36TH ANNUAL RESEARCHERS MEETING

Upper Colorado River Endangered Fish Recovery Program

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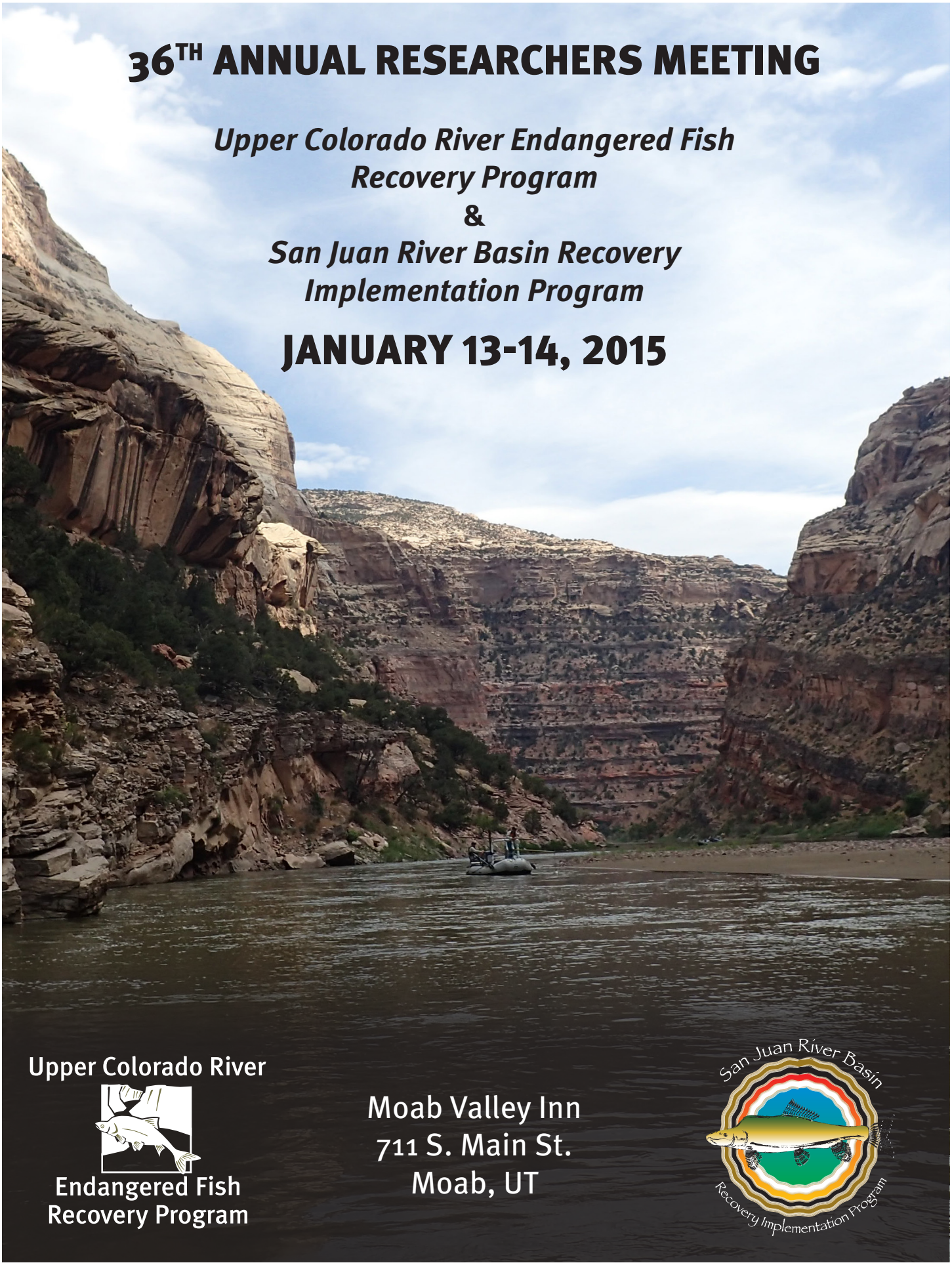
San Juan River Basin Recovery Implementation Program

JANUARY 13-14, 2015



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Upper Colorado River Endangered Fish Recovery Program

Moab Valley Inn
711 S. Main St.
Moab, UT

San Juan River Basin Recovery Implementation Program

Registration is Monday Evening 4–8 PM

Day 1, Tuesday January 13, 2015

Time	Presenter	Title
Moderator: Tom Czapla		
8:00	Chart/ Campbell	Welcome
8:05	Ward	Eradication of Invasive Aquatic Species Using Carbon Dioxide and Liquid Ammonia
8:20	Wilson	Isolation and Characterization of Twenty-Five Novel Microsatellite Loci in Colorado Pikeminnow
8:35	Wilson	Genetic Evaluation of the Humpback Chub Refuge Population at the Southwestern Native Aquatic Resources and Recovery Center, Dexter, New Mexico
8:50	Kesner	Population Dynamics of Razorback Sucker in Two Lower Colorado River Reservoirs
9:05	**Break**	
9:20	Ehlo	Nonnative Predation on Razorback Sucker Larvae in Lake Mohave
9:35	McKinstry	Razorback Sucker in Lower Grand Canyon and the Lake Mead Inflow Area—A History of the Species and Biological Opinions
9:50	Albrecht	Razorback Sucker Research and Monitoring in the Colorado River Inflow Area of Lake Mead and the Lower Grand Canyon, Arizona and Nevada
10:05	Platania	Documentation of Spawning by Razorback Sucker, in the Lower Grand Canyon during 2014
10:20	Miller	An Aquatic Ecosystem Population Model for the San Juan River: A Management Tool for Endangered Species Recovery Efforts
10:35	**Break**	
10:50	Lyons	Evaluation of Opportunities for Irrigation System Improvements and Water Markets to Support San Juan River Basin Environmental Flows
11:05	Franssen	Assessing the Case for Prey Limitation: Historical and Contemporary Trophic Positions of Colorado Pikeminnow in the San Juan River
11:20	Mohrman	Upper Colorado River Cooperative Water Management in 2014
11:35	**Lunch**	
Moderator: Melissa Trammell		
1:00	Fry	Building Bonytail (>250mm in 16 months) at Ouray National Fish Hatchery
1:15	Logan	Bonytail Chub in the Upper Colorado River Basin: Propagation and Evaluation of Hatchery-produced Fish Over the Past Two Decades
1:30	Howard	Humpback Chub in Desolation and Gray Canyons
1:45	Grippo	Changes in Backwater Habitat from 1986 to 2013 in the Middle Green River Based on Aerial Imagery Analysis
2:00	**Break**	

2:15	Hayse	Modeling Water Temperature and Growth of Colorado Pikeminnow in Backwaters of the Green River
2:30	Walston	Reassessing Floodplain Wetland Connections in the Middle Green River, Utah
2:45	Schelly	Successful Management of Stewart Lake Wetland as a Nursery for Endangered Razorback Sucker, on the Middle Green River, Utah
3:00	McAbee	Demonstrating Selenium Uptake in Endangered Razorback Sucker Reared in Stewart Lake, Utah
3:15	**Break**	
3:30	Michaud	Walleye Management on the Green and Colorado Rivers
3:50	Schelly	Smallmouth Bass Removal in the Upper Colorado River Basin: Summary of 2014 data and Recommendations from the Nonnative Fish Workshop.
4:10	Gross	Effects of a Sweeping Low Frequency Pulsed DC Electrical Field on Asian Carp Behavior in a Zero Flow Environment
4:25	**Adjourn for Social and Posters**	

Day 2, Wednesday January 14, 2015

Moderator: Jerry Wilhite

8:00	Battige	Summary of Northern Pike Removals in the Upper Colorado River Basin
8:20	Zelasko	Abundance and Population Dynamics of Invasive Northern Pike, Yampa River, Colorado, 2004–2010
8:40	Bestgen	Yampa Native Fish Response
9:10	**Break**	
9:20	Young	Use of Portable PIT Tag Antennas to Supplement Hoop and Trammel Net Surveys in Grand Canyon
9:35	Haverbeke	Monitoring of Humpback Chub, Bluehead Sucker and Flannelmouth Sucker in the Little Colorado River, Grand Canyon, AZ
9:50	Vanderkooi	Monitoring of Native and Nonnative Fishes in the Little Colorado River via Remote PIT-Tag Arrays
10:05	Cathcart	Fish Community Movement Behavior at a Mainstem-Tributary Confluence
10:20	McKinstry	Evaluation of a Weir Designed to Reduce Entrainment of Endangered Fish in Canals
10:35	**Break**	
10:45	Jones	Detecting Razorback Sucker Using Passive Integrated Transponder (PIT) Technology at a Spawning Bar
11:00	Speas	Use of a Passive Interrogation Array to Evaluate Entrainment of Endangered Fish in an Irrigation Canal
11:15	McAbee	Using Passive Detection Technology to Document Endangered Fish in the White River, Utah
11:30	Breen	Using Active and Passive Captures of Native Fishes in the White River, Utah (2008–2014) to Evaluate Vital Population Demographics

11:45 **Lunch**

Moderator: Kevin McAbee

1:00	Speas	Use of Passive Integrated Transponder Technology in Recovery of Endangered Fish in the Upper Colorado and San Juan River Basins
1:10	McKinstry	Overview and Lessons Learned for PIT-Tag Antenna Installations in the San Juan River Basin
1:25	Budy	Why Are We Doing This and What Are We Learning: Application and Context for Widespread PIT-Tagging Efforts in the Upper Colorado River Basin
1:40	Conner	Every Which Way Comes Data: Models for Analyzing PIT Tagged Fish
1:55	Open Discussion on Analysis of PIT Tag Data	
2:25	**Break**	
3:35	Speas	Recovery Program Data Pathways: Existing and Desired Future Protocols
3:45	Holfelder	Status of Recovery Program Database Development
4:15	MacKinnon	Data Acquisition and PIT Equipment Use and Applications
4:45	Open Discussion/Concluding Remarks	
5:00	**Adjourn and Mini-Social**	

PRESENTATION ABSTRACTS

Eradication of Invasive Aquatic Species Using Carbon Dioxide and Liquid Ammonia

David Ward, Rylan Morton-Starner, and Ben Vaage.

U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff AZ

Eradication of populations of nonnative aquatic species for the purpose of reintroducing native fish is often difficult because very few effective methods are available for removing aquatic organisms. This creates the need to evaluate new chemicals that could be used as management tools for native fish conservation. Carbon dioxide and ammonia are by-products of fish metabolism and are naturally present in the environment at low levels, yet are known to be toxic to most aquatic species. We evaluated the effectiveness of using carbon dioxide (baking soda + muratic acid) and liquid ammonia (29 %) as fisheries management tools in a series of small natural ponds in northern Arizona. Carbon dioxide (200 ppm) was effective at removing invasive green sunfish, *Lepomis cyanellus*, and smallmouth bass, *Micropterus dolomieu*, from small pools while allowing native roundtail chub, *Gila robusta*, to be captured and salvaged. Carbon dioxide however was not completely effective at removing invasive fishes as pond size increased and was not effective for removing northern crayfish, *Orconectes virilis*. The relatively large quantities of baking soda (1.5 g/3.78 liters) and muratic acid (2 ml/3.78 liters) required to impact fish likely limits this method of creating high carbon dioxide levels to smaller bodies of water (<379,000 liters). Ammonia was effective at eliminating green sunfish in a 2,840,000 liter earthen pond when dosed at 0.25 ml/3.78 liters, but crayfish eradication in a 2,100,000 liter earthen pond was not effective even at 1.5 ml/3.78 liters. Liquid ammonia may provide a simple, cost-effective way to manage invasive fishes even in relatively large bodies of water with no harmful residues.

Isolation and Characterization of Twenty-five Novel Microsatellite Loci in Colorado Pikeminnow

Renee M. Martin, Morgan L. Robinson, *Wade D. Wilson*

U.S. Fish and Wildlife Service, Southwestern Native Aquatic Resources and Recovery Center, Dexter, NM.

Colorado pikeminnow (*Ptychocheilus lucius*) is a federally endangered cyprinid endemic to the Colorado River system in the southwestern United States. Extant wild populations only occur in the upper basin, and a captive broodstock is maintained to supplement wild populations. Twenty-five polymorphic microsatellites were developed using Illumina paired-end sequencing. Across 32 samples, *P. lucius* exhibited 4–25 alleles per locus, and observed and expected heterozygosities per locus ranged from 0.625 to 1.000 and 0.685 to 0.934, respectively. Tests for Hardy–Weinberg equilibrium were non-significant. Cross amplification was characterized in eight other cyprinids. These microsatellite markers will

be useful for genetic monitoring of *P. lucius* captive and wild populations as well as other cyprinids.

Genetic Evaluation of the Humpback Chub Refuge Population at the Southwestern Native Aquatic Resources and Recovery Center, Dexter, New Mexico

Wade D. Wilson

U.S. Fish and Wildlife Service, Southwestern Native Aquatic Resources and Recovery Center, Dexter, NM.

As a conservation measure in Biological Opinions on the operation of Glen Canyon Dam, the Southwestern Native Aquatic Resource and Recovery Center (Southwestern Native ARRC) in collaboration with the Bureau of Reclamation, National Park Service, and other U.S. Fish and Wildlife Service offices began developing a refuge population of *G. cypha* in Fiscal Year 2009. The purpose of the current project was to provide managers with the best estimate of the effective population size (N_e) of the lower basin population and to begin to establish a genetic baseline of the refuge population using 14 microsatellite markers. Results of the summary statistics show that the *G. cypha* in the lower basin is genetically diverse with low and non-significant inbreeding coefficients, high levels of observed heterozygosity, and high allelic diversity. The refuge population is adequate and should protect some of the genetic diversity found in the lower basin population, if captive mortality is minimal.

Population Dynamics of Razorback Sucker in Two Lower Colorado River Reservoirs

Brian Kesner

Marsh & Associates, 5016 S Ash Ave Suite 108, Tempe, AZ. 85233

Populations of repatriated razorback sucker have been established and maintained in two lower Colorado River basin reservoirs, Lake Havasu and Lake Mohave, through an extensive stocking regime. Estimates of their numbers have remained in the low thousands despite stocking hundreds of thousands of fish. Low post-release survival and capture rates in the past resulted in imprecise estimates of abundance and survival using mark-recapture data, and data on timing and causes of post-stocking mortality were limited to telemetry studies with small sample sizes. Since 2006, nearly all razorback sucker stocked into the two reservoirs have had a 134.2 kHz passive integrated transponder (PIT) tag inserted prior to release. Since 2011, remote sensing of PIT tags in both reservoirs has increased post-release contact by an order of magnitude.

Although there are many similarities in basic abundance and stocking characteristics between the two reservoirs, mark-recapture analyses based on remote PIT scanning data indicate that the two populations have distinct and important demographic differences. The population of PIT tagged fish in Lake Havasu was estimated at 4456 (4089-4855, 95% confidence interval)

individuals in 2013. Remote PIT scanning in the same year contacted 1313 (29%) of these fish. In Lake Mohave, two distinct subpopulations with limited exchange were identified, one in the river downstream of Hoover Dam and one in the basin. Combined, the two subpopulations were estimated at 3284 (3067-3516, 95% confidence interval) in 2013, of which 3137 (96%) were contacted with remote PIT scanners. Total length at release was significantly correlated to post-stocking survival estimates in both reservoirs, but the specific relationship was system specific. Therefore the most effective stocking strategy may be unique for each reservoir. Efforts to locate and contact a larger portion of the estimated population in Lake Havasu, and to contact additional unknown subpopulations in Lake Mohave are ongoing.

Nonnative Predation on Razorback Sucker Larvae in Lake Mohave

Chase A. Ehlo[1], Melody J. Saltzgiver[2], Thomas E. Dowling[2], and Paul C. Marsh[1]

[1]Marsh and Associates, LLC, Native Fish Lab, Tempe, AZ
[2]Wayne State University, Department of Biological Sciences, Detroit, MI

Razorback sucker is an endangered species native to the Colorado River Drainage. The species successfully spawns in Lake Mohave and larvae are found in abundance but they disappear soon after and consequently there is no recruitment in the reservoir. There are few observations of larvae being consumed by non-native fish which likely stems from the limits of visual identification of masticated prey items. However, molecular techniques have allowed for the identification of razorback sucker DNA from the stomach contents of nonnative predators. Nonnative predators were collected from Tequila Cove in Lake Mohave using minnow traps, hoop nets, and boat electrofishing. Stomach contents were extracted from the fish and analyzed using quantitative PCR to detect razorback sucker DNA. A total of 103 nonnative fish representing four species were collected. Of the 103 fish, razorback DNA was detected in 11 of the stomachs. Predator size was evenly distributed between 35 mm and 174 mm. Fourteen percent (6 out of 43) of the green sunfish had razorback DNA in the stomach compared to 7% in bluegill indicating that it may be most effective predator of razorback larvae. Nonnative fish were not collected during peak spawning for razorback sucker, and preservation techniques were not ideal. Therefore, another sample will be taken this spring closer to peak spawning and using proper preservation techniques. In conclusion, nonnative fish are consuming razorback larvae. While the extent of larval predation is not yet known, this is likely one major cause for the population collapse and the continued absence of razorback sucker recruitment in Lake Mohave.

Razorback Sucker in Lower Grand Canyon and the Lake Mead Inflow Area—A History of the Species and Biological Opinions

Mark McKinstry

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In 1995 the US Fish and Wildlife Service (USFWS) stated in a Biological Opinion (BiOp) on the Operation of Glen Canyon Dam that the Bureau of Reclamation (Reclamation) should "…sponsor a workshop, and develop a management plan for RBS in Grand Canyon." Then, in December 2007 the USFWS issued a Biological Opinion to the Bureau of Reclamation (Reclamation) on proposed coordinated operations of Lake Powell and Lake Mead. One of the Conservation Measures in the BiOp was for Reclamation to "…examine the potential habitat in the lower Grand Canyon for the species [razorback sucker, *Xyrauchen texanus*], and institute an augmentation program in collaboration with FWS, if appropriate." A project to survey for razorback sucker at the Colorado River inflow (CRI) area of Lake Mead was also recommended in the comprehensive review report on 10 years of razorback sucker monitoring in Lake Mead. In 2010 Reclamation initiated two projects to evaluate razorback sucker use of the CRI and lower Grand Canyon. The first project was a comprehensive survey for the fish at the CRI area using captive, pond-reared, sonic-tagged razorback suckers to locate wild fish. The second project consisted of two components: (1) a thorough literature review of the species, with special emphasis on information about this species in Grand Canyon, and (2) a river trip with several experts on the species' ecology and biology, as well as representatives of various management agencies, to evaluate the habitat in the lower Grand Canyon and make recommendations regarding fulfilling the BiOp's conservation measure. In early spring of 2010 three wild adult razorback sucker were discovered using the CRI area and several larvae were captured, indicating that fish were using this area and were reproducing. The literature review found 10 records of razorback suckers being captured in Grand Canyon between 1944 and 1990, primarily near the mouths of tributaries, including the Paria River, Little Colorado River, and Bright Angel Creek. All were adult fish and none have been captured since 1990. Further work at the CRI from 2011 through 2013 showed that more fish were using the CRI area and moving between the CRI and other spawning and congregation areas in Lake Mead (Virgin and Muddy River inflows, and Las Vegas Wash) as well as moving further upstream at least 35 miles to Quartermaster Canyon. In 2014 Reclamation initiated a more comprehensive study of the fish in lower Grand Canyon concentrating on the river from Lava Falls downstream to Lake Mead. This action is being conducted under collaboration with the Glen Canyon Dam Adaptive Management Program, Lower Colorado River Multi-Species Conservation Program, Upper and Lower Colorado Regions of Reclamation, National Park Service, USFWS, Grand Canyon Monitoring and Research Center, Nevada Division of Wildlife, Arizona Game and Fish Department, Hualapai Indian Tribe, Bio-West Inc., ASIR LLC, and other stakeholders and is one of the few projects where both the upper and lower basins are working together for the conservation of Razorback Suckers.

Razorback Sucker Research and Monitoring in the Colorado River Inflow Area of Lake Mead and the Lower Grand Canyon, Arizona and Nevada

Brandon Albrecht[1], Ron Kegerries[1], Judith M. Barkstedt[2], W. Howard Brandenberg[2], Adam L. Barkalow[2], Steven Platania[2], Mark McKinstry[3], Brian Healy[4], Emily Omana[4], James Stolberg[5], and Zachary Shattuck[1]

[1]BIO-WEST, Inc.
[2]American Southwest Ichthyological Researchers, LLC
[3]U.S. Bureau of Reclamation, Upper Colorado Region
[4]National Park Service
[5]Lower Colorado River Multi-Species Conservation Program)

Based on past studies and recent movements of sonic-tagged Razorback Suckers from Lake Mead into the lower Grand Canyon (LGC) section of the Colorado River, questions regarding this population have spurred further interest into the presence of wild individuals and their relationship between the river and reservoir. For more than 20 years, Razorback Suckers were thought to be extirpated within the Grand Canyon. This collaborative and holistic study included efforts to continue monitoring Razorback Sucker (all life stages) within the Colorado River inflow of Lake Mead (CRI) with the inclusion of sonic telemetry, small-bodied fish community, and larval fish community sampling from Lava Falls downstream to Pearce Ferry, in the LGC (RM 180–280). The specific objectives outlined for these efforts included; (1) conducting larval and small-bodied fish studies to quantitatively assess annual fish reproduction, spawning, and nursery areas in the LGC, (2) determining if Razorback Suckers were present in the study area and if they associated with habitat found within the LGC through telemetry and opportunistic adult sampling, and (3) identifying habitat associations, relative spawning and reproductive effort, and population trends of Razorback Sucker in the CRI. Specifically, this paper will present findings from the CRI portion of this multi-faceted study, particularly regarding natural recruitment observed within this population, with additional results from the LGC, as informed from small-bodied fish community sampling and adult Razorback Sucker telemetry efforts.

Documentation of Spawning by Razorback Sucker, in the Lower Grand Canyon During 2014

Judith M. Barkstedt[1], Adam L. Barkalow[1], W. Howard Brandenburg[1], *Steven P. Platania*[1], Ron B. Kegerries[2], Brandon A. Albrecht[2], Brian D. Healy[3], Emily Omana[3], James R. Stolberg[4], and Mark C. McKinstry[5]

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The Grand Canyon section of the Colorado River, from Glen Canyon Dam downstream to Pearce Ferry, supports federally endangered *Gila cypha*, Humpback Chub and *Xyrauchen texanus*, Razorback Sucker. Downstream of the Grand Canyon in Lake Mead, stable reproducing Razorback Sucker populations have been documented since 1996. Recent tracking of sonic-tagged adults and captures of larval Razorback Sucker by Bio-West in the Colorado River inflow of Lake Mead suggested this species might, at least seasonally, be expanding upstream of the lake and be using the lower Colorado River in the Grand Canyon. In 2014 a study was initiated to determine the distribution of adult, juvenile, and larval Razorback Sucker in the Grand Canyon.

The 100-mile long study area for the 2014 larval fish survey in the lower Grand Canyon began near Lava Falls (RM 179.2) and extended downstream to Pearce Ferry, at the Colorado River inflow into Lake Mead (RM 280). This section of river is characterized by a narrow river corridor with limited floodplain development, gradients alternating between steep rapids and long pools and runs, and substrata ranging from silt to bedrock. A general randomized tessellation stratified (GRTS) design was used to generate fish sampling locations for this study. This technique ensures spatially balanced samples and a robust statistical design. The 40 sampling locations generated for this project were sampled monthly (n=6) from April through September 2014. The 240 larval fish sites sampled in the lower Grand Canyon during 2014 yielded 10 species and was numerically dominated by catostomids (>80% of cumulative sample). Noteworthy was the collection of over 450 larval Razorback Sucker in the lower Grand Canyon at over 20 unique sites during April and May. Collection locations of larval Razorback Sucker ranged from RM 179.1 (upper end of the study area) downstream to RM 279.1 (our lowermost sampling site). The 2014 larval fish study documented spawning of Razorback Sucker in the Grand Canyon thereby expanding the breeding range of this endangered fish and is another positive step towards recovery for this species.

An Aquatic Ecosystem Population Model for the San Juan River: A Management Tool for Endangered Species Recovery Efforts.

William J. Miller[1] and Vincent A. Lamarra[2]

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Management of long lived endangered species poses special problems for resource managers and species recovery efforts. The development of empirical data for evaluation of management alternatives can require many years of data collection to provide sufficient

information for management decisions. We constructed a conceptual framework for the fish community and endangered fishes in 180 miles of the San Juan River in 1998. We constructed a mechanistic population model based on the original conceptual model from 2000–2005. We updated the mechanistic model in 2012 through 2014 to include all reaches of the San Juan River from Navajo Dam downstream and into Lake Powell. The San Juan River population model includes bioenergetics, population, trophic components and physical habitat components. The model was developed using the following data and modeling sequence: 1) Estimates were made for biomass and population for the fish community in the San Juan River; 2) Bioenergetic relationships were developed for all trophic levels in the fish community, which provide growth and biomass components that feedback to the population model; 3) A mechanistic population model for all trophic levels was developed, which incorporates mortality, natality, predation, growth, trophic dynamics and habitat constraints; 4) Physical habitat and flow relationships were developed from 12 years of empirical data; and 5) The above sequence allows the testing of management alternatives including removal of nonnative species, augmentation of native endangered species, and habitat manipulation. Ten fish species are currently incorporated in the model. These include the two listed endangered species, Colorado pikeminnow (*Ptychocheilus lucius*) and razorback sucker (*Xyrauchen texanus*). Three additional native species in the model are flannelmouth sucker (*Catostomus latipinnus*), bluehead sucker (*Catostomus discobolus*) and speckled dace (*Rhinichthys osculus*). Nonnative species are included in the model. These are channel catfish (*lctalurus punctatus*), common carp (*Cyprinus carpio*) and red shiner (*Cyprinella lutrensis*). Data for fish populations by age class and habitat was collected during 1998 through 2001 for model development and calibration. Lower trophic level productivity included estimates of benthic invertebrate density and biomass. The population model is configured in STELLA modeling software to incorporate both the bioenergetic and population portion of the ecosystem. The bioenergetics provides the feedback on individual annual growth as a control on population growth. In addition, there are physical variables of habitat versus flow relationships, discharge, water temperature and turbidity that are linked to the model using Microsoft Excel spreadsheets. The model configuration consists of eleven model reaches to reflect the variability in habitat and populations throughout the San Juan River. Model calibration used mortality estimates, hatching success and reach to reach movement to adjust the model outputs to match the San Juan River fish monitoring data for the period 2002 through 2012. Model execution consists of a STELLA module for each river reach, Microsoft Excel workbooks with input data for physical and biological data. The output is summarized on a ri verwide basis to compare the modeling results with collection results for the 2002–2012 monitoring period. Additional model runs were made after calibration to evaluate Colorado pikeminnow and razorback sucker augmentation for the period 2001 through 2012. The model predicted populations are within the confidence interval for population estimates for these species. The San Juan River aquatic ecosystem population model provides a means to evaluate management actions for the recovery of two endangered species. The model replicates the data being collected in the San Juan River. The model can evaluate management alternatives over long time periods (up to 100 years) to provide guidance for resource management decisions.

Evaluation of Opportunities for Irrigation System Improvements and Water Markets to Support San Juan River Basin Environmental Flows

Dale W. Lyons

The Nature Conservancy, 212 E. Marcy St., Santa Fe, NM. 87501

The goal of this study was to determine whether there are opportunities for irrigation system improvements and/or water markets to support San Juan Basin environmental flows for the benefit of endangered fish. It is hoped that the study's findings will help Basin water and natural resource managers plan future efforts to further evaluate and implement the identified opportunities.

Acknowledging that there is disagreement about whether and how various agricultural conservation measures actually result in conserved water and reduced river diversions, the first phase of this study involved a review of scientific literature and agency publications to understanding the effectiveness of conservations measures in different settings. This review finds that on-farm conservation measures, while sometimes improving irrigation efficiency, often result in increased net-water usage as conserved water is used to expand agricultural production. In contrast to on-farm conservation measures, the literature review finds that when off-farm irrigation system infrastructure improvements are integrated with other off-farm actions such as flow measurement, telemetry, automation, and modified operational practices, substantial reductions in river diversions can be achieved. As with integrated off-farm irrigation system improvements, current scientific literature also indicate that water markets can be successfully used to improve environmental flow conditions.

The second phase of this study was to develop case studies that profiled three agricultural systems in the Western U.S. where off-farm conservation measures and water market programs successfully resulted in reduced agricultural river diversions. These case studies, which reinforced the findings of the scientific literature review, illustrated how integrated irrigation system improvements and water market programs could be used to reduce agricultural diversions and support environmental flows.

Based on the findings of the literature review and the case studies, both water markets and irrigation system improvements that integrate infrastructure modernization with operational changes hold potential to reduce agricultural river diversions for the benefit of endangered fish in the San Juan Basin. To identify opportunities to implement water markets and irrigation system improvements in the San Juan Basin, the third and final phase of the study involved conducting interviews of representatives from most of the Basin's ditch associations in New Mexico. Through these interviews, The Nature Conservancy developed basic irrigation system descriptions, identified multiple potential projects, funding sources, and recommended next steps. The following summarizes these potential projects in the Basin:

- Installation of automated diversion infrastructure to help Basin ditch organizations better control and limit river diversions, as well as to facilitate implementation of scheduled diversion/irrigation practices, all of which can support environmental

flows.

- Installation of ditch lining and/or piping along high priority reaches of Basin ditches to minimize seepage losses and reduce river diversion, in support of environmental flows.
- Operation of a direct San Juan River diversion facility by the City of Bloomfield during the winter months, which will eliminate seepage and other inefficiency losses now incurred through delivery of municipal drinking water by the Bloomfield Irrigation District canal.
- Development of a water market program to either lease or acquire agricultural water rights from water right owners who are currently not using their full water allocation, in order provide economic benefits to water right holders while reducing river diversions and supporting environmental flows.
- Basin-wide irrigation system optimization assessment to identify and prioritize irrigation system improvement projects among San Juan Basin ditch organizations that can reduce river diversions and support environmental flows, while at the same time benefit farmers through improved systems operation.

In order to prioritize limited resources and strategize implementation of these projects, a necessary first step would be to develop estimates of diversion reduction/instream flow benefit associated with each project.

Assessing the Case for Prey Limitation: Historical and Contemporary Trophic Positions of Colorado Pikeminnow in the San Juan River

Nathan R. Franssen[1], Eliza I. Gilbert[2], Angela James[3], Jason E. Davis[3], Keith B. Gido[4], and David L. Propst[1]

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[2]New Mexico Department of Game and Fish, Fisheries Management Division, Santa Fe, NM.
[3]United States Fish and Wildlife Service, New Mexico Fish and Wildlife Conservation Office, Albuquerque, NM.
[4]Kansas State University, Department of Biology, Manhattan, KS.

Suitable prey availability can be vital for fast growth of individuals and strong recruitment of piscivorous fish populations. In the San Juan River, low numbers of stocked Colorado pikeminnow reaching adult sizes suggests a bottleneck is limiting recruitment. Because the prey base available to Colorado pikeminnow in the river has likely changed in recent times, we investigated the potential for limited prey availability to affect recruitment. We used stable isotope analysis to assess contemporary and historical food webs in the river, quantified annual variation in prey densities and trophic positions of Colorado pikeminnow, and used a laboratory experiment to verify isotopic fractionation and turnover rates in the field. Our results indicate historical Colorado pikeminnow occupied higher trophic positions while contemporary Colorado pikeminnow (of similar sizes) occur at a lower trophic position than predicted for piscivorous fishes in the San Juan River. Our laboratory experiment

confirmed fractionation and turnover rates used to quantify the trophic position of Colorado pikeminnow relative to potential prey. Additionally, increased annual prey densities resulted in higher trophic positions and better condition of Colorado pikeminnow in contemporary collections. These results suggest that the trophic status of Colorado pikeminnow in the San Juan River has declined in recent times, potentially due to the extirpation of historical prey fishes (e.g., roundtail chub, razorback sucker) or lower abundances of other native and nonnative prey. Thus, altered predator-prey interactions may be having deleterious effects on recruitment of Colorado pikeminnow in the San Juan River.

Upper Colorado River Cooperative Water Management in 2014

Jana Mohrman

Hydrologist, U.S. Fish and Wildlife Service

A review of the 2014 hydrology will be presented. A summary of how a range of fish flow targets were met will be presented. Accomplishments in instream flow protection will be summarized.

Building Bonytail (>250mm in 16 months) at Ouray National Fish Hatchery

Matthew Fry

Ouray National Fish Hatchery, U.S. Fish and Wildlife Service, Ouray, UT

Ouray National Fish Hatchery (ONFH) was established in 1996 as a fish refugia and technology development facility to assist in the recovery of razorback sucker (RZB). Historically, ONFH has produced an excess of 15,000 >300 mm genetically diverse razorback sucker (*Xyrauchen texanus*) to meet the Recovery Program stocking goals for the Green River, and produces excess fish for flood-plain stocking, and other research purposes. The recovery program reduced call for excess fish and requested larger razorback sucker (350 mm average length) has freed up rearing space at ONFH. This allowed us to take on a new species, the bonytail ((*Gila elegans*) BYT). Utilizing a similar rearing strategy that was used on the RZB, ONFH received its first BYT in Nov. 2012. These fish were received from Whaweep Fish Hatchery as young-of-year progeny of fish that were being reared for stocking to the green river. ONFH was able to successfully raise bony tail to the specified size (250 mm) within the allotted time (2 years) and successfully stocked them to several locations on the green and white rivers in the upper basin. Since ONFH has taken on BYT stocking in the middle Green and lower White rivers there have been increase in recaptures of BYT. Possibilities for the increase in BYT sightings include the use of underwater PIT antennas, and modified stocking protocols brought about by a study of BYT thermal requirements at the Bozman Fish technology center.

Bonytail Chub in the Upper Colorado River Basin: Propagation and Evaluation of Hatchery-Produced Fish Over the Past Two Decades

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The Bonytail Chub (*Gila elegans*) is endemic to the Colorado River Basin, and was historically reported as common to abundant in warmer water reaches of larger rivers from Mexico to Wyoming. Little information is known about this species' life history and specific habitat requirements, as the fish was extirpated from most of its historical range prior to extensive data collection and evaluation by fishery biologists. The Bonytail Chub was added to the United States' list of Endangered species on April 23, 1980. Since that time, a recovery plan (USFWS 1990) and measurable, recovery criteria (USFWS 2002) have been established for this species. Re-establishing bonytail populations with hatchery-produced fish and evaluation of these populations are several management actions required within the recovery plan. This presentation will focus on the Bonytail Chub propagation program within the Colorado River drainage of Colorado and Utah, as well as the Gunnison River drainage of Colorado. Specifically, bonytail rearing and stocking methodologies will be discussed in addition to observations of these hatchery-produced fish in the wild.

Humpback Chub in Desolation and Gray Canyons

Julie Howard

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In the upper and lower Colorado River basins there are six distinct humpback chub (*Gila cypha*) populations known to exist in the following areas: Black Rocks, Westwater Canyon, Desolation and Gray Canyons, Yampa Canyon, Cataract Canyon and Grand Canyon. Of the sites actively sampled in the upper basin, the Desolation and Gray Canyons reach is the longest, encompassing about 80 miles of river. Estimating population size within this reach is difficult, as very little movement of humpback chub occurs among sites. Population estimates were calculated for each site and extrapolated across a determined number of available habitat sites within Desolation and Gray Canyons (n=63; Badame, 2010). As approximately 9% (n=6) of the available 63 sites were sampled in 2014 the extrapolated canyon-wide population estimate of 1,863 humpback chub (variance has not yet been calculated) may not be an accurate representation of the existing population. The 2014 long

term trend site catch per unit effort (CPUE) showed no significant declining trend in annual catch rate (r^2=0.058, p=0.294); however, the measure of recruitment used in this reach, the metric of first-year adults (200–220 mm) as a percentage of total adults captured, has declined from an average of 13% in 2001–2003 and 2006–2007 to just 4% in 2014. Changes in the humpback chub population in Desolation and Gray Canyons are difficult to identify with current monitoring methods, however, conflicting trends in long term metrics may signal an unstable population. Modifications in current monitoring methods, additional analysis and data collection may be necessary to reach meaningful conclusions.

Changes in Backwater Habitat from 1986 to 2013 in the Middle Green River Based on Aerial Imagery Analysis

Mark Grippo, Kirk LaGory, John Hayse, Cory Weber, and Leroy Walston

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Off-channel backwaters are important habitat for early life-stages of the Colorado pikeminnow (*Ptychocheilus lucius*). Temporal changes in backwater habitat availability in the middle Green River between Jensen and Ouray were assessed using aerial imagery analysis. Backwater habitat in the Ouray and Jensen reaches of the Green River that had been quantified using aerial images collected between 1986 and 1996 were compared to images from 2004, 2006, and 2013. Backwater areas were hand digitized from these images to estimate backwater surface area per river mile, number of backwaters per river mile, and the mean surface area of individual backwaters. The results indicate that the mean surface area of individual backwaters was higher in 2004, 2006, and 2013 compared to backwater area in 1986–1996 at similar base flows. Total backwater area per river mile in 2004, 2006, and 2013 was similar to 1987–1996, while the number of backwaters per river mile was generally higher in 1986–1996. Although backwater surface area per river mile varied significantly among years, especially at Ouray, the data indicate that the availability of backwater habitat has not decreased between 1986 and 2013 in the Ouray and Jensen reaches. The analysis also suggested that there are currently fewer, but larger, backwaters compared to earlier years for which data are available. We are currently investigating the potential reasons for this change in backwater characteristics.

Modeling Water Temperature and Growth of Colorado Pikeminnow in Backwaters of the Green River

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Shallow, low-velocity backwater areas that are narrowly connected to the main channel of the river serve as nursery habitats for young-of-the-year Colorado pikeminnow

(*Ptychocheilus lucius*) in the Green River. Average daily water temperatures tend to be warmer in backwaters than in the mainstem from late spring through the fall of each year. These warmer temperatures promote increased food production and higher Colorado pikeminnow growth rates than occur in mainstem waters. Changes in water releases from Flaming Gorge Dam to meet variable demands for electricity can result in stage changes in areas of the Green River containing backwater habitats used by young Colorado pikeminnow. These changes in stage result in movement of water into or out of backwaters, which affect water temperatures and, potentially, the growth and survival of young Colorado pikeminnow. We developed a model to evaluate effects of hourly flow fluctuations and atmospheric conditions on temperatures in backwater-habitats from late spring through fall and to estimate the resulting first year growth of Colorado pikeminnow. Detailed bathymetry of backwaters in the middle Green River was used to estimate hourly backwater area and volume at flows that occurred during the nursery period. Hourly weather station data from the region were used to calculate atmospheric heat fluxes during the same period. Daily average water temperatures were calculated from the modeled hourly temperature estimates and used to estimate first-year growth of Colorado pikeminnow. The model provides a tool for estimating the effect of changes in flows due to operations of Flaming Gorge Dam, water withdrawals, or other activities on the thermal properties of backwater habitats of the Green River and on growth of Colorado pikeminnow inhabiting those habitats.

Reassessing Floodplain Wetland Connections in the Middle Green River, Utah

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Floodplain wetlands along the middle Green River provide important nursery habitat for young-of-the-year native fish and feeding habitat for all life stages of the endangered razorback sucker (*Xyrauchen texanus*). However, the frequency, magnitude, and duration of seasonal overbank flooding in the middle Green River have been substantially reduced since closure of the Flaming Gorge Dam. Flow recommendations have been developed by the Upper Colorado River Endangered Fish Recovery Program to assist with conservation and recovery of endangered fish species downstream of the dam on the Green River, and include the management of peak releases from the dam to provide floodplain inundation in the middle Green River. Field studies to characterize inter-annual variability in floodplain connection flows were identified as research needs by the Recovery Program to inform management decisions on breach and floodplain restoration. We present survey results for eight priority floodplain wetland sites in the middle Green River near Vernal, Utah. In 2012 and 2014, surveys were conducted at levee breaches and the channels connecting them to the wetlands. Minimum breach, connection, and passage flows were calculated and compared to previously reported results from 2005 to determine if and how conditions have changed over time. All 11 surveyed upstream breach areas had higher connecting flows in 2012 and 2014 than reported in 2005. Five out of nine downstream breach areas had lower connection flows in 2012 compared to 2005, while in 2014, six out of the same nine downstream breaches had lower connection flows than in 2005. In general, connection flows for upstream breach

locations increased due to deposition of sand from peak flows and connection flows for downstream breach locations decreased due to scour since 2005.

Successful Management of Stewart Lake Wetland as a Nursery for Endangered Razorback Sucker, on the Middle Green River, Utah

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Among the threats to endangered razorback sucker (*Xyrauchen texanus*) are habitat loss related to flow regime alterations and the introduction of nonnative species. For decades, survival of wild-spawned razorback sucker to juvenile stages has been negligible, and stocking of hatchery-raised fish has been necessary to maintain populations. Here we report on the successful management of Stewart Lake, a gated wetland on the middle Green River near Jensen, Utah, as a nursery for wild-spawned razorback sucker. In a cooperative multi-year effort by Federal and State agencies called the Larval Trigger Study Plan, the detection of larval razorback sucker in the river is used to initiate increased releases from Flaming Gorge Reservoir so that peak flows coincide with larval drift. In early June, 2014, Stewart Lake was filled during this high water period to maximize entrainment of razorback sucker larvae, using a trap and weir system to exclude adult nonnative fishes. The growth and distribution of razorback suckers in the wetland was monitored throughout the summer, with the gate opened for drawdown in early September, after three months of inundation. During draining, a trap was used to sample fishes exiting the wetland, including over 700 juvenile razorback sucker up to 168 mm in total length. The management of Stewart Lake demonstrates how suitable nursery conditions can be achieved for the successful recruitment of razorback sucker, a critical advance for the recovery of this species.

Demonstrating Selenium Uptake in Endangered Razorback Sucker Reared in Stewart Lake, Utah

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Under the Larval Trigger Study Plan (LTSP) operation of Flaming Gorge Dam, fisheries managers have successfully entrained larval razorback sucker into Stewart Lake Waterfowl Wildlife Management Area (Stewart Lake WMA), reared them over the summer growing season, and released juvenile fish back into the mainstem Green River in both 2013 and 2014. This represents a major step in the recovery of this species, whose self-sustaining

populations are limited by lack of recruitment in main channel habitats. However, Stewart Lake WMA has demonstrated elevated selenium levels in sediment, water, and biota, and is currently undergoing a selenium remediation program designed to reduce selenium to acceptable levels. Selenium impacts the growth and survival of juvenile fish, and the larval offspring of adults carrying a high selenium load. To determine selenium uptake in razorback sucker reared in Stewart Lake during the selenium remediation program, we analyzed dry-weight selenium concentrations of incidental mortalities of razorback sucker collected during 2013 monitoring programs. Specifically, we analyzed selenium concentrations of a control group of riverine larval fish, fish immediately before entering Stewart Lake WMA (larval stage), one week after entrainment (larval stage), and during draining of the lake (juvenile stage). Selenium concentrations of control and pre-entrainment larval fish demonstrate that riverine razorback sucker carry an inborn selenium load from maternal or environmental sources. Additionally, selenium concentrations of fish from within Stewart Lake demonstrate that selenium uptake by razorback sucker is rapid and prolonged. While the juvenile production from Stewart Lake is substantially superior to any seen in main channel habitats, these data indicate that fish reared in Stewart Lake WMA do have elevated selenium. We recommend continuing to entrain razorback sucker into Stewart Lake under the LTSP and simultaneously continuing the Stewart Lake selenium remediation process.

Walleye Management on the Green and Colorado Rivers

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Walleye (*Sander vitreus*) are a relatively new threat to native fish communities in the Upper Colorado River Basin. These large bodied piscivores threaten native fish directly through predation and competition for resources. Walleye have been encountered in ripe condition, however, researchers have found no evidence of successful reproduction or recruitment within the Colorado or Green River systems. It is assumed these lotic populations are largely supported by emigration from nearby reservoirs. Although these fish have been present within the Green and Colorado Rivers for decades, encounters were rare until 2009. Between 2009 and 2013 walleye captures increased at an alarming rate. The Utah Division of Wildlife Resources and U.S. Fish and Wildlife Service initiated several targeted walleye removal projects in 2014 to respond to this threat. During fieldwork in 2014, a total of 594 walleye were removed from the Green and Colorado Rivers. Though a considerable number of walleye were removed during all phases of projects 123a, 123b, 126 and 127, higher catch rates were achieved during passes specifically targeting this species. Effective basin-wide

management of walleye requires biologists and managers to carefully, yet promptly, assess the degree to which source populations may be contained, develop effective removal methods and consider both long and short-term nonnative management tactics.

Effects of a Sweeping Low Frequency Pulsed DC Electrical Field on Asian Carp Behavior in a Zero Flow Environment

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The goal of this research was to evaluate the efficacy of various electric field settings to successfully direct movement of bighead and silver carp. This study characterized behavioral responses of varying sizes of bighead (4–60 cm) and silver (13–26 cm) carp to a low voltage, low frequency pulsed DC sweeping field necessary to systematically move fish in a hatchery raceway. It was demonstrated that 100% of bighead carp as small as 15.2 cm and >45 cm total length (TL) and silver carp 13–26 cm TL could be moved out of a 7.8 m x 2.4 m section of a raceway using an electrical setting considered safe for human health in less than 15 minutes with little alteration of fish swimming behavior. All (100%) bighead carp >45 cm TL passage was prevented by the terminal barrier at a setting of 0.35 V/cm (0.89 V/in), 10 Hz and 5 ms. Bighead carp 15.2–24.5 cm TL and silver carp 13–26 cm TL were less affected by the 10 Hz, 5 ms setting, with >90% of the bighead carp passages through the barrier were prevented but only 27 to 69% of the silver carp passes were prevented. 100% of the silver carp could be prevented by ensuring that the anode was initially encountered.

Summary of Northern Pike Removals in the Upper Colorado River Basin

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Removal of non-native northern pike has been occurring in the Upper Colorado River Basin with regularity since 2003. The focus of the most intensive removal and monitoring activities has taken place in the Yampa River, which harbors the highest densities of northern pike throughout the basin, due to favorable habitat and the presence of robust source populations contained within reservoirs, off-channel ponds and backwaters in the Yampa River Basin. In addition to Recovery Program funded projects, Colorado Parks and Wildlife (CPW) is independently working to control northern pike in the Upper Yampa River basin through mechanical removals and habitat manipulations. Electrofishing efforts in the buffer zone (98b) and middle Yampa River (98a) documented the lowest number of northern pike removed since the start of each program, 368 and 437 respectively in 2014. However, CPW crews removed 596 additional northern pike while conducting backwater netting operations during the spring. Researchers continue to document the presence of northern pike throughout the Upper Colorado River Basin, including the capture of young of year northern

pike in the Brown's Park area of the Green River. Overall, northern pike removal efforts in the Green River yielded relatively low numbers although concentration areas have been identified. Northern pike removals were also conducted in the Upper Colorado River including in-channel removals as well as intensive removal efforts in a seasonally connected off channel gravel pit near Rifle, Colorado where northern pike were discovered in 2012. As a whole, northern pike removal efforts continue throughout the basin with high levels of effort being expended and abundant numbers of northern pike persisting.

Abundance and Population Dynamics of Invasive Northern Pike Yampa River, Colorado, 2004–2010

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Northern Pike, *Esox lucius*, is one of the most problematic invasive aquatic species in the Yampa River basin and an impediment to recovery of endangered fishes in the upper Colorado River basin. A mechanical removal program was implemented in 2004 to reduce negative effects of Northern Pike, but population dynamics and efficacy of removal are not well understood. We analyzed mark-recapture records of 8,929 individual Northern Pike, 2004–2010, from three reaches of the Yampa River: upstream reach Hayden to Craig, HC (designated as a "buffer zone" between upstream Northern Pike production areas and downstream native fish critical habitat); middle reach South Beach-Little Yampa Canyon-Juniper, SLJ; and downstream reach Maybell-Sunbeam, MS. Survival rate estimates for average-length Northern Pike were highest in MS, averaging 0.54 (range: 0.36–0.71) across annual time intervals, followed by SLJ (average: 0.32, range: 0.18–0.48), and then HC (average: 0.25, range: 0.12–0.38). Annual abundance estimates followed the opposite pattern: highest each year in HC (range: 1192–3951), followed by SLJ (659–2446), and lowest in MS (range: 233–645). Years with highest abundance included 2004 and 2009 for all reaches. Population increases (difference between predicted abundance at the end of a survival interval and abundance estimate for the following year) due to combined recruitment and immigration averaged 496% in reach HC, 491% in reach SLJ, and 144% in reach MS. Analysis of length–frequency histograms suggested immigration of young age-classes of Northern Pike. For example, few or no individuals from 2007 and 2008 cohorts were captured in sampling of reaches HC and SLJ those years, but those cohorts were well-represented in 2009. Hence, those young Northern Pike may have moved in from another reach or off-channel source, and likely from upstream. Most young Northern Pike captured in those reaches were produced in 2004 and 2009, years with markedly different spring discharge peaks and flows; thus, the relationship between flow patterns and Northern Pike spawning success is unclear and targeted sampling for young-of-year Northern Pike is recommended. Mark-recapture records showed a preponderance of downstream movement for all sizes of Northern Pike. For example, of 394 Northern Pike that changed reaches

during their capture histories, 90% of movements were to a downstream reach, either within the Yampa River or to the Green River. Northern Pike demographic data showed that current removal efforts are inadequate to permanently reduce Northern Pike abundance in the Yampa River, mainly because recruitment and immigration exceeded removal and mortality. This was especially true in higher-density upstream reaches, where control efforts such as Northern Pike source management and spawning disruption are needed, in addition to increased removal, to reduce negative effects of Northern Pike. This information should allow managers to better evaluate the role of Northern Pike removal in the "buffer zone" on populations in downstream critical habitat and explore more effective means to reduce Northern Pike abundance river-wide to assist with recovery of native fishes.

Response of the Native Fish Communities of the Yampa and Green Rivers to Nonnative Fishes and Flows

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Mechanical removal of several non-native fish predators has been implemented in several rivers of the Upper Colorado River Basin in an effort to restore once-abundant native fishes. From 2003–2014, we sampled small-bodied fishes in low-velocity habitat in treatment (piscivorous fish removal) and control (no removal) reaches with a variety of gears to assess whether predator removal benefited the native fish community in the Yampa River, Colorado. Through 2007, main channel fish communities were dominated by non-natives, particularly young-of-year (YOY) smallmouth bass. Native fishes were rare in main channel habitat, and were usually present only in isolated pools where smallmouth bass were uncommon. Although still relatively uncommon, higher frequencies of native fishes in main stem samples since 2008 were coincident with increased removal of YOY smallmouth bass, particularly in the treatment reach. Native fish abundance in main channel samples in the control and treatment reaches increased in 2008–2011 and was particularly high in 2011. Higher flows and relatively cool water prevailed in that period, especially in 2011, compared to earlier years. In the warmer and low flow year 2012–2014, native fish abundance declined from 2011 levels likely as a result of higher smallmouth bass abundance and smallmouth bass had large body size. Positive native fish response since 2008 was likely due to synergistic effects of smallmouth bass removal and return to a higher, more normal hydrologic regime, which delayed bass spawning, and growth and perhaps abundance of smallmouth bass in the Yampa River, Colorado. Those patterns were supported by data from 1980–1984, which also suggested higher native fish abundance in years with higher peak and baseflows.

As part of the native fish response investigations, we also examined trends for Colorado pikeminnow in the Green River subbasin. Adult Colorado pikeminnow have declined throughout the Green River subbasin. We examine reasons for those trends including

abundance of drifting Colorado pikeminnow larvae, young of year Colorado pikeminnow abundance in backwater habitat, and relationships of those data to flow patterns and nonnative fish abundance. Increased summer baseflow levels in nursery habitat reaches in the middle and lower Green River reaches, to moderate levels, was associated with higher abundance of ago-0 Colorado pikeminnow in backwaters in autumn in the Green River. Immediate action is needed to arrest declines of adults and increase abundance of young and recruit-sized fish in both the middle and lower Green River.

Use of Portable PIT Tag Antennas to Supplement Hoop and Trammel Net Surveys in Grand Canyon

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Portable Li-ion powered PIT tag antennas (Marsh and Associates) were deployed along with traditional sampling gears (trammel and hoop nets) in Colorado River Grand Canyon, summer 2014. Up to two baited antennas were deployed nightly during two 18 day surveys and increased total unique contacts by 10%, and unique contacts of humpback chub, *Gila cypha*, by 27%. Portable PIT tag antennas appear to be a practical technique alongside traditional gear in study areas where PIT tags are abundantly deployed.

Monitoring of Humpback Chub, Bluehead Sucker and Flannelmouth Sucker in the Little Colorado River, Grand Canyon, AZ

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Since 2000, a series of two-pass, closed Chapman Petersen mark-recapture efforts have been conducted in the spring and in the fall in the Little Colorado River (LCR) to track the abundance of humpback chub and native suckers. During spring 2014 the estimated abundance of humpback chub ≥ 150 mm in the lower 13.57 km of the LCR was 7,983 (SE=456). Of these fish, it was estimated that 5,784 (SE=390) were ≥200 mm. During fall 2014 the estimated abundance of humpback chub ≥ 150 mm in the lower 13.57 km of the LCR was 3,956 (SE=422). Of these fish, it was estimated that 2,266 (SE=313) were ≥200 mm. These numbers indicate that the spring spawning and fall abundances of humpback chub have remained relatively stable since experiencing significant post-2006 increases. In addition, bluehead sucker and flannelmouth sucker underwent significant increases in abundance during the post-2006 spring seasons, but have since declined. The overall results suggest that sometime during the mid-2000s, conditions were favorable for all three large bodied native fishes in Grand Canyon. These favorable conditions are thought to be related to warmer water temperatures experienced in the Colorado River because of drought and a

system-wide decline of non-native salmonids in the Colorado River. In addition, it is thought that benefit may have accrued to humpback chub because of translocation efforts within the Little Colorado River, and because of LCR hydrologic conditions.

Monitoring of Native and Nonnative Fishes in the Little Colorado River via Remote PIT-Tag Arrays

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Monitoring of native and nonnative fish populations in Grand Canyon has typically been episodic due to the difficulties and expense associated with working in remote locations comprised primarily of canyon-bound rivers and streams. Despite considerable effort and use of technologies like passive integrated transponder (PIT) tags, information was limited on key topics (e.g., spawning run timing, tributary residence time, and spawning frequency) important to the monitoring of the endangered humpback chub, *Gila cypha*, and other species. In an effort to develop a more comprehensive dataset, minimize handling, and take advantage of the relatively large number of PIT-tagged fish present in the Colorado River and its tributaries in Grand Canyon, the USGS Grand Canyon Monitoring and Research Center installed two cross-channel arrays of PIT-tag antennas in the lower Little Colorado River. The original array, comprised of five individual antennas, was installed in May 2009. A second array, which has been comprised of five to six individual antennas, was installed in May 2012. The arrays detect 134 kHz, full-duplex PIT tags and were designed to cover the full wetted width of the Little Colorado River under base flow conditions (approximately 220 ft^3/s) and operate year round. The arrays have experienced variable functionality, but at least one has been operational continuously since early 2012. To date, the arrays have detected more than 9,100 individual humpback chub, and more than 7,200 individual native suckers (flannelmouth sucker, *Catostomus latipinnis*, and bluehead sucker, *C. discobolus*). During 2014, the system detected 4,864 unique humpback chub, with 2,277 detected during March. Based on detection of individuals on both arrays, fish moved upstream during the spring, likely to spawn and moved downstream during summer months, returning to the mainstem Colorado River. Ongoing operation of these arrays will provide data to improve our understanding of the status and trends as well as life history strategies of humpback chub and other fishes in the Little Colorado River outside traditional sampling periods without increased effort or handling.

Fish Community Movement Behavior at a Mainstem-Tributary Confluence

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Passive integrated transponder (PIT) technology has increasingly been incorporated throughout the Colorado River Basin, usually to monitor endangered fishes. Additionally, management and conservation efforts have more recently acknowledged and incorporated tributaries connected to mainstem habitats. We designed a movement study of PIT-tagged native and nonnative fishes using the San Juan River and McElmo Creek confluence. Specifically, we used PIT antenna data to describe movement (i.e., time of day, repeated behaviors, and detections based on tagging location) and predict detections using Random Forests. Random Forests is a classification and regression algorithm that predicts values using aggregated decision trees created with random subsets of variables. In addition to tagged Razorback Sucker and Colorado Pikeminnow, we tagged 5,454 fishes while an antenna array operated from May 2012 through July 2014. During this period we detected 2,466 fishes across nine species. Flannelmouth Sucker, Channel Catfish, Razorback Sucker, and Colorado Pikeminnow comprised over 98% of total detections. Time of movement generally occurred at night. Channel Catfish revisited the antenna array most often but monthly detections were relatively consistent for species across years. Flannelmouth Sucker and Channel Catfish tagged in McElmo Creek were more frequently detected than fishes tagged in the San Juan River. Random Forests identified important environmental variables that predicted species movements. These data show species-specific movement behavior patterns at a mainstem-tributary junction. PIT data can be used to answer questions inclusive to the variety of management questions existing in the Colorado River Basin.

Evaluation of a Weir Designed to Reduce Entrainment of Endangered Fish in Canals

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The diversion of river water for irrigation or power-generating purposes is well known to have deleterious effects on fish populations and includes entrainment into canals or

impingement on intake screens. Both Colorado Pikeminnow (*Ptychocheilus lucius*) and Razorback Sucker (*Xyrauchen texanus*) are known to undertake extended spawning migrations, increasing their risk of becoming entrained in irrigation canals, such the one at the Hogback Diversion Canal on the San Juan River near Shiprock, NM. The Hogback Diversion Canal diverts approximately 250 cfs from May through October; this diversion can take >50% of the river's flow at low-flow periods during the summer. In 2006 Renfro et al. completed a two-year study that examined the entrainment of fish in several canals along the San Juan River, especially the Hogback Canal. A total of 11,399 fish were seined in the canal during 2004 and 2005, including 201 Colorado Pikeminnow between 42 and 315 mm in length. Following this study a Value Engineering (VE) team was commissioned to develop and evaluate various proposals to modify Hogback Diversion Canal to continue to deliver water, yet eliminate or reduce the entrainment of fish in the canal. Members of the VE Team included fish biologists, construction engineers, cost engineers, design engineers, and irrigation specialists. The team concluded that the most cost effective and efficient means of reducing fish entrainment in the canal was to construct an 8-foot tall, 550-foot long weir at an oblique angle in the canal, with the goal of passing a few inches of water over the top of the weir that would be diverted into the canal, and maintaining a flow in the canal along the upstream side of the weir that would eventually transport fish and debris along the upstream side of the weir into a return channel back to the San Juan River. The decision was made to construct a weir wall, with the required facilities and water-regulation devices, for approximately $3.5 million in 2013. No fish-exclusion device of this type has ever been constructed or tested that we are aware of, but if it is effective it could be a useful design at many other locations. In March of 2014 five PIT tag antennas were installed in the facility to determine the effectiveness of the weir wall. The locations of the antennas were selected to give information on movements of fish through the facility and the fates of those fish (i.e., entrainment or safe passage). An immediate, but unexpected, finding of this study was the movement of fish upstream into the facility before it was operational. In November 2014 a week-long test was conducted to examine the effectiveness of the weir using stocked PIT-tagged fish. We stocked into the canal and upstream of the of the weir a total of 209 and 172 Razorback Sucker that were <200 and >300 mm in length, respectively; and 217 and 205 Colorado Pikeminnow that were <100 and >170 mm in length, respectively. We detected a total of 161 fish moving through the facility—143 that were bypassed back to the river and 18 that were entrained in the canal, for an overall entrainment rate of 11%, or 2% of the total stocked. Two-hundred and thirty four fish remained in the upper canal after the test was completed and the gates were opened. Another 408 fish were not detected and likely swam upstream out of the canal and back to the river. Plans for the future include installing more antennas to determine the number of fish that exit the canal through the intake and monitoring the use of the facility by fish that enter the main canal from the river during normal periods of operation (i.e., irrigation season). The Hogback Fish Weir has likely greatly reduced fish entrainment, although what effect this will have on populations of the endangered species is unknown.

Detecting Razorback Sucker Using Passive Integrated Transponder (PIT) Technology at a Spawning Bar.

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Hatchery-raised razorback sucker (*Xyrauchen texanus*) have been stocked throughout the upper Colorado River basin as part of ongoing recovery efforts for the species. Hatcheries and field stations have used a variety of techniques for propagating these fish, and recent increases in captures suggest survival in the wild is improving. Successfully recovering this species will require better information on the proportion of fish recruiting to spawning stocks and differences in survival for hatchery stocking cohorts. We used PIT tag antennas at a known razorback sucker spawning location to detect fish that were presumably spawning and to increase long term survival information for stocked fish. This technique takes advantage of fish migrating to and congregating at a relatively discrete location. It also avoids potentially adverse effects of active capture and handling techniques that may disrupt successful spawning. Over a three year period, we have detected 1,108 unique PIT tagged fish. This study was able to detect razorback sucker up to 15 years old, and for 93% of razorback sucker, the antennas were their first detection since being stocked.

Use of a Passive Interrogation Array to Evaluate Entrainment of Endangered Fish in an Irrigation Canal

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We investigated entrainment of endangered and non-listed native fish in the Green River Canal (Green River, UT) using passive integrated transponder technology during the 2013 and 2014 irrigation seasons. The Green River Canal is a 1.8 m^3/s gravity-fed irrigation canal which operates annually during the months of April through November. Working with canal company officials, we installed a solar-powered passive interrogation array (PIA) about 150 m below the canal intake gates in 2013 and a second PIA about 400 m below the gates in 2014. In 2013, 81% of all fish detected in the canal were Razorback Sucker, *Xyrauchen texanus* (499 individuals). Colorado pikeminnow, *Ptychocheilus Lucius*, and Flannelmouth Sucker, *Catostomus latipinnis*, comprised 13% (77 individuals) and 5% (33 individuals) of all entrained fish, respectively. Three Bonytail, *Gila elegans*, and a single Humpback Chub, *Gila cypha*, were also entrained. Peak rates of entrainment (up to 270 fish in a single day)

were observed immediately following cessation of spring peak flows in July, at which point the canal diverted about half of the Green River discharge at times. In 2014, about half as many fish were entrained in the canal as were in 2013, perhaps due to proportionately lower rates of river diversion in 2014. Entrainment rates of endangered fish in the Green River canal are significant and efforts are underway to reduce or eliminate entrainment most likely through exclusion structures. We will continue to monitor entrainment rates using PIAs following construction of the exclusion structures.

Using Passive Detection Technology to Document Endangered Fish in the White River, Utah

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The White River, in Utah and Colorado, offers important tributary habitat for native fish species in the Green River basin. The largely unaltered hydrology, an abundance of habitat complexity, and the lack of fish passage barriers in the lower 104 miles (below Taylor Draw Dam) provides natural ecological function for native species – something which is often lacking in other Green River tributaries. Recently, multi-agency active sampling efforts have documented endangered fish dispersal and spawning in this river. However, active sampling efforts cannot feasibly detect fish during many portions of the year, such as during frozen winter months, periods of unnavigable low flows, and at night. In order to detect fish year round, we installed a permanent passive interrogation array (PIA) near the Bonanza Bridge at river mile 59. The PIA has been in continuous operation since September 25, 2012 and has collected more than 43,000 detections, representing almost 4,400 unique fish. Detections have demonstrated: a range expansion of razorback sucker into portions of river believed to be unoccupied for more than two decades; survival and movement (when combined with active sampling captures) of resident Colorado pikeminnow; and survival and dispersal of bonytail stocked approximately 600m upstream. By analyzing unique detections of individual fish, we demonstrate seasonal fish use in the White River, relate these patterns to environmental variation (e.g., temperature and flow) when possible, and provide documentation of survival for fish not detected during active sampling. This project demonstrates that combining active mark-recapture sampling with continuous passive instream sampling creates a more complete picture of fish use in difficult to sample habitats.

Using Active and Passive Captures of Native Fishes in the White River, Utah (2008–2014) to Evaluate Vital Population Demographics

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Bluehead Sucker (*Catostomus discobolus*), Flannelmouth Sucker (*C. latipinnis*), and Roundtail Chub (*Gila robusta*), collectively referred to as the "three species", are listed as Tier I Sensitive Species in Utah due to reductions in historic distribution. However, recent investigations indicate that the White River, Utah maintains stronghold populations for all three species, thus providing an excellent opportunity to better understand vital population level processes in a relatively unaltered system. We used a combination of active capture data obtained from field surveys and passive detections (resights) with a permanent passive interrogation array (PIA) to estimate species-specific survival using the Barker open population model in Program MARK. Cataraft electrofishing was conducted from river mile (RM) 66.5–24.0 each spring/summer from 2008–2013 to initially PIT tag juvenile and adult three species (281 Roundtail Chub, 1,692 Bluehead Sucker, and 4,706 Flannelmouth Sucker). The PIA, which has been in continuous operation since September 25, 2012, was installed near the Bonanza Bridge at RM 59. Survival estimation was not possible for Roundtail Chub due to overall low encounter rates, whereas estimates for Bluehead Sucker and Flannelmouth Sucker varied considerably throughout the study period. Specifically, the reliability of survival estimates was poor (large confidence intervals) in years where PIA resights did not occur (2008–2010), but the combination of active and passive sampling (2011–2013) greatly improved model precision (CV's ≤10%). The increase in precision is primarily the result of increased PIA encounter rates (most prominent in 2012 and 2013). Bluehead Sucker survival probability shifted from 0.81 to 0.19 in 2011 and 2012 respectively; however, this result may be associated with biotic factors misrepresenting recapture rates (i.e., spawning migrations vs. timing of active sampling). When incorporating covariates, AIC model selection demonstrated that flow attributes were helpful in explaining resight rates, but did not explain variation in survival estimates from year to year. Although preliminary in nature, our analyses have provided valuable insights on the feasibility of using active and passive captures to model survival, an important consideration for the future management and conservation of three species populations range-wide.

Use of Passive Integrated Transponder Technology in Recovery of Endangered Fish in the Upper Colorado and San Juan River Basins.

Dave Speas

US Bureau of Reclamation, Salt Lake City, UT

In recent years, use of passive integrated transponder (PIT) technology in the Upper Colorado and San Juan river basins has evolved from the use of PIT tags to identify individual fish in active mark/recapture investigations to use of stationary passive interrogation arrays (PIAs) and other types of antenna technology for a variety of monitoring purposes. To date, about 18 PIAs or temporary flat plate antenna installations been deployed in the two river basins to answer a variety of research and monitoring questions related to recovery of endangered fish and/or ecology of non-listed native fish. Most of these systems were installed in the last three years (2012–2014), and more projects are anticipated in coming years. Of the 18 applications, eight (44%) were intended to document fish use of tributaries, three (17%) to document entrainment in canals, three (17%) to document fish use of restored off-channel habitats, two (11%) to document fish use of passage structures, and two (11%) to collect ancillary tag data and/or document spawning activity. Other innovative approaches which have yielded some success as data collection tools include floating PIT surveys and use of portable, submersible antennas. While PIA systems and other PIT technology collectively result in collection of large amounts of individual tagged fish data, questions remain as to integration of data from these systems with other data types as a means to improve population and survival estimation, uncertainties about sampling efficiency, the role(s) of such technologies in future recovery or conservation efforts, ability of programs to cover operation and maintenance costs, and data acquisition and stewardship.

Overview and Lessons Learned for PIT Tag Antenna Installations in the San Juan River Basin

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In the San Juan River Basin PIT tag antennas have been used in many ways and locations to assess movements, location, and survival of PIT-tagged fish, primarily endangered Colorado Pikeminnow (*Ptychocheilus lucius*) and Razorback Sucker (*Xyrauchen texanus*). Locations for stationary PIT tag antennas include upper McElmo and Yellow-Jacket creeks, lower McElmo Creek, PNM Fish Passage Facility, Hogback Fish Weir, and The Nature Conservancy restoration sites. Additionally, temporary antennas have been used in the San Juan River as floating antennas (85 miles of river), submersible antennas (near Four-Corners Bridge), or at temporary locations (Chaco Wash, Montezuma Creek, McElmo and Yellow-

Jacket creeks). River-wide PIT tag antennas have been planned and attempted in the San Juan River but have not been installed due to unexpected conditions and costs. A full-river antenna installation was attempted in December 2013 near Mexican Hat, UT but was eventually cancelled. Antenna installations have been particularly successful at the Hogback Fish Weir and PNM Fish Passage, both of which provide hard concrete or designed structures that can accommodate antennas. At the Hogback Fish Weir, PIT antennas have been useful at identifying movements of fish as they pass through a facility designed to reduce entrainment in a canal. The antennas at Hogback also detected large numbers of fish that are moving upstream through the facility, which was not an expected movement. At the PNM Fish Passage Facility the antennas have provided information on when fish were attempting to move upstream and also provide passage rates, which for this facility appear to be very low and also was not expected. Four antennas were installed at The Nature Conservancy's restoration sites downstream of Shiprock, NM. These antennas were designed to provide monitoring information on habitat use of the restoration sites by endangered fish. The floating antenna system was used in 2014 to detect tags in an 85-mile reach of the San Juan River from Hogback Canal near Shiprock, NM downstream to Bluff, UT. During the float we detected 522 total tags, of which 45 were Colorado Pikeminnow and 414 were Razorback Suckers. A future study is planned to use the floating system to provide better data for population and fish-movement models. Submersible antennas were deployed for four days in 2014 near Four-Corners Bridge in Colorado and detected 22 adult Colorado Pikeminnow as they moved through a secondary channel on their way to a suspected spawning area. Permanent and temporary antenna locations in various tributaries have provided information on use of the tributaries by both endangered and non-endangered fish species. In all cases where PIT tag antennas have been used the information that they provide has sometimes been quite surprising. Data from the antennas often illustrates movement patterns that were not previously suspected or highlights instances where current monitoring activities may not effectively detect fish. In most cases far more fish are detected by the antennas than we originally anticipated. Additional PIT tag antenna installations are planned for the future at other locations in the San Juan River Basin.

Why Are We Doing This and What Are We Learning: Application and Context for Widespread PIT-Tagging Efforts in the Upper Colorado River Basin

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Conservation assessment and recovery planning requires the ability to: (1) quantify life-history-specific survival rates, (2) detect trends and changes in population growth rates, and (3) identify critical habitat. However, these data are often very limited, incomplete temporally, and/or too variable to detect a change. In addition, while the importance of mainstem rivers and major tributaries to endangered Colorado River fishes is well documented, the use and significance of small tributary streams remains poorly understood. In part to address these needs, we have been detecting PIT-tagged fish via active sampling

and at passive interrogation arrays (PIA) in three tributaries to the Green River, in which we have 1–2 PIA systems upstream from their confluence with the Green River. In this presentation, we will: (1) provide an overview of how PIT tagging, PIA detections, and active sampling can enhance and strengthen conservation assessment and the management of imperiled fishes and (2) summarize some recent PIA data documenting extensive tributary use by the "three species", Colorado pikeminnow, razorback sucker, and bonytail in the San Rafael, Price, and White Rivers. Our findings demonstrate the importance of maintaining existing PIA and active-sampling programs and the use and the importance of small tributaries and their fragile habitats to imperiled fishes.

Every Which Way Comes Data: Models for Analyzing PIT Tagged Fish

Mary Conner

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The advent and now ubiquitous use of passive integrated transponders (PIT) to mark stream fishes, along with the installation of passive instream antenna arrays, has resulted in a dramatic increase in reencounters of marked fish. In addition to antenna arrays, PIT tagged fish can be actively reencountered using mobile antennas, which can be used by researchers walking down a stream or floated alongside a river boat. These advances in marking and resighting technology for fishes have led to a significant increases in our ability to estimate population parameters, such as life-history specific survival, and, potentially, movement parameters as well as rate of population change (λ). Traditionally, Cormac-Jolly-Seber (CJS) models have been well tested and used for survival estimation for stream or river fish. CJS models require captures and recaptures/resightings to occur during discrete and short time periods, relative to the period between active sampling occasions. However, antennas, particularly passive instream, collect data continuously and, as such, the data does not naturally fit within the CJS sampling framework. Mark-resight models, such as the Barker model, have been developed to accommodate resight and recovery data collected continuously between active sampling occasions. Here I will review the Barker model and other models relevant for analyzing data from PIT tagged fish that are reencountered via passive antennas, active mobile antennas, active recapture, or some combination thereof. As part of this, I will also discuss synthesizing data, study designs, and broad rules of thumb for sample size.

Recovery Program Data Pathways: Existing and Desired Future Protocols

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Each year, the Upper Colorado and San Juan endangered fish recovery programs acquire large amounts of endangered fish data from a variety of sources in the course of recovery

implementation. Some of this data is acquired by hatcheries during tagging of propagated fish for stocking, as incidental data during non-native fish control trips, via passive interrogation arrays (PIAs) deployed in a variety of riverine and water development infrastructure, through active mark/recapture studies to estimate population parameters, and other miscellaneous investigations related to recovery. Data is typically collected, entered and to some extent checked for quality assurance and control by individual field office personnel; these files are often (but not always) created using standardized data templates and made available to database managers within each recovery programs, who store individual data files from specific investigations within larger research database files spanning multiple years or decades. As both the volume and complexity of this data is expected to increase in the future, program managers determined that development of a centralized, web-accessible database will be necessary to provide a more cost-effective, direct and secure means to enter, store, quality-check and retrieve data. In 2014, a subset of program participants selected the Colorado Natural Heritage Program at Colorado State University to lead efforts to develop such a database. This database is currently in the development stage and staff and participants of the Recovery Programs now have an opportunity to comment on its development and specifically on the structure of how it will be designed and the information that will be available through the database.

STReaMS: The Species Tagging, Research and Monitoring System, Progress and Mockups

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We created a conceptual draft of the database structure and a short list of the core features we will develop this spring. Program members reviewed the draft, and we enhanced the database design based on their feedback. The database was then developed on the host server. During the second half of December, we developed the core code that allows us to access and retrieve records from the database. We also built basic user management features for registering users, logging in, and changing passwords. We will present the database structure and our "mockups", or rough drafts, of the features we intend to build by the mid-March meeting in Grand Junction. Pages that display tables of fish encounters, allow editing of individual records and viewing of capture history details will be available at that time.

POSTERS

Fishes of the Upper Colorado River Basin—Distribution and Abundance by HUC Subbasins, 2004–2014.

Darrel E. Snyder

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For the introduction to my pending guide to the larvae and early juveniles of (most) cyprinids in the Upper Colorado River Basin (UCRB), I'm updating earlier species lists (Snyder 1981 for the Colorado portion and Tyus et al. 1982) to represent current distribution and abundance of species reported in the basin during the past decade. This poster presents, in tabular form, the results of that effort to date based on numerous Recovery Program, state, museum, and researcher-contributed reports, datasets, maps, websites, and communications. As a draft listing, it is provided here for review, correction, and supplementation.

Species presence and general abundance since 2003 in lotic and lentic habitats were assessed for the eight 4-digit HUC subbasins (1401–1408) within the three major subbasins (Upper Main Stem, Green, and San Juan-Colorado) of the UCRB. Based on these assessments, 68 (possibly 69) fish species, 7 subspecies (1 cyprinid and 6 cutthroat trout), and 24 hybrids (4 cyprinid, 14 catostomid, 4 salmonid, 1 esocid, and 1 centrarchid) currently inhabit the UCRB. Eight species were reported in only lotic habitats and four only in lentic habitats. Among the eight subbasins, the current number of species varies from 42 (possibly 44) for HUCs 1403 and 1407 (Upper Colorado-Delores and Upper Colorado-Dirty Devil subbasins) to 49 (possibly 50) for HUC 1401 (Colorado Headwaters). Thirteen of these species are native to the basin; eight were reported in all subbasins, four in five to seven subbasins, and one in just two subbasins.

What Environmental Factors Reduce Predation Vulnerability for Native Fishes?

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The incompatibility of native Colorado River fishes and nonnative warm water fishes is well documented with predation by nonnative species causing rapid declines and even extirpation of native species in most locations. In a few rare instances native fishes are able to survive and recruit despite the presence of nonnative warm water fishes, indicating that specific environmental conditions may help reduce predation vulnerability. We experimented with turbidity, artificial water colorants, woody debris, aquatic vegetation, and rock substrates in a laboratory setting to determine if any of these types of cover could reduce predation vulnerability and confer survival advantages for juvenile bonytail, *Gila elegans*, (mean=70 mm TL), roundtail chub, *Gila robusta*, (mean=35 mm TL) and juvenile razorback sucker, *Xyrauchen texanus* (mean=74 mm TL). Bonytail, roundtail chub, and razorback suckers were exposed to predation by adult largemouth bass, *Micropterus salmoides*, smallmouth bass, *Micropterus dolomieu*, green sunfish, *Lepomis cyanellus*, and flathead catfish, *Pylodictis olivaris*, respectively in overnight trials. Turbidity above 500 NTU reduced predation vulnerability by up to 50%, for the sight-feeding predators, but increased predation vulnerability to flathead catfish. No other treatment significantly reduced predation mortality. These results may help to explain patterns of wild juvenile razorback sucker recruitment at the turbid inflow of the Colorado River into Lake Mead, an area where flathead catfish are not currently present but other nonnative fishes are.