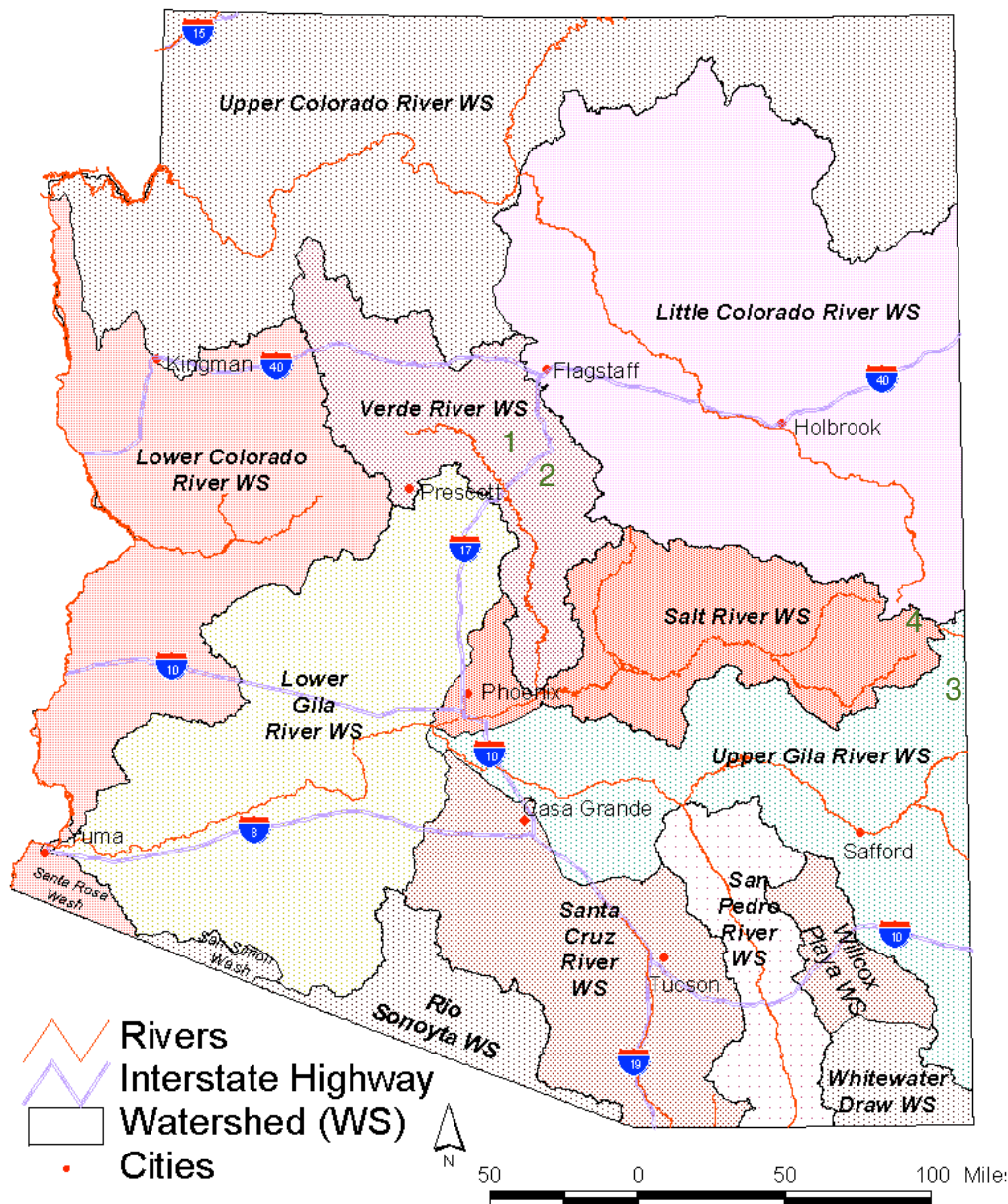


**Arizona Water Protection Fund  
Application Cover Page  
FY 2019**

<b>Title of Project:</b> Do native fish facilitate the persistence of endangered spikedace by resuspending food particles?													
<b>Type of Project:</b> <input type="checkbox"/> Capital or Other <input type="checkbox"/> Water Conservation <input checked="" type="checkbox"/> Research	<b>Stream Type:</b> <input checked="" type="checkbox"/> Perennial <input type="checkbox"/> Intermittent <input type="checkbox"/> Ephemeral	<b>Your level of commitment to maintenance of project benefits and capital improvements:</b> <input checked="" type="checkbox"/> < 5 years <input type="checkbox"/> 5-10 years <input type="checkbox"/> 11-15 years <input type="checkbox"/> 16-20 years <small>*See Note in 'Project Schematic'</small>											
<b>Applicant Information:</b> Name/Organization: ABOR for and on behalf of Northern Arizona University Address 1: Office of Sponsored Projects, PO Box 4130 Address 2: 1395 S. Knoles Drive, Rm# 252 City: Flagstaff State: Arizona ZIP Code: 86011 Phone: 928-523-4880 Fax: 928-523-1075 Tax ID No.: <span style="background-color: black; color: black;">XXXXXXXXXX</span>		<b>Inside an AMA:</b> Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>  <b>If yes, which AMA:</b> <input type="checkbox"/> Phoenix <input type="checkbox"/> Tucson <input type="checkbox"/> Prescott <input type="checkbox"/> Pinal <input type="checkbox"/> Santa Cruz											
<b>Contact Person:</b> Name: Benjamin Koch Title: Research Associate, Senior Phone: 928-523-1742 Fax: 928-523-0565 e-mail: ben.koch@nau.edu		<b>Type of Application:</b> <input checked="" type="checkbox"/> New <input type="checkbox"/> Continuation  <b>Any Previous AWPf Grants:</b> <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No  <b>If yes, please provide Grant #(s):</b>											
<b>Arizona Water Protection Fund Grant Amount Requested:</b>  \$32,496.00  If the application is funded, will the Grantee intend to request an advance: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No		<b>Matching Funds Obtained and Secured:</b> <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="text-align: left; border-bottom: 1px solid black;"><u>Applicant/Agency/Organization:</u></th> <th style="text-align: right; border-bottom: 1px solid black;"><u>Amount (\$):</u></th> </tr> <tr> <td>1. Applicant</td> <td style="text-align: right;">28,558.00</td> </tr> <tr> <td>2.</td> <td></td> </tr> <tr> <td>3.</td> <td></td> </tr> <tr> <td colspan="2" style="text-align: right; padding-top: 10px;"><b>Total: 28,558.00</b></td> </tr> </table>		<u>Applicant/Agency/Organization:</u>	<u>Amount (\$):</u>	1. Applicant	28,558.00	2.		3.		<b>Total: 28,558.00</b>	
<u>Applicant/Agency/Organization:</u>	<u>Amount (\$):</u>												
1. Applicant	28,558.00												
2.													
3.													
<b>Total: 28,558.00</b>													
Has your legal counsel or contracting authority reviewed and accepted the Grant Award Contract General Provisions? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> N/A													
<b>Signature of the undersigned certifies understanding and compliance with all terms, conditions and specifications in the attached application. Additionally, signature certifies that all information provided by the applicant is true and accurate. The undersigned acknowledges that intentional presentation of any false or fraudulent information, or knowingly concealing a material fact regarding this application is subject to criminal penalties as provided in A.R.S. Title 13. The Arizona Water Protection Fund Commission may approve Grant Awards with modifications to scope items, methodology, schedule, final products and/or budget.</b>													
Kerwin A. Lawrence <b>Typed Name of Applicant or Applicant's Authorized Representative</b>		Sponsored Projects Office, Sr. phone (928) 523-8585 <b>Title and Telephone Number</b>											
		<div style="text-align: center; font-size: 1.5em; font-family: cursive;">8/31/18</div>											
<b>Signature</b>		<b>Date Signed</b>											

# Arizona Watershed Map FY 2019



- 1: Oak Creek
- 2: Wet Beaver Creek
- 3: Blue River
- 4: Black River

**Title of Project:** Do native fish facilitate the persistence of endangered spikedace by resuspending food particles?

**Location** (include UTM's & Township/Range/Section):

**Oak Creek:** 12N 428236 3855607, S24 T17N R5E;

**Wet Beaver Creek:** 12N 437035 3837689, S23 T15N R6E;

**Blue River: 12N 668144 3685244, S6 T2S R31E;**

**Black River: 12N 655657 3747691, S6 T5N R29E**

(Location must include at least one Section delineation for large scale projects)

# **Do Native Fish Facilitate the Persistence of Endangered Spikedace by Resuspending Food Particles?**

Dr. Benjamin J. Koch, Northern Arizona University

## **Executive Summary:**

This project employs an experimental approach to quantify the extent to which native fish populations facilitate the persistence of a federally endangered fish species (spikedace; *Meda fulgida*). Spikedace are among the rarest of native fish species that remain in streams of the southwestern United States. Once widespread within the Gila watershed, this species is now known to occur in only a handful of streams in Arizona and New Mexico. Repopulating stream reaches where spikedace are currently depleted or extirpated is crucial to their recovery, however relatively little is known about the habitat features of streams that promote spikedace persistence. Preliminary research suggests that the feeding activities of conspecific native suckers may be important in resuspending organic particles and invertebrates that serve as food for spikedace. The **purpose** of this project is to evaluate the magnitude of this biotic mechanism in providing favorable conditions for spikedace persistence across a range of stream reaches that vary in native sucker abundance.

By conducting a replicated field experiment in streams throughout the Gila basin of Arizona, this research will reveal the quantity, timing, and composition of particulates resuspended via feeding activities of native Sonora suckers (*Catostomus insignis*). I **hypothesize** that native suckers, by feeding on the stream bottom, resuspend organic matter into the water column and that some portion of those particles may serve as a food resource to spikedace, which forage exclusively on drifting organic matter and invertebrates high in the water column. To **test this hypothesis**, I will use a before-after-control-impact (BACI) experimental design to manipulate the densities of suckers in three reaches in each of 3-4 streams throughout the Gila basin. Each stream site will contain an ambient-sucker-density reach where suckers are not manipulated as well as a reduced-sucker-density reach and elevated sucker-density-reach. Suckers will be captured from the reduced-density reach and temporarily relocated to the elevated-density reach. The fish assemblages, as well as the temporal dynamics and composition of suspended organic matter (i.e., percent algae, leaves, invertebrates, and detritus) will be measured before and after the sucker density manipulation in each experimental reach of the 3-4 study streams. The results from this project will directly inform current spikedace repatriation efforts in streams and rivers throughout Arizona by helping managers, including the Arizona Game and Fish Department (AZGFD) and U.S. Fish and Wildlife Service (USFWS), identify streams with fish assemblages that might promote spikedace persistence.

Accordingly, this project will **benefit the freshwater resources of Arizona** by providing new data and information to directly inform management actions undertaken to recover federally endangered spikedace in the Southwest. This project has broad support among the community of scientists and natural resource managers involved with habitat restoration and recovery of native spikedace in Arizona streams. Aquatic biologists from AZGFD, USFWS, and U.S. Geological Survey (USGS) have been actively involved in the design of the proposed research (see attached letters of support). As detailed in the attached budget, Northern Arizona University will provide matching funds for this project equivalent to 88% of the total requested funds.

## Project Overview:

### Background

The spikedace (*Meda fulgida*) is among the rarest of native fish species that remain in streams of the southwestern United States. Once widespread within the Gila watershed, this species is now known to occur in only a handful of streams in Arizona and New Mexico (Minckley 1973, Paroz and Propst 2007, USFWS 2012). Spikedace were listed as Threatened under the Endangered Species Act in 1986 (USFWS 1986) and uplisted to Endangered in 2012 (USFWS 2012). In addition, the species is considered Tier 1A Species of Greatest Conservation Need by the Arizona Game and Fish Department (AZGFD 2012).

Repopulating stream reaches where spikedace are currently depleted or extirpated is crucial to their recovery (USFWS 2012). In Arizona, spikedace repatriation has been attempted in five streams (Bonita Creek, Hot Springs Canyon, Redfield Canyon, Fossil Creek, and Spring Creek), with varying degrees of success. A variety of biotic and abiotic habitat variables are thought to limit spikedace populations (Schreiber and Minckley 1981, USFWS 2012), and a more comprehensive understanding of those habitat constraints is needed to prioritize stream reaches chosen for repatriation.

Previous and ongoing research that focused on evaluating the habitat needs for spikedace have quantified a number of physical, abiotic characteristics of streams associated with spikedace presence (Minckley 1973, Rinne 1991, 1992, Gido and Propst. *in progress*, Koch et al. *in progress*, Robinson and Eiden *unpublished manuscript*). Those abiotic habitat features include substrate size, stream size, water velocity, and patterns of riffles and pools throughout a stream reach. While abiotic habitat features such as these may be important for spikedace persistence in Arizona streams, relatively little is known about the *biotic* features and functions of streams that support spikedace populations.

Recently collected data and observations have begun to address this **knowledge gap** and suggest that certain biotic features of Arizona streams, like the composition of species comprising the fish assemblage, may further enhance the success of native and repatriated spikedace populations. Spikedace feed almost exclusively high in the water column on bits of organic matter and drifting invertebrates (Schreiber and Minckley 1981, Pilger et al. 2010, B.J. Koch *personal observation*). Preliminary data indicate that the supply of these food resources may be regulated by conspecific native fish such as Sonora suckers (*Catostomus insignis*), which feed along the stream bottom, disturbing the substrate and resuspending organic matter and invertebrates that then become available as food for spikedace. For example, preliminary data collected by my research team in Fossil Creek, Arizona indicates a strong diel pattern in the concentration of suspended particulate matter (seston) in the water column. Seston concentrations were 4 times higher at night – when suckers are most active (Booth et al. 2013) – compared to daytime concentrations. Furthermore, this day-to-night increase in seston concentration was amplified in a section of Fossil Creek with a full native fish assemblage – including suckers and spikedace – compared to a section of the stream located below a Bureau of Reclamation-installed fish barrier that only harbored non-native smallmouth bass and no spikedace (J.D. Torresdal and B.J. Koch *unpublished data*). These preliminary data are consistent with the hypothesis that native suckers may resuspend organic matter when they feed at night, providing a necessary food resource for water column-feeding spikedace. Similarly, fish telemetry data from the West Fork of the Gila River in New Mexico shows that Sonora sucker activity is closely correlated with seston concentration in the water column, indicating that sucker activity may be a primary driver of nighttime peaks in seston availability (Booth *in review*).

### Hypothesis, Goal, and Objective

Based on these preliminary data, I **hypothesize** that such bioturbation by native suckers may further facilitate the successful persistence of spikedace in streams that already have appropriate physical habitat features. To **test his hypothesis**, I propose to conduct an experimental manipulation of sucker abundance in several streams throughout the historic range of spikedace in the Gila watershed. Thus, the **goal** of this

project is to evaluate biotic habitat constraints for spinedace across a range of stream conditions that vary in native sucker abundance.

The **objective** of this research is to conduct a replicated field experiment in several streams throughout the Gila basin of Arizona in order to measure the quantity, timing, and composition of benthic organic matter resuspended via bioturbation and feeding activities of native Sonora suckers. I will use a before-after-control-impact (BACI) design to manipulate the densities of suckers in three reaches in each of 3-4 streams throughout the Gila basin. Each stream site will contain (1) an ambient-sucker-density reach where suckers are not manipulated and (2) a reduced-sucker-density reach and (3) elevated sucker-density-reach and where native suckers are captured from the reduced-density reach and relocated to the elevated-density reach. The fish assemblages, as well as the diel dynamics and composition of suspended organic matter will be measured before and after the sucker density manipulation in each reach of the 3-4 study streams (Oak Creek, Wet Beaver Creek, Blue River, and/or Black River). These streams were selected in consultation with AZGFD and USFWS aquatic biologists because they harbor populations of Sonora suckers and are amenable to experimental manipulation (see *Scope of Work* for additional details of proposed study reaches).

#### Significance to River Restoration

Results from this experiment will enable answering the following **research questions** relevant to the restoration of spinedace: (1) How much seston is resuspended by native suckers? (2) What is the composition of that seston (percent organic content and fraction that is algae, leaves, invertebrates, detritus, etc.)? (3) To what extent does the composition of resuspended seston match previously published data on the diets of spinedace?

This research will **advance scientific understanding** of the recovery of native endemic fishes to Arizona rivers and streams by quantifying the biotic interactions and ecosystem functions that facilitate the persistence of a unique native fish. Specifically, this project will generate new data that will build upon existing data to directly inform current spinedace repatriation efforts in streams and rivers throughout Arizona, by helping managers (AZGFD and USFWS) identify streams with fish assemblages that might promote, rather than confound, spinedace persistence. Because it focuses on biotic interactions that may promote the persistence of spinedace, the proposed research addresses both *biological control* and *refugia* ecosystem services (Constanza et al. 1997).

This project has broad support among the community of scientists and natural resource managers involved with habitat restoration and recovery of native spinedace in Arizona streams. My research team has, and will continue to, work closely with appropriate state and federal agencies, including AZGFD, USFWS, USGS, and the U.S. Forest Service (USFS), to coordinate this research and ensure that it is carried out in a way that will be most informative to future river management and restoration actions. I am working closely with AZGFD native fish biologists (Tony Robinson, Scott Rogers, Matt Rinker), USFWS personnel (Shaula Hedwall, Mary Richardson), USGS native fish experts (David Ward), USFS aquatic biologists (Matt O'Neill, Stephanie Coleman). Letters of support from agency partners are included in the *Supplemental Information* of this application.

As detailed in the attached *Scope of Work*, results will be reported and disseminated via at least one peer-reviewed scientific publication and a written and oral final report to the AWPFC Commission. All project results, including the final report, will be shared with the state and federal agency partners identified above. Additionally, oral and poster presentations of research results will be presented at a national scientific conference and to local public audiences. Data will be deposited in a permanent data repository.

Full citation information for the scientific literature referenced in this proposal is included in the *Supplemental Information* of this application.

## **Scope of Work:**

### **Task 1: Permits, Authorizations, Clearances, and Agreements**

**Task Description:** Our research team will obtain and submit to the Project Manager all permits, authorizations, clearances, and agreements, and perform any necessary consultations to complete the tasks listed in this Scope of Work. These include:

- a) State Historic Preservation Office (SHPO) clearance.
- b) Arizona Game and Fish Department (AZGFD) Scientific Collecting License (SCL; issued annually).
- c) Endangered Species Act Section 7 consultation and permit(s) with US Fish & Wildlife Service to conduct the proposed research.
- d) Access agreements and research permits (including final agreements of exact field site locations and NEPA compliance if required) between Grantee and Landowner (U.S. Forest Service; Coconino National Forest and Apache-Sitgreaves National Forests).
- e) Research protocols approved by Northern Arizona University's (NAU) Institutional Animal Care and Use Committee (IACUC).

**Task Purpose:** To comply with all local, state, and federal permit requirements, environmental laws such as ESA, and obtain legal access to research field sites.

**Deliverable Description:** Copies of all approved permits, authorizations, clearances, and agreements.

**Responsible personnel:** Dr. Benjamin Koch (Grantee).

**Deliverable Due Date:** Prior to any experimental fieldwork activities (Task 5).

**Reimbursable Cost:** \$818.00

### **Task 2: Hiring Project Personnel.**

**Task Description:** The Grantee will advertise, interview, and hire personnel to complete the tasks listed in this scope of work. Personnel to be hired include:

- a) A graduate student at Northern Arizona University (NAU) who will be responsible for leading the field experiment and data collection phase of the project and assisting with laboratory processing and data analysis.
- b) A temporary part-time research technician who will be responsible for assisting the graduate student in conducting field and laboratory work.

**Task Purpose:** To ensure adequate human resources to complete the tasks listed in this scope of work.

**Deliverable Description:** Copies of all hiring and/or employment agreements relevant to completing the work outlined in this proposal.

**Responsible personnel:** Dr. Benjamin Koch (Grantee).

**Deliverable Due Date:** Prior to any experimental fieldwork activities (Task 5).

**Reimbursable Cost:** \$626.00

### **Task 3: Purchasing Necessary Supplies.**

**Task Description:** Purchase supplies needed to conduct the tasks listed in this scope of work. Supplies needed to conduct the proposed research include:

- a) Water quality multi-meter to measure turbidity throughout the study reaches for the duration of the field experiments.
- b) Nets, Vexar plastic mesh screen, and snorkel gear for surveying fish populations at the sampling sites and capturing native suckers for the field experiment
- c) Consumable field and laboratory supplies (filters, ethanol, etc.) for collecting and preserving drift and seston samples.

**Task Purpose:** To ensure adequate field and sampling equipment and supplies to complete the tasks listed in this scope of work.

**Deliverable Description:** Copies of all invoices for necessary field and laboratory supplies.

**Responsible personnel:** Dr. Benjamin Koch (Grantee).

**Deliverable Due Date:** Prior to experimental fieldwork activities and as needed throughout the field data collection and laboratory data processing phases (Tasks 5 & 6).

**Reimbursable Cost:** \$3,182.00

**Task 4: Refining Project Plans.**

**Task Description:** Refine the experimental design plans and exact site locations outlined in Task 5, in consultation with agency partners.

a) Final site locations for the manipulated reaches.

b) Final sampling protocols for pre- and post-manipulation field data collection.

**Task Purpose:** To ensure scientifically sound experimental design and data collection.

**Deliverable Description:** Written summary of experimental design and plans.

**Responsible personnel:** Dr. Benjamin Koch (Grantee).

**Deliverable Due Date:** Prior to experimental fieldwork activities (Task 5).

**Reimbursable Cost:** \$488.00

**Task 5: Conducting Field Experiments and Collecting Associated Field Data.**

**Task Description:** Collect field samples of invertebrate drift and organic matter dynamics and conduct the field manipulation of sucker densities in each of 3-4 streams (Oak Creek, Wet Beaver Creek, Blue River, and/or Black River). Field experiment and data collection sub-tasks for each of the 3-4 stream sites include:

a) Pre-manipulation reach measurements at each site, including:

i) Delineating the ambient, reduced, and elevated sucker abundance reaches (3 reaches within each study site). Specific reach lengths and separating between reaches will be determined based on the discharge of each stream site and preliminary seston measurements (see below), but will likely range from 50-500m.

ii) Surveying the initial abundance and species composition of the fish assemblage in each of the three reaches.

iii) Collecting suspended particulate matter (seston) and invertebrate drift samples through time and longitudinally throughout each of the 3 reaches using a combination of 0.2µm glass-fiber filters and drift nets.

iv) Measuring turbidity and stream discharge in each of the 3 reaches.

b) Install temporary barriers to sucker movement (Vexar plastic mesh screen) at the tops and bottoms of the 3 experimental reaches.

c) Capture suckers from the reduced-abundance experimental reach and relocate them to the elevated-abundance experimental reach using USFWS and AZGFD-approved methods appropriate to each particular stream (likely seining, hoop-netting, and/or backpack electrofishing).

d) Maintain the temporary fish barriers (Vexar plastic mesh screen) as needed throughout the duration of the experimental manipulation. This includes daily cleaning of the Vexar plastic mesh screen to prevent clogging and barrier failure. Total duration of the experimental manipulations is expected to be 8-15 days (including 5-10 days for relocated suckers to recover from capture and relocation and acclimate to their new stream reach and 3-5 days to perform the post-manipulation reach measurements detailed below).

e) Post-manipulation reach measurements at each site, including:

i) Collecting suspended particulate matter (seston) and invertebrate drift samples through time and longitudinally throughout each of the 3 reaches using a combination of 0.2µm glass-fiber filters and drift nets.

ii) Measuring turbidity and stream discharge in each of the 3 reaches.



- iii) Surveying the post-manipulation abundance and species composition of the fish assemblage in each of the three reaches.
- f) Remove temporary fish barriers (Vexar plastic mesh screen) from each reach to allow fish in each reach to re-disperse naturally throughout the stream.

**Task Purpose:** To perform the necessary experimental manipulations and data collection to test the central hypothesis of the proposed research.

**Deliverable Description:** Interim progress report(s) detailing the work conducted for each experimental manipulation.

**Responsible personnel:** Dr. Benjamin Koch (Grantee), NAU graduate student, NAU technician.

**Deliverable Due Date:** Exact timing of the field experimental manipulations will depend on the approval of all permits and clearances, as well as on seasonal monsoon rains. We will conduct the field manipulations between September and July to minimize the risk of monsoon-associated floods to interfere with the experimental manipulations. All experimental manipulations will be completed by December 2021, and could start as early as June 2019.

**Reimbursable Cost:** \$19,665.00

#### **Task 6: Laboratory Processing of Field Samples.**

**Task Description:** Process samples in the laboratory to identify the macroinvertebrates and other types of organic matter (algae, leaves, detritus, etc.) present in the drift samples collected during the field experiments. We will also measure the dry weight and organic content of the suspended particulate samples collected during the field experiment.

- a) Drift sample characterization (macroinvertebrate identification and sorting and weighing different categories of organic matter using a dissecting scope and balance and drying oven).
- b) Seston sample characterization (dry mass and organic content measured using a balance, drying oven, and combustion furnace).

**Task Purpose:** To obtain the necessary data from the samples collected during the field experiment to test the central hypothesis of the proposed research.

**Deliverable Description:** Interim progress report(s) detailing the laboratory work conducted for all samples collected as part of each experimental manipulation.

**Responsible personnel:** Dr. Benjamin Koch (Grantee), NAU graduate student, NAU technician.

**Deliverable Due Date:** Laboratory processing of each set of field samples will follow each experimental manipulation. We expect that laboratory processing of samples for a given site's field experiment will be completed within 3 months of the end of the experiment. All laboratory processing of field samples will be completed by March 2022.

**Reimbursable Cost:** \$3,709.00

#### **Task 7: Data Entry and Analysis.**

**Task Description:** Enter field and laboratory data into a digital format and analyze data to test for effects of sucker abundance on the magnitude, composition, timing, and temporal dynamics of suspended organic matter. We will also compare seston and drift composition to published measures of spikedace diet.

- a) All data entered into a digital format (MS Excel workbook and/or plain-text files).
- b) Statistical analyses of experimental data to test effects of sucker abundance on seston and drift characteristics.
- c) Compare seston and drift characteristics from the different experimental treatments (ambient, reduced, and elevated sucker abundance) to published estimates of spikedace diet.

**Task Purpose:** To utilize the experimental data collected to estimate the magnitude of sucker-mediated effects on seston amount, composition, and timing. The analyses will address the extent to which the seston characteristics associated with suckers from this study match published patterns in spikedace diet.

**Deliverable Description:** Interim progress report(s) and graphs detailing the analyses conducted on the experimental data.

**Responsible personnel:** Dr. Benjamin Koch (Grantee), NAU graduate student.

**Deliverable Due Date:** Prior to submission of final project report.

**Reimbursable Cost:** \$1,547.00

**Task 8: Report and Manuscript Preparation.**

**Task Description:** Prepare manuscript(s) for publication and final report(s) on our research findings to AWPf Commission and other agency partners (AZGFD, USFWS, USGS, USFS).

a) A draft of at least one manuscript will be prepared for publication in a peer-reviewed scientific journal.

b) A written final report to the AWPf Commission and agency partners in the proposed research.

**Task Purpose:** To concisely summarize the main findings of this research in a way that facilitates such information being used by natural resource managers to guide and improve the success of spikedace repatriation efforts in streams and rivers throughout Arizona.

**Deliverable Description:** Copies of manuscript draft(s) and final report(s).

**Responsible personnel:** Dr. Benjamin Koch (Grantee), NAU graduate student.

**Deliverable Due Date:** Prior to end date of contract.

**Reimbursable Cost:** \$1,352.00

**Task 9: Dissemination of Project Results.**

**Task Description:** Giving oral and/or poster presentations on the progress of the research project and making project data available to other researchers.

a) Graduate student presentation of research findings from the project at a national scientific conference of freshwater scientists (Society for Freshwater Science).

b) Presentation of project results to the AWPf Commission and interested community partners including AZGFD, USFWS, USGS, and/or USFS personnel.

c) Presentation of project results to the NAU community and public via campus and/or community events (e.g., annual NAU Water Symposium and/or monthly Flagstaff Science on Tap talk).

d) Deposit field experiment data from this project in a long-term ecological data archive (e.g., Dryad).

**Task Purpose:** To disseminate project findings widely among members of the scientific and natural resource management communities as well as among the public at large.

**Deliverable Description:** Brief descriptions of oral and poster presentations including dates, times, venues, and audiences. Digital copies of presentations (e.g., slides, if any) and/or posters.

**Responsible personnel:** Dr. Benjamin Koch (Grantee), NAU graduate student.

**Deliverable Due Date:** Presentations of project progress and findings will be made throughout the duration of the project and prior to end date of contract.

**Reimbursable Cost:** \$1,109.00

**TOTAL Reimbursable Cost \$32,496**

**Project Schematic:**

Not applicable as the proposed project does not involve construction or investigation of physical features.

*\*Note: The proposed work is a 'Research' project, not a 'Capital' or 'Water Conservation' project. Accordingly, on the cover page, we have indicated our "level of commitment to maintaining project benefits and capital improvements" as "<5 years", because this corresponds to the timeframe that our research project will be implemented. However, as outlined in this proposal, the knowledge yielded by our research should be useful to natural resource managers going forward many years.*

## Detailed Budget Breakdown:

***Total Requested: \$32,496***

	Total	Salary or stipend	Fringe	Ave cost/hr.
Direct Labor Costs				
Graduate student	\$18,403	\$12,250	\$6,153	\$20.91
Temporary part-time technician	\$8,459	\$7,800	\$659	\$17.62
Outside Services				
not applicable				
Other Direct Costs				
Materials and supplies	\$3,030			
Domestic travel	\$1,056			
Capital Outlay & Equipment Costs				
not applicable				
Administrative Costs				
NAU overhead costs	\$1,547			

### A. Direct Labor:

#### 1. Other Personnel

We request a total of \$7,800 to fund one temporary, part-time technician: 100% effort during a total of three months of the project. Compensation based on a calendar-year salary of \$31,200 (\$15/hour). The technician will assist with the collection of field samples and will perform laboratory analyses including macroinvertebrate identification and data entry.

We request a total of \$12,250 to fund one graduate student: 100% effort for the summer months during the first year and 50% effort during one fall semester of the three-year project. Compensation based on University and Department guidelines of \$5,500 summer stipend and \$6,750 semester graduate research assistantship stipend. The graduate student will lead the collection of field samples and will perform laboratory work including macroinvertebrate identification, data entry, and data analysis.

#### 2. Fringe Benefits

Employee-related expenses (ERE) are estimates based on the projected cost of health, dental, life, disability, FICA and Medicare, unemployment, and retirement benefits relative to the employee's salary and/or wages, FTE, and election of benefits. The employee estimated ERE rate equals one's salary divided by the total cost of their benefit package.

Fringe rate for the temporary part-time technician is 8.45%. Fringe rate is 0.37% (during the academic year) and 8.02% (during the summer) for graduate student. Fringe includes one fall semester's cost of attendance for the graduate student: the cost of health insurance (\$789) for one semester and \$4898 tuition remission.

The total fringe requested for the project is \$6,812.

**B. Outside Services:** Not applicable.

**C. Other Direct Costs:**

**1. Domestic Travel:**

Total domestic travel costs estimated at \$1,056 to support travel expenses for one graduate student to present project results at a national scientific meeting (nationwide) of freshwater scientists. We estimate \$520 for airfare, \$236 for 4 days per diem (\$59 per day), and \$300 for 3 nights of lodging (\$100 per night).

**2. Foreign Travel:** Not Applicable.

**3. Materials and Supplies:**

A total of \$3,030 is requested for materials and supplies over the three-year project period, including funds (\$800) for nets, Vexar plastic mesh screen, and snorkel gear for surveying fish populations at the sampling sites and capturing native suckers for the field experiment, and field and laboratory supplies for collecting and preserving drift and seston samples (\$380). We request \$1850 to purchase one water quality probe and a handheld display. This equipment measures diurnal turbidity and conductivity concentrations to estimate reach-scale seston dynamics at the field sampling sites.

**D. Capital Outlay & Equipment:** Not applicable

**E. Total Direct Costs (TDC):** \$30,948

**F. Administrative Costs: \$1,547**

The indirect costs rate restricted to 5% by sponsor.

**G. Total Direct and Indirect Costs:** \$32,496

**H. Amount of this Request:** \$32,496

## Detailed Matching Funds Breakdown:

***Total Contributed: \$28,558***

	Total	Salary or stipend	Fringe	Ave cost/hr.
Direct Labor Costs				
Project Coordinator (PI)	\$10,733	\$8,371	\$2,362	\$44.72
Outside Services				
not applicable				
Other Direct Costs				
not applicable				
Capital Outlay & Equipment Costs				
not applicable				
Administrative Costs				
NAU foregone overhead	\$17,825			

### A. Direct Labor:

#### 1. Senior Personnel

The Principal Investigator, Dr. Benjamin Koch, will work for 0.50 month during each year of the three-year project period (240 hours). This time will be *contributed cost share to the project* for a total of **\$8,371**. The PI's compensation based on a fiscal year salary of \$65,000, base salary is \$2708 in year 1 with 3% increase in year 2 and 3. Dr. Koch will be responsible for overall project direction and coordination, and for assuring successful project completion, including submission of progress reports, as required. Dr. Koch will supervise the graduate student and technician, oversee the collection of field data, assist with the data analysis, and prepare the manuscript(s) for publication.

#### 2. Fringe Benefits

Employee-related expenses (ERE) are estimates based on the projected cost of health, dental, life, disability, FICA and Medicare, unemployment, and retirement benefits relative to the employee's salary and/or wages, FTE, and election of benefits. The employee estimated ERE rate equals one's salary divided by the total cost of their benefit package.

Fringe rate is 27.6% for the PI and increases 0.6% in years 2 and 3; PI's fringe will be *contributed cost share to the project* for a total of **\$2,362**.

### B. Total Direct Cost \$10,733

### C. Administrative Costs:

Indirect costs (IDC) rate restricted to 5% by sponsor, therefore we are using foregone indirect cost as a *contributed cost share to the project*. The foregone modified total direct costs (MTDC) rate is 52% - 5% = 47%.

The MTDC on-campus research rate in accordance with Northern Arizona University's approved Colleges and Universities Rate Agreement (March 16, 2017, Cognizant Agency: U.S. Dept. of Health and

Human Services). The MTDC base consists of all direct salaries and wages, applicable fringe benefits, materials and supplies, services, travel, and subawards and subcontracts up to the first \$25,000 of each subaward or subcontract. MTDC *excludes* equipment, capital expenditures, charges for patient care, rental costs, tuition remission, scholarships and fellowships, participant support costs and the portion of each subaward and subcontract in excess of \$25,000.

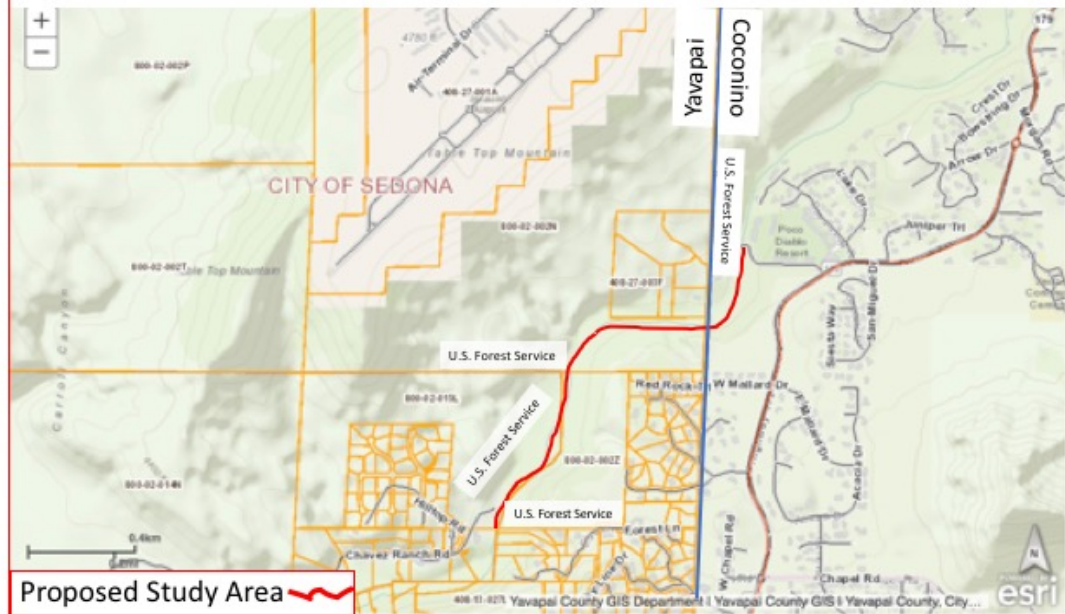
***Total Indirect Costs (IDC) Contributed \$17,825***

	IDC Rate	IDC Base	Total Foregone IDC
Foregone IDC - Year 1			
TDC	47%	\$26,050	\$12,244
Foregone IDC on Match – Year 1 to 3			
MTDC	52%	\$10,733	\$5,581
Total NAU Foregone overhead			\$17,825

**D. Total Cost Share: \$28,558**

## Project Location/Ownership Maps:

### Oak Creek: Chavez Crossing

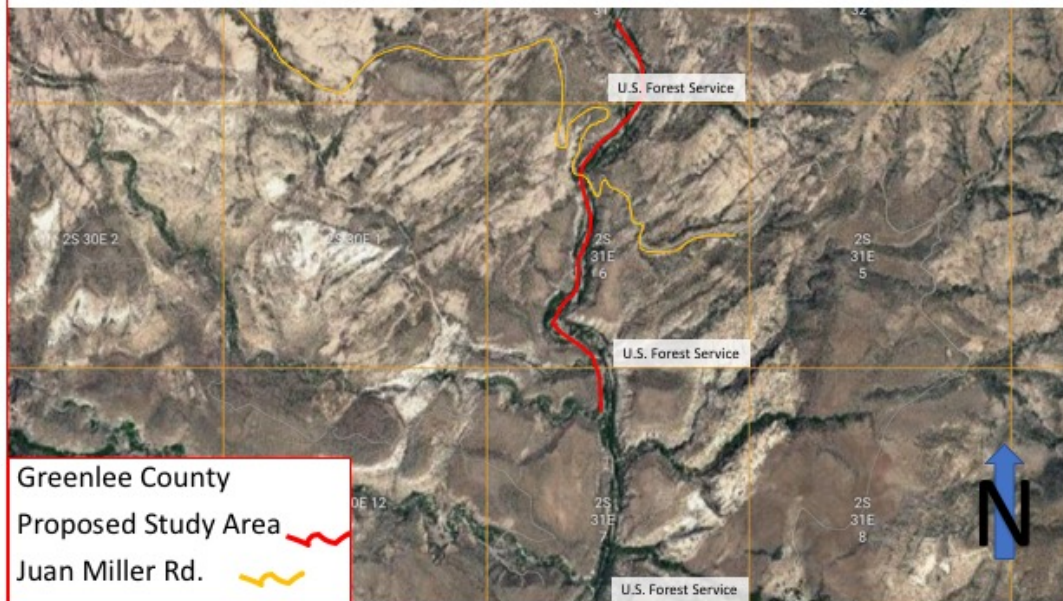


### Wet Beaver Creek

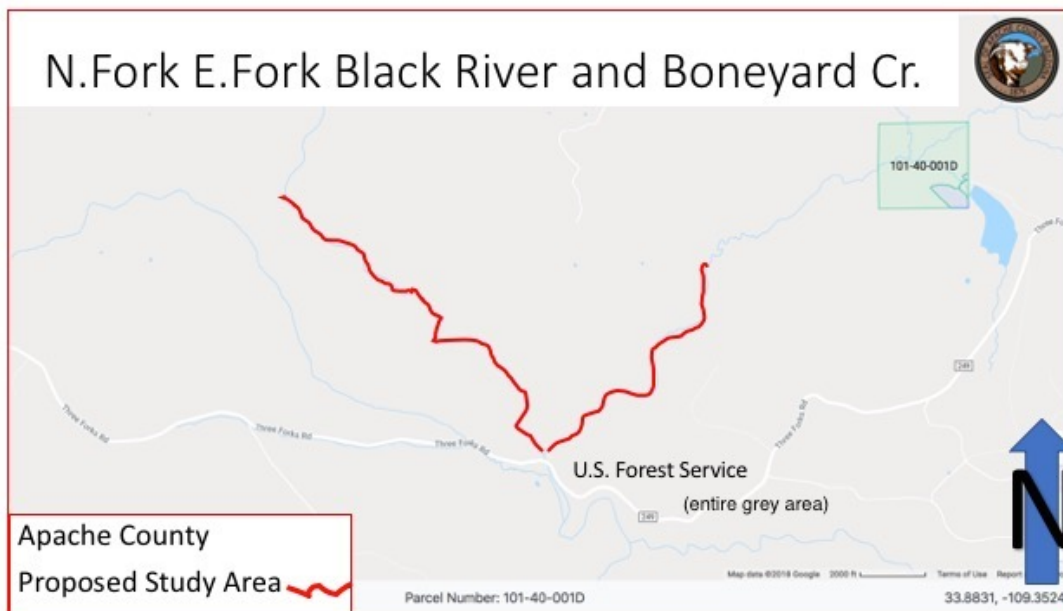




# Blue River: Juan Miller Crossing



# N.Fork E.Fork Black River and Boneyard Cr.



## Literature Cited:

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- Rinne, J.N. 1991. Habitat use by spikedace, *Meda fulgida* (Pisces: Cyprinidae), in southwestern streams, with reference to probable habitat competition by red shiner, *Notropis lutrensis* (Pisces: Cyprinidae). *The Southwestern Naturalist* 36:7-13.
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- USFWS (U.S. Fish and Wildlife Service). 1986. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Spikedace. Federal Register 51:23769-23781.
- USFWS (U.S. Fish and Wildlife Service). 2012. Endangered and Threatened Wildlife and Plants; Endangered Status and Designations of Critical Habitat for Spikedace and Loach Minnow. Federal Register 77:10810-10932.

## Key Personnel:

Dr. Benjamin Koch (Project Coordinator) will serve as the lead investigator for Northern Arizona University. A temporary part-time research technician (to be named) will be responsible for conducting field and laboratory work and a NAU graduate student (to be named) will be responsible for leading the field experiment and data collection phase of the project and assisting with laboratory processing and data analysis. The graduate student will also present research findings from the project at a national scientific conference of freshwater scientists. A brief biographical sketch for Dr. Koch is included below.

### Biographical Sketch Benjamin J. Koch

#### (a) Professional Preparation

University of Virginia	Charlottesville, VA	Biology	B.A. 1998
University of Wyoming	Laramie, WY	Zoology and Physiology	M.S. 2005
University of Wyoming	Laramie, WY	Ecology, with Statistics minor	Ph.D. 2011
University of Maryland	College Park, MD	Ecosystem Ecology	2011-2014
Northern Arizona University	Flagstaff, AZ	Quantitative Ecology	2014-present

#### (b) Appointments

Adjunct Professor, Department of Biological Sciences, Northern Arizona University, 2018-present  
Research Scientist, Center for Ecosystem Science and Society, Northern Arizona University, 2017-present

Assistant Research Professor, Center for Ecosystem Science and Society, Northern Arizona University, 2016-2017

Postdoctoral Research Scholar, Center for Ecosystem Science and Society, Northern Arizona University, 2014-2016

Postdoctoral Research Associate, University of Maryland, College Park and University of Maryland Center for Environmental Science 2011-2014

#### (c) Selected Relevant Peer-Reviewed Publications (from a total of 22)

Gibson, C.A., **B.J. Koch**, Z.G. Compson, B.A. Hungate, and J.C. Marks. 2018. Ecosystem responses to restored flow in a travertine river. *Freshwater Science* 37:169-177.

**Koch, B.J.**, T.A. McHugh, M. Hayer, E. Schwartz, S.J. Blazewicz, P. Dijkstra, N. van Gestel, J.C. Marks, R.L. Mau, E.M. Morrissey, J. Pett-Ridge, and B.A. Hungate. 2018. Estimating taxon-specific population dynamics in diverse microbial communities. *Ecosphere* 9:e02090.

Vanni, M.J., **B.J. Koch**, and 72 others. 2017. A global database of nitrogen and phosphorus excretion rates of aquatic animals. *Ecology* 98:1475.

Hayer, M., E. Schwartz, J.C. Marks, **B.J. Koch**, E.M. Morrissey, A.A. Schuettenberg, and B.A. Hungate. 2016. Identification of growing bacteria during litter decomposition in freshwater through H<sub>2</sub><sup>18</sup>O quantitative stable isotope probing. *Environmental Microbiology Reports* 8:975-982.

**Koch, B.J.**, C.M. Febria, R.M. Cooke, J.D. Hosen, M.E. Baker, A.R. Colson, S. Filoso, K. Hayhoe, J.V. Loperfido, A.M.K. Stoner, and M.A. Palmer. 2015. Suburban watershed nitrogen retention: Estimating the effectiveness of stormwater management structures. *Elementa: Science of the Anthropocene* 3:000063, doi:10.12952/journal.elementa.000063

Febria, C.M., **B.J. Koch**, and M.A. Palmer. 2015. Operationalizing an ecosystem services-based approach for managing river biodiversity. Pages 26-34 In: Martin-Ortega, J., R.C. Ferrier, I.J. Gordon, and S. Khan (eds.) *Water ecosystem services: A global perspective*. Cambridge University Press, Cambridge, UK.

- Price, L.B., **B.J. Koch**, and B.A. Hungate. 2015. Ominous projections for global antibiotic use in food-animal production. *Proceedings of the National Academy of Sciences* 112:5554-5555.
- Palmer, M.A., K.L. Hondula, and **B.J. Koch**. 2014. Ecological restoration of streams and rivers: shifting strategies and shifting goals. *Annual Review of Ecology, Evolution, and Systematics* 45:247-269.
- Koch, B.J.**, C.M. Febria, M. Gevrey, L.A. Wainger, and M.A. Palmer. 2014. Nitrogen removal by stormwater management structures: a data synthesis. *Journal of the American Water Resources Association* 50:1594-1607.
- Pokallus, J.W., G.M. Campbell, **B.J. Koch**, and J.N. Pauli. 2011. The landscape of ecology. *Ecosphere* 2:22, doi:10.1890/ES10-00173.1
- Hall, R.O., M.A. Baker, C.D. Arp, and **B.J. Koch**. 2009. Hydrologic control of nitrogen removal, storage, and export in a mountain stream. *Limnology and Oceanography* 54:2128-2142.
- Hall, R.O., **B.J. Koch**, M.C. Marshall, B.W. Taylor, and L.M. Tronstad. 2007. How body size mediates the role of animals in nutrient cycling in aquatic ecosystems. Pages 286-305 In: Hildrew, A.G., D.G. Raffaelli, and R. Edmonds-Brown (eds.) *Body size: The structure and function of aquatic ecosystems*. Cambridge University Press, Cambridge, UK.

(d) *Contracts and Grants (funded as principal investigator)*

- 2016-2019 *Habitat evaluation to maximize success of spinedace and loach minnow repatriation*. Lead PI: Benjamin Koch, Co-PIs: Jane Marks, Bruce Hungate. Arizona Game and Fish Department, Heritage Fund. (\$66,033)
- 2016 *The effects of alpine lakes on freshwater food webs in mountain watersheds*. Charles Redd Center for Western Studies, Faculty Research Award. (\$3,000)
- 2016 *Geomorphic controls on freshwater food web energy flow in mountain watersheds: preliminary research*. Rocky Mountain Biological Laboratory, Navjot Sodhi Research Fellowship. (\$1,000)
- 2008 *Impacts of non-native trout on the food base in high-elevation cutthroat trout refugia in Colorado*. North American Native Fishes Association, Conservation Research Grant. (\$675)
- 2008 *Estimating consumptive and non-consumptive interactions between brook trout and aquatic insects*. Sigma Xi Scientific Research Society, Grant-in-Aid of Research. (\$500)
- 2007 *Predator-prey interactions in high-elevation streams: estimating the strength of consumptive and non-consumptive interactions between brook trout and aquatic insects*. American Museum of Natural History, Theodore Roosevelt Memorial Grant. (\$1,500)
- 2007 *Consumptive and non-consumptive interaction strength estimates derived from population energetics: impacts of brook trout on prey productivity*. Sigma Xi Scientific Research Society, Grant-in-Aid of Research. (\$400)
- 2007 *Brook trout impacts on high-elevation stream food webs in Colorado*. University of Wyoming School of Environment and Natural Resources, Haub Grant for Student Research and Creative Activities. (\$1,000)

(e) *Synergistic Activities*

i. *Graduate Research Mentor*

Jack Torresdal, Northern Arizona University: *Habitat evaluation to maximize success of spinedace and loach minnow repatriation*. 2017-present.

ii. *Undergraduate Research Mentor*

Hannah Pigg, Northern Arizona University: *Isotopic Analysis of Freshwater Food Webs*. 2016-2018.

Grant Campbell and John Pokallus, University of Wyoming: *Hotspots of ecology and ecologists across the United States*. 2009-2010.

Christine Bell, University of Wyoming: *Do mayflies and their parasites behave differently in the absence of predaceous trout?* 2009-2010

Mercedi Carpenter, University of Wyoming, Zoology and Physiology Internship. 2009

Kevin Barnes, University of Wyoming, Wildlife Management Internship. 2009

Trista Niekum, University of Wyoming: *The effects of fish chemical cues on mayfly allometry*. 2008-2009

Karla Jarecke, Rocky Mountain Biological Laboratory and Rockhurst University: *Linking drift and benthic density along fishless to fish transitions in Rocky Mountain streams*. 2008.

Supervised 14 field and laboratory research technicians. 2003-2018

iii. *Computational tools to support uncertainty quantification*

Developed a set of computational tools (*R environment*) to estimate taxon-specific microbial growth and uncertainty from quantitative stable isotope probing data for 16S-resolved microbial assemblages. Center for Ecosystem Science and Society, Northern Arizona University. 2014-present.

Developed a set of computational tools (*R environment*) to efficiently estimate secondary production and uncertainty from a massive, multi-year dataset of the aquatic invertebrate assemblage in a 360-km reach of the Colorado River, Grand Canyon. USGS Grand Canyon Monitoring and Research Center. 2010-2011.

iv. *Scientific Service*

Peer Reviewer: *Axios, Ecosphere, Ecosystems, Ecological Engineering, Environmental Science & Technology, Freshwater Biology, Journal of Applied Ecology, PLoS One, Restoration Ecology, Science of the Total Environment*

v. *Invited International & National Lectures to Facilitate Scientific Exchange*

Developing ecological production functions for freshwater ecosystem services. 2012. *Global Change Research Program, National Center for Environmental Assessment*, U.S. EPA Office of Research and Development, Washington, D.C.

Field estimates of consumptive and nonconsumptive interaction strengths from subalpine streams. 2012. *GlobalWeb II: The Future of Food Web Research*, Barcelona, Spain.

Predation and risk effects in prey populations: insights from Rocky Mountain streams. 2010. *Centro Ecología Aplicada de Neuquén*, Gobierno de la Provincia del Neuquén, Junín de los Andes, Argentina.

Lethal and sublethal predator effects on prey: a case study in Rocky Mountain streams. 2010. *Facultad de Ciencias Naturales y Museo*, Universidad Nacional de La Plata, La Plata, Argentina.

vi. *Media Outreach*

Op-Ed article on invasive species in Wyoming: *Casper Star Tribune* 03/2009



**Project Site Photographs:**

*Oak Creek:*



*(photo credit: Joe Edwards)*

Representative reach; compass direction: approx. Northeast.



Wet Beaver Creek:



*(photo credit: USDA Forest Service)*

Representative reach; compass direction: approx. Northeast.

*Blue River:*



*(photo credit: Clifton Union Hall)*

Representative reach; compass direction: approx. South.



*Black River:*



*(photo credit: Park & Co.)*

Representative reach; compass direction: approx. North.

## **Plans:**

### *Project plans*

In the arid Southwest, Arizona streams and riparian areas are valuable in supporting a rich diversity of endemic animals and plants. This project, through research and public dissemination of results, will raise public awareness of how Arizona streams function to enable the persistence of species found nowhere else in the world. The proposed research will advance the science of river restoration in the Southwest by quantifying the in-stream ecosystem functions necessary to restore an intact biotic community that facilitates the persistence of rare native species such as spikedace.

Core elements of the research plan for the proposed project are detailed below:

To accomplish the objective of this project the NAU research team will collect field samples of invertebrate drift and organic matter dynamics and conduct the field manipulation of sucker densities in each of 3-4 streams (Oak Creek, Wet Beaver Creek, Blue River, and/or Black River). Field experiment and data collection sub-tasks for each of the 3-4 stream sites include:

- a) Pre-manipulation reach measurements at each site, including:
  - i) Delineating the ambient, reduced, and elevated sucker abundance reaches (3 reaches within each study site). Specific reach lengths and separating between reaches will be determined based on the discharge of each stream site and preliminary seston measurements (see below), but will likely range from 50-500m.
  - ii) Surveying the initial abundance and species composition of the fish assemblage in each of the three reaches.
  - iii) Collecting suspended particulate matter (seston) and invertebrate drift samples through time and longitudinally throughout each of the 3 reaches using a combination of 0.2µm glass-fiber filters and drift nets.
  - iv) Measuring turbidity and stream discharge in each of the 3 reaches.
- b) Install temporary barriers to sucker movement (Vexar plastic mesh screen) at the tops and bottoms of the 3 experimental reaches.
- c) Capture suckers from the reduced-abundance experimental reach and relocate them to the elevated-abundance experimental reach using USFWS and AZGFD-approved methods appropriate to each particular stream (likely seining, hoop-netting, and/or backpack electrofishing).
- d) Maintain the temporary fish barriers (Vexar plastic mesh screen) as needed throughout the duration of the experimental manipulation. This includes daily cleaning of the Vexar plastic mesh screen to prevent clogging and barrier failure. Total duration of the experimental manipulations is expected to be 8-15 days (including 5-10 days for relocated suckers to recover from capture and relocation and acclimate to their new stream reach and 3-5 days to perform the post-manipulation reach measurements detailed below).
- e) Post-manipulation reach measurements at each site, including:
  - i) Collecting suspended particulate matter (seston) and invertebrate drift samples through time and longitudinally throughout each of the 3 reaches using a combination of 0.2µm glass-fiber filters and drift nets.
  - ii) Measuring turbidity and stream discharge in each of the 3 reaches.
  - iii) Surveying the post-manipulation abundance and species composition of the fish assemblage in each of the three reaches.
- f) Remove temporary fish barriers (Vexar plastic mesh screen) from each reach to allow fish in each reach to re-disperse naturally throughout the stream.

*Existing plans*

In addition, this research will produce results that could lead to greater success of spiketail repatriation efforts, an important component of the 1991 USFWS Spiketail Recovery Plan (attached). The 1991 USFWS Spiketail Recovery Plan details the comprehensive strategy for recovering spiketail throughout the Southwest.

**Control and Tenure of Land:**

The land on which the proposed research will be conducted is owned and managed by the U.S. Forest Service (USFS; see *Project Location/Ownership Maps*). The four sites proposed for the field experiments (Oak Creek, Wet Beaver Creek, Blue River, and /or Black River) are managed as publicly-accessible land. Research activities conducted proposed on these lands must be approved via a USFS research-permitting process prior to the start of any on-the-ground field activities (see Task 1). Dr. Koch has already contacted the appropriate aquatic program managers with the relevant national forests (Coconino National Forest for Oak Creek and Wet Beaver Creek, and Apache-Sitgreaves National Forests for Blue River and Black River) about proceeding with the USFS research permitting process for the proposed research. Dr. Koch will continue working with those USFS personnel (Coconino National Forest: Dr. Matt O'Neill, Apache-Sitgreaves National Forests: Stephanie Coleman) throughout the autumn of 2018 to secure access to study sites for the purpose of conducting the proposed research. The target date for securing final research permit approvals is December 31, 2019 – prior to the target AWPf grant award date.

**Physical and Legal Availability of Water:**

Water will not be used for this project. All fieldwork will take place in free-flowing streams and will not involve any water withdrawals or pumping.

## Project Location & Environmental Contaminant Information FY 2019

<b>Project Location Information</b>			
1. County: <u>Yavapai</u>	2. Section(s): <u>24</u>	3. Township: <u>17N</u>	4. Range: <u>5E</u>
<p>5. Watershed: <u>Verde River</u></p> <p>6. 8 or 10 Digit Hydrologic Unit Code (HUC): <u>15060202</u></p> <p>7. Name of USGS Topographic Map where project area is located: <u>Sedona</u></p> <p>8. State Legislative District: <u>1</u></p> <p style="margin-left: 20px;">(Information available at: <a href="http://azredistricting.org/districtlocator/">http://azredistricting.org/districtlocator/</a>)</p> <p>9. Land ownership of project area: <u>U.S. Forest Service</u></p> <p>10. Current land use of project area: <u>Public Land</u></p> <p>11. Size of project area (in acres): <u>&lt;2 DIRECT</u></p> <p>12. Stream Name: <u>Oak Creek</u></p> <p>13. Length of stream through project area: <u>1-2 miles</u></p> <p>14. Miles of stream benefited: <u>NA miles</u></p> <p>15. Acres of riparian habitat: <u>NA acres</u> will be:</p> <div style="margin-left: 350px;"> <input type="checkbox"/> Enhanced  <input type="checkbox"/> Maintained  <input type="checkbox"/> Restored  <input type="checkbox"/> Created         </div>			
<p>16. General description and/or delineation for the area of impact of the project within the watershed.  <u>Project is a temporary manipulation of sucker density within 1-2 miles of the stream channel only.</u></p>			
<p>17. Provide directions to the project site from the nearest city or town. List any special access requirements:  <u>Access from Chavez Ranch Road or Oak Creek Cliffs Drive.</u></p>			
<b>Environmental Contaminant Location Information</b>			
<p>1. Does your project site contain known environmental contaminants? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO If yes, please identify the contaminant(s) and enclose data about the location and levels of contaminants: _____</p> <p>2. Are there known environmental contaminants in the project vicinity? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO If yes, please identify the contaminant(s) and enclose data about the location and levels of contaminants: _____</p> <p>3. Are you asking for Arizona Water Protection Fund monies to identify whether or not environmental contaminants are present? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO</p>			

## Project Location & Environmental Contaminant Information FY 2019

<b>Project Location Information</b>			
1. County: <u>Yavapai</u>	2. Section(s): <u>23</u>	3. Township: <u>15N</u>	4. Range: <u>6E</u>
<p>5. Watershed: <u>Verde River</u></p> <p>6. 8 or 10 Digit Hydrologic Unit Code (HUC): <u>15060202</u></p> <p>7. Name of USGS Topographic Map where project area is located: <u>Casner Butte</u></p> <p>8. State Legislative District: <u>1</u></p> <p style="margin-left: 20px;">(Information available at: <a href="http://azredistricting.org/districtlocator/">http://azredistricting.org/districtlocator/</a>)</p> <p>9. Land ownership of project area: <u>U.S. Forest Service</u></p> <p>10. Current land use of project area: <u>Public Land</u></p> <p>11. Size of project area (in acres): <u>&lt;2 DIRECT</u></p> <p>12. Stream Name: <u>Wet Beaver Creek</u></p> <p>13. Length of stream through project area: <u>1-2 miles</u></p> <p>14. Miles of stream benefited: <u>NA miles</u></p> <p>15. Acres of riparian habitat: <u>NA acres</u> will be:</p> <div style="margin-left: 350px;"> <input type="checkbox"/> Enhanced  <input type="checkbox"/> Maintained  <input type="checkbox"/> Restored  <input type="checkbox"/> Created         </div>			
<p>16. General description and/or delineation for the area of impact of the project within the watershed.  <u>Project is a temporary manipulation of sucker density within 1-2 miles of the stream channel only.</u></p>			
<p>17. Provide directions to the project site from the nearest city or town. List any special access requirements:  <u>Access from Forest Service Road 618.</u></p>			
<b>Environmental Contaminant Location Information</b>			
<p>1. Does your project site contain known environmental contaminants? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO If yes, please identify the contaminant(s) and enclose data about the location and levels of contaminants: _____</p> <p>2. Are there known environmental contaminants in the project vicinity? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO If yes, please identify the contaminant(s) and enclose data about the location and levels of contaminants: _____</p> <p>3. Are you asking for Arizona Water Protection Fund monies to identify whether or not environmental contaminants are present? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO</p>			

## Project Location & Environmental Contaminant Information FY 2019

<b>Project Location Information</b>			
1. County: <u>Greenlee</u>	2. Section(s): <u>6</u>	3. Township: <u>2S</u>	4. Range: <u>31E</u>
<p>5. Watershed: <u>Upper Gila River</u></p> <p>6. 8 or 10 Digit Hydrologic Unit Code (HUC): <u>15040004</u></p> <p>7. Name of USGS Topographic Map where project area is located: <u>Fritz Canyon</u></p> <p>8. State Legislative District: <u>1</u>            (Information available at: <a href="http://azredistricting.org/districtlocator/">http://azredistricting.org/districtlocator/</a>)</p> <p>9. Land ownership of project area: <u>U.S. Forest Service</u></p> <p>10. Current land use of project area: <u>Public Land</u></p> <p>11. Size of project area (in acres): <u>&lt;2 DIRECT</u></p> <p>12. Stream Name: <u>Blue River</u></p> <p>13. Length of stream through project area: <u>1-2 miles</u></p> <p>14. Miles of stream benefited: <u>NA miles</u></p> <p>15. Acres of riparian habitat: <u>NA acres</u> will be:</p> <div style="margin-left: 400px;"> <input type="checkbox"/> Enhanced  <input type="checkbox"/> Maintained  <input type="checkbox"/> Restored  <input type="checkbox"/> Created         </div>			
<p>16. General description and/or delineation for the area of impact of the project within the watershed.  <u>Project is a temporary manipulation of sucker density within 1-2 miles of the stream channel only.</u></p> <p>17. Provide directions to the project site from the nearest city or town. List any special access requirements:  <u>Access from Juan Miller Road.</u></p>			
<b>Environmental Contaminant Location Information</b>			
<p>1. Does your project site contain known environmental contaminants? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO If yes, please identify the contaminant(s) and enclose data about the location and levels of contaminants: _____</p> <p>2. Are there known environmental contaminants in the project vicinity? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO If yes, please identify the contaminant(s) and enclose data about the location and levels of contaminants: _____</p> <p>3. Are you asking for Arizona Water Protection Fund monies to identify whether or not environmental contaminants are present? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO</p>			



## Project Location & Environmental Contaminant Information FY 2019

<b>Project Location Information</b>			
1. County: <u>Apache</u>	2. Section(s): <u>6</u>	3. Township: <u>5N</u>	4. Range: <u>29E</u>
<p>5. Watershed: <u>Salt River</u></p> <p>6. 8 or 10 Digit Hydrologic Unit Code (HUC): <u>15060101</u></p> <p>7. Name of USGS Topographic Map where project area is located: <u>Buffalo Crossing</u></p> <p>8. State Legislative District: <u>1</u></p> <p style="margin-left: 20px;">(Information available at: <a href="http://azredistricting.org/districtlocator/">http://azredistricting.org/districtlocator/</a>)</p> <p>9. Land ownership of project area: <u>U.S. Forest Service</u></p> <p>10. Current land use of project area: <u>Public Land</u></p> <p>11. Size of project area (in acres): <u>&lt;2 DIRECT</u></p> <p>12. Stream Name: <u>North Fork East Fork Black River</u></p> <p>13. Length of stream through project area: <u>1-2 miles</u></p> <p>14. Miles of stream benefited: <u>NA miles</u></p> <p>15. Acres of riparian habitat: <u>NA acres</u> will be:</p> <div style="margin-left: 350px;"> <input type="checkbox"/> Enhanced  <input type="checkbox"/> Maintained  <input type="checkbox"/> Restored  <input type="checkbox"/> Created         </div>			
<p>16. General description and/or delineation for the area of impact of the project within the watershed.  <u>Project is a temporary manipulation of sucker density within 1-2 miles of the stream channel only.</u></p>			
<p>17. Provide directions to the project site from the nearest city or town. List any special access requirements:  <u>Access from Forest Service Road 249.</u></p>			
<b>Environmental Contaminant Location Information</b>			
<p>1. Does your project site contain known environmental contaminants? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO If yes, please identify the contaminant(s) and enclose data about the location and levels of contaminants: _____</p> <p>2. Are there known environmental contaminants in the project vicinity? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO If yes, please identify the contaminant(s) and enclose data about the location and levels of contaminants: _____</p> <p>3. Are you asking for Arizona Water Protection Fund monies to identify whether or not environmental contaminants are present? <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO</p>			

NOTE THAT THE TOPO MAPS (ITEM #05) ARE NOT IN PDF, BECAUSE THE FILE SIZE IS TOO LARGE.

Below are links to those large files, so that you can download them:

- (1) [https://www.dropbox.com/s/jj4qdvs6kf7d4fx/05\\_AWPF\\_Koch\\_Topo\\_Map\\_AllSites.pdf?dl=0](https://www.dropbox.com/s/jj4qdvs6kf7d4fx/05_AWPF_Koch_Topo_Map_AllSites.pdf?dl=0)
- (2) [https://www.dropbox.com/s/ckf03lziduusgi4/05\\_AWPF\\_Koch\\_Topo\\_Map\\_AllSites\\_zoom.pdf?dl=0](https://www.dropbox.com/s/ckf03lziduusgi4/05_AWPF_Koch_Topo_Map_AllSites_zoom.pdf?dl=0)

Note that there are TWO versions of the topographic maps (at the links above):

- (1) The full versions for inclusion in the electronic copy of the application are in "05\_AWPF\_Koch\_Topo\_Map\_AllSites.pdf"
- (2) The zoomed in versions for printing out in color on 8.5"x11" paper and including with the hard copies are in "05\_AWPF\_Koch\_Topo\_Map\_AllSites\_zoom.pdf"

## STATE HISTORIC PRESERVATION OFFICE

### Review Form

In accordance with the State Historic Preservation Act (SHPO), A.R.S. 41-861 *et seq.*, effective July 24, 1982, each State agency must consider the potential of activities or projects to impact significant cultural resources. Also, each State agency is required to consult with the State Historic Preservation Officer with regard to those activities or projects that may impact cultural resources. Therefore, it is understood that **recipients of state funds are required to comply with this law** throughout the project period. All projects that affect the ground-surface that are funded by AWPf require SHPO clearance, **including those on private and federal lands.**

The State Historic Preservation Office (SHPO) must review each grant application recommended for funding in order to determine the effect, if any, a proposed project may have on archaeological or cultural resources. To assist the SHPO in this review, the following information **MUST** be submitted with each application for funding assistance:

- A completed copy of this form, and
  - A United States Geological Survey (USGS) 7.5 minute map
  - A copy of the cultural resources survey report if a survey of the property has been conducted, and
  - A copy of any comments of the land managing agency/landowner (i.e., state, federal, county, municipal) on potential impacts of the project on historic properties.
- NOTE: If a federal agency is involved, the agency must consult with SHPO pursuant to the National Historic Preservation Act (NHPA); a state agency must consult with SHPO pursuant to the State Historic Preservation Act (SHPA),
- OR**
- A copy of SHPO comments if the survey report has already been reviewed by SHPO.

#### Please answer the following questions:

1. Grant Program: Arizona Water Protection Fund FY 2019
2. Project Title: Do native fish facilitate the persistence of endangered spikedace by resuspending food particles?
3. Applicant Name and Address: ABOR for and on behalf of Northern Arizona University
4. Current Land Owner/Manager(s): U.S. Forest Service
5. Project Location, including Township, Range, Section: S24 T17N R5E; S23 T15N R6E; S6 T2S R31E; S6 T5N R29E
6. Total Project Area in Acres (or total miles if trail): up to 8 miles (river channel)
7. Does the proposed project have the potential to disturb the surface and/or subsurface of the ground?  
☐ YES    ☒ NO
8. Please provide a brief description of the proposed project and specifically identify any surface or subsurface impacts that are expected: Project is a temporary manipulation of sucker (fish) density within 1-2 miles of up to four different stream reaches. Surface impacts are limited to walking along the stream bank. There is no ground disturbance associated with this project.

9. Describe the condition of the current ground surface within the entire project boundary area (for example, is the ground in a natural undisturbed condition, or has it been bladed, paved, graded, etc.). Estimate horizontal and vertical extent of existing disturbance. Also, attach photographs of project area to document condition: Project are included the stream channel. It is naturally undisturbed.

10. Are there any known prehistoric and/or historic archaeological sites in or near the project area? ☐ YES  
☒ NO

11. Has the project area been previously surveyed for cultural resources by a qualified archaeologist? ☐ YES  
☐ NO ☒ UNKOWN

**If YES, submit a copy of the survey report. Please attach any comments on the survey report made by the managing agency and/or SHPO**

12. Are there any buildings or structures (including mines, bridges, dams, canals, etc.), which are 50-years or older in or adjacent to the project area? ☐ YES ☒ NO

**If YES, complete an Arizona Historic Property Inventory Form for each building or structure, attach it to this form and submit it with your application.**

13. Is your project area within or near a historic district? ☐ YES ☒ NO

**If YES, name of the district:**

**Please sign on the line below certifying all information provided for this application is accurate to the best of your knowledge.**

\_\_\_\_\_  
Applicant Signature                      /Date

\_\_\_\_\_  
Applicant Printed Name

FOR SHPO USE ONLY	
SHPO Finding: <input type="checkbox"/> Funding this project will not affect historic properties. <input type="checkbox"/> Survey necessary – further GRANTS/SHPO consultation required ( <i>grant funds will not be released until consultation has been completed</i> ) <input type="checkbox"/> Cultural resources present – further GRANTS/SHPO consultation required ( <i>grant funds will not be released until consultation has been completed</i> )	
SHPO Comments:     	
For State Historic Preservation Office:	Date:

# STATE OF ARIZONA

## HISTORIC PROPERTY INVENTORY FORM

*Please type or print clearly. Fill out each applicable space accurately and with as much information as is known about the property.*

### **PROPERTY IDENTIFICATION**

*For properties identified through survey:* Site No. Not applicable Survey Area: \_\_\_\_\_

Historic Names (*enter the name(s), if any that best reflect the property's historic importance*): \_\_\_\_\_

Address: \_\_\_\_\_

City or Town: \_\_\_\_\_ ☐ Vicinity County: \_\_\_\_\_ Tax Parcel No.: \_\_\_\_\_

Township: \_\_\_\_\_ Range: \_\_\_\_\_ Section: \_\_\_\_\_ Quarters: \_\_\_\_\_ Acreage: \_\_\_\_\_

Block: \_\_\_\_\_ Lot(s): \_\_\_\_\_ Plat (Addition): \_\_\_\_\_ Year of plat (addition): \_\_\_\_\_

UTM Reference – Zone: \_\_\_\_\_ Easting: \_\_\_\_\_ Northing: \_\_\_\_\_

USGS 7.5' quadrangle map: \_\_\_\_\_

ARCHITECT: \_\_\_\_\_ ☐ not determined ☐ known Source: \_\_\_\_\_

BUILDER: \_\_\_\_\_ ☐ not determined ☐ known Source: \_\_\_\_\_

CONSTRUCTION DATE: \_\_\_\_\_ ☐ known ☐ estimated Source: \_\_\_\_\_

### **STRUCTURAL CONDITION**

- ☐ Good (*well maintained; no serious problems apparent*)  
☐ Fair (*some problems apparent*) Describe: \_\_\_\_\_  
☐ Poor (*major problems; imminent threat*) Describe: \_\_\_\_\_  
☐ Ruin/Uninhabitable

### **USES/FUNCTIONS**

Describe how the property has been used over time, beginning with the original use: \_\_\_\_\_

Sources: \_\_\_\_\_

### **PHOTO INFORMATION**

Date of photo: \_\_\_\_\_

View Direction (looking towards): \_\_\_\_\_

Attach a recent photograph of property in this space.  
Additional photographs may be appended.

## **SIGNIFICANCE**

*To be eligible for the National Register, a property must represent an important part of the history or architecture of an area. The significance of a property is evaluated within its historic context, which are those patterns, themes, or trends in history by which a property occurred or gained importance. Describe the historic and architectural contexts of the property that may make it worthy of preservation.*

A. HISTORIC EVENTS/TRENDS – *Describe any historic events/trends associated with the property:* \_\_\_\_\_

B. PERSONS – *List and describe persons with an important association with the building:* \_\_\_\_\_

C. ARCHITECTURE – Style: \_\_\_\_\_ ☐ no style

Stories: \_\_\_\_\_ ☐ Basement Roof Form: \_\_\_\_\_

Describe other character-defining features of its massing, size and scale: \_\_\_\_\_

## **INTEGRITY**

*To be eligible for the National Register, a property must have integrity (i.e. it must be able to visually convey its importance). The outline below lists some important aspects of integrity. Fill in the blanks with as detailed a description of the property as possible.*

Location - ☐ Original Site ☐ Moved: Date: \_\_\_\_\_ Original Site: \_\_\_\_\_

## **DESIGN**

Describe alterations from the original design, including dates: \_\_\_\_\_

## **MATERIALS**

*Describe the materials used in the following elements of the property:*

Walls (structure): \_\_\_\_\_

Walls (sheathing): \_\_\_\_\_

Windows: \_\_\_\_\_

Roof: \_\_\_\_\_

Foundation: \_\_\_\_\_

## **SETTING**

Describe the natural and/or built environment around the property: \_\_\_\_\_

How has the environment changed since the property was constructed? \_\_\_\_\_

## **WORKMANSHIP**

Describe the distinctive elements, if any, of craftsmanship or method of construction: \_\_\_\_\_

## **NATIONAL REGISTER STATUS (if listed, check the appropriate box)**

☐ Individually Listed; ☐ Contributor; ☐ Non-contributor to \_\_\_\_\_ Historic District

Date Listed: \_\_\_\_\_ ☐ Determined eligible by Keeper of National Register (date: \_\_\_\_\_)

**RECOMMENDATIONS ON NATIONAL REGISTER ELIGIBILITY (opinion of SHPO staff or survey consultant)**

Property ☐ is ☐ is not eligible individually.

Property ☐ is ☐ is not eligible as a contributor to a listed or potential historic district.

☐ More information needed to evaluate.

If not considered eligible, state reason: \_\_\_\_\_

## STATE HISTORIC PRESERVATION OFFICE

### Review Form

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  - A copy of the cultural resources survey report if a survey of the property has been conducted, and
  - A copy of any comments of the land managing agency/landowner (i.e., state, federal, county, municipal) on potential impacts of the project on historic properties.
- NOTE: If a federal agency is involved, the agency must consult with SHPO pursuant to the National Historic Preservation Act (NHPA); a state agency must consult with SHPO pursuant to the State Historic Preservation Act (SHPA),
- OR**
- A copy of SHPO comments if the survey report has already been reviewed by SHPO.

#### Please answer the following questions:

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2. Project Title: Do native fish facilitate the persistence of endangered spikedace by resuspending food particles?
3. Applicant Name and Address: ABOR for and on behalf of Northern Arizona University
4. Current Land Owner/Manager(s): U.S. Forest Service
5. Project Location, including Township, Range, Section: S24 T17N R5E; S23 T15N R6E; S6 T2S R31E; S6 T5N R29E
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☐ YES    ☒ NO
8. Please provide a brief description of the proposed project and specifically identify any surface or subsurface impacts that are expected: Project is a temporary manipulation of sucker (fish) density within 1-2 miles of up to four different stream reaches. Surface impacts are limited to walking along the stream bank. There is no ground disturbance associated with this project.



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10. Are there any known prehistoric and/or historic archaeological sites in or near the project area? ☐ YES  
☒ NO

11. Has the project area been previously surveyed for cultural resources by a qualified archaeologist? ☐ YES  
☐ NO ☒ UNKNOWN

**If YES, submit a copy of the survey report. Please attach any comments on the survey report made by the managing agency and/or SHPO**

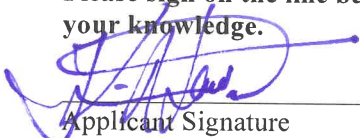
12. Are there any buildings or structures (including mines, bridges, dams, canals, etc.), which are 50-years or older in or adjacent to the project area? ☐ YES ☒ NO

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13. Is your project area within or near a historic district? ☐ YES ☒ NO

**If YES, name of the district:**

**Please sign on the line below certifying all information provided for this application is accurate to the best of your knowledge.**

 /  
Applicant Signature /Date

KEVIN A. LAWRENCE, SPO, Sr.  
Applicant Printed Name

**FOR SHPO USE ONLY**

SHPO Finding:

- ☐ Funding this project will not affect historic properties.  
☐ Survey necessary – further GRANTS/SHPO consultation required (*grant funds will not be released until consultation has been completed*)  
☐ Cultural resources present – further GRANTS/SHPO consultation required (*grant funds will not be released until consultation has been completed*)

SHPO Comments:

For State Historic Preservation Office:

Date:



August 24, 2018

Arizona Water Protection Fund Commission  
1110 West Washington Street, Suite 310  
Phoenix, AZ 85007

This is a letter in support of a research proposal titled: 'Do native fish facilitate the persistence of endangered spinedace by resuspending food particles?' being submitted to Arizona Water Protection Fund. This research will help Arizona Game and Fish Department (Department) and partner agencies better select locations for population establishment of spinedace, an endangered small minnow endemic to the Gila River drainage. There are historical records of spinedace in 20 streams. However, currently there are only three locations with remnant spinedace populations. There have been several attempts to establish new populations, but about half of those have failed. Dr. Koch has been partnering with the Department to evaluate if various components of the habitat were related to establishment success or failure. The proposed research would inform us if other species of native fish are needed in locations to increase the chance of successful population establishment. Therefore, I recommend funding his proposed research.

Sincerely,

A handwritten signature in black ink, appearing to read "Anthony Robinson", is written over a horizontal line.

Anthony Robinson  
Gila River Basin Native Fishes Lead

ATR:ar

azgfd.gov | 602.942.3000

5000 W. CAREFREE HIGHWAY, PHOENIX AZ 85086

GOVERNOR: DOUGLAS A. DUCEY COMMISSIONERS: CHAIRMAN, JAMES S. ZIELER, ST. JOHNS | ERIC S. SPARKS, TUGSON | KURT R. DAVIS, PHOENIX  
LELAND S. "BILL" BRAKE, ELGIN | JAMES R. AMMONS, YUMA DIRECTOR: TY E. GRAY DEPUTY DIRECTOR: TOM P. FINLEY



## United States Department of the Interior

Fish and Wildlife Service  
Arizona Ecological Services Office  
9828 North 31<sup>st</sup> Avenue, Suite C3  
Phoenix, Arizona 85051

Telephone: (602) 242-0210 Fax: (602) 242-2513



In reply refer to:

AESO/ES/02EAAZ00-2018-TA-1183

August 24, 2018

Arizona Water Protection Fund Commission  
1110 West Washington Street, Suite 310  
Phoenix, Arizona 85007

Dear Arizona Water Protection Fund Commission:

This letter of support is for the FY 2019 Arizona Water Protection Fund proposed research project, "Do Native Fish Facilitate the Persistence of Endangered Spikedace by Re-suspending Food Particles?", submitted by Dr. Benjamin Koch of Northern Arizona University. The proposed project involves field manipulations of fish populations in streams known to harbor federally listed species, and therefore requires permitting and approval by the U.S. Fish and Wildlife Service prior to any on-site experimental work. Dr. Koch has been and will continue to work with us on acquiring appropriate permits.

The proposed research has the potential to provide useful data on the roles of native suckers in supplying food resources to water-column feeding fish such as spikedace (*Meda fulgida*). Spikedace are listed as an endangered species, and are currently threatened by a variety of factors including nonnative aquatic species and loss of habitat. The Spikedace and Loach Minnow Recovery Team and state, tribal, and federal partners are continuing to implement elements of the 1991 Recovery Plan for spikedace, which includes repatriating them to locations within their historical range. Dr. Koch's work on food resources will help the Recovery Team to refine their repatriation efforts, and potentially lead to greater successes, leading in turn to recovery of this endangered species.

We have been communicating with Dr. Koch about this project and are supportive of the proposed research. We will work with Dr. Koch within the standard research permitting process to facilitate this project being conducted in compliance with the Endangered Species Act of 1973, as amended. In addition, Dr. Koch is coordinating with appropriate staff at the Arizona Game and Fish Department.

Should you require further assistance or if you have any questions, please contact Mary Richardson at (602) 242-0210. Thank you for your continued efforts to conserve endangered species.

Sincerely,

Acting Field Supervisor

cc (electronic):

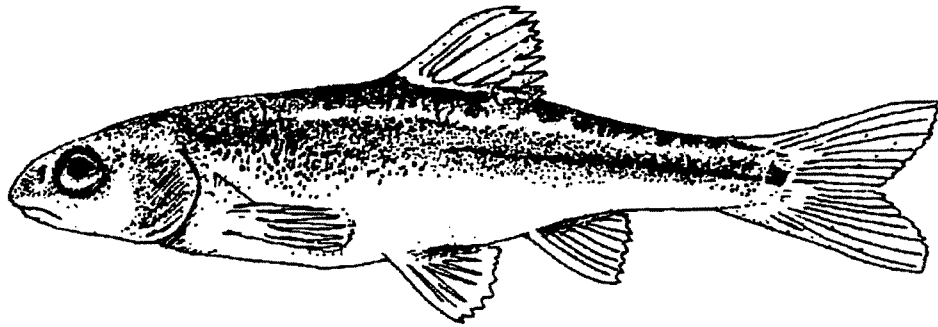
Chief, Habitat Branch, Arizona Game and Fish Department, Phoenix, AZ

Native Fish Program, Arizona Game and Fish Department, Phoenix, AZ (Attn: Tony Robinson)

Wildlife Biologist, Fish and Wildlife Service, Flagstaff, AZ (Attn: Shaula Hedwall)

W:\Mary Richardson\AWPF\_Ltr\_for\_Koch\_NAU-formatted.docx

# Spikedace



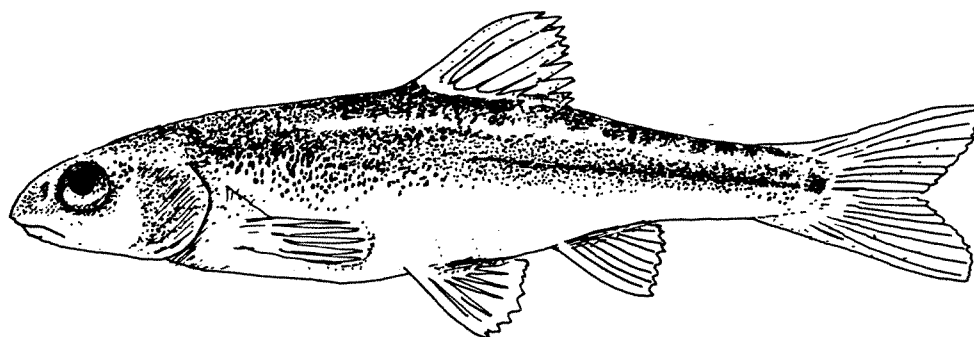
*Meda fulgida*

## Recovery Plan

September 1991



U. S. Fish and Wildlife Service  
Phoenix, Arizona



Spikedace, Meda fulgida

Frontispiece

## DISCLAIMER

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect the species. Plans are prepared by the U.S. Fish and Wildlife Service, sometimes with the assistance of recovery teams, contractors, State agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish Wildlife Service. They represent the official position of the U.S. Fish and Wildlife Service only after they have been signed by the Regional Director or Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1990. Spikedace Recovery Plan.  
Albuquerque, New Mexico.  
38 pp.

Additional copies may be purchased from:

Fish and Wildlife Reference Service  
5430 Grosvenor Lane, Suite 110  
Bethesda, Maryland 20814  
301/429-6403  
or  
1-800/582-3421

The fee for the plan varies depending on the number of pages in the plan.

## ACKNOWLEDGEMENTS

Preparation of the spikedace recovery plan benefited from review and comment by the following members of the U.S. Fish and Wildlife Service, Region 2 Desert Fishes Recovery Team:

W. L. Minckley, Chairman, Arizona State University  
Thomas A. Burke, U.S. Bureau of Reclamation  
Gene Dahlem, U.S. Bureau of Land Management  
Dean A. Hendrickson, Arizona Game and Fish Department  
Lourdes Juarez-Romero, Centro Ecologico de Sonora  
David L. Propst, New Mexico Department of Game and Fish  
Jerome A. Stefferud, U.S. Forest Service  
William G. Kepner, U.S. Fish and Wildlife Service



## EXECUTIVE SUMMARY

**Current Species Status:** The spokedace is a threatened fish which has been extirpated from most of its historic range in the Gila River Basin. It is presently found only in the upper Gila River in New Mexico, and in Aravaipa and Eagle creeks and the upper Verde River in Arizona. All existing populations are under threat.

**Habitat Requirements and Limiting Factors:** This fish inhabits riffles and runs in shallow flowing waters over gravel, cobble, and sand bottoms. The primary habitat for adults consists of shear zones where fast water meets slow water. Major threats include dams, water diversion, watershed deterioration, groundwater pumping, channelization, and introduction of non-native predatory and competitive fishes.

**Recovery Objective:** Protection of existing populations, restoration of populations in portions of historic habitat, and eventual delisting, if possible.

**Recovery Criteria:** This plan sets forth mechanisms to obtain information necessary to determine quantitative criteria for describing a spokedace population capable of sustaining itself in perpetuity. Delisting is dependent upon establishment of such populations.

**Actions Needed:**

1. Protection of existing populations.
2. Monitoring of existing populations.
3. Studies of interactions of spokedace and non-native fishes.
4. Quantification of habitat and effects of habitat modification.
5. Enhancement of habitats of depleted populations.
6. Reintroduction of spokedace into historic range.
7. Quantification of characteristics of a self-sustaining population.
8. Captive propagation.
9. Information and education.

**Total Estimated Cost of Recovery:** Cost of recovery estimated over a minimum 20 year recovery period yields a minimum total cost of \$115,000.00 per year. This estimate is in 1989 dollars. The estimate does not include land or water acquisition. Although acquisition is a potential recovery action, it is not possible to estimate costs until areas to be acquired, if any, are identified.

**Date of Recovery:** Until work is completed to allow quantification of delisting criteria, it is not possible to predict a date of recovery. However, based on the evaluation period of 10 years for determination of success of reintroduced populations, recovery of this species could not occur in less than 20 years.

## TABLE OF CONTENTS

DISCLAIMER . . . . .	ii
ACKNOWLEDGEMENTS . . . . .	iii
EXECUTIVE SUMMARY . . . . .	iv
I. INTRODUCTION . . . . .	1
Description . . . . .	1
Distribution and Abundance . . . . .	2
<u>Historical</u> . . . . .	2
<u>Present</u> . . . . .	2
Life History . . . . .	4
<u>Habitat</u> . . . . .	4
<u>Reproduction</u> . . . . .	4
<u>Growth</u> . . . . .	5
<u>Foods</u> . . . . .	5
<u>Co-occurring fishes</u> . . . . .	5
Reasons for Decline . . . . .	6
II. RECOVERY . . . . .	8
Objective . . . . .	8
Stepdown Outline . . . . .	8
Narrative . . . . .	11
Literature Cited . . . . .	28
III. IMPLEMENTATION SCHEDULE . . . . .	32
IV. APPENDIX A: PROPOSED CRITICAL HABITAT . . . . .	37
V. APPENDIX B: COMMENTS . . . . .	38



## I. INTRODUCTION

The spikedace (*Meda fulgida*) is a small, stream-dwelling fish endemic to the Gila River system of Arizona and New Mexico, USA (Miller and Hubbs 1960, Minckley 1973); the species also likely occurred in the past in the San Pedro River in Sonora, Mexico (Miller and Winn 1951). Although the biology of this unique, monotypic genus is relatively well known among Southwestern stream fishes (Barber et al. 1970, Anderson 1978, Schreiber and Minckley 1981, Barber and Minckley 1983, Propst et al. 1986), substantial gaps still exist and the basic ecology of spikedace remains in need of further study. The spikedace was apparently not considered imperiled by Miller (1961), although it had by 1937 been locally extirpated from much of the Salt River, Arizona, and elsewhere (Miller 1961). Marked reduction in its over-all range was noted by Barber and Minckley (1966) and widespread depletions were reported by Minckley (1973). Once widely distributed among moderate-sized, intermediate-elevation streams in the Gila River system, at least upstream of Phoenix, Arizona, the spikedace is now restricted to scattered populations in relatively short stream reaches. Minckley (1985), Propst et al. (1986) and Rhode (1980) figured historic and recent distributions of the species.

The spikedace was proposed (U.S. Fish and Wildlife Service [FWS] 1985) and subsequently listed (FWS 1986) as a threatened species under authority of the Endangered Species Act of 1973, as amended. Listing was justified on the basis of reductions in habitat and range due to damming, channel alteration, riparian destruction, channel downcutting, water diversion, and groundwater pumping, and continued threats to its survival posed by ongoing habitat losses and non-native, predatory and competitive fish species (FWS 1985). Critical habitat was initially proposed (FWS 1985, Appendix), but a subsequent rule (FWS 1986) deferred its designation until 18 June 1987. Although that date has passed, proposed critical habitat is still in force, providing limited protection. Final designation of critical habitat is under administrative review.

The spikedace is classified by the State of Arizona as a threatened species, which are those whose continued presence in Arizona could be in jeopardy in the near future (Arizona Game and Fish Department 1988) and by the State of New Mexico as a group 2 endangered species, defined as those "... whose prospects of survival and recruitment within the State are likely to become jeopardized in the foreseeable future" (New Mexico Department of Game and Fish 1988). The latter listing provides protection under the New Mexico Wildlife Conservation Act. The species can be taken only under a special collection permit in both States. Neither state listing otherwise protects spikedace or the habitats it occupies. Deacon et al. (1979), Williams et al. (1985), and Johnson (1987), also recognized the spikedace as imperiled.

### Description

The spikedace (Frontispiece) is a small, sleek, stream-dwelling member of the minnow family (Cyprinidae). Its following description is summarized from Girard (1857), Miller and Hubbs (1960) and Minckley (1973):

The body is slender, almost spindle-shaped, and slightly compressed laterally. Scales are present only as small plates deeply embedded in the skin. There are two spinose rays at the leading edge of the dorsal fin, the first being obviously the strongest, sharp-pointed, and nearly as long as the second. The eyes and mouth both are large. Barbels are absent. There are seven rays in the dorsal fin, and the anal fin usually has nine. Pharyngeal teeth are in two rows, with the formula 1,4-4,1.

Coloration is bright silvery on the sides of the body, with vertically-elongated, black specks. The back is olive-gray to brownish, and usually is mottled with darker pigment. The underside is white. Males in breeding condition become brightly golden or brassy, especially on the head and at the fin bases.

#### Distribution and Abundance

Historical. The spikedace is endemic to the upper Gila River basin of Arizona and New Mexico, USA (Figure 1). The species was abundant in the San Pedro River, Arizona, and although never collected in that stream in Sonora, Mexico, probably occurred there also (Miller and Winn 1951). Distribution in Arizona was widespread in large and moderate-sized rivers and streams, including the Gila, Salt, and Verde rivers and their major tributaries upstream of the present Phoenix metropolitan area, and the Agua Fria, San Pedro, and San Francisco river systems (Minckley 1973, Rhode 1980). Populations transplanted from Aravaipa Creek into Sonoita Creek, Santa Cruz County in 1968, and 7-Springs Wash, Maricopa County in 1970, have since been extirpated (Minckley and Brooks 1985). Distribution in New Mexico was in both the San Francisco and Gila rivers (Koster 1957, Propst et al. 1986, Sublette et al. 1990), including the East, Middle, and West forks of the latter. There are no records of spikedace transplants in New Mexico.

There are substantial spatial and/or temporal gaps in quantitative data from which to assess the historical abundance of spikedace. Generally, the species must have been common and likely locally abundant in preferred habitats. Although habitat suitable for spikedace was probably not continuous, it was widespread throughout the species' range. Like most western cyprinids, population abundances and distributions of spikedace probably fluctuated in natural response to local and regional environmental conditions. Recent examples of such variation in the species abundance have been recorded in Aravaipa Creek, Arizona (Minckley and Meffe 1987) and the Red Rock reach of the Gila River, New Mexico (Marsh and Propst, unpublished data).

Present. The spikedace occurs in Arizona only in Aravaipa Creek, tributary to San Pedro River in Graham and Pinal Counties; Eagle Creek, tributary to Gila River in Graham and Greenlee Counties; and upper Verde River in Yavapai County (Figure 1). All three streams support at least moderate-sized, sustaining populations in relatively undisturbed reaches. The Eagle Creek population, considered "quite small" by FWS (1986) has since been found to be more substantial (Brooks, Marsh, Minckley, unpublished data). In New Mexico, spikedace now are restricted to the mainstem Gila River and its East, Middle, and West Forks; a few individuals may occasionally be encountered in lowermost reaches of perennial tributaries (Figure 1). Propst et al. (1986) considered only the population occupying the Cliff-

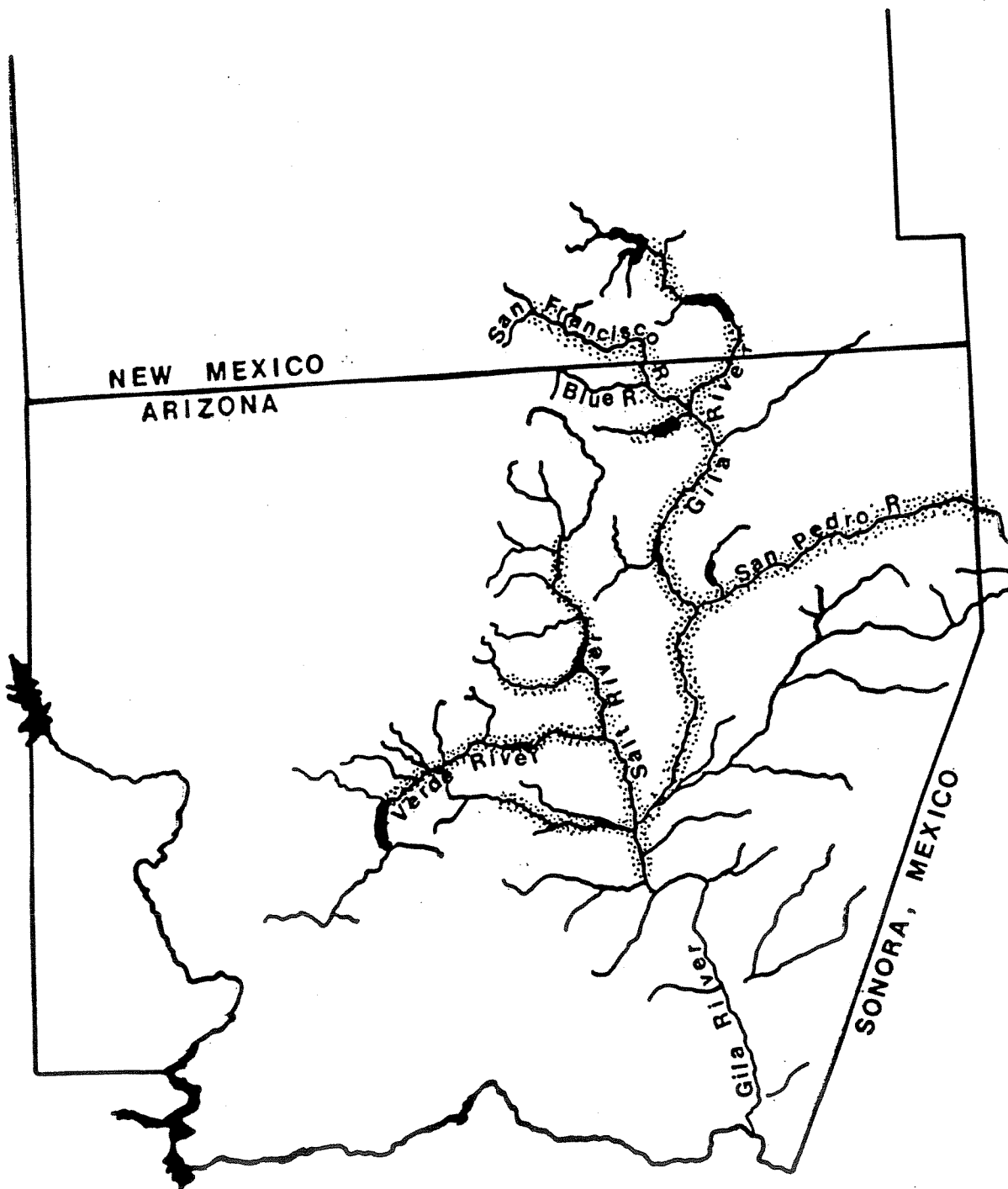


FIGURE 1. HISTORIC AND PRESENT DISTRIBUTION OF SPIKEDACE  
 (Historic distribution is represented by stippled areas; present  
 distribution is represented by solid black.)

Gila Valley, New Mexico, comparable in abundance to that of earlier years; others have been substantially diminished. Undiscovered populations of spikedace may occur in places which have not been surveyed or completely inventoried, especially within expansive, remote portions of San Carlos Apache and Fort Apache Indian Reservations, on U.S. Forest Service lands, or in Sonora where the Gila River drainage remains inadequately studied.

Both distribution and abundance of spikedace have become dramatically reduced in the past century, with major changes occurring in recent decades (Minckley 1973, Propst et al. 1986). Major rivers and streams, such as lower reaches of the mainstem Gila, Salt, and Verde rivers that once supported substantial populations in several places have been recently depleted. Past changes in range and density must have occurred in response to natural spatial and temporal variations in the environment, but the current threatened status of spikedace appears a direct or indirect result of man's activities.

### Life History

Biology of spikedace has been studied intensively in only a few places, but those investigations have provided a relatively broad base of information summarized below. In Arizona, only the population in Aravaipa Creek has received substantial attention (Barber and Minckley 1966, 1983; Barber et al. 1970, Minckley 1981, Schreiber and Minckley 1981, Turner and Tafanelli 1983, Rinne and Kroeger 1988), in part because that stream retains an intact native fauna in relatively pristine habitat. In New Mexico, Anderson (1978) examined spikedace populations primarily from a reach of the Gila River downstream from the community of Cliff and the lowermost East Fork of the Gila. Investigations by Propst et al. (1986) and Propst and Bestgen (1986) concentrated on the mainstem Gila River in the Cliff-Gila Valley, in part because that was one of the few places where the species was abundant enough to provide necessary information, and collected ecological data from several other localities in the upper Gila system. Most other work on spikedace has been survey-type monitoring to assess distribution, or status of local populations of fish communities (e.g. Jester et al. 1968, LaBounty and Minckley 1973, Anderson and Turner 1977, Ecology Audits 1979, Barrett et al. 1985, Bestgen 1985, Montgomery 1985, Propst et al. 1985), and does not contribute significant new information.

Habitat. Spikedace occupy flowing waters, usually less than a meter deep, and as adults often aggregate in shear zones along gravel-sand bars, quiet eddies on the downstream edge of riffles, and broad, shallow areas above gravel-sand bars (Propst and Bestgen, 1986, Rinne and Kroeger 1988). Smaller, younger fish are found in quiet water along pool margins over soft, fine-grained bottoms. In larger rivers (e.g., Salt River canyon), spikedace often were in the vicinity of tributary mouths. The fish use shallower, strongly-flowing areas in springtime, often over sandy-gravelly substrates. Specific habitat associations vary seasonally, geographically, and ontogenetically (Anderson 1978, Rinne 1985, Propst et al. 1986, Propst and Bestgen 1986, Rinne and Kroeger 1988, Rinne 1991).

Reproduction. Spikedace breeding in spring (April-June) is apparently initiated in response to a combination of stream discharge and water temperature; timing varies annually and geographically (Anderson 1978, Barber et al. 1970, Propst et al. 1986). Males patrol in shallow, sandy-gravelly riffles where current is moderate. There is no indication of

territoriality, although males generally remain evenly spaced within an occupied area. Receptive females move into the area, often from up-or downstream pools, and are approached at once by up to six males, two of which remain immediately alongside and slightly behind the female. Gametes are presumably deposited into the water column or on or near the substrate. No fertilized ova have been recovered; however, because they are adhesive and demersal based on eggs stripped and fertilized in the laboratory (P. Turner, pers. comm.), they likely adhere to substrates. Sex ratio among reproductive adults is not constant, varying from near unity among younger fish to a greater abundance of females among older individuals. Females may be fractional spawners, with elapsed periods of a few days to several weeks between spawnings. Fecundity of individual females based on gonad examination ranges from 90 to 250 ova, and is significantly correlated with both length and age. Ovum diameter at spawning is near 1.5 millimeters (mm). No specific information incubation times or size at hatching is available.

Growth. Growth varies annually with water temperature (and thus geographic location), and among year classes (Anderson 1978, Barber et al. 1970, Propst et al. 1986). Generally, young grow rapidly during summer and autumn, attaining 35 to 40 mm standard length (SL)<sup>1</sup> by November. Winter growth is slow in some places, negligible in others. Fish average near 40 mm SL at the end of one year, and 50 to 63 mm SL at the end of the second year. Maximum size is near 65 mm in Aravaipa Creek, Arizona, and 68 mm SL in the upper Gila River, New Mexico. Longevity typically is one to two years; a few fish reach age three and exceptional individuals may survive four years. Growth of males and females appears similar, although there may be differences within particular year classes (Propst et al. 1986).

Foods. Spikedace are carnivores that feed mostly upon aquatic and terrestrial insects entrained in stream drift (Anderson 1978, Barber and Minckley 1983, Propst et al. 1986). Kinds and quantities consumed vary with spatial and temporal availability of foods. Among aquatic forms, larval ephemeropterans, hydropsychid trichopterans, and chironomid dipterans are most important. Prey body size is small, typically ranging from 2 to 5 mm long. At times of emergence, pupal, imago or adult stages of benthic insects, especially ephemeropterans, are consumed in large quantities. Other foods, including larval fishes, are occasionally eaten, but these constitute a minor component of the diet. Diversity of diet is greatest among smaller (post-larval) spikedace, which consume a variety of small, soft-bodied animals, while adults specialize on larger, drifting nymphal and adult ephemeropterans.

Co-occurring fishes. Among native fishes, loach minnow (Tiaroga cobitis), speckled dace (Rhinichthys osculus), Sonora sucker (Catostomus insignis), and desert sucker (Pantosteus clarki) are commonly in the same habitats occupied by adult spikedace. Longfin dace (Agosia chrysogaster) may also occur with spikedace in shallow, sandy, laminar-flowing reaches. Larval and juvenile spikedace in quiet habitats along stream margins may encounter small desert and Sonoran suckers, small loach minnow, larval and adult longfin dace, and perhaps small roundtail chub (Gila robusta).

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<sup>1</sup>Standard and total (TL) lengths of spikedace are convertible by the expression  $SL = 0.85TL - 0.12$  ( $r^2 = 0.99$ ,  $n = 100$ ) (Marsh, unpublished data).



Introduced red shiner (Cyprinella lutrensis) occupies habitats similar to those occupied by spikedace, and may sometimes be taken in the same seine haul as spikedace. The red shiner now occurs at all places known to be formerly occupied by spikedace, with the exception of the San Francisco River above Frisco Hot Springs, and the two species overlap spatially (the native upstream, the exotic downstream, and a zone of contact between) in upper reaches of both the Gila and Verde rivers. These facts have led to extensive speculation about the nature of the relationship between the two species (FWS 1985, 1986, Minckley 1973, Minckley and Carufel 1967, Minckley and Deacon 1968, Propst et al. 1986, Bestgen and Propst 1986, Marsh et al. 1989). Various theories which have been put forth include: 1) red shiner invade previously unoccupied niches; 2) red shiner invade vacant niches left by spikedace (and other native minnows) extirpated due to habitat alteration; and, 3) red shiner invade areas occupied by spikedace and displace spikedace through competition and/or predation. Studies of spikedace in the upper Gila River led the investigators to conclude that the second theory was the most likely mode in that system (Propst et al. 1986, Bestgen and Propst 1986). In the upper Verde River, limited data indicate that the two species are maintaining a relatively stable region of sympatry and appear to be coexisting. A recent study of spikedace and red shiner interaction in various portions of its range and in laboratory experiments found apparent displacement of spikedace by red shiner based on shifts in habitat use by spikedace in the presence of red shiner (Marsh et al. 1989).

Among other non-native fishes, channel catfish (Ictalurus punctatus) of all sizes, and small flathead catfish (Pylodictis olivaris) frequent riffles occupied by spikedace, especially at night when catfishes move onto riffles to feed. Largemouth (Micropterus salmoides) and smallmouth (M. dolomieu) bass in some habitats, and introduced trouts (Salmonidae) at higher elevations, may also co-occur with spikedace. Interaction between the native and these non-native fishes is likely as prey and predators; however, importance of such relationships is yet to be established.

#### Reasons for Decline

Habitat destruction or alteration and interaction(s) with non-native fishes have acted both independently and in concert to extirpate or deplete spikedace populations. In the San Pedro and Aqua Fria rivers, plus major reaches of the Salt and Gila rivers, dewatering and other such drastic habitat modifications resulted in demise of spikedace, and most other native fishes. Downstream reaches of the Verde, Salt, and mainstem Gila rivers have been affected by impoundments and highly-altered flow regimes. Spikedace do not persist in reservoirs, and populations occupying tailwaters are subjected to impacts ranging from dewatering to altered chemical and thermal conditions. Stream channelization, bank stabilization, or other instream management for flood control or water diversion, have also directly destroyed spikedace habitats.

Natural flooding of desert streams and rivers may play a significant role in life histories of native fishes because they rejuvenate habitats (Propst et al. 1986), but perhaps more importantly because desert fishes effectively withstand such disturbances while non-native forms apparently do not (Meffe and Minckley 1987, Minckley and Meffe 1987). Activities that alter natural flow regimes may thus have negative impacts on native fishes.

Both historic and present landscapes surrounding spikedace habitats have been impacted to varying degrees by domestic livestock grazing, mining, agriculture, timber harvest, or other development (Hastings and Turner 1965, Hendrickson and Minckley 1985). These activities contribute to habitat degradation by altering flow regimes, increasing watershed and channel erosion and thus sedimentation, and adding contaminants such as acutely- or chronically-toxic materials, or nutrient-enriching fertilizers to streams and rivers. These perturbations may affect fishes in a variety of ways, such as direct mortality, interference with reproduction, and reduction in requisite resources such as invertebrate foods. In one example, a wastewater spill at the Cananea Mine, Sonora, Mexico, killed aquatic life including all fishes throughout a 100-km reach downstream (Eberhardt 1981).

Non-native fishes, introduced for sport, forage, bait, or accidentally, impact upon native fishes. Ictalurid catfishes, and centrarchids, including largemouth bass, smallmouth bass, and green sunfish (Lepomis cyanellus), prey upon native fishes. At higher elevations, introduced salmonids (brown trout, Salmo trutta, and rainbow trout, Oncorhynchus mykiss) may similarly influence spikedace populations. Red shiner may be particularly important as regards spikedace, because the two species where allopatric occupy essentially the same habitats, and where sympatric there is some evidence that there is displacement of the native to habitats which otherwise would scarcely be used (Marsh et al. 1989). Moreover, the concomitant reduction of spikedace and expansion of the shiner is powerful circumstantial evidence that red shiner may have displaced spikedace in suitable habitats throughout much of its former range.

Undoubtedly, demise of spikedace has been a result of combined effects of habitat change and introduced fishes. Because relative importance of the two factors has yet to be established, both must be considered in management toward recovery of this threatened species.

## II. RECOVERY

### Objective

The primary objective of this recovery plan is to identify steps and delineate mechanisms considered necessary to protect existing populations and restore depleted and extirpated populations of spokedace and their habitats, and to ensure the species' non-endangered, self-sustenance in perpetuity. Realization of this objective will constitute justification for delisting of the spokedace. This plan will require modification as new information becomes available; only at that time can quantitative criteria for delisting be elaborated. Interaction with non-native fishes and habitat modification, whether acting independently or in concert, are both considered contributory to decline and extirpation of spokedace. This plan recognizes the need to deal with both impacts in order to achieve the recovery objective.

### Stepdown Outline

1. Protect existing populations of spokedace.
  - 1.1 Identify extent of existing populations and level of protection afforded to each.
  - 1.2 Prioritize existing populations as to need or imminent need for protection.
  - 1.3 Designate critical habitat.
  - 1.4 Enforce existing laws and regulations affecting spokedace.
    - 1.4.1 Inform as necessary appropriate agencies of applicable management/enforcement responsibilities.
    - 1.4.2 Assure compliance with Section 7 of the Endangered Species Act.
    - 1.4.3 Assure compliance with Section 9 of the Endangered Species Act.
  - 1.5 Discourage detrimental land and water use practices.
  - 1.6 Insure perennial flows with natural hydrographs.
  - 1.7 Curtail transport and introduction of non-native fishes.
    - 1.7.1 Discourage seining and use of live bait in streams occupied by spokedace.
  - 1.8 Examine efficacy of barrier construction to preclude invasion by non-native fishes.
  - 1.9 Identify important, available private lands and water rights not already protected.
  - 1.10 Acquire important lands and associated water rights as they become available.
  - 1.11 Protect acquired lands.
2. Monitor status of existing populations.
  - 2.1 Establish and implement standard monitoring locations for extant populations.
  - 2.2 Establish and implement standard techniques and their application.
  - 2.3 Establish and maintain a computerized database for tracking of monitoring and reintroduction information.

- 2.4 Determine range of natural variation in absolute abundance and age-class structure.
  - 2.4.1 Develop standard methods for quantifying abundance.
  - 2.4.2 Conduct bi-annual (spring, autumn) population estimates.
- 2.5 Monitor community composition.
  - 2.5.1 Apply standard locations and techniques (2.1, 2.2).
  - 2.5.2 Determine range of natural variation in relative abundances of community members.
- 2.6 Determine genetic characteristics of existing populations.
3. Identify nature and significance of interaction with non-native fishes.
  - 3.1 Direct interaction (predation, displacement).
    - 3.1.1 Field investigations and experimental manipulations.
    - 3.1.2 Laboratory studies.
  - 3.2 Indirect interaction (mediated by other fishes of the community).
    - 3.2.1 Field investigations and experimental manipulations.
    - 3.2.2 Laboratory studies.
4. Quantify, through research, spikedace habitat needs and the effects of physical habitat modification on life cycle completion.
  - 4.1 Substrate.
  - 4.2 Velocity and depth.
  - 4.3 Water Temperature.
  - 4.4 Water Chemistry.
  - 4.5 Interactions among 4.1-4.3.
  - 4.6 Watershed size and flood frequency and volume.
5. Enhance or restore habitats occupied by depleted populations.
  - 5.1 Identify target areas amenable to management.
  - 5.2 Determine necessary habitat and landscape improvements.
  - 5.3 Implement habitat improvement.
6. Reintroduce populations to selected streams within historic range.
  - 6.1 Identify stocks amenable to use for reintroduction.
  - 6.2 Identify river or stream systems for reintroduction.
    - 6.2.1 Determine suitability of habitat.
    - 6.2.2 Enhance habitat as necessary (4, 5.3).
    - 6.2.3 Assess status of non-native fishes in the watershed.
    - 6.2.4 Assure closure of potential immigration routes to preclude reinvasion by non-native fishes.
    - 6.2.5 Reclaim as necessary to remove non-native fishes.
  - 6.3 Reintroduce spikedace to selected reaches.
  - 6.4 Monitor success/failure of reintroductions.
  - 6.5 Determine reasons for success/failure.
  - 6.6 Rectify as necessary cause(s) of failure and restock.
7. Determine quantitative criteria for describing a self-sustaining population.
  - 7.1 Acceptable levels of natural variation.
    - 7.1.1 Absolute numbers.
    - 7.1.2 Age-class structure.
    - 7.1.3 Reproduction.

- 7.1.4 Recruitment.
  - 7.2 Minimum stock size.
  - 7.3 Environmental variables.
    - 7.3.1 Physical characteristics.
    - 7.3.2 Chemical characteristics.
    - 7.3.3 Biological community.
- 8. Plan and conduct investigations on captive holding, propagation and rearing.
  - 8.1 Determine wild stocks suitable for contribution to hatchery stocks.
  - 8.2 Collect and transfer wild stocks to suitable facility.
  - 8.3 Develop procedures and facilities for holding and maintaining.
  - 8.4 Evaluate potential techniques for propagation.
  - 8.5 Assess life-cycle requirements in hatchery environment.
  - 8.6 Supply individuals as needed for reintroduction, research, public education, etc.
- 9. Information and education.
  - 9.1 Public sector.
    - 9.1.1 Local media and target campaigns.
    - 9.1.2 States of Arizona and New Mexico.
    - 9.1.3 National exposure.
    - 9.1.4 Assist appropriate Mexican agencies and organizations in information and education.
    - 9.1.5 Open communication among States, Federal agencies, and local residents and water users.
  - 9.2 Professional information.
    - 9.2.1 Open circulation of information among concerned parties.
    - 9.2.2 Periodic information-exchange meetings.
    - 9.2.3 Presentations at professional, scientific meetings.
    - 9.2.4 Publication in peer-reviewed, open literature.

## Narrative

### 1. Protect existing populations of spikedace.

Remaining populations of spikedace in Verde River, Aravaipa Creek, and Eagle Creek, Arizona, and upper Gila River and its major tributaries in New Mexico, plus other potential locations, continue to be threatened by habitat modification or destruction, predation by introduced fishes, inadequacy of existing regulations, and continued introduction and dispersal of non-native fishes. Recovery of the species cannot be accomplished without first identifying and protecting remaining populations.

#### 1.1 Identify extent of existing populations and level of protection afforded to each.

Undiscovered populations of spikedace may occur in unsurveyed or incompletely inventoried habitats; these populations should be identified so that the present distribution and range of the species is known. General areas which should be thoroughly sampled to determine potential occurrence of spikedace include the Gila River drainage in Sonora, Mexico, and lands in the United States controlled or owned by the U.S. Forest Service and San Carlos and White Mountain Apache Indian tribes. After geographic locations of all populations are known, the existing level of protection afforded by any public or private entity should be determined for each population. Completion of these preliminaries will enable prioritization of the various habitats/populations as regards implementation of specific recovery activities outlined below.

#### 1.2 Prioritize existing populations as to need or imminent need for protection.

Populations of spikedace that occupy relatively undisturbed habitat and are afforded substantial protection by one or more governmental or private entities (e.g., Aravaipa Creek, Arizona) are considered in less imminent need of additional protection than those in degraded habitats or which are minimally protected. Prioritization of all known populations as regards need for protection should be accomplished so steps toward the species recovery can proceed in a logical manner. Recovery activities for populations in most imminent danger of decline or extirpation should be accomplished first.

#### 1.3 Designate critical habitat.

Critical habitat (Appendix A) was proposed by FWS (1985), but formal designation was deferred until 18 June 1987. That designation has not yet occurred, and although the existing proposal continues in force, it provides only limited protection. Pending outcome of 1.1 (above), it may be appropriate to consider additional stream reaches for inclusion in the designated critical habitat. Existing information on the spikedace in Eagle Creek is sufficient at this time to recommend consideration of a portion of that creek (Appendix A) for addition to the legally designated critical habitat. Much land adjacent to streams or stream reaches occupied by spikedace is under full or partial jurisdiction and/or presumed protection by U.S. Bureau of Land Management (Aravaipa Creek, Gila River);

The Nature Conservancy (Aravaipa Creek, Gila River); New Mexico Department of Game and Fish (West and Middle Forks Gila River); New Mexico State Land Office (Gila River); New Mexico Museum of Natural History (East Fork Gila River); National Park Service Gila Cliff Dwellings National Monument, administered by U.S. Forest Service (West Fork Gila River); U.S. Forest Service, Gila National Forest, including Gila Wilderness Area, Lower Gila River Bird Habitat Management Area, and Gila River Research Natural Area (Gila River); U.S. Forest Service, Prescott National Forest (Verde River); State of Arizona (Verde River); U.S. Forest Service, Apache-Sitgreaves National Forests (Eagle Creek); and San Carlos Apache Indian Reservation (Eagle Creek). However, protection of spikedace on Federal and other lands will be greatly enhanced when the species' critical habitat is formally designated and compliance with the Endangered Species Act is fully implemented. Other significant stream reaches occupied by spikedace flow through privately-owned lands, and with exception of reaches owned by conservation organizations, receive minimal or no protection.

#### **1.4 Enforce existing laws and regulations affecting spikedace.**

Failure of any entity to recognize and comply with laws and regulations that protect spikedace and its habitat may contribute to its imperiled status, result directly or indirectly in further population declines, and impede recovery of the species.

##### **1.4.1 Inform as necessary appropriate agencies of applicable management/enforcement responsibilities.**

Where not so informed, agencies and their personnel should be made aware of their responsibilities regarding laws protecting listed species and their habitats, and the appropriate roles each agency would play to most effectively insure their protection.

##### **1.4.2 Assure compliance with Section 7 of the Endangered Species Act.**

Federal agencies should comply with Section 7 of the Endangered Species Act and should consult with the U.S. Fish and Wildlife Service on any project that has potential to affect spikedace.

##### **1.4.3 Assure compliance with Section 9 of the Endangered Species Act.**

Compliance of all private and public entities with the Section 9 prohibitions and implementing regulations regarding take of a threatened species should be insured.

#### **1.5 Discourage detrimental land and water use practices.**

Wise use of water and land can benefit both the user and the physical and biotic natural resources of the area. Practices which are detrimental to or destructive of habitats and extant populations of spikedace should be discouraged in all places. Information and education should be provided that will enable all users, especially private landowners, to be aware of detrimental practices and their acceptable alternatives.

#### **1.6 Insure perennial flows with natural hydrographs.**

Spikedace cannot exist in dewatered places, and populations can be expected to decline or disappear from stream reaches which are intermittent or ephemeral. Permanence of flows of sufficient quantity and quality must be assured to maintain integrity of spikedace populations and their habitats. Also, Southwestern stream fishes apparently are enhanced relative to non-native species where streams are characterized by a natural hydrograph (Minckley and Meffe 1987). Formal agreements that stream flows will not be modified by activities such as damming or diversion that substantially alter natural flow regimes should thus be an integral part of insuring perennial flows. For example, U.S. Bureau of Land Management is in the final stages of applying for an instream flow water right for Aravaipa Creek, Arizona.

#### **1.7 Curtail transport and introduction of non-native fishes.**

Where they do not already exist, appropriate regulations should be promulgated that discourage transport and stocking of non-native fishes, especially red shiner, into habitats from which they have access to stream reaches occupied by spikedace. State, Federal or other fish management agencies and private entities should discontinue stockings of non-native, warmwater sport, forage, or bait fishes into or upstream from streams occupied by spikedace, and upstream from the first absolute barrier to upstream fish movement into spikedace habitats.

Operation and future siting of State, Federal, or private facilities that hold, propagate, rear, or participate in other fish or aqua-cultural activities with non-native fishes should ensure that escapement to waters occupied by spikedace is precluded.

##### **1.7.1 Discourage seining and use of live bait in streams occupied by spikedace.**

Introductions of non-native fishes may occur as a result of intentional or inadvertent release of bait fishes used for sport angling. Where sport fishes and spikedace are known to co-occur or in areas of sport fishing which are not separated by barriers from stream reaches occupied by spikedace, responsible resource agencies should discourage or disallow use of live bait. Furthermore, bait fish seining should not be allowed to occur in stream reaches occupied by spikedace, which could be unknowingly taken and unnecessarily destroyed.

#### **1.8 Examine efficacy of barrier construction to preclude invasion by non-native fishes.**

Construction of fish barriers should be considered as a preventive measure for protection of existing populations of spikedace from contamination by non-native fishes. For example, a cooperative effort has determined that construction of such a barrier on Aravaipa Creek, Arizona would protect upstream populations of native fishes, including spikedace, from invasion by red shiner and other non-native fishes. Other streams occupied by spikedace may also be amenable to such management, and responsible agencies should fully evaluate efficacy of this action.



**1.9 Identify important, available private lands and water rights not already protected.**

Although a significant proportion of lands adjacent to presently occupied spokedace habitat already receive some degree of protection from State, Federal, or private entities, other lands through which potentially important stream reaches pass have no such benefit. Unwise land- or water-use practices in and adjacent to occupied reaches could have detrimental impacts upon spokedace residing in the same drainage. Obviously, fishes must have sufficient water to survive and flourish. Thus, water rights associated with important stream reaches must be acquired. The U.S. Fish and Wildlife Service should designate the appropriate agencies to identify these areas and their water rights, determine their ownership, and assess the potential availability of necessary water rights.

**1.10 Acquire important lands and associated water rights as they become available.**

A variety of mechanisms exist by which lands, management rights, and/or water rights may be acquired by State, Federal, or private entities inclined to do so in behalf of protecting spokedace and its habitat. Acquisition of these lands and water rights will add to assurance that existing populations and their habitats are secure.

**1.11 Protect acquired lands.**

Once important lands and stream reaches are known and in appropriate ownership, they can be administered and managed in ways consistent with perpetuation of spokedace populations and habitats.

**2. Monitor status of existing populations.**

Standardized, long-term monitoring is necessary to detect changes in population status, assess success of recovery-management actions, and determine when applicable criteria for delisting have been fulfilled. The U.S. Fish and Wildlife Service and States of Arizona and New Mexico, advised by the Desert Fishes Recovery Team, should specify a standardized monitoring program, based upon biological considerations plus practical constraints, to address elements outlined below.

**2.1 Establish and implement standard monitoring locations for extant populations.**

Stream and river reaches representing typical habitats actually or potentially occupied by spokedace populations in Arizona and New Mexico should be selected for routine monitoring. Only when data are obtained from standard areas can natural or other changes in habitat or population status be determined.

**2.2 Establish and implement standard techniques and their application.**

Techniques for assessing spokedace habitat and population status should be consistent spatially, temporally, and among investigators. Standard monitoring techniques should be developed and implemented to insure that results are comparable among years, populations, and groups involved in this monitoring. In some instances, use of specific techniques

may be restricted, for example, use of motorized equipment, and such constraints should be considered in selection of methodologies.

**2.3 Establish and maintain a computerized database for tracking of monitoring and reintroduction information.**

Adequate data tracking would allow management actions to be based on the best up-to-date information and would insure rapid assessment of recovery progress. A centralized, computerized database should be established that will contain all available historic information on distribution and abundance of spokedace throughout its range. All monitoring data on existing populations, plus information on establishment and monitoring of reintroduced populations should be placed into this database as soon as the information is available.

**2.4 Determine range of natural variation in absolute abundance and age-class structure.**

Populations of spokedace vary substantially, both spatially and temporally, in response to dynamics of individual populations and natural changes in their environment. Changes in status of spokedace populations can be attributed to other than natural causes only when the range of variation expected from intact populations in relatively unperturbed habitats has been assessed. Population status is most readily assessed by knowing absolute abundance of individuals in the population, and distribution of individuals among age-classes (cohorts) and their sex ratio.

**2.4.1 Develop standard methods for quantifying abundance.**

Several techniques are available for determination of absolute abundance of fishes, including depletion sampling, mark-and-recapture, etc; these may be modified or others developed specifically for application to spokedace. Such techniques should be adjusted as dictated by experience, and uniformly applied thereafter.

**2.4.2 Conduct bi-annual (spring, autumn) population estimates.**

Population estimates should be conducted at times of year that are most likely to provide managers with the most useful information as regards status of spokedace. Spring sampling allows assessment of adult reproductive condition, while autumn sampling provides opportunity to evaluate year-class strength, survival, and recruitment relative to the spawning population. Both are necessary to adequately determine population status.

**2.5 Monitor community composition.**

Populations of spokedace may be subject to influences of other members of the fish community. Changes in status of other species, especially non-native kinds, may serve notice that spokedace status also may be expected to change. At least a minimum of predictability of change within a normal range of variation is necessary to manage populations of spokedace, and any information that will enhance that capability may enable management decisions and implementation before potential negative impacts are realized.

#### 2.5.1 Apply standard locations and techniques (2.1, 2.2).

Techniques for assessing status of the fish community should be compatible with those specifically selected for spokedace monitoring, and should be standardized as regards time, place, and methods.

#### 2.5.2 Determine range of natural variation in relative abundances of community members.

A most easily obtained and readily interpreted datum is relative abundance of fish community constituents. However, change caused by other than natural factors cannot be reliably assessed unless an indication of the range of normal variation experienced by communities in relatively unperturbed habitats is first known. Baseline data already available should be augmented by information from future, routine sampling of fishes.

#### 2.6 Determine genetic characteristics of existing populations.

Baseline information on the genetic characteristics of existing spokedace populations should be gathered to elucidate relationships and degree of variation among populations and to provide guidance in protection, propagation, and reintroduction programs (Echelle 1988; 6.1, 6.3, and 8.1, below). Results of an initial survey will be required to insure that any genetic differences among populations are considered in the implementation of this plan.

### 3. Identify nature and significance of interaction with non-native fishes.

Impacts of non-native fishes on spokedace cannot be alleviated or otherwise managed until the mechanism(s) of such interactions are known and an assessment as to the qualitative and quantitative significance of the interaction has been completed.

#### 3.1 Direct interaction (predation, displacement).

Research has shown that certain non-native fishes prey intensively upon native fishes (e.g., Meffe 1983, 1985). Likewise inferential evidence suggests that introduced fishes displace native species (e.g., Minckley and Deacon 1968, Marsh et al. 1989). These kinds of interaction thus appear most fruitful for investigation in the case of spokedace. Other potential mechanisms of interaction should also be investigated where data suggest they may be important.

##### 3.1.1 Field investigations and experimental manipulations.

Evidence of direct interaction is most convincing when derived from studies on in situ populations. Because spokedace and potentially detrimental non-native fishes co-occur in several places (e.g., Gila and Verde rivers, Eagle Creek), these habitats and communities should be selected for intensive field studies. Experimental manipulations in which selected species are variously included or excluded among available habitats would provide a powerful tool for evaluating interactions (e.g., Power et al. 1985). Appropriate study reaches, specific experimental

designs, etc., should be determined by consensus among knowledgeable individuals.

### 3.1.2 Laboratory studies.

Some aspects of direct interaction among spokedace and non-native fishes can be determined best under controlled, laboratory conditions. These studies would provide a framework and direction for applied field investigations (3.1.1).

### 3.2 Indirect interaction (mediated by other fishes of the community).

Effects of non-native fishes upon spokedace may not be caused by direct interaction, but rather indirectly by the effect of non-native fishes on other members of the fish community. Regardless, prudent management of spokedace populations cannot be implemented until the nature and significance of each is evaluated.

#### 3.2.1 Field investigations and experimental manipulations.

Field studies and in-stream experiments would be necessary to qualitatively and quantitatively describe indirect interactions among spokedace and non-native fishes (see 3.1.1).

#### 3.2.2 Laboratory studies.

Studies of spokedace, other native fishes, plus non-native species, under controlled, laboratory conditions, could identify a range of biological and habitat parameters important to indirect interactions; these then could be applied toward intensive field studies (3.2.1).

## 4. Quantify, through research, spokedace habitat needs and the effects of physical habitat modification on life cycle completion.

Localized depletion or extirpation of spokedace may be caused by changes in proximal physical habitat acting on one or more life history stage or function. Likewise, widespread depletion or extirpation may be caused by far-reaching alterations of watershed characteristics acting on one or more life history stage or function. Qualitative and quantitative relationships among specific kinds of habitat modification and spokedace biology must be established before management can be directed toward correcting and removing the cause(s) of deleterious habitat conditions. Such analyses will be dependent upon prior determinations of spokedace habitat needs and usage. Research must consider all life history stages as well as variations in seasonal and diurnal use.

### 4.1 Substrate.

Erosion and siltation which result in filling of interstitial spaces of gravel riffles occupied by spokedace may interfere with successful egg deposition and incubation, and thus impact recruitment, population abundance, and age-class structure (Propst et al. 1986). Substrate armoring which renders suitable egg incubation sites unavailable to spokedace may have similar effects. Quantitative relationships must be established so that conditions characterizing suitable habitats can be

described, changes can be assessed, and management strategies for reclamation of impaired habitat can be assessed and implemented.

#### 4.2 Velocity and depth.

Land- and water-use practices that alter water velocity and depth may affect spikedace, which have demonstrated specializations for these parameters (Turner and Tafaelli 1983, Rinne 1985, Propst et al. 1986, Rinne and Kroeger 1988). Available data should be reviewed and augmented so that preferenda can be determined, and tolerance limits established.

#### 4.3 Water temperature.

Water- and land-use practices may influence thermal regimes in habitats occupied by spikedace. Relationships among spikedace life history and temperature are poorly known, and must be established as regards optima, preferenda, and tolerated extremes, so that conditions characterizing suitable habitats can be described, changes can be assessed, and management strategies for reclamation of impaired habitat can be evaluated and implemented.

#### 4.4 Water chemistry.

Water- and land-use practices may influence various chemical parameters of the waters occupied by spikedace. Preferenda and tolerance limits of spikedace life history stages need to be established for basic parameters, such as pH, turbidity, alkalinity, and dissolved oxygen, so that the effects of changes in those parameters may be assessed.

#### 4.5 Interactions among 4.1-4.3.

Water- and land-use practices may affect one or several environmental parameters important to successful spikedace life cycle completion. Thus, synergistic or antagonistic effects of changes in substrate, velocity, depth, and water temperature should be assessed to determine combinations representing optima, preferenda, and tolerance limits.

#### 4.6 Watershed size and flood frequency and volume.

It has been speculated that spikedace may be limited to occupation of streams with a certain minimum watershed size and/or water volume (Propst pers. comm.), based on the absence of spikedace from small tributary streams even if habitat is apparently available. Impoundment and/or diversion of upstream waters, watershed vegetation alteration resulting in changing runoff patterns, and other human actions functionally modify both watershed size and water volume. Flooding has been shown to be a major factor in the relationship of native to non-native fishes (Minckley and Meffe 1987, Propst et al. 1986). Flood frequency and volume is frequently modified in southwestern streams during the course of water development. Relationships between watershed characteristics and spikedace biology must be established so that conditions characterizing suitable habitats can be described, effects of changes can be assessed, and management strategies can be prepared and implemented.

## **5. Enhance or restore habitats occupied by depleted populations.**

Management strategies developed to minimize or eliminate negative impacts resulting from habitat modifications and/or interactions with non-native fishes should be applied to habitats in which spokedace populations have been depleted. Such management provides opportunity for continued study of relationships between spokedace and its biological and physical environment, to assess efficacy and modify specific practices of management implementation, and contributes toward recovery of the species.

### **5.1 Identify target areas amenable to management.**

Some habitats occupied by depleted populations of spokedace, and their adjacent landscapes, may be amenable to restoration, while others may be in a state of continuing degradation such that they cannot reasonably be revived to suitable condition. These former places should be identified so that management can be implemented that will enhance or restore them to pre-impact condition.

### **5.2 Determine necessary habitat and landscape improvements.**

Habitat improvements can be effected only when physical characteristics necessary for spokedace occupation, reproduction, and self-sustenance are known. Moreover, habitat restoration likely will require removal of conditions which have led to degradation. Some stream and river reaches may "self-improve" if natural forces are allowed to reign in absence of sources of perturbation. Examples include curtailment of overgrazing, stabilization of bankline or other erosion sites, altered timber management strategies, etc. Moreover, depletion or removal of non-native fishes, if identified as significant deterrents to survival or enhancement of spokedace, may be necessary.

### **5.3 Implement habitat improvement.**

Once sources of impacts and habitat parameters in need of improvement have been identified, measures should be implemented to remove impacts and restore damaged habitats to conditions suitable for occupation by spokedace. Where removal of non-native fishes is indicated, measures should be adopted to preclude future invasion and establishment in the area by such fishes. This may require installation of barriers to up- or downstream movement, or alternatively may demand repeated management to remove non-natives.

## **6. Reintroduce populations to selected streams within historic range.**

One of the most critical goals to be achieved toward spokedace recovery is establishment of secure, self-reproducing populations in habitats from which the species has been extirpated. Successful implementation of this management goal will provide a clear indication that both the biology of the species and the impacts resulting in its demise are well enough understood and management strategies effective enough that attainment of recovery is probable.

#### 6.1 Identify stocks amenable to use for reintroduction.

Stable, self-sustaining populations with capacity to contribute individuals for reintroduction without sustaining unnecessary depletion should be identified. To the extent practicable, local stocks with affinities to those formerly occupying target streams should be utilized (e.g., Aravaipa Creek for San Pedro, Gila River for San Francisco). Results of a genetic survey (2.6, above) will be used as guidance in selecting appropriate donor stock. If it is determined that extant populations do not have capacity to supply adequate numbers of individuals for reintroduction, hatchery-produced fish may be required (8, below).

#### 6.2 Identify river or stream systems for reintroductions.

Among streams from which spikedace have been extirpated, the San Pedro River system, Arizona, probably represents the most amenable, for several reasons, to its reestablishment. San Pedro River is the type locality for spikedace (Girard 1857), but it and 10 other native fishes were extirpated as a result of drastic habitat destruction, plus introduction of exotic fishes, over the last 100 years (Eberhardt 1981, Minckley 1987). Not only the mainstream San Pedro may be readily amenable to restoration for spikedace, but also certain perennial reaches of major tributaries (e.g., Redfield Canyon, Babocomari River) may have potential for reestablishment of the species. Aravaipa Creek, which is home to one of the most secure remaining spikedace populations in Arizona, is tributary to the San Pedro. The San Francisco River and Mescal Creek (tributary to the Gila River), plus other yet-to-be-identified locations, should also be evaluated as potential recipients of reintroduced populations.

##### 6.2.1 Determine suitability of habitat.

Specific stream reaches that fulfill known requirements plus areas amenable to restoration should be identified. Causes and sources of former and continuing habitat degradation and the cause of the original extirpation need to be evaluated, and extant ichthyofaunas must be assessed.

##### 6.2.2 Enhance habitat as necessary (4, 5.3).

Habitats amenable to physical restoration should be subject to management implementation to restore them to pre-impact condition. This may require modification or discontinuance of certain land- or water-use practices if it is determined that these continue to contribute to habitat degradation.

##### 6.2.3 Assess status of non-native fishes in the watershed.

Non-native fishes pose potential threats to reestablishment of spikedace. These may occupy the stream reach selected for reintroduction, tributaries, and isolated waters within the watershed. Assessment should be made of distribution, community composition, and relative abundances of non-native fishes.

6.2.4 Assure closure of potential immigration routes to preclude reinvasion by non-native fishes.

Stream reaches identified to receive plantings of spiketail should be isolated as much as practicable from non-native fishes, which might preclude or otherwise interfere with successful reestablishment of the native. Closure of immigration routes might include construction of barrier dams or other structures to insure that downstream populations of exotics do not access habitats occupied by reintroduced stocks of spiketail.

6.2.5 Reclaim as necessary to remove non-native fishes.

Non-native species in places from which they could invade spiketail habitat, or those occupying target areas themselves, should be removed or depleted as completely as possible. Removal from live stream reaches would likely be accomplished by piscicide application, while other waters, such as cattle tanks, could be reclaimed by either drainage or pumping, piscicide treatment, or a combination thereof.

6.3 Reintroduce spiketail to selected reaches.

Spiketail should be collected, transported, and reintroduced into selected stream reaches after habitat restoration and exotic species removals have been accomplished. Stocking should be of numbers of individuals necessary to assure maintenance of reasonable genetic heterogeneity of the reintroduced population (Echelle 1988).

6.4 Monitor success/failure of reintroductions.

Reintroduced spiketail populations should be periodically monitored; location, time of year, and methods (2., above) should be standardized so data are comparable with previous information for other populations and can be used to assess changes in status.

6.5 Determine reasons for success/failure.

Success of reintroductions will be indicated by establishment of reproducing, sustaining populations of spiketail with characteristics of abundance, age-class structure, and recruitment in the range of natural variation determined from extant stocks. Causes of reintroduction failure, indicated by aberrancies in population characteristics or extirpation, must be identified and evaluated. These could be a result of incomplete implementation of identified management strategies, or due to other natural or anthropogenic factors. Using monitoring data, preliminary evaluation of success should be made five years after reintroduction. Failed populations should then be reassessed and decisions regarding rectification of problems, restocking, or abandonment made. Populations which are questionable or successful at that time should be monitored for an additional five years before being judged successful or not.

6.6 Rectify as necessary cause(s) of failure and restock.

Identified sources of failure should be rectified. This may require implementation of the same, or refinements of, strategies identified previously, or implementation of additional ones. Additional reintroduction-stocking may be indicated once sources of initial failure



are identified and removed. In some instances, repeated sequences of reintroduction, monitoring, assessment, and refinement may be necessary before local goals are satisfied.

7. Determine quantitative criteria for describing a self-sustaining population.

Recovery goals call for protecting existing populations, restoration of depleted stocks, reestablishment of spokedace in places from which the species has been extirpated, and insurance that the animal has opportunity to self-sustain in perpetuity. Attainment of each can be determined only from quantifiable criteria applied to populations under consideration. In particular, acceptable levels of natural variation within certain parameters of stable, reproducing populations must be determined (see Meffe and Minckley 1987). Absolute and relative abundance, age-class structure and sex ratio, and recruitment are variables most likely to provide needed data as regards population status. These must be interpreted within a context of security of the habitat and watershed against future detrimental change, and of integrity of the fish community as regards invasion and establishment of non-native species.

7.1 Acceptable levels of natural variation.

Populations behave in response to normal variations in their physical and biological environments. Thus, population density, for example, can be expected to vary naturally in time and space. Determination that a population is "healthy" can be made only when the range of normal variation of key population parameters is known.

7.1.1 Absolute numbers.

Presence/absence data provide valuable information, and usually can be assessed expediently. However, such data may not generally be useful for evaluating change in populations status relative to normal environmental variation. Absolute abundance can be determined by any of several methods, such as depletion sampling or mark-and-recapture studies. When standardized as to location, time of year, and method, data are comparable among samples and populations and can be used to establish "mean" conditions and acceptable limits of normal variation.

7.1.2 Age-class structure.

Age-class structure can readily be determined from measurements of individuals sampled during population abundance estimation. Relative health of the population is indicated by a normal distribution of individuals among age-classes, i.e., natural mortality acts to diminish the number of individuals in each successive, older age-class. Obvious aberrancies, such as complete failure of a year class or absence of an age-class, or markedly skewed sex ratio, likely indicate substantial pressure on the population, and may require remedial action.

7.1.3 Reproduction.

Populations can perpetuate themselves only if reproduction replaces individuals lost to natural (or other) sources of mortality. Spokedace reproduction should be assessed by determination that the

population includes an adequate stock of reproductive fish of both sexes in a "normal" ratio, and that egg deposition, embryo incubation, and larval hatch are successful.

#### 7.1.4 Recruitment.

Larval fish must have opportunity to grow, mature, and eventually contribute their gametes to future generations. Thus, dynamics of a healthy population require that an appropriate number of offspring survive to reproduce. Assessment of recruitment would be in concert with evaluations of absolute numbers and age-class structure.

#### 7.2 Minimum stock size.

For each population in time and space, there is a minimum size (number) of reproductive fish necessary for perpetuation of the stock. When numbers dwindle below this minimum stock size, natural (and other) sources of mortality will eventually result in extirpation, even though diminished reproduction and recruitment may occur for a time. While it is probably impractical to attempt to quantify minimum stock size for all present and future populations of spokedace, some consensus should be achieved among knowledgeable individuals as to what represents reasonable minimum stocks for spokedace in various habitats. Depletion of a population near or below that minimum should be taken as indication that one or more environmental factor(s) is negatively impacting the population. Further investigation to determine and rectify the cause would be necessary. A self-sustaining population would not dwindle below minimum stock size.

#### 7.3 Environmental variables.

Self-sustenance in perpetuity requires that habitat at all times meet at least the minimum requirements for life-cycle completion by the species. Some habitats may support spokedace populations for a period of time, then fail. It thus is important that characteristics which describe suitable, long-term habitat be known.

##### 7.3.1 Physical characteristics.

Basic habitat parameters include depth, current velocity, substrate, water temperature, etc. These, plus others determined significant, must be available within tolerance ranges acceptable to spokedace.

##### 7.3.2 Chemical characteristics.

Fishes require varying levels of certain chemical substances to insure completion of all life history functions. For example, dissolved oxygen must remain above certain minima for fishes to survive. Also, levels of environmental chemicals, both natural and anthropogenic, must be maintained such that they do not induce acute or chronic symptoms of toxicity among spokedace, or otherwise interfere with life cycle completion.

### 7.3.3 Biological community.

Maintenance of spikede populations in perpetuity requires that the composition and integrity of the biological community of which it is a member also be maintained. Spikede existence depends in various ways on parts of that community (e.g., aquatic insect food resources). Moreover, perturbation of the community may indicate future changes about to occur in spikede status. Invasion by exotic forms, especially non-native fishes, may have severe impacts upon spikede and other native fishes. Attempts should thus be made to assess, at least in general terms, the nature and condition of the biological communities that characterize habitats occupied by spikede.

## 8. Plan and conduct investigations on captive holding, propagation and rearing.

Captive holding, propagation, and rearing programs are important aspects of recovery plans for most southwestern fishes. At present, it does not appear necessary that such plans be instituted in behalf of spikede. The species continues to occupy in substantial numbers a variety of dispersed habitats, and probability of protecting existing populations and environments appears high. However, conditions could change rapidly and existing populations could be severely depleted or extirpated. In such event, availability of a viable hatchery plan could be indispensable to maintenance of the species. Hatchery-produced fish may also be necessary to support reintroductions of sufficient numbers in attempts to reestablish populations in historic habitats.

### 8.1 Determine wild stocks suitable for contribution to hatchery stocks.

An assessment should be made as to which extant populations are most capable of contributing individuals for captive programs without suffering unnecessary depletion which could impair status of the parent stock. Consideration should be given to maintaining genetic integrity of captive stocks in the context of existing wild populations (Echelle 1988; 2.6, above).

### 8.2 Collect and transfer wild stocks to suitable facility.

Adult spikede should be collected and transferred to an appropriate facility where investigations on holding, captive propagation, and maintenance may be pursued.

### 8.3 Develop procedures and facilities for holding and maintaining.

Standardized techniques and facilities should be developed by which spikede of all sizes and ages can be safely held and maintained without threat of excessive mortality.

### 8.4 Evaluate potential techniques for propagation.

Stream minnows may reproduce voluntarily if placed into suitable artificial habitat. Or, the species may require artificial induction, maturation, expression and fertilization of gametes, and incubation of

embryos. Techniques should be found that are effective and efficient, and which minimize mortality to adult fish.

#### **8.5 Assess life-cycle requirements in hatchery/environment.**

Certain environmental requirements may need to be met to insure successful life cycle completion in the hatchery. For example, specific temperatures may be necessary for spawning and normal larval development, or a certain sex ratio may be required if fish are to spawn voluntarily. Such factors should be determined and optimized where practicable.

#### **8.6 Supply individuals as needed for reintroduction, research, public education, etc.**

Spikedace propagated and reared in a hatchery can serve many purposes. Fish can be transported to selected sites for reestablishment of extirpated populations. Research programs to answer basic questions of spikedace life history and ecology undoubtedly could utilize captive-reared individuals. And, progeny from hatchery stocks could be distributed to schools, museums, zoos, etc., where they could be displayed along with appropriate literature or other information on spikedace in particular and endangered species in general. In each instance where hatchery fish were used, wild populations would be protected against any potential damage which could result from removal of individuals.

### **9. Information and education.**

Free exchange of information and ideas among individuals representing scientific, managerial, and private concerns, and the public sector including citizens groups, should be recognized as essential for a successful recovery program. Information on goals, plans, and progress of recovery implementation should be readily available to all interested parties. Awareness of the general public, in whose behalf the Endangered Species Act was conceived and passed into law, is critical to this plan and to conservation of all imperiled species.

#### **9.1 Public sector.**

Spikedace represents a National resource of value to all people. Because the laws designed to protect this animal, and by which this recovery plan is enabled, originated with desires of the public, it is essential that they be offered every opportunity to be informed and to participate in all aspects of spikedace recovery. Public support has capability to greatly enhance and thereby assure success of spikedace recovery; such support is derived from informed people.

##### **9.1.1 Local media and target campaigns.**

Because people who reside in proximity to habitats occupied by spikedace are often those who express greatest interest in, and may be most affected by, activities associated with recovery, they should be informed of and provided opportunity to participate in all aspects of recovery. Local media including television, radio, newspapers, and circulars should be provided regular, timely, and accurate summaries of plans and progress toward spikedace recovery. They should be encouraged to

express their opinions, and thereby provide input to improve the plan and enhance probability of success.

#### 9.1.2 States of Arizona and New Mexico.

Media with statewide distribution and readership in Arizona and New Mexico should be targeted for receipt of periodic information on spikedace recovery. In this way a larger audience with interest in the program can be accessed, and their support encouraged through education.

#### 9.1.3 National exposure.

Federal laws that protect threatened and endangered plants and wildlife are of interest to all residents of the Nation. It, thus is appropriate that they be allowed to assess efficacy of that legislation through information received on projects throughout the country. In this way, persons with interests in species conservation in general can be assured an opportunity to be informed on a diversity of plans and programs.

#### 9.1.4 Assist appropriate Mexican agencies and organizations in information and education.

A significant portion of the San Pedro River is in Mexico, and stream reaches within that Country may be occupied by undiscovered populations of spikedace. Moreover, health of aquatic biota including possible reintroduced populations of spikedace in portions of that river in the United States may be dependent upon conditions upstream in Mexico. It, thus is important that appropriate Mexican agencies and organizations be apprised of recovery efforts, and that assistance be provided to these groups to enhance awareness in Mexico of continuing threats to this threatened species.

#### 9.1.5 Open communication among States, Federal agencies, and local residents and water users.

It is imperative that all parties interested in or affected by recovery actions in behalf of spikedace be afforded an opportunity to comment on and participate in that program. While unanimity is unlikely to ever be the case, meaningful progress is best assured when all have access to complete information.

#### 9.2 Professional information.

Professional information, including results of field and laboratory research, monitoring data, trip reports, agency reports, and open literature must be readily available to all professionals involved in spikedace recovery. Ideas must be exchanged freely so that optimal strategies may be outlined and implemented. A central clearing house and repository for such information, with capability to distribute it as necessary, should be designated.

##### 9.2.1 Open circulation of information among concerned parties.

All persons working on spikedace and/or their habitats should be encouraged to make information available to other concerned parties. They should be made aware of the clearing house (9.2) and requested to submit their findings there for distribution.

#### 9.2.2 Periodic information-exchange meetings.

Face-to-face meetings of interested professionals and the public should be encouraged on a regular basis, or in response to special circumstances. Such meetings provide opportunity to discuss ideas and resolve difficulties that otherwise could be difficult to accomplish.

#### 9.2.3 Presentations at professional, scientific meetings.

Preliminary or refined research or monitoring data should be presented at local, regional, and National scientific-gatherings so that a broader professional audience may have opportunities to comment on and thereby potentially enhance recovery of spikedace.

#### 9.2.4 Publication in peer-reviewed, open literature.

Participants in studies of spikedace at all levels should be encouraged to publish their findings as appropriate within the peer-reviewed, open literature. Such publication indicates that results have had benefit of critical review and meet the standards of excellence to which professionals subscribe. It also enhances the credibility of individuals involved, and thus contributes to overall success of the recovery program.

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### III. IMPLEMENTATION SCHEDULE

#### Definition of Priorities

- Priority 1 - Those actions that are absolutely essential to prevent the extinction of the species in the foreseeable future.  
Priority 2 - Those actions necessary to maintain the species' current population status.  
Priority 3 - All other actions necessary to provide for full recovery of the species.

#### General Categories for Implementation Schedules

##### Information Gathering - I or R      Acquisition - A

- |                               |                         |
|-------------------------------|-------------------------|
| 1. Population status          | 1. Lease                |
| 2. Habitat status             | 2. Easement             |
| 3. Habitat requirements       | 3. Management agreement |
| 4. Management techniques      | 4. Exchange             |
| 5. Taxonomic studies          | 5. Withdrawal           |
| 6. Demographic studies        | 6. Fee title            |
| 7. Propagation                | 7. Other                |
| 8. Migration                  |                         |
| 9. Predation                  |                         |
| 10. Competition               |                         |
| 11. Disease                   |                         |
| 12. Environmental contaminant |                         |
| 13. Reintroduction            |                         |
| 14. Other information         |                         |

##### Management - M

1. Propagation
2. Reintroduction
3. Habitat maintenance and manipulation
4. Predator and competitor control
5. Depredation control
6. Disease control
7. Other management

##### Other - O

1. Information and education
2. Law enforcement
3. Regulations
4. Administration

#### Abbreviations used

FWS - USDI Fish and Wildlife Service	AZG&F - Arizona Game and Fish Department
FWE - Fish and Wildlife Enhancement	NMG&F - New Mexico Department of Game and Fish
FR - Fisheries Resources	FS - USDA Forest Service
WR - Wildlife Resources	BLM - USDI Bureau of Land Management
LE - Law Enforcement	BR - USDI Bureau of Reclamation
DFRT - Desert Fishes Recovery Team	
PA - Public Affairs	

Part III - IMPLEMENTATION SCHEDULE

GENERAL CATEGORY	PLAN TASK	TASK #	PRIORITY #	TASK DURATION	RESPONSIBLE AGENCY FWS			FISCAL YEAR COSTS (EST.)			COMMENTS
					REGION	PROGRAM	OTHER	FY1	FY2	FY3	
I-1	Identify all populations and determine level of protection	1.1	1	3 years	2	FWE FR	AZG&F NMG&F FS BLM	4,000	4,000	4,000	
I-1	Prioritize populations based on need for protection	1.2	2	1 year	2	FWE	DFRT			500	Task will be conducted by the DFRT
O-3	Designate critical habitat	1.3	1	1 year	2	FWE		1,000			Final rule is under review
O-2	Enforce laws and regulations	1.4	1	Ongoing	2	FWE LE	FS BLM BR AZG&F NMG&F	5,000	5,000	5,000	
M-3	Discourage detrimental land and water uses	1.5	1	Ongoing	2	FWE	FS BLM BR AZG&F NMG&F	5,000	5,000	5,000	
A-7	Insure natural flows	1.6	1	Ongoing	2	FWE WR	FS BLM BR	-----unknown-----			Could involve the purchase of instream flows
M-4	Curtail introductions of non-native fishes	1.7	1	Ongoing	2	FR FWE	NMG&F AZG&F				
M-4	Identify need for and construct barriers	1.8	1	Ongoing	2	FWE	BR AZG&F NMG&F BLM FS	100,000	100,000	100,000	
I-2	Identify available unprotected private lands and water rights	1.9	2	Ongoing	2	FWE	WR DFRT NMG&F AZG&F	3,000	3,000	3,000	

Part III - IMPLEMENTATION SCHEDULE

GENERAL CATEGORY	PLAN TASK	TASK #	PRIORITY #	TASK DURATION	RESPONSIBLE AGENCY			FISCAL YEAR COSTS (EST.)			COMMENTS
					FWS REGION	PROGRAM	OTHER	FY1	FY2	FY3	
A-1 through A-6	Acquire available lands and associated water rights	1.10	2	Ongoing	2	WR	FWE FS BLM	-----unknown-----			
O-2 & O-3	Protect acquired lands	1.11	2	Ongoing	2	WR FWE LE	BLM FS	-----unknown-----			
I-1	Establish standard monitoring locations and techniques	2.1 2.2	1	1 year	2	FWE	FS BLM NMG&F AZG&F DFRT	1,500			
I-1 & I-2	Establish and maintain computerized database	2.3	2	Ongoing	2	FWE	AZG&F	2,000	2,000	2,000	
R-1	Determine natural variation in abundance and age-class structure	2.4	1	3 years	2	FWE	AZG&F NMG&F FS BLM	10,000	10,000	10,000	
R-1	Determine standard methods for quantifying abundance	2.4.1	1	2 years	2	FWE	NMG&F AZG&F FS BLM	2,500	2,500	2,500	
I-1	Conduct bi-annual population estimates	2.4.2	1	Ongoing	2	FWE	NMG&F AZG7F FS BLM	3,000	3,000	3,000	
I-1	Monitor community composition including range of natural variation	2.5 2.5.1 2.5.2	1	Ongoing	2	FWE	NMG&F AZG&F FS BLM	5,000	5,000	5,000	Tasks 2.4.2 to 2.5.2 would be done simultaneously
I-14	Determine genetic characteristics of existing populations	2.6	1	2 years	2	FWE	AZG&F NMG&F FS	8,000	8,000		

Part III - IMPLEMENTATION SCHEDULE

GENERAL CATEGORY	PLAN TASK	TASK #	PRIORITY #	TASK DURATION	RESPONSIBLE AGENCY FWS		FISCAL YEAR COSTS (EST.)			COMMENTS	
					REGION	PROGRAM	OTHER	FY1	FY2		FY3
R-9 & R-10	Determine significance of interaction with non-native fishes	3.1 through 3.2.2	2	3 years	2	FWE	AZG&F NMG&F FS BLM	25,000	25,000	25,000	
R-3	Quantify effects of physical habitat modification	4.1 through 4.6	2	3 years	2	FWE	NMG&F AZG&F FS BLM	25,000	25,000	25,000	
M-3	Identify management areas and determine necessary habitat improvements	5.1 5.2	2	1 year	2	FWE	DFRT NMG&F AZG&F FS BLM			5,000	To be done following completion of tasks 4.1 to 4.4
M-3	Implement habitat improvement	5.3	3	Ongoing	2	FWE	AZG&F NMG&F FS BLM	-----unknown-----			
M-2	Identify stocks to be used for reintroduction	6.1	3	1 year	2	FWE	DFRT			2,000	
M-2	Identify and prepare sites for reintroduction	6.2 through 6.2.5	3	3 years	2	FWE	DFRT NMG&F AZG&F FS BLM	-----unknown-----			Cost will depend upon kind and amount of work
M-2	Reintroduce into selected reaches and monitor	6.3 6.4	3	Ongoing	2	FWE	NMG&F AZG&F FS BLM				\$7,000/yr once reintroduction
M-2	Determine reasons for success/failure and rectify as necessary	6.5 6.6	3	Ongoing	2	FWE	DFRT AZG&F NMG&F BLM FS				Evaluation will begin 5 years after reintroduction

Part III - IMPLEMENTATION SCHEDULE

GENERAL CATEGORY	PLAN TASK	TASK #	PRIORITY #	TASK DURATION	RESPONSIBLE AGENCY FWS		FISCAL YEAR COSTS (EST.)			COMMENTS
					REGION	PROGRAM	FY1	FY2	FY3	
R-1	Determine quantitative criteria for describing a self-sustaining population	7.1 through 7.3.3	2	3 years	2	FWE	20,000	20,000	20,000	
						AZG&F NMG&F FS BLM DFRT				
M-1	Select stocks to be used for hatchery brood stock	8.1	3	1 year	2	FWE FR			1,000	
						DFRT NMG&F AZG&F				
M-1	Collect hatchery stocks	8.2	3	1 year	2	FWE FR			3,000	
						AZG&F NMG&F				
M-1	Hold and maintain stocks in a hatchery	8.3	3	Ongoing	2	FR FWE				\$10,000/yr once stocks are taken
M-1	Evaluate and assess propagation techniques and life-cycle requirements	8.4 through 8.5	3	1 year	2	FR FWE			8,000	
						DFRT NMG&F AZG&F				
M-1	Supply hatchery reared fish as needed	8.6	3	Ongoing	2	FR FWE				\$1,500/yr once begun
						AZG&F NMG&F				
O-1	Provide information and education relative to the species to the public sector	9.1 through 9.1.5	2	Ongoing	2	FWE PA FR	3,000	3,000	3,000	
						NMG&F AZG&F FS BLM BR				
O-1	Ensure all professional information is made available	9.2.1 through 9.2.4	2	Ongoing	2	FWE FR	2,500	2,500	2,500	Costs include information publication in scientific journals
						BR AZG&F NMG&F BLM FS				

#### IV. APPENDIX A: PROPOSED CRITICAL HABITAT

Proposed critical habitat for spikedace, Meda fulgida, in Arizona and New Mexico, as originally proposed by FWS 1985 (all reaches figured in FWS 1985). Legal descriptions (township, range, and section) are not included here; format modified from original publication. Additional stream reaches may be appropriate for consideration as future additions to the designated critical habitat. Any such additions will be subject to the standard rulemaking process, including publication of a proposal in the Federal Register and a public review period.

##### Arizona:

1. Graham and Pinal Counties: Aravaipa Creek, the perennial stream portion (approximately 24 kilometers [km] long). This area includes Bureau of Land Management and privately owned lands.
2. Yavapai County:
  - a. Verde River, approximately 57 km of river extending from approximately 0.8 km below the confluence with Sycamore Creek upstream to Sullivan Lake. This area includes U.S. Forest Service, private, and State lands.
  - b. Sycamore Creek, approximately 1.5 km of stream near the confluence with the Verde River. This includes U.S. Forest Service and privately owned lands. (Note: although originally proposed by the FWS [1985], this stream segment is not expected to be included in a final rule formally designating critical habitat.)

##### New Mexico:

1. Grant and Catron Counties: Gila River, three sections of river totaling approximately 73 km in length. The first section, approximately 50 km long, extends from the mouth of the Middle Box canyon upstream to the confluence with Mogollon Creek. A second section, approximately 11.5 km long, extends up the West Fork from the confluence with the East Fork. The last section, approximately 11.5 km long, extends up the Middle Fork from its mouth upstream to the confluence with Big Bear Canyon. These river sections flow through U.S. Forest Service, Bureau of Land Management, New Mexico Department of Game and Fish, and privately owned lands.

In addition to the above areas which have been formally proposed for critical habitat designation, the following reach of Eagle Creek is recommended by this plan for addition to the designated critical habitat.

Graham and Greenlee Counties: Eagle Creek, approximately 38 km of stream extending from the Phelps Dodge Corporation diversion dam upstream to the mouth of Sheep Wash. The stream flows through San Carlos Apache Indian, U.S. Forest Service, and private lands. This population was undiscovered at the time critical habitat was originally proposed by FWS [1985]. Because of the relatively unperturbed character of the stream segment and viable spikedace population found there, it is a recommendation of this plan that the reach be proposed for designation as critical habitat.



## V. APPENDIX B: COMMENTS

Appendix B is combined for two recovery plans; the spikedace and the loach minnow. It contains a list of plan reviewers, copies of comment letters received, and Service responses to those comments. Comments for both plans were solicited at the same time, and all comment letters address both plans. Therefore, to reduce paper consumption, Appendix B has been printed under separate cover from the body of either recovery plan. Appendix B was distributed along with copies of the plans to a mailing list of interested parties, including Federal and State agencies and parties who submitted comments. Further distributions of either recovery plan will be made without Appendix B, unless it is requested. Separate copies of Appendix B are also available upon request.



Office of Sponsored  
Projects

928-523-4880  
928-523-1075 fax  
PO Box 4130  
Flagstaff, AZ 86011-4130

August 31, 2017

Mr. Reuben Teran  
Executive Director  
Arizona Water Protection Fund  
Arizona Department of Water Resources  
1110 W. Washington Street, Suite #310  
Phoenix, AZ 85007

RE: Matching Commitment

Dear Mr. Teran,

I am writing on behalf of Northern Arizona University (NAU), and it is our pleasure to submit our proposal to the Arizona Water Protection Fund, entitled "*Do native fish facilitate the persistence of endangered spikedace by resuspending food particles?*" that is being submitted to AWPF for consideration for the 2019 Funding Cycle.

Please accept this letter as confirmation that NAU is committed to the matching funds detailed in the proposal narrative and to submitting the deliverables in a timely manner, should the grant opportunity be funded.

NAU commits to matching funds for the entire performance period covered by the proposal. It is our understanding that NAU will match funds of \$28,558 for their efforts as described in the proposal narrative. NAU looks forward to being able to contribute to this project.

Sincerely,

A handwritten signature in blue ink, appearing to read "K. Lawrence", is written over a horizontal line.

Kerwin A. Lawrence  
Sponsored Projects Officer, Sr.



## United States Department of the Interior

Fish and Wildlife Service  
Arizona Ecological Services Office  
9828 North 31<sup>st</sup> Avenue, Suite C3  
Phoenix, Arizona 85051

Telephone: (602) 242-0210 Fax: (602) 242-2513



In reply refer to:

AESO/ES/02EAAZ00-2018-TA-1183

August 24, 2018

Arizona Water Protection Fund Commission  
1110 West Washington Street, Suite 310  
Phoenix, Arizona 85007

Dear Arizona Water Protection Fund Commission:

This letter of support is for the FY 2019 Arizona Water Protection Fund proposed research project, "Do Native Fish Facilitate the Persistence of Endangered Spikedace by Re-suspending Food Particles?", submitted by Dr. Benjamin Koch of Northern Arizona University. The proposed project involves field manipulations of fish populations in streams known to harbor federally listed species, and therefore requires permitting and approval by the U.S. Fish and Wildlife Service prior to any on-site experimental work. Dr. Koch has been and will continue to work with us on acquiring appropriate permits.

The proposed research has the potential to provide useful data on the roles of native suckers in supplying food resources to water-column feeding fish such as spikedace (*Meda fulgida*). Spikedace are listed as an endangered species, and are currently threatened by a variety of factors including nonnative aquatic species and loss of habitat. The Spikedace and Loach Minnow Recovery Team and state, tribal, and federal partners are continuing to implement elements of the 1991 Recovery Plan for spikedace, which includes repatriating them to locations within their historical range. Dr. Koch's work on food resources will help the Recovery Team to refine their repatriation efforts, and potentially lead to greater successes, leading in turn to recovery of this endangered species.

We have been communicating with Dr. Koch about this project and are supportive of the proposed research. We will work with Dr. Koch within the standard research permitting process to facilitate this project being conducted in compliance with the Endangered Species Act of 1973, as amended. In addition, Dr. Koch is coordinating with appropriate staff at the Arizona Game and Fish Department.

Should you require further assistance or if you have any questions, please contact Mary Richardson at (602) 242-0210. Thank you for your continued efforts to conserve endangered species.

Sincerely,

Acting Field Supervisor

cc (electronic):

Chief, Habitat Branch, Arizona Game and Fish Department, Phoenix, AZ

Native Fish Program, Arizona Game and Fish Department, Phoenix, AZ (Attn: Tony Robinson)

Wildlife Biologist, Fish and Wildlife Service, Flagstaff, AZ (Attn: Shaula Hedwall)

W:\Mary Richardson\AWPF\_Ltr\_for\_Koch\_NAU-formatted.docx