites	0.7	0.4	0.6	1.0	0%
May 2012	12 of 20 sites	1.1	0.1	0.6	2.0	0%
June 2012	9 of 20 sites	0.3	0.1	<0.1	0.5	50%
July 2012	10 of 20 sites	0.3	0.2	0.09	0.4	0%
August 2012	7 of 20 sites	0.2	0.4	0.05	0.1	8%
September 2012	3 of 20 sites	0.07	0.2	0	0.3	0%
October 2012	0 of 20 sites	0	0	0	0	0%
December 2012	13 of 20 sites	2.76	0.18	0.92	5.35	0%
May 2013	4 of 20 sites	0.12	0	0.07	0.22	100%
June 2013	4 of 20 sites	0.07	0	0.0	0.16	71%
July 2013	7 of 20 sites	0.56	0	0.2	1.33	96%
August 2013	3 of 20 sites	0.05	0	0.03	0.09	20%
September 2013	3 of 20 sites	0.04	0	0.03	0.07	0%

Available information for 2013 indicates that silvery minnow densities remain extremely low (Table 1), with few wild adult silvery minnows having been captured during the 2012 and 2013 population monitoring efforts (Dudley and Platania 2012; Dudley et al. 2013b).

Recovery efforts

Recovery efforts are currently guided by the First Revision of the Rio Grande Silvery Minnow Recovery Plan, which was finalized and issued on February 22, 2010 (75 FR 7625, Service 2010b). The revised Recovery Plan describes recovery goals for silvery minnow and actions to complete these (USFWS 2010a). The three goals identified for the recovery and delisting of the silvery minnow are:

1. prevent the extinction of the silvery minnow in the MRG of New Mexico;
2. recover the silvery minnow to an extent sufficient to change its status on the List of Endangered and Threatened Wildlife from endangered to threatened (downlisting); and
3. recover the silvery minnow to an extent sufficient to remove it from the List of Endangered and Threatened Wildlife (delisting).

Downlisting (Goal 2) of the silvery minnow may be considered when the criteria have been met resulting in three populations (including at least two that are self-sustaining) are established within the historical range of the species and that have been maintained for at least 5 years.

Delisting (Goal 3) of the species may be considered when the criteria have been met resulting in three self-sustaining populations are established within the historical range of the species and have been maintained for at least 10 years (USFWS 2010a).

Captive propagation and augmentation

In 2000, the Service identified captive propagation and augmentation as an appropriate strategy to assist in the recovery of the silvery minnow. Augmentation of the MRG with silvery minnow is a management action taken to prevent extinction of the species. Because the silvery minnow's status is precarious, the species is intensively managed through captive propagation, genetics management, and augmentation into the wild. The augmentation program is described in section 3.2.2 of the Recovery Plan (U.S. Fish and Wildlife Service 2010a) and follows a protocol developed by the Service (Remshardt 2001) and further developed to include a formal genetics plan for captive propagation and augmentation efforts (Remshardt et al. 2009).

Silvery minnows stocked in the MRG are primarily raised in the U.S. Fish and Wildlife Service's Southwest Native Aquatic Resources and Recovery Center (SNARRC, formerly Dexter National Fish Health and Technology Center). Other stock comes from the New Mexico Interstate Stream Commission's Los Lunas Refugium and the City's Bio Park breeding facility. Of the total number of silvery minnows released in the MRG in 2011, approximately 72% were reared at SNARRC, 27% at the Bio Park and 2% at Los Lunas. In 2012, approximately 90% came from SNARRC, almost 10% from the Bio Park, and less than 0.5% coming from Los Lunas. In 2013, more than 99% of the silvery minnow augmented into the MRG were reared at the SNARRC.

Since 2002, over 2 million silvery minnows have been released in the MRG (Figure 9). Numbers of silvery minnow released prior to 2008 varied greatly and may have been related more to production numbers and less on a specific target silvery minnow density in the MRG. The augmented numbers have increased annually between 2010 and 2013. Approximately

135,990 were released in 2010, 191,000 in 2011, 274,557 in 2012, and 292,927 in 2013. Of these, approximately 53,990 were released in the Isleta Reach and 82,000 in the San Acacia Reach in 2010, 47,000 in the Isleta Reach and 144,000 in the San Acacia Reach in 2011 (U.S. Fish and Wildlife Service 2012b), 130,500 in the Isleta Reach and 144,000 in the San Acacia Reach in 2012 (Archdeacon and Remshardt 2013), and 123,850 in the Angostura Reach, 89,077 in the Isleta Reach, and 80,000 in the San Acacia Reach in 2013. The number of release sites requiring stocking also increased from 8 in 2010, to 10 in 2011 and 16 in 2012 (Remshardt 2012c). Captive propagated and released fish supplement the native population and have most likely prevented extinction throughout the MRG during the extremely low water years of 2002 and 2003, allowing for quicker and more robust population responses in all reaches during improved water conditions in 2004-2008. Similarly, augmentation in 2011 and 2012 has likely prevented extirpation in Isleta and San Acacia Reaches of the MRG during these low flow years.

Augmentation has likely sustained the silvery minnow population throughout its range in the MRG and contributes to the availability of silvery minnows affected by the proposed action. Releases of captive-propagated fish generally occur in the fall or early winter, although spring stocking may be done with overwintered fish under favorable conditions (Remshardt 2001). Stocking rates for each reach are based upon the September capture rates at the fixed monitoring stations (Remshardt 2012c). Improvements in captive propagation, transport and release techniques have enhanced the survival of silvery minnows augmented (Caldwell et al. 2010).

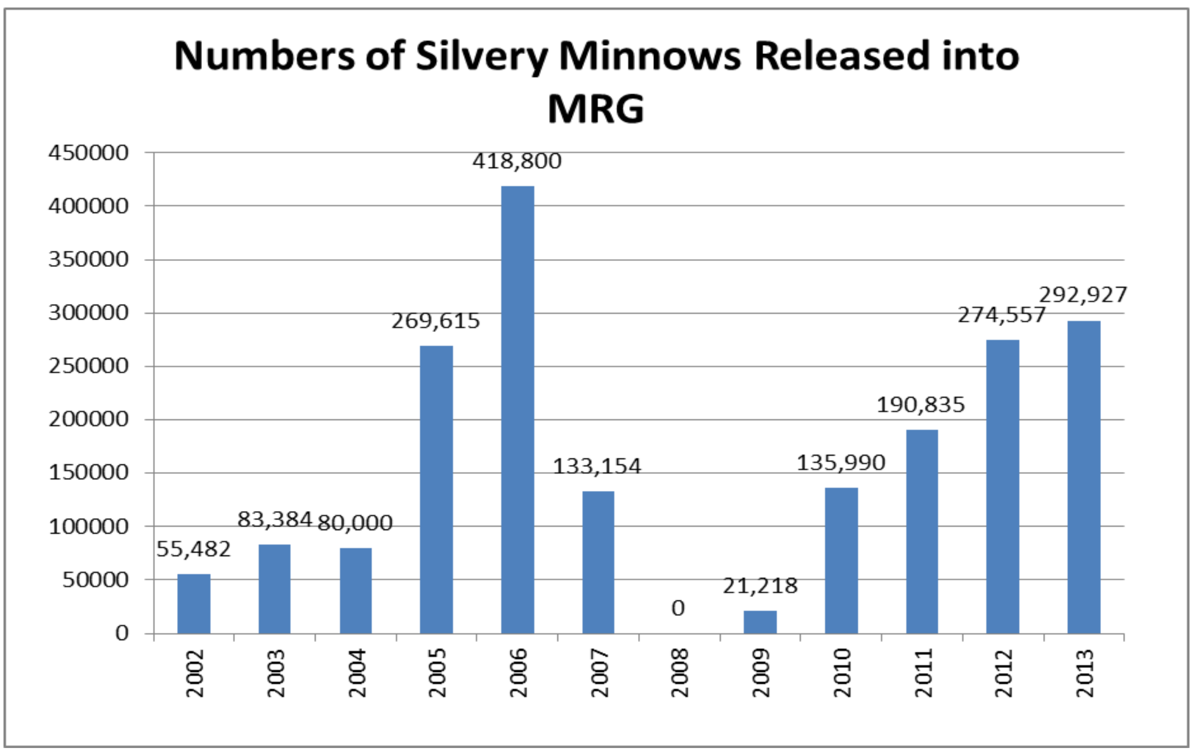


Figure.9. Numbers of silvery minnows released into the MRG (augmentation) from 2002-2013 (USFWS 2013).

From 2001 to 2007, the Angostura Reach was the focus of augmentation efforts. From 2008 to 2012, augmentation has only occurred in the Isleta and San Acacia Reaches (Remshardt 2012c). To determine the success of these efforts and the continued effects of these releases, this five–year period (2008-2012) without augmented stocking was evaluated for the Angostura Reach. If the overall catch rate for the Angostura Reach had dropped below 0.1 fish /100 m^2 during October population monitoring, augmentation would have been implemented in this reach during that year as well (Remshardt 2008b). This reach experienced little to no intermittency during this time, and catch rates in Angostura reach remained above the 0.1 fish/100 m^2 evaluation metric during the October monitoring (Remshardt 2012c) and did not trigger the need to augment this reach. Augmentation was re-initiated for the Angostura Reach in 2013, with 123,850 silvery minnows released at four sites (Archdeacon 2013). Augmentation is scheduled to continue in the Angostura Reach, as necessary, to maintain a minimum abundance of silvery minnows there.

Salvage and Relocation

During river drying, the Service's silvery minnow salvage crew captures and relocates silvery minnows to wetted portions of the MRG. Through 2009, approximately 802,700 silvery minnows have been rescued and relocated to wet reaches, the majority of which were released in the Angostura Reach. Studies are being conducted to determine survival rates for salvaged fish. Caldwell et al. (2009) reported on studies that assessed the physiological responses of wild silvery minnows subjected to collection and transport associated with salvage. The authors examined primary (plasma cortisol), secondary (plasma glucose and osmolality), and tertiary indices (parasite and incidence of disease) and concluded that the effects of stressors associated with river intermittency and salvage resulted in a cumulative stress response in wild silvery minnows. They also concluded that fish in isolated pools experienced a greater risk of exposure and vulnerability to pathogens (parasites and bacteria), and that the stress response and subsequent disease effects were reduced through a modified salvage protocol that applied specific criteria to determine which wild fish are to be rescued from pools during river intermittency (Caldwell et al. 2009).

Conservation efforts targeting silvery minnows in the MRG are also summarized in the revised Recovery Plan and elsewhere (Tetra Tech 2004; USFWS 2010; SWCA 2010). These efforts have included habitat restoration activities; research and monitoring of the status of the silvery minnow, its habitat, and the associated fish community in the MRG; and programs to stabilize and enhance the species, such as tagging fish and egg monitoring studies, salvage operations, captive propagation, and augmentation efforts (see http://mrgescp.dbstephens.com/ for more details). In addition, specific water management actions in the MRG over the past several years have been used to meet river flow targets and March 2003 BO requirements (USFWS 2003).

Status of the species near Big Bend National Park, Texas

Historically, the silvery minnow occurred in 3,967 km (2,465 mi) of the Pecos and Rio Grande rivers in New Mexico and Texas (Smith and Miller 1986; Sublette et al. 1990). To reach the recovery goals of downlisting and eventual delisting, at least two self-sustaining populations of silvery minnow need to be established prior to either of these reclassifications (USFWS 2010a). In December 2008, 2009, and 2010, silvery minnows have been introduced into the Rio Grande near Big Bend, Texas, as a nonessential, experimental population under section 10(j) of the ESA (73 FR 74357, Service 2008a). This reintroduction area extends from near Fort Quitman, below El Paso, Texas, to Amistad Reservoir and up the lower Pecos River to Independence Creek.

Over 1,880,000 silvery minnow have been released in the Big Bend reintroduction area as of October 2012, when the last of five scheduled releases in the current reintroduction plan occurred. Monitoring of this population, including genetics and reproduction, began in May 2009 and is ongoing. Seven adult silvery minnows were found during the first monitoring effort at the four release sites in May 2009. In 2010, the Service found evidence of successful reproduction with the detection of silvery minnow eggs, and both larvae and juvenile fish. An extensive monitoring effort in June 2011 determined that silvery minnow had extended its range in the recovery area almost 70 miles downstream and 15 miles upstream from the furthest downstream and upstream release sites, respectively (Edwards and Garrett 2013).

Relevant information from this effort will be assessed as additional river reaches are considered for potential reintroductions. At least one more section 10(j) nonessential population will be required to achieve the recovery goals for the silvery minnow (U.S. Fish and Wildlife Service 2010a). The next NEP reintroduction site planning effort is currently being conducted.

Status of the species in the MRG

Historically, the silvery minnow occurred in 3,967 km (2,465 mi) of the Pecos and Rio Grande rivers in New Mexico and Texas (Smith and Miller 1986; Sublette et al. 1990). Silvery minnows have been reported to occur upstream to Española, New Mexico, and in the downstream portions of Rio Chama and Jemez River, throughout the Middle and Lower Rio Grande to the Gulf of Mexico; and in the Pecos River from Sumner Reservoir downstream to the confluence with the Rio Grande (Sublette et al. 1990; Bestgen and Platania 1991). The current distribution of the silvery minnow is limited to the Rio Grande between Cochiti Dam and Elephant Butte Reservoir, which amounts to approximately 7 percent of its historical range.

The construction of mainstem dams, such as Cochiti Dam and several irrigation diversion dams have contributed to the decline of the silvery minnow (USFWS 2010a). Cochiti Dam was constructed on the main stem of the MRG in 1973 for flood control and sediment retention (Julien et al. 2005). The construction of Cochiti Dam affected silvery minnows by reducing the magnitude and frequency of peak flow events and floods that help to create and maintain habitat for the species (Julien et al. 2005). In addition, the construction of Cochiti Dam has resulted in geomorphic and thermal degradation of silvery minnow habitat within the Cochiti Reach downstream. River water outflows released from Cochiti Dam are now generally cool and with reduced sediment. There is relatively little channel braiding, and areas with reduced velocity and sand or silt substrates are now uncommon below the dam (Julien et al. 2005). Substrate immediately downstream of the dam is often composed of gravel and cobble (rounded rock fragments generally 8 to 30 cm [3 to 12 in] in diameter). Farther downstream, the riverbed is gravel with some sand and silt substrate. Tributaries including Galisteo Creek and Tonque Arroyo introduce sand and silt during stormwater runoff to the lower sections of the Cochiti Reach, and some of this sediment is transported further downstream along with flows (Salazar 1998; USFWS 1999, 2001, 2011). The MRG below Angostura Diversion Dam becomes a predominately sand-bed river with low, sandy banks in the downstream portion of the Angostura Reach and into Isleta Reach (Figure 2). The construction of Cochiti Dam also created a barrier for movement upstream by silvery minnow (Cowley 2006; USFWS 2010a). As recently as 1978, the silvery minnow was collected upstream of Cochiti Lake; however surveys since 1983 suggest that the fish is now extirpated from that area (USFWS 1999, 2010a; Torres et al. 2008).

Long-term monitoring of silvery minnows in the MRG began in 1993 and has continued annually, with the exception of portions of 1998-1999 (Dudley and Platania 2011). The long-term monitoring of silvery minnow populations has recorded substantial fluctuations (order of magnitude increases and decreases) over time (Figure 4). Silvery minnow catch rates declined two to three orders of magnitude between 1993 and 2003, but then increased three to four orders of magnitude by 2005 and continue to fluctuate (see Figure 4). Population density data presented in Figure 4 indicate that silvery minnow catch rates, after declining through the early 2000, had increased by 2005, but by 2010 were again below the population level identified at the time of its listing as an endangered species in 1994. Population size has been correlated hydrologic conditions, particularly the magnitude and duration of the spring runoff (Dudley and Platania 2008b). The capacity of the species to respond to good hydrologic years (e.g., 2005) is dependent on a variety of factors including the previous year's survivorship, number of adults available to reproduce, fecundity, and good habitat conditions, particularly larval habitat.

Augmentation has likely sustained the silvery minnow population throughout its range over the last decade (Remshardt 2008). Over 1,136,100 silvery minnows have been released since 2002. Hatchery-propagated and released fish supplement the native adult population, most likely prevented extinction during the extremely low water years of 2002 and 2003, and allowed for quicker and more robust population response in all reaches due to improved water conditions observed in recent years (USFWS 2010a). Since 2001, the Angostura Reach has been the focus of augmentation efforts; however, beginning in 2008, augmentation shifted focus to the Isleta and San Acacia Reaches only (Remshardt 2010a). The success of these augmentation efforts during a period of 5 years (2008–2012) without intensive stocking is currently being evaluated. If the overall average catch rate for Angostura Reach drops to below 0.1 per 100 m^2 (1.2 per 100 ft^2) during October, then augmentation will be reinitiated for this reach the following year (Remshardt 2008). During 2010, Dudley and Platania (2011) reported the range 0 to 0.7 per m^2 (0 to 7.5 per 100 ft^2) silvery minnow densities found in the Angostura Reach during their surveys and the average density in December 2010 was 0.1 per 100 m^2 (1.2 per 100 ft^2).

During the early 1990s, the density of silvery minnows generally increased from upstream (Angostura Reach) to downstream (San Acacia Reach). During surveys in 1999, over 98 percent of the silvery minnow captured were downstream of San Acacia Diversion Dam (Dudley and Platania 2002). This distributional pattern may be attributed to downstream drift of eggs and larvae and an inability of adults to repopulate upstream reaches because of diversion dams, or other factors including the relative availability of appropriate slow-velocity habitat.

The distribution pattern of silvery minnow abundance has changed over time. In 2004, 2005, and 2007, catch rates were highest in the Angostura Reach and lower in the Isleta and San Acacia Reaches. Routine augmentation of silvery minnows in the Angostura Reach (the focus of augmentation efforts started in 2001) may partially explain this pattern. Transplanting of silvery minnows rescued from drying reaches (approximately 802,700 through 2009) has also occurred since 2003; however, it is not possible to quantify the effects of those rescue efforts on silvery minnow distribution patterns (Remshardt 2010b). Good recruitment conditions (i.e., high and sustained spring runoff) throughout the MRG during May followed by wide-scale drying in the Isleta and San Acacia Reaches from June to September in these years, may also explain the shift. High spring runoff (greater than 86 m^3/s [3,000 cubic feet per second (cfs)] for 7 to10 days) and perennial flow tends to lead to increased availability of habitat and increased survivorship in the MRG. In contrast, portions of the MRG south of the Isleta and San Acacia Diversion Dams, have had large stretches of river (48 km [30 mi]) routinely dewatered and young silvery minnows in these areas were either subjected to poor recruitment conditions (i.e., lack of suitable habitats during low flows) or were trapped in pools during intermittency where they may perish.

In 2006, densities of silvery minnows were again highest downstream of the San Acacia Diversion Dam. Spring runoff volumes were exceedingly low in 2006. Flows at the Albuquerque gage never exceeded 65 m^3/s (2,300 cfs) in 2006 (USGS 2010), and likely little nursery habitat was inundated during critical recruitment times.

Status of the Species in the Action Area (Angostura Reach)

In the Angostura Reach, silvery minnows have been routinely monitored at five locations in the MRG both upstream and downstream of the confluence of the North Diversion Channel (for example, see Dudley et al. 2013). For the last five years (2009-2013), the average density of silvery minnows ranged from 0 to 5 RGSM/100m^2 by month (Figure 10) and the overall average density was 2.4 RGSM/100m^2, but was highly skewed by data from 2009, and after stocking.

Additional monitoring for silvery minnows in the Angostura Reach have also been carried out since 2002, by other researchers (Remshardt and Davenport 2003; Remshardt 2005, 2007, 2008a, 2008b, 2010b, 2012; SWCA 2010, to name a few). One of the monitoring sites has been in the area below the North Diversion Channel (RM 193.2) (Remshardt 2010b). Monitoring in the action area showed an increase in numbers of silvery minnow there sampled since 2002, with considerable annual and seasonal variation. The most consistent seasonal peak in abundance was noted during June and July, following silvery minnow spawning with the increase of juveniles.

Note that Remshardt (USFWS, written communication, January 17, 2012) seined or removed 3,577 silvery minnows from the Embayment during its reshaping. Those data suggested that the density of silvery minnows in the Embayment was ~1.5 RGSM/100m^2. The occurrence of silvery minnows in the North Diversion Channel Embayment indicate its importance as a slack water habitat providing areas for feeding, breeding, and sheltering activities of silvery minnows.

Since the population of silvery minnows varies widely, and sampling efforts may find higher or lower silvery minnow densities during routine surveys (e.g., Dudley et al. 2011), the density of silvery minnows affected by the proposed action, during any one month is difficult to project for the five year duration of the MRG Watershed MS4 Permit. During summer (May-August), when water temperatures are highest and low oxygen stormwater discharges in the North Diversion Channel tend to predominate (USFWS 2011; and see Figure 11), the average density during the last five years was 1.0 RGSM/100m^2. Additionally, the Service will attempt to use augmentation to maintain a density of 1.0 RGSM/100m^2 in the Angostura Reach through 2017 (USFWS 2013). Therefore, the Service used an average density of 1.0 RGSM/100m^2 for the expected density of silvery minnows exposed to stormwater discharges through the North Diversion Channel Embayment in the MRG for the duration of the MRG Watershed MS4 Permit in this BO. Should the average silvery minnow density increase and be *significantly* higher than 1.0 RGSM/100m^2 during the MRG Watershed MS4 Permit term, then EPA would need to evaluate its findings of effects for silvery minnow and determine if the levels of incidental take were exceeded (as described below) and as necessary, re-initiate consultation with the Service.

Silvery minnow reproductive activity has been documented to occur in May and June each year (Platania and Dudley 2000, 2008, 2012) including in the Angostura Reach. Silvery minnow egg and larval fish monitoring has been conducted in the action area. The range of silvery minnow eggs in this area ranged from 0 to 0.05 per 100 m^2 (0 to 0.5 per 100 ft^2) and averaged approximately 0.005 per 100 m^2 (0.05 per 100 ft^2) (SWCA 2010). Therefore, we anticipate that as many as 20 eggs and/or larvae could enter the North Diversion Channel Embayment per day during mid- to late-May for a total of 20 x 15 = 300 silvery minnow eggs and larvae, per year, for a total of 1,500 eggs and larvae during the five-year MRG Watershed MS4 Permit.

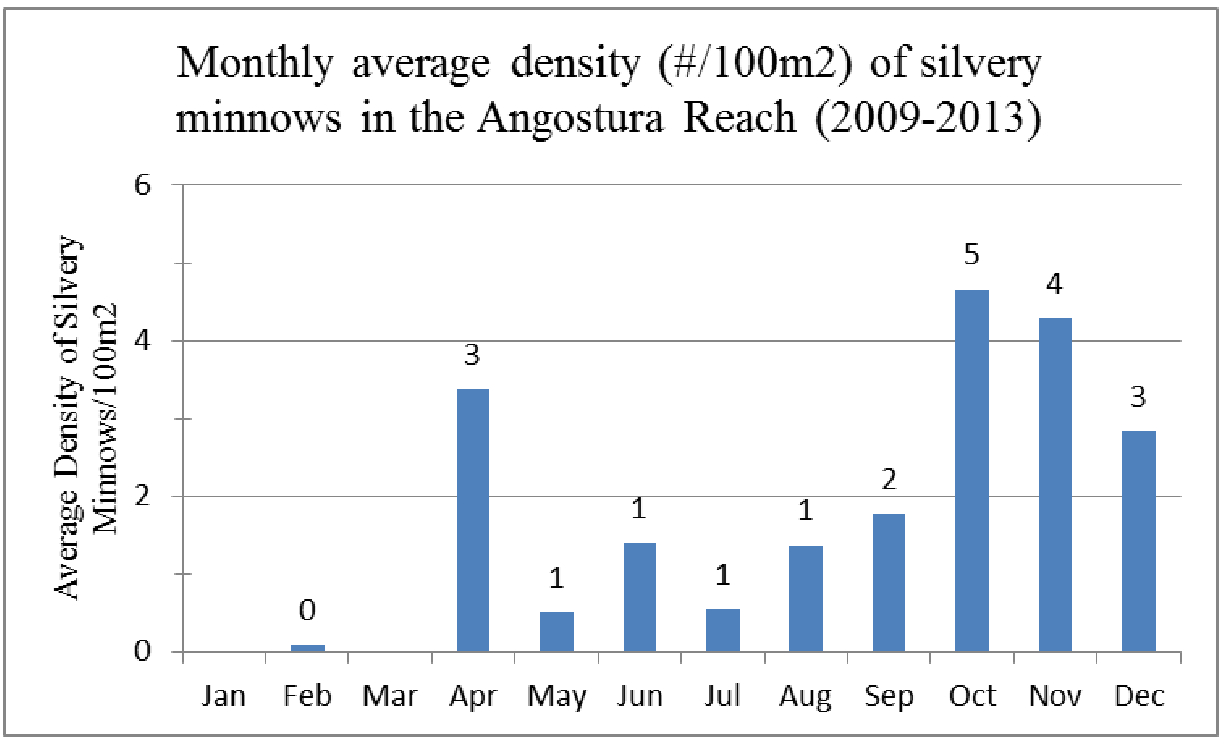


Figure 10. Average density of silvery minnows in the Angostura Reach by month (2009-2013).

Several activities have contributed to the status of the silvery minnow and its habitat in the action area, and are believed to affect the survival and recovery of silvery minnows in the wild. These include the current weather patterns, changes to the natural hydrology of the Rio Grande, changes to the morphology of the channel and floodplain, degradation of water quality, storage of water and later release of spring flows, captive propagation and augmentation, silvery minnow salvage and relocation, ongoing research and authorized incidental take, and past projects in the Angostura Reach of the MRG that are discussed in the Environmental Baseline section below.

III. ENVIRONMENTAL BASELINE

Under section 7(a)(2) of the ESA, when considering the effects of the action on federally listed species, we are required to take into consideration the environmental baseline. Regulations implementing the ESA (50 CFR 402.02) define the environmental baseline as the past and present impacts of all Federal, State, or private actions and other human activities in the action area; the anticipated impacts of all proposed Federal actions in the action area that have already undergone formal or early section 7 consultation; and the impact of State and private actions that are contemporaneous with the consultation in process. The environmental baseline defines the effects of these activities in the action area on the status of the species and its habitat to provide a platform to assess the effects of the action now under consultation. The total effects on listed species and their habitat are the aggregate of effects due to the proposed action, when added to the environmental baseline, along with cumulative effects to estimate likelihood of extinction.

Factors affecting the Species Environment within the Action Area

Changes in Hydrology

There have been two primary changes in hydrology because of the construction of dams on the Rio Chama and Rio Grande that affect the silvery minnow: 1) loss of water in silvery minnow habitat, and 2) changes to the magnitude and duration and timing of peak and other flows.

Loss of Water in Silvery Minnow Habitat

Prior to measurable human influence on the system, up to the 14th century, the Rio Grande was a perennially flowing, aggrading river with a shifting sand substrate (Biella and Chapman 1977). There is now strong evidence that the MRG first began drying up periodically after the development of Colorado's San Luis Valley in the mid to late 1800s (Scurlock 1998). After humans began exerting greater influence on the river, there are two documented occasions when the river became intermittent during prolonged, severe droughts in 1752 and 1861 (Scurlock 1998). The silvery minnow may have historically survived low-flow periods because such events were infrequent and were of lesser magnitude than they are today. There were also no diversion dams to block repopulation of upstream areas, the fish had a much broader geographical distribution, and there was bank storage, and likely, oxbow lakes, cienegas, and sloughs associated with the Rio Grande that supported fish until the river was connected again.

Water use and management has resulted in a large reduction of suitable habitat for the silvery minnow. Agriculture accounts for 90 percent of surface water consumption in the MRG (Bullard and Wells 1992) associated with human activities. The average annual diversion of water in the MRG by the Middle Rio Grande Conservancy District (MRGCD) was 0.7×10^7 m^3 (535,280 acre-feet [af]) for the period from 1975 to 1989 (U.S. Bureau of Reclamation (BOR) 1993). In 1990, total water withdrawal (groundwater and surface water) from the Rio Grande Basin in New Mexico was 2.3×10^9 m^3 (1,830,628 af), significantly exceeding a sustainable rate (Schmandt

1993). Water withdrawals have not only reduced overall flow quantities, but also caused the river to become locally intermittent or dry for extended reaches. Diversions for water consumption, as well as by riparian vegetation, significantly reduce water volumes in the river. However, the total water use (surface and groundwater) in the MRG by the MRGCD may range from 28 to 37 percent (S.S. Papadopulos & Associates, Inc. 2000; Bartolino and Cole 2002). A portion of the water diverted by the MRGCD returns to the river (through drains) and may be diverted from the river again for other uses, sometimes more than once (Bullard and Wells 1992). Although the river below Isleta Diversion Dam may be drier than in the past, small inflows may contribute to maintaining flows in portions of the MRG.

Since 2001, improvements to physical and operational components of the irrigation system have contributed to a reduction in the total diversion of water from the MRG by the MRGCD. Prior to 2001, average annual diversions were ~$0.8x10^7$ m^3 (630,000 af) and now average annual diversions are approximately $0.5x10^7$ m^3 (370,000 af). That reduction was possible because of the considerable efforts of MRGCD and farmers to reduce crop irrigation, schedule and rotate water diversions among water users, and improve record keeping by installing new gages and automating gates at diversions. The new operations reduce the amount of water diverted; however, this also reduces return flows that previously supported some flows in the river. In February 2007, the City and Albuquerque Bernalillo County Water Utility Authority, along with six conservation groups established a fund that provide the opportunity to lease water from MRG farmers and that will have water remain in the river channel to support the silvery minnow and other beneficial uses of the water.

Groundwater withdrawals may also affect flow in the MRG. Under New Mexico State law, municipal and industrial users are required to offset the effects of groundwater pumping on the surface water system (BOR 2003). Effects of pumping by private landowners are less known.

River reaches particularly susceptible to drying occur immediately downstream of the Isleta Diversion Dam (RM 169), a 8-km (5-mi) reach near Tome (RM 150–155), a 8-km (5-mi) reach near the U.S. Highway 60 Bridge (RM 127–132), and an extended 58-km (36-mi) reach from near Brown’s Arroyo (downstream of Socorro) to Elephant Butte Reservoir. Extensive fish kills, including tens of thousands of silvery minnows, have occurred in these lower reaches when the river has dried. It is assumed that mortalities during river intermittence are likely greater than documented levels, for example due to predation in isolated pools by birds (USFWS 2010a). From 1996 to 2007, an average of 51 km (32 mi) of the MRG has dried each year, mostly in the San Acacia Reach. The most extensive drying occurred in 2003 and 2004 when 97 and 110.6 km (60 and 68.7 mi) respectively, were dewatered. Most documented drying events lasted an average of 2 weeks before flows returned. In contrast, 2008 was considered a wet year, with above average runoff and at least an average monsoon season. As a result, there was no river intermittency that year, which was the first time there has been no river drying since 1996.

Changes to Magnitude and Duration of Peak Flows

Water management (along with climatic variation) has also resulted in a loss of peak flows that historically triggered the initiation of silvery minnow spawning. The reproductive cycle of the silvery minnow is tied to the natural river hydrograph. A reduction in peak flows or altered timing of flows may inhibit reproduction or reduce their nursery habitat. Since completion of Elephant Butte Dam in 1916, three additional dams have been constructed on the MRG (Scurlock 1998). Construction and operation of these dams, which are either irrigation diversion dams (Cochiti-Sile, Angostura, Isleta, San Acacia), flood control (Cochiti), or water storage dams (Elephant Butte, Abiquiu, El Vado), have modified the natural flow of the river. Mainstem reservoirs and their management store spring runoff and summer inflow, which would normally cause flooding, and release of this water back into the river channel over a prolonged period. Managed releases are often made during the winter months, when low flows would normally occur. For example, release of carryover storage from Abiquiu Reservoir to Elephant Butte Reservoir during the winter of 1995–96 represented a substantial change in the flow regime. The Corps consulted with the Service on the release of water from November 1, 1995 to March 31, 1996, during which time $0.1x10^7$ m^3 (98,000 af) of water was released at a rate of 9.2 m^3/s (325 cfs). Such releases depart from presumed natural, historical winter flow rates, and can substantially alter habitat for silvery minnows. In spring and summer, artificially low flow may limit the amount of habitat available and may limit dispersal of the species (USFWS 1999).

In the spring of 2002 and 2003, an extended drought raised concerns that silvery minnows would not spawn because of a lack of spring runoff. River discharge was artificially elevated through short duration reservoir releases during May to induce silvery minnow spawning. In response to the releases, significant silvery minnow spawning occurred in all reaches except the Cochiti Reach (Dudley et al. 2005; Service 2010a). Fall populations in 2003 and 2004 continued to decrease despite large spawning events, indicating a lack of recruitment.

By contrast, spring runoff in 2005 was above average, leading to a peak of over 170 m^3/s (6,000 cfs) at Albuquerque and sustained high flows (greater than 85 m^3/s [3,000 cfs]) for more than two months. These flows improved conditions for both spawning and fall recruitment. October 2005 monitoring indicated a significant increase in silvery minnows in the MRG compared to 2003 and 2004. In 2006, however, October numbers declined again after an extremely low runoff period and after channel drying in June and July (Dudley et al. 2006). October samples that year yielded no or few juvenile silvery minnows, indicating poor fall recruitment.

Changes in climate (addressed in cumulative effects), mainstem dams, diversions, and reservoirs alter flow regimes and can affect silvery minnow habitat by preventing overbank flooding, trapping nutrients, altering sediment transport, altering natural, daily or seasonal thermal regimes, reducing and dewatering main channel habitat, modifying or eliminating native riparian vegetation, and creating conditions that favor nonnative fish species. These changes may affect the silvery minnow by reducing its food supply; altering its preferred or nursery habitat, preventing dispersal, and fostering nonnative fish or other species that may compete with or prey upon silvery minnows. Altered flow regimes may also result in improved conditions for other native fish species that occupy the same habitat, causing those populations to expand at the expense of the silvery minnow (USFWS 1999).

In addition to providing a cue for spawning, flood flows also maintain a channel morphology to which the silvery minnow is adapted. The changes in channel morphology that have occurred from the loss of sediment input and reduced flood flows are discussed below.

Changes in Channel and Floodplain Morphology

Historically, the MRG was sinuous, braided, and freely migrated across the valley floodplain. Changes in natural flow regimes, narrowing and deepening of the channel, and restraints to channel migration (e.g., jetty jacks) adversely affected the silvery minnow. These effects result directly from constraints placed on channel capacity by structures built in the floodplain. These anthropogenic changes have and continue to degrade and eliminate spawning, nursery, feeding, resting, and refugia areas required for the species' survival and recovery (USFWS 1993; 2010a).

The active river channel within occupied habitat is also being narrowed by the encroachment of vegetation, resulting from continued flow reductions and a reduction in overbank flooding. The lack of flood flows has allowed nonnative riparian vegetation such as salt cedar (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*) to encroach on the river channel (BOR 2001). These nonnative plants are resistant to erosion, and enhance channel narrowing, often with subsequent increases in average water velocity. Higher velocities result in fine sediment such as silt and sand being carried away, leaving coarser bed materials such as gravel and cobble. Habitat studies during the winter of 1995 and 1996 (Dudley and Platania 1996), demonstrated that a wide, braided river channel with low velocities resulted in higher catch rates of silvery minnows, and narrower channels resulted in fewer fish captured. The availability of wide, shallow habitats that are important to the silvery minnow has decreased over time. Narrow channels have few backwater habitats with low velocities that are important for all life stages of silvery minnows.

Within the current range of the silvery minnow, human development and use of the floodplain has also restricted the floodplain width available to the active river channel. A comparison of river area between 1935 and 1989 shows a 52 percent reduction, from 10,764 ha (26,598 acres) to 5,626 ha (13,901 acres) (Crawford et al. 1993). These data refer to the MRG from Cochiti Dam downstream to Elephant Butte Reservoir, but that include the action area. Within the same stretch, 378 km (235 mi) of levees occur, including levees on both sides of the river. Analysis of aerial photography taken by BOR in February 1992, for the same river reach, shows that of the 290 km (180 mi) of river, only 1.6 km (1 mi), or 0.6 percent of the floodplain has remained undeveloped. Development in the floodplain, particularly associated with flood protection and levees also makes it difficult to send large quantities of water downstream that would create low velocity side channels that silvery minnow may prefer. As a result, reduced releases have decreased available habitat for silvery minnows and allowed encroachment of nonnative species into the floodplain.

Water Quality

Many natural and anthropogenic factors affect water quality in the MRG, including in the action area. Water quality in the MRG varies spatially and temporally throughout its course primarily due to inflows of groundwater, as well as surface water discharges and tributary deliveries to the river (Ellis et al. 1993). Factors that are known to cause poor fish habitat include altered thermal regimes, alteration of turbidity and sediment concentrations, organic loading, reduced oxygen content, pesticides, and an array of other toxic or hazardous substances. Both point source pollution (e.g., pollution discharges from a pipe or other discreet conveyance) and nonpoint source pollution (i.e., from diffuse sources such as stormwater runoff) affect the MRG (NMED

2007, 2009, 2010). Major point sources include discharges from wastewater treatment plants and animal feeding operations. Major nonpoint sources include urban stormwater, agricultural activities (e.g., fertilizer and pesticide application, livestock grazing), atmospheric deposition, and mining activities (Ellis et al. 1993).

Effluents from WWTPs contain pollutants that may affect the water quality of the river. It is anticipated that WWTP effluent may also be the primary source of perennial flow during extended periods of intermittency in the lower portion of the Angostura Reach. For that reason, the water quality of effluent discharges is important. Near the project area, the largest WWTP discharges are from the City, followed by two WWTPs in Rio Rancho and Bernalillo (Bartolino and Cole 2002). Since 1989, ammonia and chlorine have been discharged unintentionally at concentrations that exceed protective levels for the silvery minnow (Passell et al. 2007) and as recently as 2011 (Chwirka 2011; Lusk 2011a). In addition to ammonia and chlorine, WWTP effluents may also include cyanide, chloroform, organophosphate pesticides, semivolatile compounds, volatile compounds, heavy metals, and pharmaceuticals and their derivatives, which can pose a health risk to silvery minnows when discharged in concentrations that exceed protective water quality criteria (Lusk 2003; NMED 2010). Additionally, even if the concentration of a single chemical compound is not harmful by itself, chemical mixtures can be additive in their toxicity to silvery minnows (Buhl 2002). Marcus et al. (2010) described the concentrations of chemicals in the MRG that may affect fish health or produce localized mortalities. However, the long-term effects and population level impacts of toxic chemical discharges in the MRG on silvery minnow are generally not fully known.

Pesticides

Pesticide contamination can occur from agricultural activities, as well as from the cumulative impact of residential and commercial landscaping and other activities (Anderholm et al. 1995). Stormwater runoff, irrigation return, and riverside drain return flows and aeolian processes (i.e., windblown) likely contribute a portion of these pesticides to the MRG. The presence of pesticides in surface water can depend on the amount applied, timing, location, and method of application. Water quality standards have not been set for some pesticides, but existing criteria often do not consider cumulative effects of multiple stressors in the water at the same time or as part of the food chain. Ong et al. (1991) recorded the concentrations of heavy metals and organochlorine pesticides in water, suspended sediment and bed sediment samples between 1978 and 1988. Several researchers (Anderholm et al. 1995; Abeyta and Lusk 2004a; Langman and Nolan 2005; NMED 2009; Marcus et al. 2010) reported various pesticides in MRG water or in sediment samples collected from the MRG.

Roy et al. (1992) reported that DDE, a degradation product of DDT, was detected in whole body fish collected throughout the Rio Grande. They suggested that fish in the lower Rio Grande were accumulating DDE in concentrations that may be harmful to fish and their predators. The NMED reported that two sites in the Angostura Reach contained total DDT at levels toxic to fish (Schmitt et al. 2004, see Table 15). Lusk (2011b) analyzed silvery minnow collected in the MRG for DDT residues and found that the sum of DDT residues and metabolites ranged from 8.8 to 30.7 micrograms per kilogram (µg/kg) wet weight. The concentrations of DDT residues in silvery minnow, while elevated, were not above concentrations of concern for lethality (890 µg/kg wet weight), but may be associated with sublethal effects (greater than 5 µg/kg wet weight) particularly if similar DDT residues are found in silvery minnow eggs (Beckvar and Lotufo 2011), or to other fish and those that consume them (Schmitt et al. 2004; Lusk 2011b).

Heavy Metals and other Stormwater Pollutants

The EPA (2010a) reviewed the ambient stormwater water quality data for the MRG Watershed MS4 Permit Area (NPDES Permit Number NMR04A000. www.epa-otis.gov/otis/). The EPA (2010a) reported lead, zinc, bacteria, and cold temperature exceeded applicable water quality standards. There are no controls in place or proposed to reduce lead and zinc to applicable water quality standards other than BMPs. In their BE, the EPA (2010a) reviewed the accumulation of lead and zinc in fish tissue and sediment. The lack of acute toxicity reported by Bio-Aquatic Testing Inc. (2010) and the lack of concentrations greater than those that are lethal to 50 percent of test animal populations was used in support of EPAs decision that that no additional controls for these heavy metals was needed at this time. The NMED (2010) confirmed that lead and zinc were below levels of concern in the action area during monitoring in 2007 to 2009. The MRG Watershed MS4 Permit has described additional controls for bacteria (EPA 2013b). A review of the ambient stormwater temperature exceedances were considered erroneously high and therefore, no additional temperature controls were necessary or identified (EPA 2013b).

Sediment and Sediment Quality

Sediment is inorganic (sand, silt, and clay are used to describe sediment particle sizes) and organic matter deposited below the water column in a river or other water body. It is an important component of fish habitat in the MRG (USFWS 1999). Sediment suspended in the water column, from erosion and other processes, can be described in terms of suspended sediment concentration (SSC) or as total suspended solids (TSS), though these measurements are not identical (Gray et al. 2000). The method for determining TSS, used in NPDES permitting, has been shown to be biased as sand particles are often excluded from analysis (Gray et al. 2000). Sediment concentrations and suspended sediment loads are important sources of sediment contamination often conveyed by stormwater (Harwood 1995; EPA 2002). EPA (2002) identified a number of pollutants that are more likely to partition onto sediment than remain dissolved in the water column, such as heavy metals, certain semivolatile organic compounds such as polycyclic aromatic hydrocarbons (PAHs), PCBs, and organochlorine pesticides. Large precipitation events wash sediment and the pollutants that adhere to sediment into the river from surrounding lands through storm drains and intermittent tributaries. Stormwater produces high levels of SSC and TSS, and consequently high levels of contaminants for those constituents that commonly bound to sediment particles have been detected (e.g., metals, radionuclides, PCBs) (NMED 2009, 2010).

PCBs

The chemicals known as PCBs are mixtures of synthetic organic chemicals with the same basic chemical structure and similar physical properties that range from oily liquids to waxy solids (EPA 2011). No known natural sources of PCBs exist. Because they are nonflammable with properties of high chemical stability, high boiling point, and electrical insulation, PCBs were used in hundreds of industrial and commercial applications. Prior to 1974, PCBs were used both for nominally closed applications (e.g., capacitor and transformers, and heat transfer and hydraulic fluids) and in open-end applications (e.g., flame retardants, inks, adhesives, paints, pesticide extenders, plasticizers, surface coatings, wire insulators, and metal coatings) (see ASTDR 2001). While production of PCBs was banned in 1979, there are many PCB containing applications still in use, which can become sources for PCB in the environment (EPA 2011). PCBs enter aquatic environments from atmospheric deposition, river inflows, groundwater flow, and discharges from industrial facilities. Dry and wet deposition may be the most important sources to water bodies such as lakes and large watersheds (Wenning et al. 2010).

PCBs have been detected in the MRG samples from below the North Diversion Channel and in stormwater the San Jose Drain during stormwater runoff events (Yanicek 2006; NMED 2010). PCB concentrations in some of these stormwater samples exceeded New Mexico's water quality criteria for the protection of wildlife as well as human health criteria (NMED 2010). PCBs in suspended sediments (0.09 micrograms per gram (µg/g)) in the MRG at Alameda were 90 times the values for the MRG above the North Diversion Channel. This indicates that stormwater; including stormwater from above the North Diversion Channel, may convey PCBs (NMED 2010). The NMED (2010) noted a correlation between the concentrations of PCBs in suspended sediment and stormwater discharges, suggesting that management techniques that reduce suspended sediment in stormwater may reduce sediment contamination loads to the MRG. Comparison of sediment PCBs (Yanicek 2006) with PCBs in fish tissue samples found similar patterns collected in the action area (NMED 2010).

All fish collected from the MRG by the NMED (2009) contained detectable PCBs ranging from 12.4 to 120.2 nanograms per gram (ng/g) wet weight. The New Mexico Department of Game and Fish, New Mexico Department of Health, and New Mexico Environment Department (2010) subsequently issued fish consumption advisories to protect the public from PCB ingestion due to health concerns in the action area. Lusk (2011b) reported that all twelve samples of silvery minnows collected from the MRG contained detectable concentrations ranging from 4.7 to 38.2 ng/g wet weight. Olsson et al. (1999) reported skeletal deformities associated with fish injected with 360 ng/g PCBs on a lipid basis. Lusk (2011b) reported that silvery minnow had PCBs concentrations lower than 36 ng/g, on a lipid basis. This suggested that PCB-induced deformity would be unlikely in the silvery minnow unless it was more sensitive than test fish (*Danio rerio*). Compared to upstream, concentrations of PCBs are elevated in stormwater, sediment, and fish collected below the North Diversion Channel mixing zone in the action area; however, while the concentrations pose a risk to human health and wildlife, the levels do not exceed current known toxic effect concentrations (Wenning et al. 2011) within the silvery minnow.

Dissolved Oxygen

Oxygen is the amount of oxygen dissolved in the water column (Benson and Krause 1980). The amount of oxygen in water depends upon water temperature, atmospheric pressure, and the surface area of water exposed to the atmosphere (turbulence), and the oxygen byproducts of photosynthesis by plants (Odum 1956; Bott 1996). The capacity of water to hold oxygen in solution is inversely proportional to the water temperature (Benson and Krause 1980). Increased water temperature lowers the concentration of oxygen at saturation. Saturation is the maximum quantity of oxygen that water, in equilibrium with the atmosphere, can contain at a given temperature and pressure (i.e., based on the elevation of the water body). Oxygen is lost from the water column because of respiration and the oxygen demand of substances oxidizing in the water or sediment (Odum 1956; Bott 1996). Diurnal fluctuations in oxygen concentrations may result from photosynthesis in excess of respiration as source of oxygen during the day and at night when photosynthesis ceases respiration consumes oxygen and reduces the oxygen concentrations in the water column (Ignjatovic 1968; Bott 1996). Diurnal oxygen fluctuations may also be associated with changes in water temperature. Low oxygen, termed hypoxic in this BO, occurs when oxygen concentrations are below those expected at 100 percent saturation of oxygen between the air and water at the normal pressures and temperatures for the area. In this BO, water with critically low oxygen levels (that is, below 2 mg/L) are termed anoxic.

Oxygen is critical to the biological community and for the breakdown of organic matter. In fact, oxygen, at appropriate saturation, is essential to not only keeping fish like silvery minnows and other aquatic organisms alive, but also for sustaining their reproduction, development, vigor, immune capacity, behavior, movement, and predator response actions (Hughes 1973; Kramer 1987; Breitburg 1992; Pörtner and Peck 2010). Oxygen depletion in streams and lakes is usually associated with excessive temperature, heavy growth of aquatic plants, algal blooms, high concentrations of organic matter, elevated nutrients, or combinations of these conditions (EPA 1995). Understanding and modeling oxygen in rivers helps identify where and when low oxygen events occurs and allows for the identification of pollutant sources that reduce oxygen. BMPs that control excess delivery of oxygen demanding substances, such as sediment, nutrients, and organic matter additions to rivers, which maintain normal water temperatures, and that provide good re-aeration or habitat are effective in maintaining adequate oxygen levels (EPA 1995).

Fish can attempt to compensate for low oxygen conditions by behavioral responses, such as increased use of aquatic surface respiration, changes in activity level or habitat use, and avoidance behavior, though these activities are known to come at a higher energy cost (Kramer 1987; British Columbia Ministry of the Environment (BCME) 1997). Below some threshold oxygen saturation, fish will be expending excess energy to maintain homeostasis and that some degree of physiological stress will occur (Heath 1995). Ventilation rates are often increased, reduced feeding and movement activity are decreased and increased glycolysis and cortisol release can be induced even by short-term low oxygen conditions (Kramer 1987; Heath 1995; BCME 1997). Eventually fish suffocate at critically low oxygen concentrations and begin to die. Additionally, hypoxic conditions may also cause a wide range of chronic effects and behavioral responses in fish that affect them (Downing and Merkens 1957; Kramer 1987; Breitburg 1992).

Chemical Oxygen Demand

Chemical oxygen demand (COD) refers to an environmental test used to determine the amount of organic compounds in water and indicates the mass of oxygen consumed per liter of solution (Veenstra and Nolen 1991). The primary sources of COD are often recalcitrant compounds (e.g., organic matter, iron, ammonia, sulfides, certain nutrients, etc.) and usually it occurs in or on sediment. The depletion of oxygen from the water overlying the bottom sediment is primarily caused by the decomposition of organic matter in sediment. For example, algae, bacteria, and organic matter often settle out of the water column and onto sediment, or, may become re-suspended into the water column whereupon it provides COD and reduces dissolved oxygen (Fillos and Molof 1972; Kreutzberger et al. 1980; Wang 1980; Walker and Snodgrass 1986, Caldwell and Doyle 1995). Sources of COD can include organic matter associated with sediment erosion from arroyo or stream banks, re-suspension of sediment, biotic deposits, biotic activity that re-suspends sediment, and constituents added from point or nonpoint sources. Kreutzberger et al. (1980) reported that low oxygen in the Milwaukee River were primarily associated with COD churned up by stormwater discharges scouring sediment into the water column. Using variables of population density, percentage of impervious surfaces, slope, and expected runoff, Bennett (2013) developed an algorithm score to attribute sources and magnitudes of COD loads in the MRG Watershed MS4 Permit area (Figure 11).

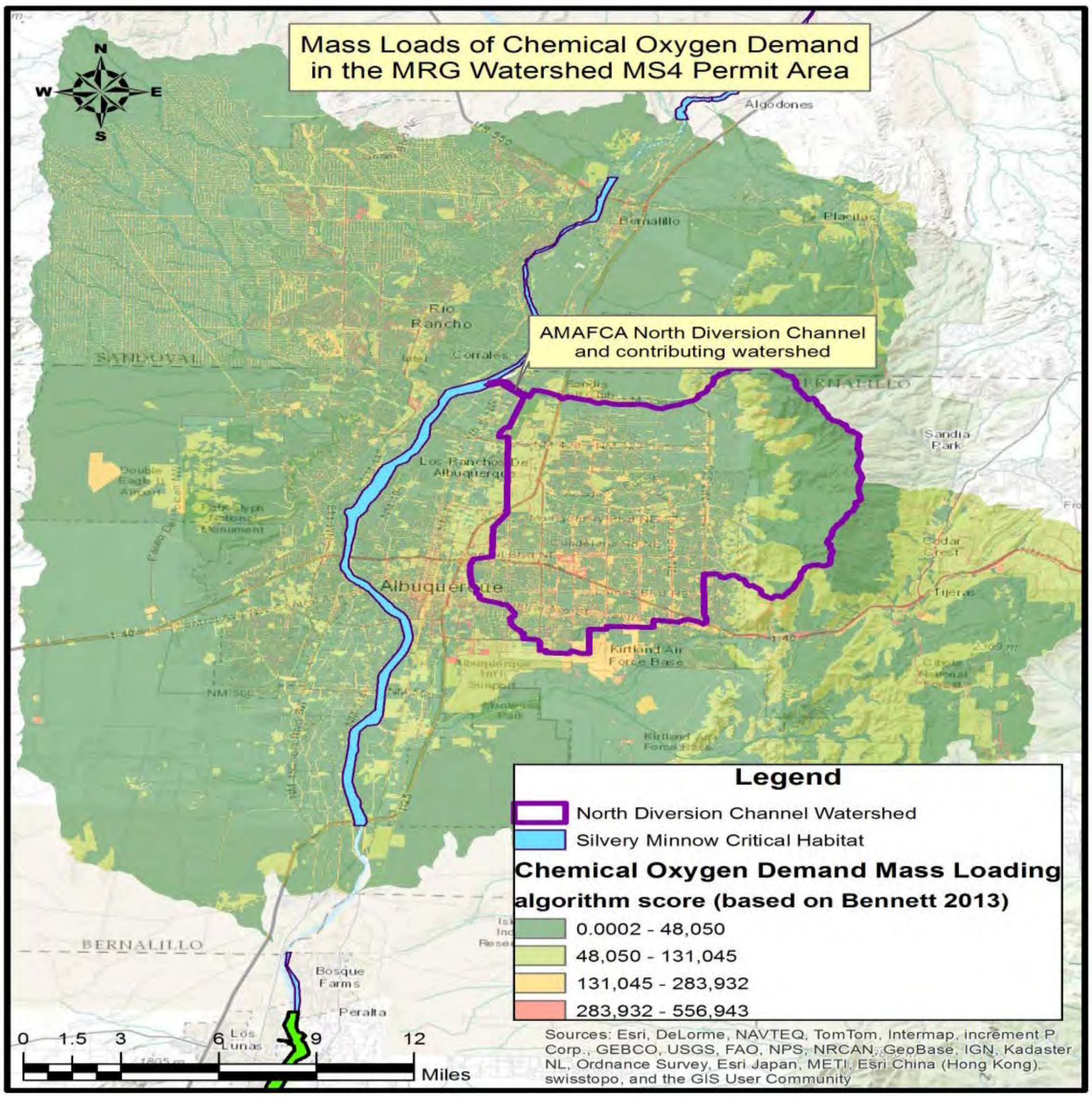


Figure 11. Mass loading of Chemical Oxygen Demand in the MRG Watershed MS4 Permit Area (based on an algorithm developed by Bennett (2013)).

Floodplain Flooding

In the MRG, Valett et al. (2005) found that flooding of the riparian forest soils (floodplain or "bosque") increased the rates of respiration during the flood pulse. In floodplains that were infrequently flooded, inundation of the forest resulted in widespread low oxygen in the floodwaters. For example, Abeyta and Lusk (2004b) reported a fish kill due to low oxygen in a large stagnant floodplain pool after flooding along the MRG. Contributions from the stagnant floodwaters into the main channel would also be expected to decrease temporarily the oxygen content within the MRG downstream. Depending on how the annual cycle of the flood pulse influences primary productivity, plant respiration, decomposition of woody and other vegetation, and water residence time, floodplains may produce and retain enough organic matter to reduce the oxygen of floodwaters on an annual basis (Valett et al. 2005; DBSA 2009). However, the flood events evaluated were not necessarily a "natural phenomena" as the flood frequency and depositional character of the MRG floodplain has been substantially changed, and frequently flooded areas did not experience low oxygen conditions to the same extent as did infrequently flooded areas (Ellis et al. 1998; Valett et al. 2005).

Precipitation events of sufficient intensity can result in increased turbidity, increased or decreased water temperatures, decreased pH, and increased input of oxygen demanding substances (Huggins and Anderson 2005). Conditions in the MRG have led to erosion and sedimentation including natural or anthropogenic-induced variation in water and sediment discharge due to high and low flows, poor land management, flooding, fire, or other activities in the Rio Grande basin (Graf 1994; Scurlock 1998; Julien et al. 2005; Massong et al. 2007). When tributaries and riverbeds are scoured by stormwater runoff, water operations, or other events of sufficient velocity, sediments are re-suspended. The elevated SSC likely creates mixing zones that may scour or smother sessile organisms (algae, bacteria, some invertebrates), or increase turbidity that shades light levels and that reduce temporarily algal production, and may create stressful or suffocating conditions for fish, at least temporarily, until the sediment-water interface is quiescent and rates of respiration decrease. Rainfall and stormwater events of sufficient or even moderate intensity likely increase SSC and turbidity, alter water temperatures, and increase the amount of oxygen demanding substances in the water column (Huggins and Anderson 2005). In addition, stormwater runoff and flow conditions in the MRG can result in physical scouring, reduced light levels, and water fluctuation that can disturb attached plant communities (Huggins and Anderson 2005: Bixby and Burdett 2009). Moderate to large changes in any one of these factors because of a single or multiple events may affect the level of oxygen in the MRG and potentially adversely affect silvery minnows, depending on exposure duration and life stage.

Petroleum Spills and PAHs

There are concerns about the potential petroleum spills (and other chemicals) from pipelines or during transportation in vehicles or by rail along and across the MRG. Based on information reported in the National Response Center database (http://www.nrc.uscg.mil Accessed April 27, 2011), one spill incident involving crude oil has occurred near the action area (upstream). In April 1999, a 41-cm (16-inch) transmission pipeline fitting was ruptured by a backhoe, releasing crude oil into the environment; reports indicated that some might have entered the MRG. Fuels, such as diesel, that are carried by pipelines have documented toxicity to aquatic life due in part to semivolatile compounds. PAHs are known occur during petroleum spills and may persist in contaminated sediments. These PAHs and other organic materials deposited into watersheds through combustion may be transported to fish and into their tissues through foraging on contaminated sediments or prey where they can reach concentrations toxic to fish (Eisler 1987; Schein et al. 2009). A petroleum pipeline break, if it were to spill into the MRG, has the potential to reduce oxygen in the water column as well as contaminate the water, and can cause adverse effects on downstream water quality and to exposed silvery minnows (Lusk 2010). However, the lack of available information on past spill events does not allow the estimation of those effects to silvery minnows or to forecast future frequencies of potential spills.

Using sediment PAH concentrations compared with guidelines, Marcus et al. (2010) identified heavy metal- and PAH-contaminated sediment as posing the greatest toxicity risk to silvery minnows. PAH compounds have been detected in MRG sediment for decades, and are widespread in the MRG (Levings et al. 1998; NMED 2009; Marcus et al. 2010). PAHs can be associated with petroleum spills, but wet and dry atmospheric deposition combustion is a predominant source in the environment (Eisler 1987). Tian et al (2014) identified the three largest sources of PAHs in sediment they studied as from vehicular emissions, coal combustion, and wood combustion. PAHs in sediment are often toxic to aquatic life and may reduce prey populations, and when incorporated into prey or through sediment ingestion can become carcinogenic to fish and other predators (Eisler 1987).

Data on PAHs in MRG sediments can be compared to numerical sediment quality criteria (Probable Effect Concentrations (PECs)) proposed by MacDonald et al. (2000). According to MacDonald et al. (2000) most of the PECs provide an accurate basis for predicting toxicity to aquatic life, and a reliable basis for assessing sediment quality in freshwater ecosystems. Levings et al. (1998) found one or more PAH compounds at 14 sites along the MRG with high concentrations found below the City. Using guidelines similar to PECs, the NMED (2009) identified PAHs as sediment contaminants of concern to silvery minnows in the action area, particularly at Alameda, New Mexico, below the North Diversion Channel. Concentrations of naphthalene, an indicator PAH, ranged up to 17 µg/kg wet weights were found in silvery minnows collected from the MRG (Lusk 2011b). Lusk (2011b) did not ascribe any negative health consequences to the concentrations detected except to note that they were elevated. Except for evaluating PAHs in sediment by various criteria (e.g., PECs), there are few diagnostic criteria for evaluation of PAHs in silvery minnow tissues or methods of evaluation for potential effects to their prey, or how silvery minnow behavior, habitat, feeding, and health (physiological function) may specifically be affected by their widespread exposure to PAHs in the MRG.

Other Stressors

In addition to the compounds and conditions discussed above, several other constituents are present and affect the water quality of the MRG. These include nutrients such as forms of nitrates and phosphorus, total dissolved solids (salinity), and radionuclides. These and other pollutants and physical stressors have the potential to affect the aquatic ecosystem and silvery minnows. Other physical stressors can affect the exposure and response of silvery minnows. For example, as the river dries, pollutants and temperatures tend increase in isolated pools (Caldwell et al. 2009). Toxic pollutants have not eliminated silvery minnows in the MRG, though some localized mortalities have been documented (Marcus et al. 2010). Papoulias et al. (2009) suggested that water quality and other stressors in the MRG might be affecting the health of the silvery minnows they observed.

Climate Change

Warming of the earth's climate is unequivocal, as is now evident from increased average global air and ocean temperatures, widespread melting of glaciers and the polar ice cap, and rising sea level (Intergovernmental Panel on Climate Change [IPCC] 2007). The IPCC (2007) describes changes in natural ecosystems with potential widespread effects on many organisms, including freshwater fish. The potential for rapid climate change poses a significant challenge for fish and wildlife conservation. Species abundance and distribution is dynamic, and dependent on a variety of factors, including climate (Parmesan and Galbraith 2004). Typically, as climate changes, the abundance and distribution of fish and wildlife will also change. Highly specialized or endemic species are likely to be most susceptible to the stresses of changing climate. Based on these findings, the Department of the Interior requires agencies under its direction to consider potential climate change effects as part of their long-range planning activities.

Predicting with certainty the amount of warming that may occur in the future is not possible; however, the IPCC (2007) predicts that continued warming of the climate. Over western North America, median temperatures are projected to increase between 1.3 ºC (2.3 ºF) and 4.4 ºC (7.9 ºF) by year 2100 depending on the rate of greenhouse gas emissions (Christensen and Lettenmaier 2006). The IPCC (2007) also projects that there will very likely be an increase in the frequency of hot extremes, heat waves, and heavy precipitation events. Climate forecasts project a northward shift in the jet stream and associated winter-spring storm tracks, which are consistent with observed trends over recent decades (Trenberth et al. 2007). This would likely result in future drier conditions for the Southwest and an increasing probability of drought for the region (Trenberth et al. 2007). Seager et al. (2007) show that there is a broad consensus among climate models that the Southwest will get drier in the 21st century and that the transition to a more arid climate is already under way.

The New Mexico Office of the State Engineer report (2006) made the following observations about the impact of climate change in New Mexico:

1. warming trends in the Southwest exceed global averages by about 50 percent;
2. modeling suggests that even moderate increases in precipitation would not offset the negative impacts to the water supply caused by increased temperature;
3. temperature increases in the Southwest are predicted to continue to be greater than the global average;
4. there will be a delay in the arrival of snow and acceleration of spring snow melt, leading to a rapid and earlier seasonal runoff; and
5. the intensity, frequency, and duration of drought may increase.

Most of the upper Rio Grande basin is arid or semi-arid, generally receiving less than 25 cm (10 in) of precipitation per year (BOR 2011). In contrast, some of the high mountain headwater areas receive on average over 100 cm (40 in) of precipitation per year. Most of the total annual flow in the Rio Grande basin results, ultimately, from runoff from mountain snowmelt (BOR 2011). In the MRG, there is expected an earlier peak of spring flows, reduced total stream flow, and more water will be lost to evaporation (Hurd and Coonrod 2007). Four major effects on silvery minnow habitat are anticipated associated with a changed climatic regime including: 1) increased water temperature; 2) decreased stream flow; 3) a change in the hydrograph; and 4) an increased occurrence of extreme events (fire, drought, and floods). Overall, climatic changes are expected to degrade silvery minnow habitat quantity and quality and reduce their abundance.

Increased water temperature

Kundzewicz et al. (2007) reported that freshwater ecosystems would have a high proportion of species threatened with extinction due to climate change. Small changes in water temperature are known to have considerable effects on freshwater fishes by affecting a variety of life history, behavioral, and physiological aspects (Morgan et al. 2001; Carveth et al. 2006). Alterations in the thermal regime from natural background conditions could negatively affect population viability, when considered at the scale of the watershed or individual stream (McCullough 1999). Both silvery minnow hatching success, larval survival and development are affected by water temperature (Platania 2000). Primary productivity and oxygen saturation are also affected by higher temperatures. As such, silvery minnows may be adversely affected by increased water temperatures due to climatic changes in addition to existing alterations in their thermal regimes.

Decreased stream flow

Consistent with the outlook presented for New Mexico, Hoerling and Eischeid (2007) stated that, relative to 1990 through 2005, simulations indicated that a 45 percent decline in stream flow is anticipated to occur from 2035 through 2060 in the Southwest. Current modelling suggested a decrease in precipitation in the Southwest (Kundzewicz et al. 2007; Seager et al. 2007), which would lead to reduced stream flows and a reduced amount of habitat for silvery minnows. Stream flows are predicted to decrease in the Southwest even if precipitation were to increase moderately (New Mexico Office of State Engineer 2005; Hoerling and Eischeid 2007). Winter and spring warming may cause an increased fraction of precipitation to fall as rain, resulting in a reduced snow pack, an earlier snowmelt, and decreased summer flows (Regonda et al. 2005; Stewart et al. 2005). Earlier snowmelt and warmer air temperatures can lead to a longer dry season. Warmer air temperatures lead to increased evaporation, increased evapotranspiration, and decreased soil moisture. These three factors could lead to decreased stream flows even if precipitation were to increase moderately.

The effect of decreased stream flow on the MRG include a smaller wetted area; more frequent intermittent or dry conditions; and greater conflicts among water users (Hurd and Coonrod 2007). As such, there will likely be reduced habitat available for aquatic species such as silvery minnows. Reductions in spring flow may reduce the amount of silvery minnow nursery habitat and therefore, result in reduced abundance of silvery minnows in the MRG. As the MRG becomes more intermittent, silvery minnows isolated in pools may be subject to increased predation from terrestrial predators, degraded water quality, or otherwise be more likely to perish.

Change in the hydrograph

Another projected impact of climate change is that warming in the Southwest will result in a shift of the timing of spring snowmelt (BOR 2011). Stewart et al. (2005) show that timing of spring stream flow in the Southwest during the last 5 decades has shifted so that the major peak now arrives 1 to 4 weeks earlier, potentially resulting in less flow in the spring necessary for optimal spawning, nursery, and larval development conditions for silvery minnows. Stewart et al. (2005) concluded that almost everywhere in North America, a 10 to 50 percent decrease in the fraction of spring-summer stream flow will accentuate the seasonal summer dry period with important consequences for water supplies, ecosystems, and wildfire risks. Enquist et al. (2008) found that 93 percent of New Mexico's watersheds have become relatively drier from 1970 to 2006 and that snowpack in New Mexico's major mountain ranges has declined over the past 2 decades resulting in reduced spring flows. The timing of peak stream flow from snowmelt in New Mexico is an average of 1 week earlier than in the mid-20th century (Enquist et al. 2008). Rauscher et al. (2008) suggested that with air temperature increases of 3 to 5 ºC (37 to 41 ºF), snowmelt runoff in the Southwest could occur as much as 2 months earlier than present. Changes in the hydrograph could potentially alter the native fish assemblages and affect the reproductive success of the silvery minnows that are dependent on spring flows for spawning and fall recruitment (Platania and Hoagstrom 1996; Dudley et al. 2013).

Increased occurrence of extreme events

It is anticipated that an increase in extreme events (droughts, floods, fires) will most likely affect fish populations living at the edge of their physiological tolerances. The predicted increases in extreme temperature and precipitation events may lead to dramatic changes in the distribution of species or to their extirpation or extinction (Parmesan and Matthews 2006). Of these extreme events drought may be most important to silvery minnows.

As of July 12, 2011, the MRG basin is experiencing severe to extreme drought conditions (University of Nebraska-Lincoln 2010). These conditions often result in greater human water use rates, evaporation, and conflict among water users. The low stream flow conditions during drought and after agricultural, municipal and riparian vegetation consumption can leave the MRG in an intermittent or drying condition that does not fully support silvery minnow habitats and reduces its survivorship and abundance. Thus, we can expect a decline in silvery minnow abundance during drought years with management actions taken to prevent their extirpation.

Flows and Water Quality in the North Diversion Channel

Several scientists have reported on water quantity and quality of the water in the North Diversion Channel and downstream (Harwood 1995; Kelly and Romero 2003; Buhl 2005; Kelly et al. 2006; Van Horn 2008; DBSA 2009; USFWS 2011, 2012). The Service further queried the USGS National Water Information System for results from all field and laboratory water-quality samples collected from USGS Gage 08329900 North Floodway Channel near Alameda, NM, (at the website: http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=08329900). We discuss those results here to better characterize the quality of stormwater discharges in the North Diversion Channel and that may enter the MRG at its confluence and flow downstream.

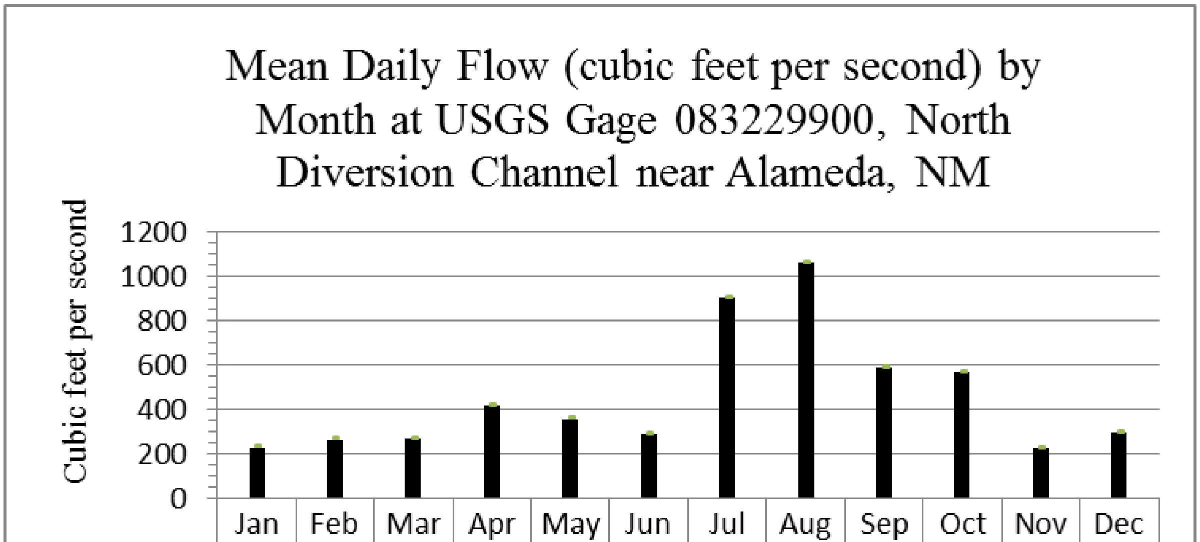
Mean daily flow at the North Diversion Channel averaged 8 cfs and ranged from 0 to 1060 cfs, with most stormwater discharges occurring in July and August (Figure 12) associated with precipitation events in the City or in the mountainous watersheds to the east. Concentrations of suspended sediment (SSCs, in mg/L) varied widely in stormwater discharges at North Diversion Channel gage over time and ranged from 1 to 14,900 mg/L (Figure 13). Since SSC substantially declined after 1990, only those post-1990 data were summarized by month (Figure 14), which indicated July and August had the highest SSCs, which also corresponded to precipitation events.

There is a complex relationship between flow and SSCs in sand-bed streams, with some physical processes involved in sediment detachment and transport indicating that increased energy, from storm events, will mobilize more sediment in the discharge (Wright 2003; Shoemaker et al. 2012). At least 40 percent of the SSC increased with increased flow as measured by instantaneous discharge (Figure 15). However, because the proportion of small-sized particles (e.g., clay, silt, and very fine sand) in the SSCs is high (average of 70 percent were less than 0.0625 mm in diameter, n=97) in the North Diversion Channel, SSCs would also be expected to be high during low flow events too (Figure 15).

SSCs in stormwater discharges are of interest because they contain some proportion of organic matter, which tends to increase the amount of COD in stormwater discharges that may travel through the North Diversion Channel and into the MRG (Figure 16). Using continuously monitored oxygen concentrations in the North Diversion Channel and in the MRG upstream, the rates of decline of oxygen were estimated on an hourly basis (Figure 17) by extrapolating from plots of continuously monitored oxygen (Stearns 2013). The average loss of oxygen in the MRG was 0.18 mg/hour, whereas, the loss of oxygen in the North Diversion Channel averaged 0.35 mg/hour. Therefore, the rate of the oxygen loss in the North Diversion Channel was nearly twice the rate of oxygen loss in the MRG. This also suggested that MRG water and sediment may not be the only source of oxygen decline in the North Diversion Channel or that temperature, turbulence, or respiration rates in these two areas may variously affected the rates of oxygen loss.

In summary, SSCs were generally associated with storm events that commonly occurred in July and August with the increased volume of stormwater discharges in the North Diversion Channel. The amount of COD was related to concentrations of suspended sediment in the North Diversion Channel. The rate of oxygen loss in the North Diversion Channel was nearly twice the rates in the MRG. Solutions to the problem of low oxygen events in the North Diversion Channel could involve the reduction of SSCs in stormwater discharges that may also reduce the amounts of COD and therefore, the frequency or magnitude of low oxygen events in the Embayment and downstream. Not all SSCs should be reduced, however, just those known to contain high COD.

According to EPA (2010d, 2013b) and the City et al. (2010), stormwater discharges from urbanized areas are a concern because of the higher concentration of pollutants typically found in these discharges. Polluted stormwater runoff generally happens anywhere people use or alter the land. Some common examples include over-fertilizing lawns, improper pesticide use, pet and bird wastes, using salt or other compounds to de-ice a driveway, letting oil drip out of vehicles, and littering. In developed areas, the water that falls on hard surfaces like roofs, driveways, parking lots, and roads cannot seep into the ground. These impermeable surfaces create high-velocity runoff that can easily pick up debris and pollutants (including sediments with COD)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	0	0	0	0	0	0	0	0	0	0	0	0
Max	225	260	266	413	352	285	902	1060	585	564	223	292
Average	3	4	5	6	5	7	18	20	12	11	5	4

Figure 12. Statistical summary and monthly distribution of mean daily flows (cubic feet per second) at the North Diversion Channel gage (083229900) near Alameda, New Mexico.

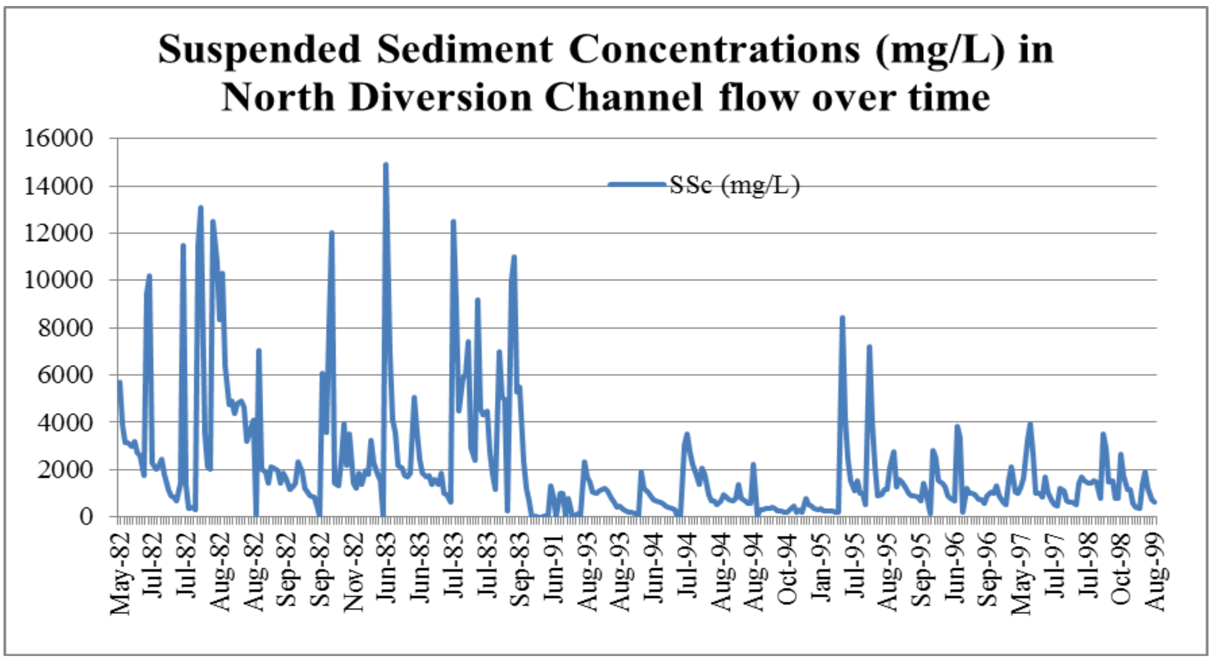
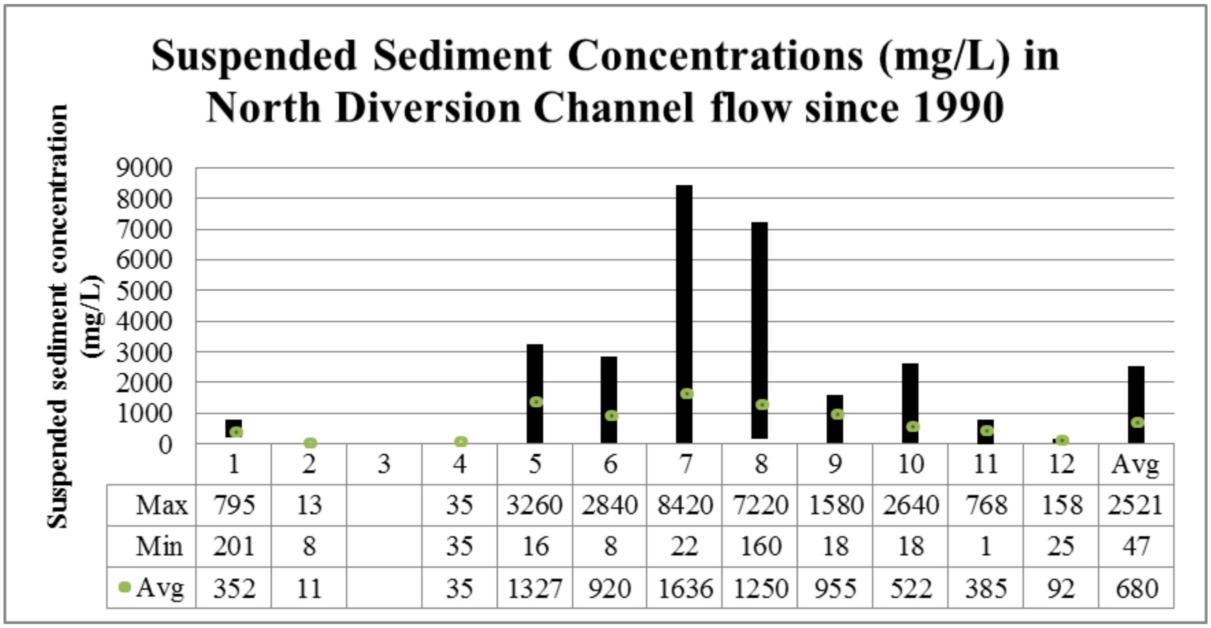


Figure 13. Suspended sediment concentrations (mg/L) measured over time at the North Diversion Channel gage (083229900) near Alameda, New Mexico.



	1	2	3	4	5	6	7	8	9	10	11	12	Avg
Max	795	13		35	3260	2840	8420	7220	1580	2640	768	158	2521
Min	201	8		35	16	8	22	160	18	18	1	25	47
Avg	352	11		35	1327	920	1636	1250	955	522	385	92	680

Figure 14. Statistical summary and monthly distribution of suspended sediment concentrations (mg/L) measured at the North Diversion Channel gage (083229900), since 1990.

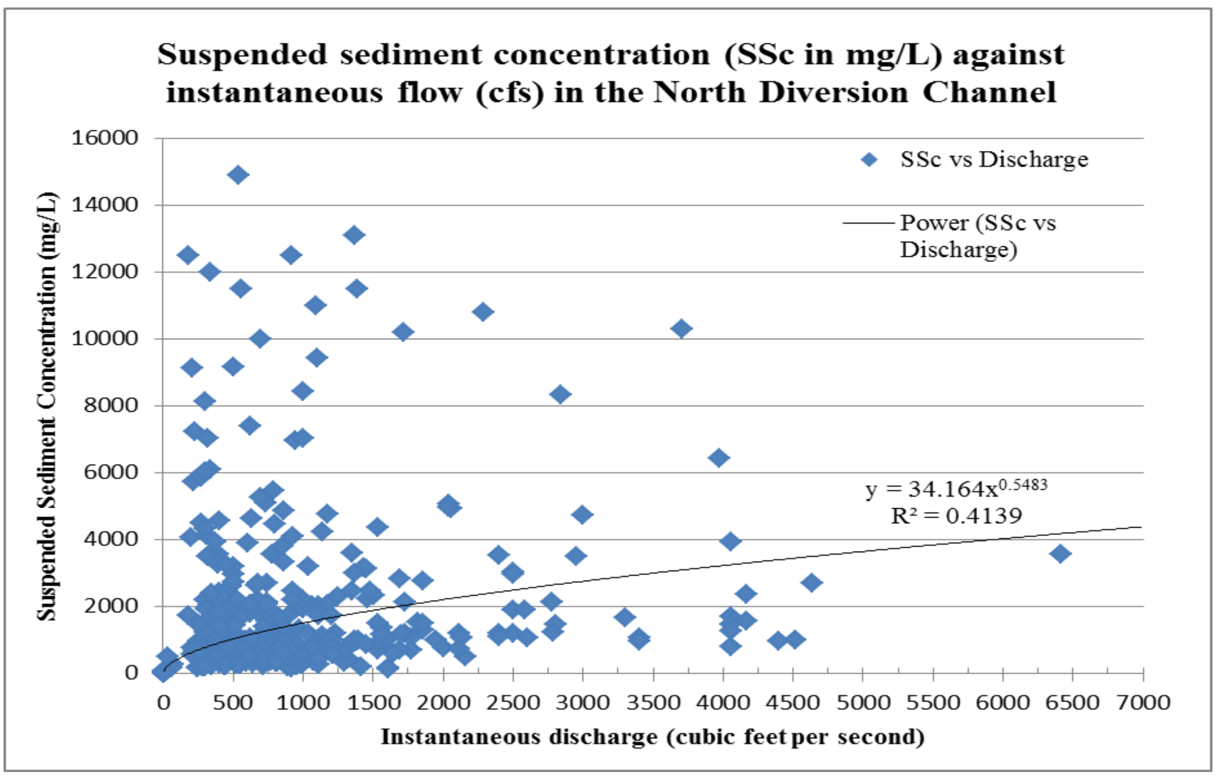


Figure 15. Suspended sediment concentrations (mg/L) versus instantaneous flow (cfs) at the North Diversion Channel gage (083229900) near Alameda, New Mexico.

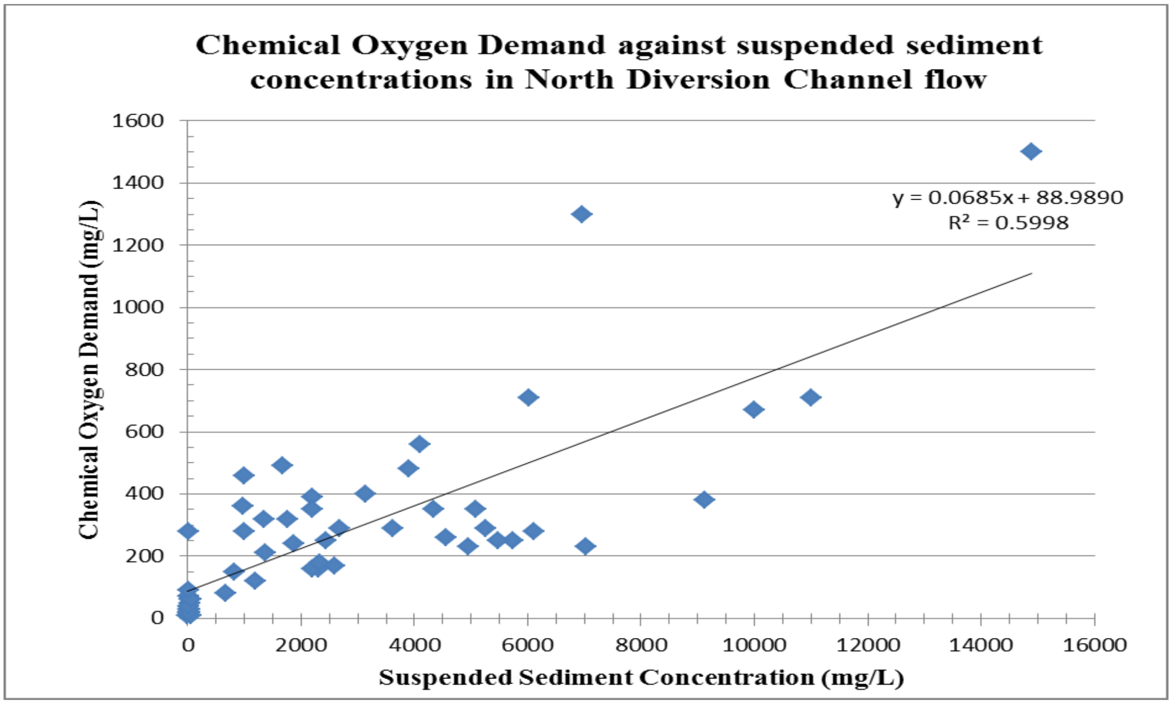


Figure 16. Chemical Oxygen Demand (mg/L) versus suspended sediment concentrations (mg/L) measured at the North Diversion Channel gage (083229900) near Alameda, New Mexico

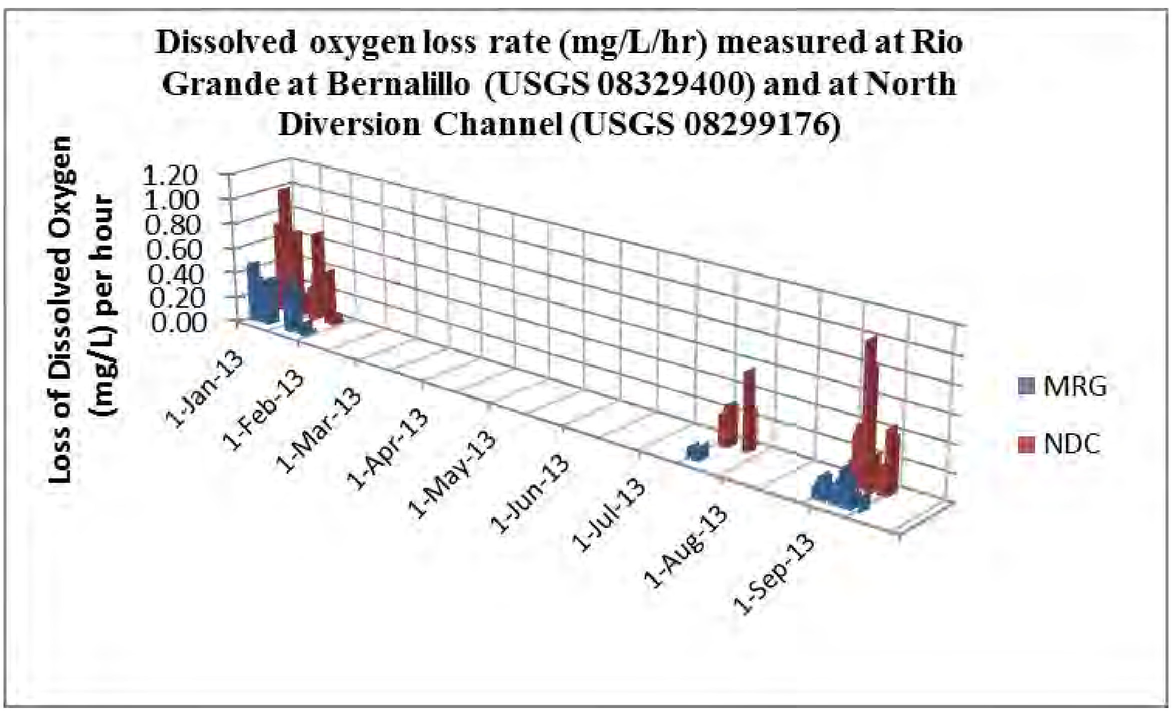


Figure 17. Rates of dissolved oxygen loss (mg/hour) based on extrapolation of diurnal oxygen curves from continuous monitoring stations in the North Diversion Channel and in the MRG.

and wash them into nearby storm drains and downstream into the MRG. Stormwater with sediment may have adhered pollutants that are carried with their transport and conveyance if inadequately treated. Sometimes, stormwater is not treated at all or is not treated adequately before entering the MRG, which the proposed action seeks to address.

According to Hoover (2010), more than 2.4 x 10^7 cubic meters (m^3) (6.4 billion gallons) of stormwater are discharged annually in the MRG Watershed MS4 Permit Area. The average total suspended solids (TSS) concentration of this stormwater was 640 milligrams per liter (mg/L). When this TSS concentration is multiplied by the discharge volume of stormwater, it equates to approximately 1.5 x 10^6 kilograms (kg) per year (3.4 x 10^6 pounds per year) of sediment and other solids conveyed to the MRG. While the MRG receives many tons of the sediment from natural runoff and erosion, the introduction of polluted sediments from urban stormwater poses an additional risk to the receiving water and to silvery minnows. Pollutants commonly found in stormwater discharges in the MRG Watershed (often adhering to sediment) include petroleum hydrocarbons (from oil spills, parking lot runoff, illicit dumping, roadways, atmospheric deposition); metals (aluminum, cadmium, lead, nickel, copper, chromium, mercury, and zinc); nutrients (phosphates, nitrogen compounds, potassium, trace elements, salts); pesticides (herbicides, insecticides, fungicides, etc.); toxic chemicals (PCBs, radionuclides) and solid waste (Kelly and Romero 2003; Kelly et al. 2006; EPA 2002, 2010a, 2010b; NMED 2010; Lusk 2011).

The City, AMAFCA, and USGS began collecting and analyzing stormwater quality data in the Albuquerque area in 1976 (Kelly and Romero 2003). Beginning in 1994, the USGS sampling program has been included as part of an urban stormwater monitoring program (Kelly and Romero 2003). Currently, there are five discharges monitored for the MRG Watershed MS4 Permit and those stations provide data on the quality of stormwater discharges in the action area. Parameters analyzed include priority pollutants, conventional, nonconventional, organic toxics, and other pollutants. Conventional pollutants and metals are reported annually while monitoring for the other parameters was performed biannually (Kelly et al. 2006).

Actions Taken to Address the North Diversion Channel Low Oxygen Conditions

AMAFCA (DBSA 2009) identified the oxygen-depleted water standing in the Embayment, a large, narrow, water body within the North Diversion Channel between the earthen retaining feature and the MRG (Figure 2), as contributing to the low oxygen conditions measured there and downstream. The Embayment is approximately 1,400 ft (423 m) in length by 260 ft (79 m) in width, with a surface area of approximately 8.5 acres (34,398 m^2), and with depths ranging from 1 to 3 ft (0.3 to 0.9 m). Previously, the Embayment surface area was approximately 4.7 acres (USFWS 2012). Stormwater that passes the USGS gage station (08329900, North Floodway near Alameda) prior to entering the Embayment, often contains oxygen contents ranging from 4.9 to 11.5 mg/L (DBSA 2009). However, whenever stormwater discharging through the North Diversion Channel stands, including in the Embayment (i.e., where flow and current velocity may stop), the water will quickly become stagnant, and may eventually contain little to no oxygen (less than 0.1 mg/L) (DBSA 2009; Stearns 2013, 2014). The dynamics of MRG flows and sediment deposition at the mouth of the Embayment have not been fully characterized, and may play a role in the development of low oxygen events there. Therefore, while oxygen contents in stormwater upstream of the Embayment appear to be adequate, sediment deposited by the MRG may nonetheless contain or introduce oxygen-demanding substances that contribute to the reduction of oxygen in the waters, whenever they stand or when they mix in the Embayment. However, it is the oxygen-demanding substances conveyed by stormwater discharges and their breakdown in the Embayment that likely plays a major role.

DBSA (2009) identified that as long as the Embayment remains in place, oxygen-depleted water in the Embayment could continue to cause short-term decreases in oxygen concentrations in the MRG. They identified three possible solutions to the low oxygen problem including aeration, mixing the MRG with the water in the Embayment, or removing the Embayment by filling (DBSA 2009). In 2012, AMAFCA partially filled and reshaped the Embayment to allow stormwater to flow over the earthen fill in a modified channel configuration and mix more immediately with the MRG (Paulsgrove 2011, USFWS 2012). Additionally, in August 2013, AMAFCA installed windmill-powered air diffusion that provides additional aeration to the water column in the Embayment. AMAFCA has indicated they will seek to modify this outfall further.

Mixing calculations (DBSA 2009) demonstrated that the volume of Embayment water was sufficient to cause significant decreases in oxygen of the MRG downstream (Van Horn 2008; DBSA 2009; USFWS 2011) as far as 33 km (20 mi) downstream (Van Horn 2008; DBSA 2009; USFWS 2011), when the Embayment had a surface area of 4.7 acres. The Embayment contains nearly twice the surface area (8.5 acres), but less volume, and therefore the distance stagnant water in the Embayment is pushed by stormwater runoff conveyed through the North Diversion Channel into the MRG has not been adequately characterized. However, the relative frequency of low oxygen (hypoxic) and zero oxygen (anoxic) events were 98 times and 20 times per year, respectively, with the previous Embayment width and area (AMAFCA 2011; USFWS 2011). After the reshaping of the Embayment, the frequency of low oxygen and zero oxygen events in the Embayment and downstream were estimated to be approximately 50 times and 22 times per year, respectively (using Stearns 2013). However, data available after reshaping and the installation of air diffusion are few and preliminary (Stearns 2013).

The frequency of low oxygen events were estimated by the Service without regard to the number of qualifying events based on Stearns (2013). When using only qualifying stormwater events, the frequency of hypoxic and anoxic oxygen conditions in the Embayment and downstream were estimated to be 16 times and 8 times per year in 2013 (Stearns 2014). Using ratios, Stearns (2014) estimated that the projected annual maximum frequency of hypoxic and anoxic oxygen conditions in the Embayment and downstream would be approximately 28 times and 14 times per year. The Service recognizes there are uncertainties in projecting future qualifying storm events based on previous precipitation data (Hurrell et al. 2009; Murphy et al. 2010; Goddard et al. 2012; Vermeulen et al. 2013) and associated runoff data (Stearns 2014). To address these uncertainties, the Service used the coefficient of variation (0.3) (from the natural logarithm transformed instantaneous flows reported in the North Diversion Channel), to bias Stearns (2014) projected annual maximum frequency, and thereby estimate the total future frequency of hypoxic and anoxic oxygen conditions in the Embayment and downstream at 36 and 18 times per year, respectively, during the proposed MRG Watershed MS4 Permit action.

Compared to 2009-10 (USFWS 2011), the frequency of low oxygen events does appear to have reduced some after changes to the width and depth of the Embayment, and perhaps, with the addition of the windmill-powered air diffusion after August 2013, but the volume of anoxic water in the Embayment is an acute problem and remains sufficient to decrease the oxygen content of the MRG as far as 33 km (20 mi) downstream. Therefore, the Service remains concerned that low oxygen events may continue to occur in the Embayment and downstream in the MRG after implementation of the MRG Watershed MS4 Permit action based upon the frequency and duration of anoxic events even after the recent implementation of BMPs that addressed the shape of the Embayment or deployed aeration. However, AMAFCA, the City, EPA, and the Service remain committed to working on these issues involving stormwater discharges in the North Diversion Channel for the next few years to address these problems.

Past Projects in the Middle Rio Grande including the Angostura Reach

The Service has issued permits authorizing take for scientific research and enhancement purposes under ESA section 10(a)(1)(A), and incidental take under section 7 for Federal actions. Applicants for ESA section 10(a)(1)(A) permits must also acquire a permit from the State of New Mexico to "take" or collect silvery minnow. Many of the section 10 permits issued by the Service allow take for the purpose of collection and salvage of silvery minnows or their eggs for captive propagation. Eggs, larvae, and adults are also collected for scientific studies to further our knowledge about the species and how best to conserve the silvery minnow. Because of the population decline from 2002 to 2004, the Service has reduced the amount of take permitted for voucher specimens in the wild. With the overall reduction in abundance, the Service has also reduced the amount of take permitted under ESA section 10(a)(1)(A) permits.

However, the largest sources of incidental takes of silvery minnows are associated with federal projects. The Service has conducted numerous section 7 consultations on past projects in the MRG. In 2001 and 2003, the Service issued jeopardy biological opinions resulting from programmatic section 7 consultations with BOR and Corps, which addressed water operations and management on the MRG and the effects on the silvery minnow and flycatcher (USFWS 2001, 2003a). Incidental take of listed species was authorized associated with the 2001 programmatic BO (USFWS 2001), as well as consultations that tiered off that opinion.

A jeopardy finding was issued on March 17, 2003 (2003 BO), and is the current programmatic biological opinion on water operations for the MRG, and contains one RPA with multiple elements (USFWS 2003a). These elements set forth a flow regime in the MRG and describe habitat improvements necessary to alleviate jeopardy to both the silvery minnow and flycatcher. In 2005, the Service revised the incidental take statement (ITS) for the 2003 BO using a formula that incorporates October monitoring data, habitat conditions during the spawn (spring runoff), and augmentation (USFWS 2005b). Incidental take of silvery minnows is authorized with the 2003 BO (with 2005 revised ITS), and now fluctuates on an annual basis relative to the total number of silvery minnows found in October across the 20 population monitoring locations. Incidental take is authorized through consultations tiered off this programmatic BO and on projects throughout the MRG.

Within the Angostura Reach of the MRG, the Service has conducted numerous section 7 consultations on past projects, including the following formal consultations:

- In 1999, the Service consulted with BOR on a restoration project on the Santa Ana Pueblo in an area where the river channel was incising and eroding into the levee system. The second phase of this Rio Grande Restoration Project at Santa Ana Pueblo underwent consultation in 2008, and the Service anticipated that up to 36,688 silvery minnow would be harassed by construction, fill placement in the river, and movement of equipment; no mortality was expected (USFWS 2008b).
- In 2003, the Service completed consultation with the BOR on the City's Drinking Water Project, which involved the construction and operation of a new surface diversion at Almeida in the action area, conveyance of raw water to a new treatment plant, transmission of treated water to customers throughout the Albuquerque metropolitan area, and aquifer storage and recovery. The Service anticipated that up to 20 silvery minnows would be killed or harmed during construction, up to 25,000 eggs would be entrained each year at the diversion, and up to 7,000 larval fish would be harmed, wounded, or killed during operational activities (USFWS 2004).
- The Service consulted on habitat restoration projects on the MRG near Albuquerque, including the 2005 Phase I, the 2007 Phase II, and the 2009 Phase IIa projects (USFWS 2005b, 2007c, 2009) with BOs issued that reviewed the effects on silvery minnows. Incidental take authorized included 190 silvery minnows in 2005 due to harm or harassment, in 2007 the harassment of up to 3,365 minnows and mortality of up to 341 minnows, and in 2009 the harassment of up to 4,094 minnows and mortality of up to 187 silvery minnows.
- In 2006 and 2007, the Service consulted with BOR on the Bernalillo Priority Site Project and the Sandia Priority Site Project for river maintenance activities (USFWS 2006b, 2006c). The Bernalillo project was anticipated to kill no more than 42 silvery minnows due to channel modification, berm removal, dewatering, and sediment deposition in the river. The most recent consultation on the Sandia Priority Site Project concluded that take of up to 539 silvery minnows, and harassment of 53,853 silvery minnows would occur due to construction activities.
- In 2007, the Service determined through consultation with the Corps on the Rio Grande Nature Center Habitat Restoration Project, that up to 10 silvery minnows would be harassed during construction and that up to 154 silvery minnows would be killed due to entrapment in constructed channels (USFWS 2007d).
- In 2007, consultation on the Corrales Siphon River Maintenance Project concluded that the harassment of up to 244 silvery minnows would occur during construction, fill placement in the river, and movement of equipment (USFWS 2007e).
- In 2008, the Service concluded an intra-Service consultation on the Pueblo of Sandia Management of Exotics for the Recovery of Endangered Species Habitat Restoration Project. The Service anticipated that up to 2,449 silvery minnows would be harassed due to construction, and up to 770 killed due to potential entrapment in channels (USFWS 2008c).
- In 2009, the Service concluded a consultation with the BOR on the Pueblo of Sandia Bosque Rehabilitation Project, which anticipated that up to 85 silvery minnows, would be harassed during the proposed restoration activities, and up to 269 would be killed due to potential entrapment in a restored channel (USFWS 2009b).

- In 2010, the Service consulted with BOR for a habitat restoration project located on the Pueblo of Sandia. The Service anticipated that take in the form of harassment may affect up to 36,318 silvery minnow due to proposed construction and river crossings, as well as the harassment and mortality of up to six silvery minnows due to potential stranding in restored features after peak flows recede (USFWS 2010c).
- In 2011, the Service (2011) consulted with EPA for the Albuquerque MS4 permit. The Service anticipated that up to 10,548 silvery minnows would be harassed by low oxygen events and as many as 1,528 silvery minnows would suffocate to death.
- In 2012, the Service consulted with Corps for the AMAFCA embayment project. The Service anticipated that 5,670 silvery minnows would be trapped by activities and 847 silvery minnows would die due to stress and water quality degradation.
- Additionally, there have been or are planned, numerous habitat restoration projects in the Angostura Reach of the MRG. Projects have been funded by many organizations including the Collaborative Program, MRG Bosque Initiative, and the Corps. Examples of ongoing and completed projects include:
    - The Pueblo of Santa Ana is creating over 100 acres of riparian wetland habitat along the active floodplain, 40 of which are complete. More than 725 acres of cottonwood bosque have been restored through the clearing of saltcedar and Russian olive (a total of 1,300 acres are slated for restoration).
    - The Pueblo of Sandia cleared and revegetated 29 acres of bosque and completed in-channel modifications to an adjacent 10 acres island/bar.
    - At the Rio Grande Nature Center, the Corps created a high-flow side channel (3 acres) that reconnects the Rio Grande with the bosque, and 10 acres of exotic vegetation removal and native shrub plantings.
    - The NMISC has completed several habitat restoration projects in the Angostura and Isleta Reaches. These projects total approximately 257 acres and include such features as backwaters, embayments, scoured and terraced banklines, modified islands, ephemeral channels, lateral constraint removal (e.g., jetty jacks), placement of large woody debris to create scour flows, and floodplain vegetation management.
    - The City has completed a riverine and bosque habitat restoration project on approximately 58.3 acres of land managed by the City and the MRGCD. The project utilized techniques such as passive restoration, modification of islands and bars, construction of ephemeral channels, backwater channels and back waters, removal of lateral confinements, placement of woody debris, and active restoration of riparian vegetation.
    - The Corps has completed a 121-acre bosque restoration project near Central Avenue in Albuquerque, New Mexico. This project included the removal of jetty jacks and non-native vegetation, the creation of 3 high flow channels, the enhancement of an outfall wetland, the creation of willow swales and planting of native vegetation.
    - The Pueblo of Sandia completed a restoration project at 11 locations within the Angostura Reach. This project totaled approximately 36 acres and involved the creation of backwaters, bankline benches, modifications to river islands and bars, placement of large woody debris, and seeding with native vegetation.

- The New Mexico State Land Office has begun work on a 22 acre riverine restoration project in the Angostura Reach between RM 172.6 and 173.4 that will involve riverbank terracing, placement of large woody debris, the creation of ephemeral and backwater channels, the removal of jetty jacks, the removal and treatment of exotic species and planting of native vegetation.
- The Corps has begun work on a bosque restoration project involving approximately 916 acres along 26 miles of the Rio Grande. The project aims to improve hydrologic functions through the construction of high flow channels, willow swales and wetlands, and to restore native vegetation and habitat through jetty jack removal, thinning of exotic species and re-vegetation with native species.
- The Albuquerque Bernalillo County Water Utility Authority has proposed restoration of riparian habitat involving approximately 161 acres centered on the Paseo del Norte bridge crossing, between RM 189.8 and 191.3. The project will include non-native vegetation clearing, floodplain expansion through removal of jetty jacks, channel widening and destabilization, terrace lowering to re-establish floodplain hydraulic connectivity, and construction of ephemeral (high flow) side channels.
- The Pueblo of Santa Ana Bar 3 Modification Project will create ephemeral channels within an existing river bar to create aquatic habitat for larval and juvenile silvery minnows. This project will comprise approximately 22 acres when completed in 2013 or 2014 and is located on the east side of the Rio Grande in the Angostura Reach between RM 205.8 and RM 206.3.
- The New Mexico State Land Office has proposed restoration of riparian habitat involving approximately 21.5 acres of State Trust Land in the Angostura Reach, between RM 172.6-173.4. This project will include non-native vegetation removal and native vegetation restoration, removal of jetty jacks, high flow side channel and backwater creation, and large woody debris placement in-channel.

Most of the restoration projects have focused on the creation and improvement of silvery minnow habitat, and to a lesser extent flycatcher habitat. Many included an objective of providing additional low velocity habitats during inundation of channel and floodway. Currently, restoration projects are monitored individually without standardized objectives, protocols or parameters for data collection and determining effectiveness. Anticipated beneficial effects of habitat restoration projects to silvery minnow have not yet been realized at the population level. The silvery minnow habitat constructed to date can provide suitable depths and velocities at certain discharges and silvery minnows have been detected using constructed habitats. However, it is likely that the availability of habitats has not compensated for former habitat loss or is at an insufficient scale to lead to a favorable population level response.

Summary of the Environmental Baseline

The remaining population of the silvery minnow is restricted to approximately 7 percent of its historical range. With the exception of 2008, every year since 1996 has exhibited at least one drying event in the river that has negatively affected silvery minnows. The species is unable to expand its distribution because of poor habitat quality and irrigation diversion dams, Cochiti Dam prevents upstream movement and Elephant Butte Reservoir blocks downstream movement (USFWS 2010). Augmentation of silvery minnow with captive-reared fish has been ongoing, and monitoring and evaluation of these fish provide information regarding the survival and movement of individuals. Augmentation is now scheduled to continue in the Angostura Reach.

Water withdrawals affect the survival of silvery minnow. The consumption of surface water and shallow groundwater for municipal, industrial, and irrigation uses continues to reduce the flow in the MRG and degrade habitat for the silvery minnow (BOR 2003). The effect of water withdrawals means that discharges from WWTPs, urban stormwater discharges, and irrigation return flows will have greater importance to silvery minnows and a greater effect on water quality. Lethal levels of chlorine and ammonia have been released into the environment, but their frequency of release has declined over time. Stormwater discharges appear to contribute to low oxygen conditions in the MRG that can harm silvery minnow feeding and sheltering activities. In addition, a variety of organic chemicals, heavy metals, and pesticides have been documented in stormwater or wastewaters feeding into the river and that may cumulatively contribute to the overall degradation of water and sediment quality in the MRG.

Various conservation efforts have been undertaken in the past and others are currently being carried out in the MRG for the benefit of the silvery minnows. Population monitoring indicates that densities of this species have declined to densities less than observed at the time of its listing as endangered in 1994. In 2013, in the Angostura Reach, densities of wild silvery minnow are as low as ever measured (Dudley and Platania 2013b). The threat of extinction for the silvery minnow continues because of reductions in the frequency and magnitude of spring flow, decreased water availability and habitat, increased reliance on captive propagation, the degraded fragmented and isolated nature of currently occupied habitat, and the absence of silvery minnows throughout most of its historical range.

IV. EFFECTS OF THE ACTION

Regulations implementing the ESA (50 CFR 402.02) define the *effects of the action* as the direct and indirect effects of an action on the species or designated critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, which will be added to the environmental baseline. Indirect effects are those that are caused by the proposed action and are later in time, but are still reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification; interdependent actions are those that have no independent utility apart from the action under consideration. The following sections describe the anticipated effects on silvery minnow and its designated critical habitat resulting from the proposed action.

Effects on Silvery Minnow

Oxygen depletion is usually associated with excessive temperature, heavy growth of aquatic plants, algal blooms, or high concentrations of organic matter and nutrients (EPA 1995). Oxygen depletions in the MRG have been associated with stormwater discharges from tributaries and urban areas, and floodplain inundation in areas with high concentrations of organic matter

(Abeyta and Lusk 2004b; Valett et al. 2005; Van Horn 2008; DBSA 2009; USGS 2011a, b; Lusk 2011b). Fish can attempt to compensate for low oxygen conditions by behavioral responses, such as increased use of aquatic surface respiration, changes in activity level or habitat use, and avoidance behaviors, though these responses come at a higher energy cost (Kramer 1987; BCME 1997). Below some threshold oxygen saturation, fish will be expending excess energy to maintain homeostasis and that some degree of physiological stress will occur (Heath 1995). Ventilation rates are often increased, reduced feeding and movement activity are decreased and increased glycolysis and cortisol release can be induced by short-term low oxygen conditions (Kramer 1987; Heath 1995; BCME 1997). Additionally, low oxygen conditions may also cause a wide range of chronic effects and behavior responses in fish (Downing and Merkens 1957; Kramer 1987; Breitburg 1992).

Buhl (2007, 2011) reported that 50 percent of the test population of silvery minnow larvae (6-days post-hatch in age) died when exposed to water containing oxygen at 0.7 mg/L (8.7 percent oxygen saturation) during 24 to 96 hr exposures, even when allowed access to the water surface. Buhl (2011) reported that 50 percent of the test population of adult silvery minnow exposed to water containing oxygen from 0.8 mg/L (6.7 to 13.2 percent oxygen saturation) for 3-hr exposure without access to the water surface. Buhl (2011) reported that the highest oxygen concentration observed without acute mortality to larval silvery minnow (that had no access to the water surface) was 14.3 mg/L (i.e., at 29.8 percent saturation). Buhl (2011) reported that the highest oxygen concentration observed without acute mortality to adult silvery minnow (that had no access to the water surface) was 4.4 mg/L (i.e., at 54.3 percent saturation).

From these data, we assumed that silvery minnows in water at 25.7 °C (78.3 °F) with oxygen less than or equal to 4.4 mg/L (i.e., at 54.3 percent saturation) will begin to experience mortality as well as experience adverse effects such as changes in their ventilation rates, increased use of surface water respiration, lack of feeding, and metabolism changes. In addition, the condition or position of the fish may be altered and lead to an increased risk of predation. Using the Buhl (2011) results, oxygen concentrations at 0.7 mg/L (8.7 percent oxygen saturation) are identified as lethal to 50 percent of larvae silvery minnow, and below 4.4 mg/L (54.3 percent saturation) begins the onset of mortality and other acute adverse effects in adult silvery minnows. Temperature and pressure can affect the solubility of oxygen in water, in the MRG (as compared to Buhl (2011) temperature and pressure); we used the oxygen saturation values (8.7 and 54.3 percent respectively) to generate effect levels for adverse effects (for lethality and harassment) in this BO by water temperature and atmospheric pressures expected at the North Diversion Channel and surrounding area in the MRG (Table 2).

When stormwater or MRG water is anoxic (approximately 0 to 2 mg/L), that is, the saturation of oxygen in water for any seasonal water temperature is at or less than 8.7 percent, we define those conditions as lethal to silvery minnows (Table 2). Stormwater or MRG water is hypoxic (less than 100 percent saturation based on the temperature of the water and the atmospheric pressure at the time), when the saturation of oxygen in water for any seasonal water temperature is less than 54.3 percent. We define hypoxic conditions when oxygen saturation is at or less than 54.3 percent as harassment (even though there may be some minor lethality). Hypoxic conditions when oxygen saturation is 54.3 percent or less are known to cause changes in silvery minnows behaviors such as causing them to flee from the adverse environmental conditions or begin aquatic surface respiration instead of their normal feeding and sheltering activities) (Table 2). When anoxic or hypoxic stormwater accumulates in the North Diversion Channel Embayment and/or is discharged to the MRG, we refer to those as low oxygen events. We describe a frequency of occurrence for low oxygen events, some are which are anoxic and some of which are hypoxic.

When a discharge of anoxic stormwater occurs from the Embayment into the MRG, it has a mixing zone where anoxic conditions may occur, which we termed the "lethal zone" and a mixing zone where hypoxic conditions occur, which we term the "impact area." When hypoxic conditions occur in the stormwater in the Embayment or hypoxic stormwater is discharged into the MRG, the mixing zone is termed an impact area where the harassment of silvery minnows occurs. When anoxic conditions occur in the stormwater in the Embayment or anoxic stormwater is discharged into the MRG, the mixing zone is termed a lethal zone where death of silvery minnows is inevitable, if they are unable to flee the anoxic conditions. As those anoxic conditions subside, yet remain hypoxic, an impact area remains until dilution by saturated oxygen conditions return to the area restoring suitable silvery minnow habitat. Hypoxic or anoxic stormwater both cause adverse effects to silvery minnows and may adversely affect critical habitat where those conditions occur in critical habitat.

There will be adverse effects to silvery minnows during the period in which the MRG Watershed MS4 Permit is authorized resulting from stormwater discharges containing low dissolved oxygen (oxygen) occurring in AMAFCA's North Diversion Channel Embayment and downstream. This finding is based upon information provided in the draft MRG Watershed MS4 Permit (EPA 2013b,c), the BE (EPA 2013a), the observed frequency and magnitude of stormwater discharges that contain low oxygen in AMAFCA's North Diversion Channel Embayment or in the MRG (AMAFCA 2011; Stearns 2013, 2014), and based on other information. The Service recognizes that a number of management actions have recently been implemented in the North Diversion Channel that seek to reduce the magnitude and frequency of low oxygen events that impact silvery minnows and water quality in the MRG (DBSA 2009; EPA 2010a; USFWS 2011, 2012; EPA 2013a; Stearns 2013, 2014). However, silvery minnows will continue to be harassed, or their habitats temporarily harmed, by stormwater discharges that contain low oxygen. Silvery minnows will likely flee hypoxic storm water discharges or die within anoxic waters in or near the North Diversion Channel Embayment in proportion to the frequency and magnitude stormwater discharges that are conveyed to the MRG or that occur in the Embayment (i.e., mouth and confluence of the North Diversion Channel and the MRG).

The North Diversion Channel Embayment has had substantially lower oxygen concentrations, including a greater frequency and duration of low oxygen events compared to that measured during equivalent times in the MRG. Lusk (2011b) reported oxygen concentrations in the MRG were hypoxic (less than 4.4 mg/L) for approximately 9.8 days (3.1 percent of the time) in their cumulative duration during of monitoring for 313 days during 2006 to 2008. The USGS (2011a) also provided data on oxygen in the MRG upstream of the Embayment collected during 2009 and 2010. Hypoxic conditions (oxygen was less than 4.4 mg/L) occurred for only approximately 1 hr (less than 0.02 percent of the time) in duration during 328 days of continuous monitoring in the MRG (USGS 2011a). Recently, the frequencies of hypoxic conditions in the MRG upstream have been observed to increase in relation to stormwater runoff from fire scarred areas (Dahm

Table 2. Concentrations of dissolved oxygen in water at various atmospheric pressures and temperatures with 100 percent oxygen saturation, 54.3 percent oxygen saturation (associated with hypoxia and harassment of silvery minnows), and 8.7 percent oxygen saturation (associated with anoxia and lethality of silvery minnows) at the North Diversion Channel (NDC) (based on USGS DO website <http://water.usgs.gov/software/DOTABLES/> for pressures between 628 to 648 millimeters of mercury (Hg)).

Water temp.	100% Oxygen Saturation at NDC			54.3% saturation = Harassment			8.7% saturation= 50%Lethality		
(°C)	628mmHg	638mmHg	648mmHg	628mmHg	638mmHg	648mmHg	628mmHg	638mmHg	648mmHg
0	12.1	12.3	12.5	6.6	6.7	6.8	1.1	1.1	1.1
1	11.7	11.9	12.1	6.4	6.5	6.6	1.0	1.0	1.1
2	11.4	11.6	11.8	6.2	6.3	6.4	1.0	1.0	1.0
3	11.1	11.3	11.5	6.0	6.1	6.2	1.0	1.0	1.0
4	10.8	11	11.2	5.9	6.0	6.1	0.9	1.0	1.0
5	10.5	10.7	10.9	5.7	5.8	5.9	0.9	0.9	0.9
6	10.3	10.4	10.6	5.6	5.6	5.8	0.9	0.9	0.9
7	10	10.2	10.3	5.4	5.5	5.6	0.9	0.9	0.9
8	9.8	9.9	10.1	5.3	5.4	5.5	0.9	0.9	0.9
9	9.5	9.7	9.8	5.2	5.3	5.3	0.8	0.8	0.9
10	9.3	9.5	9.6	5.0	5.2	5.2	0.8	0.8	0.8
11	9.1	9.2	9.4	4.9	5.0	5.1	0.8	0.8	0.8
12	8.9	9	9.2	4.8	4.9	5.0	0.8	0.8	0.8
13	8.7	8.8	9	4.7	4.8	4.9	0.8	0.8	0.8
14	8.5	8.6	8.8	4.6	4.7	4.8	0.7	0.7	0.8
15	8.3	8.4	8.6	4.5	4.6	4.7	0.7	0.7	0.7
16	8.1	8.3	8.4	4.4	4.5	4.6	0.7	0.7	0.7
17	8	8.1	8.2	4.3	4.4	4.5	0.7	0.7	0.7
18	7.8	7.9	8	4.2	4.3	4.3	0.7	0.7	0.7
19	7.6	7.8	7.9	4.1	4.2	4.3	0.7	0.7	0.7
20	7.5	7.6	7.7	4.1	4.1	4.2	0.7	0.7	0.7
21	7.3	7.4	7.6	4.0	4.0	4.1	0.6	0.6	0.7
22	7.2	7.3	7.4	3.9	4.0	4.0	0.6	0.6	0.6
23	7	7.2	7.3	3.8	3.9	4.0	0.6	0.6	0.6
24	6.9	7	7.1	3.7	3.8	3.9	0.6	0.6	0.6
25	6.8	6.9	7	3.7	3.7	3.8	0.6	0.6	0.6
26	6.7	6.8	6.9	3.6	3.7	3.7	0.6	0.6	0.6
27	6.5	6.6	6.8	3.5	3.6	3.7	0.6	0.6	0.6
28	6.4	6.5	6.6	3.5	3.5	3.6	0.6	0.6	0.6
29	6.3	6.4	6.5	3.4	3.5	3.5	0.5	0.6	0.6
30	6.2	6.3	6.4	3.4	3.4	3.5	0.5	0.5	0.6
31	6.1	6.2	6.3	3.3	3.4	3.4	0.5	0.5	0.5
32	6	6.1	6.2	3.3	3.3	3.4	0.5	0.5	0.5
33	5.9	6	6.1	3.2	3.3	3.3	0.5	0.5	0.5
34	5.8	5.9	6	3.1	3.2	3.3	0.5	0.5	0.5
35	5.7	5.8	5.9	3.1	3.1	3.2	0.5	0.5	0.5

and Candelaria-Ley 2011; NMED 2013). These low oxygen events occurred in MRG upstream of the North Diversion Channel and appeared to be related to stormwater runoff events from tributaries such as the Gallisteo and Jemez Rivers and other tributaries, upstream of the action area. However, frequency of hypoxic conditions measured in the MRG was relatively infrequent (< 5 percent) during periods not associated with runoff from fire-scarred, upland areas.

During an equivalent time of measurement, oxygen concentrations measured in the Embayment during 2009 and 2010 (USGS 2011b) were hypoxic (less than 4.4 mg/L) for approximately 98 days during 301 days of continuous monitoring (33 percent). In addition, the Embayment had anoxic conditions occurring with oxygen concentrations less than 0.7 mg/L for approximately 21 days during 301 days of monitoring (USGS 2011b). During 2012, AMAFCA reshaped the Embayment creating conditions that were shallower and wider creating conditions that were thought to increase the penetration of sunlight and increase algal generation of oxygen there (Paulsgrove 2011; USFWS 2012). During 2013, AMAFCA installed a windmill-powered air diffusion system that pumped air into the surface water in the Embayment.

During storms, anoxic water in the Embayment is displaced by stormwater as it is discharged into the MRG, where it mixes as this pulse of low oxygen stormwater moves downstream. Those low oxygen events in the MRG, which may be associated with hypoxic or anoxic stormwater discharges through the Embayment, are often followed by fresh stormwater flows with adequate oxygen saturation as they move through the North Diversion Channel (DBSA 2009) or by saturated, freshwater of the MRG. The pulse of low oxygen water travels along the MRG, and is mixed and dispersed by the physical processes of interaction with substrate and dilution through inflows. After the pulse of low oxygen water travels downstream, it is often replaced by well-oxygenated MRG water from upstream. However, occasionally, upstream MRG may also have decreased oxygen content due to stormwater runoff events through natural arroyos and rivers and associated with storm events over intensely burned areas (NMED 2013).

The EPA (2010b) describes stormwater discharges from the MRG Watershed MS4 Permit area as flowing into waters of the Pueblo of Sandia and the Pueblo of Isleta, but no mixing zone size estimates were provided in EPA's BE. Therefore, the Service used the MacIntyre Method (described by EPA and Corps (1988, in their Appendix C)) to estimate mixing zone size with a range of peak flows from the North Diversion Channel, and the MRG (this BO, Appendix A). Depending on a variety of flow assumptions, a maximum mixing distance of up to 14 km (9 mi) was estimated. This is likely the maximum mixing distance stormwater flows from the North Diversion Channel when it flows for 24 hr at 56.6 m^3/s (2,000 cfs) and when the MRG is flowing at 14.2 m^3/s (500 cfs). Such flows likely occur during summer when it rains only in the City.

However, the plume of low oxygen water is not likely continuous, and this pulse of water is likely to disperse as it interacts with the substrate and with other flows that enter the MRG. Pulse events are likely to disperse due to interaction with the riverbed, banks, and broader channel in the MRG in the action area, which create longer flow paths and increase dispersion because of larger wetted perimeters that increase the interaction of the water flow with the substrate (Langman 2007). Additionally, the City's Southside Water Reclamation Plant and other tributaries such as Tijeras Arroyo, as well as the Albuquerque and Atrisco Riverside Drains provide dilution water. The change in flow velocities that occurs at the Isleta Diversion Dam may also affect stormwater plume dispersion in the MRG.

A pulse of Embayment anoxic water of 0.1 mg/L oxygen is likely to increase above 0.7 mg/L within 1 hr of mixing with the MRG. During that hour, the lethally anoxic water (i.e., less than 0.7 mg/L) would suffocate any silvery minnow unable to escape it. Additionally, surviving juvenile and adult silvery minnow would likely flee the area affected by water containing less oxygen than 4.4 mg/L in the impact area. Some silvery minnows are expected to exhibit an adverse avoidance response to these low oxygen events. However, avoidance behavior, or fleeing from the disturbance, represents a disruption in normal behaviors and an expenditure of energy that an individual silvery minnow would not have experienced to the same degree in the absence of the proposed action. Such additional energy expenditures reduce the amount that the animal can devote to natural activities, growth, survival and reproduction. This form of harassment is expected to be short, with pre-exposure behaviors expected to resume after fleeing the disturbance by the plume as it mixes, or after replenishment of well-oxygenated MRG water.

The EPA (2013b; p. 18, 3(a)(ii)) describes the proposed action as identifying a plan for the remedy of the low oxygen conditions to be completed within a year from the permit issuance date by the City and AMAFCA, with progress reports submitted to EPA and Service annually thereafter for the duration of the permit or until such time as the stormwater controls eliminate or reduce conditions that exceed water quality standards (for dissolved oxygen). The EPA also describes other efforts to protect endangered species including the 3(a)(i) and 3(a)(ii) “Dissolved Oxygen Strategy in the Receiving Waters of the Rio Grande” and the 3(b) “Sediment Pollutant Load Reduction Strategy” that are applicable to all MRG Watershed MS4 Applicants.

The “Dissolved Oxygen Strategy,” proposed by EPA and to be developed by the City and AMAFCA, is expected to reduce the frequency of low oxygen events and adverse effects to silvery minnows. However, the performance of this Dissolved Oxygen Strategy is unknown at this time. The Service notes that it is difficult to characterize the relative impact of these potentially beneficial strategies on the frequency and magnitudes of low oxygen events in the Embayment and in the MRG. Available oxygen data from the Embayment and in the MRG downstream during 2013 indicated that the frequency of anoxic events (less than 0.7 mg/L) of 22 days per year and a frequency of hypoxic events (less than 4.4 mg/L) of 50 days per year (Table 3). EPA’s MRG Watershed MS4 Permit strategies may place a period of performance on the reduction of the frequency of low oxygen events in the Embayment or the MRG. Therefore, the Service will use the maximum expected future frequency and magnitude of low oxygen events in the Embayment as surrogates for estimating the numbers of silvery minnows that may be adversely affected by the proposed action.

In summary, when anoxic water is discharged, there is likely an initial lethal zone of anoxic water that occurs in the Embayment and in the MRG during the first hour of discharge from the Embayment. The maximum distance of this lethal zone is likely 3.9 km (2.4 mi) in length. When hypoxic water is discharged, there is likely an impact area where hypoxic water that occurs in the Embayment, or downstream in the MRG, that will harass silvery minnows until oxygen levels in the water return to above 54.3 percent saturation. We expect that this impact area of harassment will extend a maximum distance of 14.3 km (8.9 mi) and achieve complete mixing within 20 hr (Appendix A).

Sources of the water in the Embayment have not been adequately quantified. As rates of oxygen consumption in the Embayment exceed those in the MRG, we assumed that low oxygen events in the Embayment were mainly associated with stormwater discharges. Using the MacIntyre Equation (results are in Appendix A), we identified 128 different mixing scenarios where a range of flow exposures and the overlap with a range silvery minnows based on the expected density of 1.0 per $100m^2$ where low oxygen water would occur in inhabited mixing zones. The number of silvery minnow adversely affected in the mixing zone would be equal to 1.0 per $100m^2$ for all the mixing scenarios in Appendix A, and the average of those scenarios would equal 906 silvery minnows on average, potentially affected by hypoxia, and 99 silvery minnows, on average, affected by anoxia. That is, for all mixing scenarios with hypoxia the average exposure is 906 silvery minnows and for all mixing scenarios with anoxic the average exposure is 99 silvery minnows. These averages of exposed silvery minnows are then multiplied by the annual maximum future frequency of exposure to anoxic or hypoxic events to estimate incidental take.

Based on an analysis of data provided (Stearns 2013; Table 3), the frequencies of hypoxia and anoxia appeared to have been reduced from 2010-2011. Based on the data available (Stearns 2014) times the transformed coefficient of variation (of 0.3, above), the maximum future frequency of anoxic conditions expected would be 1.3 x 14 = 18 times per year. Based on the data available (Stearns 2014) times the transformed coefficient of variation (of 0.3, above), the maximum future frequency of hypoxia expected would be 1.3 x 28 = 36 times per year. Over the five-year proposed action, additional data of robust quality will need to be collected and provided to make additional assessments and comparisons of the relative frequency of low oxygen events in the Embayment and in the MRG downstream with data collected previously.

Therefore, even though the volumes of flow in the MRG and those in the North Diversion Channel vary extensively, we used the frequency of low oxygen events mainly associated with stormwater discharges, and the areas of exposure, to estimate adverse effects to individual silvery minnows based on their average density and average exposure in the mixing scenarios. Note that during the previous permit term, the average density of silvery minnows was ~0.1 RGSM/$100m^2$, resulting in few silvery minnows exposed. More recently, and with the Service (USFWS 2013) augmenting the Angostura population, the silvery minnow density of 1.0 RGSM/$100m^2$ was used to estimate the number of silvery minnows adversely affected by the proposed MRG Watershed MS4 Permit action, and therefore, the estimated incidental takes will be higher in number than identified in the previous BO (USFWS 2011).

If the average number of silvery minnows affected in 18 discharge events of anoxic stormwater were to occur (based on the annual maximum future frequency (in Table 3)), then we expect that as many as 10,410 silvery minnows, including eggs and larvae, would be killed during the proposed MRG Watershed MS4 Permit action. If anoxic water would also continue to mix until it was hypoxic, or if additional 36 hypoxic discharges per year would occur, an additional 163,080 silvery minnows would be harassed in the mixing zone. In summary, the total number of eggs, larvae, juveniles and adults that would suffocate or be harassed by anoxic or hypoxic stormwater discharges and resultant conditions would be 173,490 silvery minnows over the five-year MRG Watershed MS4 Permit action (Table 4).

Table 3. Frequency (number) of anoxic and hypoxic events associated with qualifying stormwater discharges in the North Diversion Channel Embayment and in the MRG downstream based on calendar year, projected annual maximum, and as used in this BO for the annual maximum expected future frequency for the MRG Watershed MS4 Permit.

Type of Qualifying Stormwater Discharge Event	Frequency of Events in Calendar Year 2013 (using available data) (Stearns 2014)	Frequency of Events in Calendar Year 2013 (extrapolating with available data to remainder of year) (Stearns 2014)	Maximum Annual Frequency of Events based on historical data for the North Diversion Channel (Stearns 2014)	Annual maximum future frequency of proposed action (based on historical data times a coefficient of variation = 0.3)
Anoxic*	7	8	14	18
Hypoxic**	14	16	28	36

* Anoxic = see Table 2, for oxygen saturation and dissolved oxygen concentrations at various water temperatures and atmospheric pressures for the North Diversion Channel area that are considered anoxic and associated with Rio Grande silvery minnow lethality.

** Hypoxic = see Table 2, for oxygen saturation and dissolved oxygen concentrations at various water temperatures and atmospheric pressures for North Diversion Channel area that are considered hypoxic and associated with Rio Grande silvery minnow harassment.

Table 4. Estimate of adverse effects to silvery minnows (using an average density of 1.0 RGSM/100m^2) due to anoxic stormwater in the North Diversion Channel Embayment and in the lethal zone in the MRG and due to hypoxic stormwater discharges in the North Diversion Channel Embayment and in the impact area in the MRG. (Based on an average of all mixing scenarios provided in Appendix A).

MRG Watershed MS4 Permit (expected to be issued in 2014)	Annual Maximum Future Frequency of Anoxic Events/year	Annual Maximum Future Frequency of Hypoxic Events/year	Number of Silvery Minnows (based on 1.0 fish/100m^2) suffocated during anoxic events/year	Number of Silvery Minnows harassed (based on 1.0 fish/100m^2) during hypoxic events/year
Permit Year 1	18/year	36/year	18 x 99 = 1,782 + 300 eggs/larvae = 2,082 per year	36 x 906 = 32,616
Permit Year 2	18/year	36/year	18 x 99 = 1,782 + 300 eggs/larvae = 2,082 per year	36 x 906 = 32,616
Permit Year 3	18/year	36/year	18 x 99 = 1,782 + 300 eggs/larvae = 2,082 per year	36 x 906 = 32,616
Permit Year 4	18/year	36/year	18 x 99 = 1,782 + 300 eggs/larvae = 2,082 per year	36 x 906 = 32,616
Permit Year 5	18/year	36/year	18 x 99 = 1,782 + 300 eggs/larvae = 2,082 per year	36 x 906 = 32,616
EPA's five year MRG Watershed MS4 Permit (Incidental Take Authorized for 2014-2020)			10,410 silvery minnows may be suffocated or harmed by anoxic stormwater in the Embayment or in MRG downstream	163,080 silvery minnows may be harassed by hypoxic stormwater in the Embayment or in the MRG downstream

Effects on Silvery Minnow Designated Critical Habitat

Low oxygen is a water quality condition that degrades designated critical habitat (PCE 4). Hypoxia (less than 4.4 mg/L) has not been commonly observed in the MRG, except associated with runoff events from burned areas. In the designated critical habitat, Lusk (2011b) observed the occurrence of hypoxia during 3 percent of the times measured, whereas the USGS (2011a) observed the occurrence of hypoxia at less than 0.02 percent of the times measured. No anoxic conditions have been observed in the MRG (Van Horn 2008; Lusk 2011b; USGS 2011b), although fish kills were observed in association with the Los Conchas Fire (NMED 2013).

The USGS (2011b) observed hypoxia in the Embayment at approximately 35 percent of the times measured. In addition, the Embayment had oxygen concentrations less than or equal to 0.7 mg/L (anoxia) for approximately 8 percent of the times measured. While the frequency of stormwater events that push Embayment water into the MRG is low, the likelihood of increased water quality degradation from low oxygen events is expected to decrease in designated critical habitat, when additional remedial actions are taken. Therefore, the proposed action may affect, is likely to adversely affect, silvery minnow designated critical habitat. Low oxygen associated with proposed action will likely affect up to 14.3 km (8.9 mi) downstream, or up to 5 percent of the designated critical habitat, for a limited time (usually less than 20 hours).

Using a variety of mixing scenarios, we determined a range of areas that we expect silvery minnows will be harassed or suffocated by exposure to low oxygen stormwater discharges through the North Diversion Channel Embayment. There will also be areas of designated critical habitat ranging from less than 0.4 to 14 ha (1 to 34 acres) and average 0.5 ha (1.3 acres) that will be temporarily adversely affected (Appendix A). We expect that low oxygen water will travel as a pulse downstream, eventually disperse, and the oxygen content will return to background saturation levels after replenishment by oxygen-saturated MRG water or as fresh stormwater enters their habitat (DBSA 2009).

V. CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, Tribal, local or private actions that are reasonably certain to occur within the action area considered in this biological opinion (50 CFR 402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

The Service expects the natural and anthropogenic phenomena in the action area will continue to influence silvery minnows as described in the Environmental Baseline. The Service also expects the continuation of habitat restoration projects and research that will benefit silvery minnows in the action area. In addition, we expect cumulative effects to include the following:

- Increased development and urbanization in the historical floodplain may result in reduced conveyance of peak flows because of the threat of flooding damages. Development in the floodplain makes it more difficult, if not impossible, to transport large quantities of water that would overbank and create low velocity habitats that silvery minnow prefer. Development also reduces overbank flooding favorable for the silvery minnow. Gradual changes in the floodplain vegetation from native riparian species to nonnative species (e.g., saltcedar), as well as riparian clearing activities or herbicide treatment for vegetation control and associated with agricultural crops could adversely affect the silvery minnow and its habitat. Silvery minnow larvae require shallow, low velocity habitats for their development. Therefore, encroachment of nonnative species will result in habitat reduction for the silvery minnow.
- Increased consumptive use of surface water including for municipal and private uses will reduce river flow and thereby decrease available habitat for the silvery minnow.
- Increased groundwater pumping will reduce river recharge.

- Increased water contamination associated with wastewater treatment plant effluent discharges; stormwater runoff from other urban areas, runoff from small feedlots and dairies; and residential, industrial, and commercial development, or illegal discharges can contribute to decreased water quality.
- Increased human activities (recreational use and large woody debris removal) that cause habitat disturbance and may reduce riparian shading.

The Service anticipates the continued and expanded degradation of silvery minnow habitat because of these types of activities. Effects from these activities will continue to threaten the survival and recovery of the species by reducing the quality and quantity of minnow habitat.

VI. CONCLUSION

After reviewing the current status of the silvery minnow, the environmental baseline for the action area, the anticipated effects of the proposed action, and the cumulative effects, it is the Service's biological opinion that the issuance of the MRG Watershed MS4 Permit (EPA 2013b) is not likely to jeopardize the continued existence of the silvery minnow and is not likely to destroy or adversely modify designated critical habitat.

As many as 10,410 (2,082 per year) silvery minnows, eggs, and larvae, will suffocate and die during the 5-year authorization period due to exposure in anoxic stormwater in or discharged through the North Diversion Channel Embayment (Table 4). As many as 163,080 silvery minnows during the 5-year authorization period will be harassed by exposure to hypoxic stormwater in or discharged through the North Diversion Channel Embayment (Table 4). However, the direct and indirect effects of the proposed action are not expected to reduce appreciably the likelihood of both the survival and recovery of the Rio Grande silvery minnow.

We expect that the silvery minnow population will be augmented in the Angostura Reach to offset the losses of the silvery minnows that succumb to anoxic stormwater discharges until those conditions in the North Diversion Channel watershed are improved by implementation of the MRG Watershed MS4 Permit and other conditions identified in the Incidental Take Statement described below. Working with others, the Service established the silvery minnow augmentation program is a temporary population management measure, which does not preclude achieving a self-sustaining population in the long-term. It is possible that these mortalities may influence the meta-population in the Angostura Reach, but we do not expect these mortalities to result in any significant long-term effects on the species viability as a whole. We expect harassment of over one hundred and sixty thousand silvery minnows will occur in the Angostura Reach, but the duration and intensity of these effects will be short term and though hypoxic stormwater could have effects on the fitness of individual silvery minnows, we do not anticipate long-term adverse impacts on the species viability as a whole. Silvery minnows are likely to return to feed, breed, and shelter in habitats that are occasionally adversely affected by low oxygen stormwater discharge events due to the proposed action in the Angostura Reach. Furthermore, implementation of the “Dissolved Oxygen Strategy in the Receiving Waters of the Rio Grande,” any remedial actions taken, and implementation of the Reasonable and Prudent Measures are expected to reduce adverse effects to silvery minnow from the levels described in this BO.

The proposed action will not result in destruction or adverse modification of critical habitat because we expect no appreciable diminishment of the value of critical habitat for both the survival and recovery of the species. Adverse impacts to critical habitat PCEs are anticipated only in a portion of designated critical habitat, the impacts will be temporary, and the antecedent environmental conditions will be restored with dilution of fresh stormwater or with water from the MRG. We expect designated critical habitat to rapidly return to a functional condition, and remain suitable to serve its function and conservation role for the silvery minnow. Therefore, while low oxygen events will degrade water quality of designated critical habitat, it be of short duration, and we find designated critical habitat will not be destroyed nor adversely modified.

The maximum number of silvery minnows killed yearly (2,082) is expected to be relatively small compared to the expected population of silvery minnows that may occur in the Angostura Reach yearly, on average, (1.0 RGSM/100m^2 x 8,660,175 m^2 = 86,600), or are that are augmented. The actual numbers of silvery minnows affected are likely to be less than the maximum number estimated as affected by the authorized stormwater discharges as flows and oxygen are used as surrogates for estimated affects to silvery minnows, and the annual maximum future frequency of low oxygen events has been quantified to account for uncertainty.

Therefore, it is the Service's opinion that the proposed MRG Watershed MS4 Permit action is not likely to jeopardize the continued existence of endangered silvery minnow. Additionally, while adverse effects will occur to silvery minnow critical habitat, the adverse effects are expected to dissipate quickly with dilution with oxygen saturated MRG flow. Reasonable and prudent measures as well as terms and conditions necessary to minimize the incidental take of silvery minnows associated with the proposed MRG Watershed MS4 Permit are provided below.

INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this incidental take statement.

The measures described below are nondiscretionary, and must be undertaken by EPA so that they become binding conditions of any permit issued, as appropriate, for the exemption in section 7(o)(2) to apply. The EPA has a continuing duty to regulate the activity covered by this incidental take statement. If EPA 1) fails to assume and implement the terms and conditions or 2) fails to require adherence to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, EPA or the Applicants must report the progress of the action and its impact on the species to the Service as specified in the incidental take statement (50 CFR 402.14(i)(3)).

Amount or Extent of Take Anticipated

The Service has developed the following incidental take statement based on the premise that the MRG Watershed MS4 Permit will be implemented as proposed (EPA 2010b, 2013a,b,c). Take of silvery minnow is expected in the form of harm and harassment due to the discharge of stormwater pulses that create low oxygen conditions in North Diversion Channel Embayment and that subsequently push low oxygen water or oxygen demanding pollutants into the MRG.

The Service anticipates that take in the form of harassment may affect up to 32,616 silvery minnows per year of the 5-year authorization (163,080 silvery minnows total) due to hypoxic stormwater containing less than 4.4 mg/L oxygen. The Service also anticipates that take in the form of harm may affect up to 1,782 silvery minnows per year (8,910 silvery minnows total) due to suffocation mortality caused by stormwater containing less than 0.7 mg/L oxygen. Additionally, if stormwater discharges containing less than 0.7 mg/L oxygen occur during the period from May 15 to May 31, then up to 300 eggs or larval silvery minnow per year (1,500 in total) would also die. Total authorized incidental take, due to lethality, is 10,410, but actual takes will be reduced by implementation of the Reasonable and Prudent Measures below. These estimates of the adverse effects to silvery minnow are presented in Table 4. We base these estimates on the best available information on silvery minnow density in the area impacted by the proposed activities and the maximum annual future frequency of low oxygen stormwater discharges occurring in or through the North Diversion Channel Embayment (Appendix A). If the actual incidental take exceeds this level of authorized incidental take, in any given year, then EPA should reinitiate consultation.

Effect of Take

The Service has determined that the level of anticipated take is not likely to result in jeopardy to the Rio Grande Silvery Minnow. The proposed action may affect, is likely to adversely affect, silvery minnow. However, those adverse effects are not anticipated to result in long-term impacts on the species or to critical habitat. The cumulative effects of climatic variation, when added to the effects of the proposed action, including baseline variation in flow, water quality, and population abundance of silvery minnows in the action area, were indeterminable for the duration of a five-year proposed action. Anticipated take may be overestimated based on the use of flow and oxygen as a surrogate for effects to silvery minnows and the projected variation of annual maximum future frequency of hypoxic and anoxic events. The Service notes that this represents a best estimate of the extent of take that is likely during the proposed action. Authorized incidental take may be modified through re-consultation and by amendment to this BO, should actual measured parameters differ significantly from those that were estimated.

Reasonable and Prudent Measures

The Service believes the following reasonable and prudent measures (RPMs) are necessary and appropriate to minimize impacts of incidental take of the silvery minnow resulting from the proposed action:

1. Reduce the incidences of low dissolved oxygen associated with stormwater discharges occurring in the North Diversion Channel Embayment and in the MRG downstream by 50 percent after two years and another 50 percent after four years from issuance of the MRG Watershed MS4 Permit.

2. Monitor oxygen and temperature in the water column in the North Diversion Channel Embayment and in the MRG downstream to determine the effectiveness of the Dissolved Oxygen Strategy implemented.

Terms and Conditions

Compliance with the following terms and conditions must be achieved in order to be exempt from the prohibitions of section 9 of the ESA. These terms and conditions implement the Reasonable and Prudent Measures described above. These terms and conditions are nondiscretionary. EPA or the Applicants must report to the Service on the implementation of these terms and conditions.

To implement RPM 1, EPA shall:

1. Ensure that actions are taken to reduce incidences of low dissolved oxygen in the North Diversion Channel Embayment and in the MRG downstream by 50 percent after two years and another 50 percent after four years from the MRG Watershed MS4 Permit issuance as indicated in Table 5, below:

Table 5. MRG Watershed MS4 Permit Year, annual maximum future frequency of anoxic events and hypoxic events associated with adverse effects to Rio Grande silvery minnows through authorized stormwater discharges, by Permit year.

Permit Year	Anoxic Events*, max	Hypoxic Events**, max
Year 1	18	36
Year 2	18	36
Year 3	9	18
Year 4	9	18
Year 5	4	9

* See Table 2, for oxygen saturation and dissolved oxygen concentrations at various water temperatures and atmospheric pressures for the North Diversion Channel area that are considered anoxic and associated with Rio Grande silvery minnow lethality.

** See Table 2, for oxygen saturation and dissolved oxygen concentrations at various water temperatures and atmospheric pressures for North Diversion Channel area that are considered hypoxic and associated with Rio Grande silvery minnow harassment.

Through its permit authorization, EPA requires that AMAFCA and the City develop a Dissolved Oxygen Strategy that should reduce the frequency of low oxygen events that occur in association with stormwater discharges. If a Dissolved Oxygen Strategy were implemented that reduced the frequency of low oxygen events in half every two years, then the Service estimates that fewer silvery minnow would likely die, or likely be harassed by low oxygen events associated with stormwater discharges through the North Diversion Channel Embayment. Potential actions associated with the Dissolved Oxygen Strategy, could include, but are not limited to, installation of more powerful air diffusion in the Embayment, modification of the topology of the Embayment, increased flow velocities and dilution in the Embayment, or a targeted reduction of the major COD or other pollutant sources that are discharged in the upstream North Diversion Channel watershed. All such actions would be expected to have beneficial effects on oxygen saturation in the water occupied by silvery minnows in the long term by reducing the frequency or magnitude of low oxygen events in their habitat. If a 50 percent reduction in the frequency of low oxygen events associated stormwater discharges were to occur every two years, then the number of silvery *minnows harassed or killed will be reduced by ~35 percent. Therefore, implementation of this RPM would result in no more than 6,435 silvery minnow lethality and no more than 147,678 silvery minnow harassments over five years.*

To implement RPM 2, EPA shall:

1. Implement continuous monitoring of oxygen and temperature in the Embayment and at one location in the MRG downstream of the North Diversion Channel outfall within the action area (e.g., Central Bridge) to verify the pollutant reduction or remedial actions implemented through the "Dissolved Oxygen Strategy" are successful for the duration of the permit.

   Flow discharges and oxygen and temperature data are used as a surrogate for the number of affected silvery minnow because fish observation during storm events would be unsafe and is unlikely to result in quantifiable observations of death or harassment. Surveys for fish kills are also unlikely to reveal the extent to incidental take of silvery minnows in turbid rivers affected by multiple stormwater discharges and widely varying flows. There are uncertainties associated with the estimates of the frequency and duration of low oxygen events that mix with the MRG, the water available for dilution during times of drought, its oxygen saturation, and the number of silvery minnow exposed, that could all increase or decrease the estimated level of harm and harassment of silvery minnows during the MRG Watershed MS4 Permit term. This BO describes the collection of information about flow rates through the North Diversion Channel, when the flow cumulatively exceeds that necessary to enter the Embayment, the daily flow of the MRG upstream, water temperature and the oxygen concentration measured in the Embayment water associated with qualifying stormwater runoff events, as determined from continuous monitoring, which are critical to determination of incidental takes of silvery minnows and any adverse effects to critical habitat.

2. Cite and describe all standard operating procedures, quality assurance and quality control plans, maintenance, and implementation schedules that assure timely and accurate water temperature, dissolved oxygen, and flow data are collected, transferred, stored, summarized, and evaluated in Annual Reports. As requested, provide provisional oxygen and water temperature data, and associated metadata such as flows, dates, and times, to the Service within two weeks after formal request.

   Flow discharges and oxygen and temperature data are used as surrogates for the number of affected silvery minnows because fish observation during storm events would be unsafe and is unlikely to result in quantifiable observations of death and harassment. Surveys for fish kills are also unlikely to reveal the extent to incidental take of silvery minnows in turbid rivers affected by multiple stormwater discharges and widely varying flows. Therefore, the EPA must review, approve or include a monitoring plan, including a quality assurance and quality control plan for estimating oxygen data when any oxygen monitoring equipment fail for any reason. Until a monitoring plan with quality assurance and quality control is submitted and *approved by EPA, any data, including provisional or incomplete data from the most recent measurement period shall be used as substitutes for all values in the calculations for determination of incidental takes. The monitoring plan to be developed will describe the data collected, assure its quality, and will identify the means necessary to address any gaps that occur during monitoring, in a timely manner (that is, within 24 to 48 hours). Given that these data collected are used as surrogates for incidental takes, all oxygen and water temperature data, and associated metadata (date, time, qualifying event discharges, etc.), even if provisional, and preferably in a spreadsheet or database format, shall be provided to the Service within two work weeks, whenever requested through EPA, for evaluation under this BO.*

3. Provide an Annual Incidental Take Report to the Service that includes the following information: beginning and end date of any qualifying stormwater events, dissolved oxygen values and water temperatures in the North Diversion Channel Embayment, dissolved oxygen values and water temperature at a downstream monitoring station in the MRG, flow rates in the North Diversion Channel, mean daily flow rate in the MRG, evaluation of oxygen and temperature data as either anoxic or hypoxic using Table 2, and estimate of the number of silvery minnows taken based on Appendix A.

   Appendix A includes the flow rate (binned to 500 cfs units) of the North Diversion Channel, whenever the flow cumulatively equals or exceeds that which flows into the Embayment, the mean daily flow of the MRG upstream, and oxygen concentration and temperature measured in the Embayment water, as determined from continuous monitoring. These flow discharges and oxygen and temperature data are used as a surrogate for the area of critical habitat affected and the number silvery minnows adversely affected as visual observations would be unsafe or unlikely to quantify silvery minnows affected during storm events. In the event that flow discharges differ from values in Appendix A, then a value should be rounded to the nearest flow value category listed. All flows through the North Diversion Channel are expected to exceed 250 cfs and/or 13 acre feet prior to discharge to the Embayment or MRG downstream; therefore, all qualifying flow events are rounded to the nearest values listed in Appendix A.

   On an annual basis, incidental take will be estimated and reported for qualifying stormwater events where the Embayment is anoxic or hypoxic or when cumulative flow has exceeded the volume of water in the Embayment and discharges to the MRG, using the following procedure and information in Appendix A:

   Step 1. Determine the season of the event. Spring (March 21 to June 20), summer (June 21 to September 22), fall (September 23 to December 20), and winter (December 21 to March 20).

   Step 2. Determine the flow rate at the North Diversion Channel Gage (USGS Station 08329900) and the daily discharge rate at the upstream MRG Gage (USGS Station 083296806).

Step 3. Determine the oxygen concentration and oxygen saturation in the Embayment just prior or at the onset of stormwater discharge (currently at USGS Gage 083299176).

Step 4. If dissolved oxygen is less than 0.7 mg/L (i.e., if saturation is less than 8.7 percent) in the Embayment, then determine the number of silvery minnows killed by summing the number in column S over all qualifying events. Calculate the number of slivery minnows harassed by summing the number in column T over all qualifying events. If any qualifying event occurs between May 15 and 31 then add 300, once, to the total number killed to estimate any adversely affected eggs and/or larvae affected during that same May period.

Step 5. If oxygen is greater than 0.7 mg/L and less than or equal to 4.4 mg/L (i.e., if oxygen saturation is less than or equal to 54.3 percent), calculate the number of silvery minnows harassed by summing the number in column T over all events.

Step 6. If the sum of all silvery minnows killed or harassed over each year of the MRG Watershed MS4 Permit reported in the annual incidental take report does not exceed the incidental take statement (2,280 killed or 45,300 harassed per year), then describe and list all events in a table, sum the incidental take for all events, and submit an annual report summarizing all incidental takes and events to EPA and the Service. If the sum of silvery minnows killed or harassed during the year exceeds the incidental take statement, then EPA must reassess its findings and reinitiate consultation with the Service.

4. Provide the Service with electronic copies of all provisional data or Annual Reports described in the MRG Watershed MS4 Permit no later than December 1 for the preceding calendar year, to email address nmesfo@fws.gov and joel_lusk@fws.gov, or by mail to the New Mexico Ecological Services Field Office, 2105 Osuna Road NE, Albuquerque, New Mexico, 87113.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or designated critical habitat, to help implement recovery plans, or to develop information. The Service recommends the following conservation activities:

1. Identify chemical oxygen demanding substances, sources and transport pathways in the stormwater discharges in the North Diversion Channel Watershed and in other urban basins of the MRG Watershed MS4 Permit area.

2. Model chemical oxygen demand, SOD, SSC, and nutrient concentrations associated with stormwater and their relationship to low oxygen events in the MRG and estimate the potential for effects to silvery minnow life stages and their habitat.

3. Improve the accuracy of the mixing models used to describe stormwater discharges and their mixing with MRG water and subsequent oxygen concentrations in MRG.

4. Identify the chronic effects or avoidance of low oxygen concentrations to silvery minnow under a range of water temperatures from 1 to 35 °C (34 to 95 °F).

5. Measure PCBs in insect prey of the flycatcher or during collection of any addled flycatcher eggs (eggs that fail to hatch) by scientists through Service's issuance of ESA 10(A)1(a) permits and analyze those eggs for PCBs and other pollutants.

6. Facilitate, coordinate with others, and develop a "Bosque Conservation Corps" or cadre of volunteers, educators, scientists, and citizens that routinely monitor the physical, chemical, and biological attributes of the MRG ecosystem using a comprehensive and standardized monitoring program as appropriately authorized.

7. Encourage volunteers, educators, and classrooms to "adopt-a-watershed" for the stormwater basins that their schools reside in.

8. Federal Highway Administration should update guidance and specifically describe a case study whereby BMPs are developed, implemented, and monitored in the MRG Watershed MS4 Permit area that quantifies how roadway designs and BMPS reduce the frequency or magnitude of low oxygen events in MRG.

9. U.S. Army Corps of Engineers should evaluate and identify any stipulations or best management practices necessary to protect downstream water quality and ensure no net reduction in oxygen saturation of Waters of the United States in their issuance of Section 404 Clean Water Act permits for construction that may affect such waters.

In order for the Service to be kept informed of actions minimizing or avoiding adverse or benefitting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

REINITIATION NOTICE

This concludes formal consultation on the action of issuance of the MRG Watershed MS4 Permit as outlined (EPA 2010a,c). As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: 1) the amount or extent of incidental take of silvery minnow is exceeded; 2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this BO; 3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this BO; or, 4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the manner of amount of incidental take exceeds that authorized, any operations causing such take must cease, pending reinitiating of ESA consultation.

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Appendix A. Incidental take of Rio Grande silvery minnow (RGSM) for stormwater events that are anoxic or move anoxic or hypoxic water through the North Diversion Channel (NDC) Embayment and/or discharge into the Rio Grande, by season. Areas were estimated using the MacIntyre method (EPA and Corps 1998, Appendix C).

SPRING (March 21 – June 20)

			S	**T**
Flow Rate in NDC (cfs)	**Daily Flow Rate in Rio Grande (cfs)**	**Lethal Zone Area (ft^2)**	**No. of RGSM killed in Lethal Zone**	**No. of RGSM harassed in Impact Area**
500	500	16,463	50	137
500	1000	13,372	41	36
500	1500	11,840	36	17
500	2000	10,861	33	9
500	2500	10,158	31	6
500	3000	9,617	29	4
500	3500	9,183	28	2
500	4000	8,822	27	2
1000	500	32,925	100	1,094
1000	1000	26,744	82	289
1000	1500	23,681	72	133
1000	2000	21,723	66	74
1000	2500	20,316	62	47
1000	3000	19,235	59	32
1000	3500	18,365	56	19
1000	4000	17,644	54	14
1500	500	49,388	151	3,694
1500	1000	40,116	122	977
1500	1500	35,521	108	449
1500	2000	32,584	99	251
1500	2500	30,474	93	159
1500	3000	28,852	88	108
1500	3500	27,548	84	65
1500	4000	26,466	81	48
2000	500	65,851	201	7,800
2000	1000	53,488	163	2,315
2000	1500	47,361	144	1,065
2000	2000	43,445	132	596
2000	2500	40,632	124	376
2000	3000	38,469	117	256
2000	3500	36,731	112	155
2000	4000	35,289	108	114

Appendix A. Continued.

SUMMER (June 21 – September 22) **S** **T**

Flow Rate in NDC (cfs)	**Daily Flow Rate in Rio Grande (cfs)**	**Lethal Zone Area (ft^2)**	**No. of RGSM killed in Lethal Zone**	**No. of RGSM harassed in Impact Area**
500	500	22,865	70	366
500	1000	18,572	57	97
500	1500	16,445	50	45
500	2000	15,085	46	25
500	2500	14,108	43	16
500	3000	13,357	41	11
500	3500	12,754	39	6
500	4000	12,253	37	5
1000	500	45,730	139	2,932
1000	1000	37,144	113	775
1000	1500	32,890	100	357
1000	2000	30,170	92	199
1000	2500	28,217	86	126
1000	3000	26,715	81	86
1000	3500	25,508	78	52
1000	4000	24,506	75	38
1500	500	68,595	209	8,125
1500	1000	55,716	170	2,617
1500	1500	49,335	150	1,203
1500	2000	45,256	138	673
1500	2500	42,325	129	425
1500	3000	40,072	122	289
1500	3500	38,261	117	175
1500	4000	36,759	112	129
2000	500	91,460	279	10,833
2000	1000	74,288	226	6,202
2000	1500	65,780	200	2,852
2000	2000	60,341	184	1,596
2000	2500	56,434	172	1,007
2000	3000	53,430	163	686
2000	3500	51,015	155	415
2000	4000	49,012	149	305

Appendix A. Continued.

FALL (September 23 – December 20) **S** **T**

Flow Rate in NDC (cfs)	Daily Flow Rate in Rio Grande (cfs)	Lethal Zone Area (ft²)	No. of RGSM killed in Lethal Zone	No. of RGSM harassed in Impact Area
500	500	20,578	63	267
500	1000	16,715	51	71
500	1500	14,800	45	32
500	2000	13,577	41	18
500	2500	12,698	39	11
500	3000	12,022	37	8
500	3500	11,478	35	5
500	4000	11,028	34	3
1000	500	41,157	125	2,138
1000	1000	33,430	102	565
1000	1500	29,601	90	260
1000	2000	27,153	83	145
1000	2500	25,395	77	92
1000	3000	24,043	73	63
1000	3500	22,957	70	38
1000	4000	22,055	67	28
1500	500	61,735	188	7,214
1500	1000	50,145	153	1,907
1500	1500	44,401	135	877
1500	2000	40,730	124	491
1500	2500	38,093	116	310
1500	3000	36,065	110	211
1500	3500	34,435	105	128
1500	4000	33,083	101	94
2000	500	82,314	251	9,749
2000	1000	66,859	204	4,521
2000	1500	59,202	180	2,079
2000	2000	54,307	166	1,163
2000	2500	50,790	155	734
2000	3000	48,087	147	500
2000	3500	45,914	140	303
2000	4000	44,111	134	223

Appendix A. Continued.

Flow Rate in NDC (cfs)	Daily Flow Rate in Rio Grande (cfs)	Lethal Zone Area (ft^2)	No. of RGSM killed in Lethal Zone	No. of RGSM harassed in Impact Area
WINTER	(December 21–March 20)		**S**	**T**
500	500	15,830	48	122
500	1000	12,858	39	32
500	1500	11,385	35	15
500	2000	10,444	32	8
500	2500	9,767	30	5
500	3000	9,247	28	4
500	3500	8,830	27	2
500	4000	8,483	26	2
1000	500	31,659	96	973
1000	1000	25,715	78	257
1000	1500	22,770	69	118
1000	2000	20,887	64	66
1000	2500	19,535	60	42
1000	3000	18,495	56	28
1000	3500	17,659	54	17
1000	4000	16,966	52	13
1500	500	47,489	145	3,284
1500	1000	38,573	118	868
1500	1500	34,155	104	399
1500	2000	31,331	95	223
1500	2500	29,302	89	141
1500	3000	27,742	85	96
1500	3500	26,489	81	58
1500	4000	25,449	78	43
2000	500	63,318	193	7,500
2000	1000	51,430	157	2,058
2000	1500	45,540	139	946
2000	2000	41,774	127	530
2000	2500	39,069	119	334
2000	3000	36,990	113	228
2000	3500	35,318	108	138
2000	4000	33,931	103	101

Appendix A – Instructions for Spreadsheet Oxygen Mixing Model
Calculations of the impact area and number of silvery minnows affected were made in an Excel spreadsheet, **Appendix A. oxygen mixing model_NDC_MRG_2014.xlsx**.

Column A. Determine season. Spring (March 21-June 20), Summer (June 21-September 22), Fall (September 23-December 20) and Winter (December 21- March20). Water temperature affects oxygen saturation of water (Odum 1956, Ignjatovic 1968). This temperature based phenomena affects all calculations and must be standardized. Lusk (2011) reported that average water temperatures in the Middle Rio Grande varied by season. Water temperature averages approximately 15 °C in spring, 25 °C in summer, 20 °C in fall, and 10 °C in winter, in the MRG.
Column B. Daily Rio Grande discharge was determined from an upstream gage (USGS Gage 083296806). For ease of table use, each flow was binned into 500 cfs units. For all qualifying flows, round to nearest 500 cfs bin.
Column C. Flow rates in the North Diversion Channel is determined from a gage upstream of the Embayment (USGS Gage 08329900). Each flow was binned to 500 cfs units. For all qualifying NDC flows, round to nearest 500 cfs bin. Only flows greater than 250 cfs are anticipated to discharge into or through the NDC Embayment.
Column D. River widths for this reach and for different discharges were obtained from Table 4.6 in Mussetter Engineering Inc (MEI) (2008). FLO-2D Model Development - Existing Conditions and Restoration Alternatives 1 to 5 Albuquerque Reach, New Mexico. Report to the U. S. Army Corps of Engineers. Fort Collins, Colorado. http://www.spa.usace.army.mil/FONSI/bosque/Engineering%20Appendix/App%20A_H&H%20Main%20report.pdf . Accessed May 17, 2011.
Column E. Average river depth for this reach and for different discharges were obtained from Table 4.6 in MEI (2008).
Column F. Pressure and temperature adjusted dissolved oxygen (oxygen) concentration. We used 630 mm Hg barometric pressure based on site elevation and an upstream oxygen saturation of 100 percent. Oxygen was adjusted using the USGS oxygen website (http://water.usgs.gov/cgi-bin/dotables. Accessed May 17, 2011).
Column G. Lowest oxygen in the Embayment is from DBSA (2009). It can be zero, but it creates calculation error with division by zero. A small positive value (0.1 mg/L) was used here instead.
Column H. Rio Grande cross sectional area determined using the MacIntyre Method (EPA and Corps 1998, Appendix C).
Column I. Average river velocity for this reach and for different discharges were obtained from Table 4.6 in MEI (2008).
Column J. Rio Grande shear velocity determined using the MacIntyre Method (EPA and Corps 1998, Appendix C.) and slopes for this reach and for different discharges were obtained from Table 4.6 in MEI (2008).
Column K. Rio Grande lateral mixing coefficient determined using the MacIntyre Method (EPA and Corps 1998, Appendix C).
Column L. Lethal oxygen concentration for silvery minnow. Buhl (2011) reported lethality at 8.7 percent saturation (i.e., 0.7 mg/L at 26 °C in South Dakota at about 1000 ft elevation). To determine 8.7 percent saturation at the MRG at 25 °C, use 100 percent saturation determined using USGS oxygen tables (http://water.usgs.gov/cgi-bin/dotables. Accessed May 17, 2011) and multiply by 8.7 percent. Therefore 6.8 mg/L at 25 °C times 0.087 = 0.6 mg/L; 8.6 mg/L at 15 °C times 0.087 = 0.7mg/L; 9.3 mg/L at 10 °C times 0.126 = 1.17 mg/L.
Column M. Mixing zone length for lethality in feet calculated using the MacIntyre Method (EPA and Corps 1998, Appendix C).
Column N. Mixing zone length for lethality in feet converted to miles.
Column O. Mixing zone width for lethality in feet calculated using the MacIntyre Method (EPA and Corps 1998, Appendix C).
Column P. Area of the lethal zone in square feet calculated by multiplying length (N) and width (O).
Column Q. Area of the lethal zone converted to square meters.
Column R. Average density of silvery minnow per 100 m^2 multiplied by area of the lethal zone. A density of 1.0 RGSM/100m2 was used.
Column S. Area of the lethal zone converted to acres. Determine the size of area that is lethal to silvery minnow?
Column T. No adverse affect oxygen concentration for silvery minnow. Buhl (2011) reported the no adverse effect concentration at 54.3 percent saturation (i.e., 4.4 mg/L at 25 °C in South Dakota at about 1,000 ft elevation).

To determine 54.3 percent saturation at the Middle Rio Grande site at 25 °C, assume 100 percent saturation and determined using USGS oxygen tables (http://water.usgs.gov/cgi-bin/dotables. Accessed May 17, 2011) and multiply by 54.3 percent. Therefore 6.8 mg/L at 25 °C times 0.543 = 3.7 mg/L; 8.6 mg/L at 15 °C times 0.543 = 4.7mg/L; 9.3 mg/L at 10 °C times 0.543 = 5.0 mg/L; 10.5 mg/L at 5 °C times 0.543 = 5.7 mg/L.
Column U. Mixing zone length for harassment in feet calculated using the MacIntyre Method (EPA and Corps 1998, Appendix C).
Column V. Mixing zone length for harassment in feet converted to miles. How far downstream is there harassment?
Column W. Mixing zone width for harassment in feet calculated using the MacIntyre Method (EPA and Corps 1998, Appendix C).
Column X. Impact area of harassment in square feet calculated by multiplying length (U) and width (W).
Column Y. Impact area of harassment converted to square meters.
Column Z. Average density of silvery minnow per 100 m^2 multiplied by impact area. How many silvery minnow are harassed?
Column AA. Impact area of harassment converted to acres. How big of an area does the harassment occur?