San Juan River Larval Razorback Sucker and Colorado Pikeminnow Monitoring
Fiscal Year 2018 Scope of Work

Submitted to the U.S. Bureau of Reclamation

From

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SAN JUAN RIVER LARVAL RAZORBACK SUCKER AND COLORADO PIKEMINNOW MONITORING FISCAL YEAR 2018 PROJECT PROPOSAL

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Razorback Sucker project history:

The apparent absence of Razorback Sucker, *Xyrauchen texanus*, in the San Juan River drainage necessitated experimental stocking of adults (n=672) of this species in 1994 between Hogback, New Mexico, and Bluff, Utah. In their 1995 report of activities, Ryden and Pfeifer (1996) suggested that the majority of the 1994 experimentally stocked Razorback Sucker would achieve sexual maturity in 1996 and spawning by those individuals might begin a few years afterwards.

At the November 1996 San Juan River Basin Biology Committee integration meeting, it was suggested that the Colorado Pikeminnow, *Ptychocheilus lucius*, larval fish drift study (= Passive Drift Netting Study; RM 127.5 and RM 53.3; July-August) be expanded in an attempt to document spawning of the stocked Razorback Sucker (presumed to be during April-May). In addition to temporal differences in spawning between Colorado Pikeminnow and catostomids (suckers), researchers were attempting to document reproduction by hatchery reared Razorback Sucker whose spawning potential was unknown. Sampling for larval Razorback Sucker was to be conducted to determine if the stocked population of adult Razorback Sucker would spawn in this system. Conversely, data from the passive drift-netting study continued to document Colorado Pikeminnow reproduction in the San Juan River and, because of this certainty, larval fish sampling efforts for this fish would (initially) be different than those for Razorback Sucker.

Numerous Upper Colorado River Basin researchers reported light-traps as one of the best means of collecting larval Razorback Sucker. Most of their light trapping efforts was concentrated in floodplain habitats during high spring flows. Light-trap sampling was employed during the first year (calendar year 1997) of the San Juan River larval Razorback Sucker survey. The lack of inundated floodplain habitats in the San Juan River, in comparison to the Upper Colorado River Basin, meant that the light-traps would have to be set in low velocity riverine habitats. The only previous San Juan River fish investigations that had employed light-traps were in 1994 and 1995 (conducted by the National Park Service) near the San Juan River-Lake Powell confluence. That sampling effort produced an extremely large number of larval fish (ca. 25,000) from a modest number of samples (n=20), of which over 99% were Red Shiner. Similar sampling in 1995 yielded 25,455 specimens in 47 light-traps samples and as in 1994, Red Shiner numerically dominated the catch. Both sampling efforts were conducted during July-August but neither Colorado Pikeminnow nor Razorback Sucker was present in the 1994-1995 light-trap samples.

During the 1997 Razorback Sucker larval fish survey, light-traps were set nightly in low-velocity habitats between Aneth and Mexican Hat, Utah, from late March through mid-June. The traps were distributed at dusk and retrieved about four hours later. Fish taken in those samples were preserved in the field. Sampling success during the 1997 Razorback Sucker larval fish study was poor. While there were over 200 light-trap sets, those sampling efforts produced only 297 fish. Of those, about 200 (66%) were larval catostomids (either Flannelmouth Sucker or Bluehead

Sucker). Larval Razorback Sucker was not present in the 1997 sampling survey. While there were probably several factors to account for the poor light-trap catch rate, a principal factor was the limited access to suitable habitats. We determined that being limited to specific collecting sites was not the most efficient means of collecting large numbers of individuals; a prerequisite for this study.

In 1998 a new study design was developed to allow for the sampling of a greater portion of the San Juan River and the collection of a significantly larger number of larval fish throughout several river reaches. An inflatable raft was used to traverse the San Juan River and allowed us the opportunity to sample habitats that were either not formerly accessible or observable under the constraints of the previous sampling protocol. Six sampling forays were conducted at approximately bi-weekly intervals from 17 April to 6 June 1998 between the Four Corners drift station (RM 127.5) and Mexican Hat, Utah (RM 53.3). Both active (seining) and passive (light-traps) sampling techniques were used to collect larval fish. The primary sampling method was a fine mesh larval seine (1 m x 1 m x 0.8mm). If appropriate aquatic mesohabitats could be located, light-traps would be set adjacent to nightly campsites of the sampling crew.

The 1998 sampling protocol resulted in 183 collections containing over 13,000 specimens between river miles 127.5 and 53.3 with the majority of these individuals (n=9,960) being larval catostomids. This 43-fold increase in number of specimens, as compared with 1997, provided substantially better resolution of spawning periodicity of the catostomid community. In addition, the 1998 samples produced enough individuals for us to determine, with a high degree of confidence, if Razorback Sucker reproduction occurred in the San Juan River during that period. None of the aforementioned information was obtainable from 1997 light-trap samples. In 1998, two larval Razorback Sucker were collected providing verification of spawning by the hatchery reared stocked population.

The use of active sampling to determine the reproductive success of Razorback Sucker has proven to be effective. To date, the results of this investigation have provided 19 consecutive years of unequivocal documentation of reproduction in the San Juan River by Razorback Sucker that have been stocked as part of the San Juan River Basin Recovery Implementation Program (Table 1). The data collected during the larval Razorback Sucker survey provide not only valuable data concerning the distribution (spatial and temporal), duration, and magnitude of Razorback Sucker reproduction but also equally informative data on the reproductive efforts of other native fishes in the San Juan River.

Table 1. Collection information of Razorback Sucker (Xyrtex) collected during the larval Razorback Sucker survey, 1998 – 2016.

Year	*Sampling method*	*Study Area (River Miles)*	*River Miles sampled*	*RM Percent change*	*Specimens collected*	*Xyrtex n=*
1998	Larval seine Light traps	127.5 – 53.3	74.2	na	13,608	2
1999	Larval seine Light traps	127.5 – 2.9	124.6	+ 67.4%	20,711	7
2000	Larval seine Light traps	127.5 – 2.9	124.6	na	13,549	129
2001	Larval seine Light traps	141.5 – 2.9	138.6	+ 11.2%	95,629	50
2002	Larval seine Light traps	141.5 – 2.9	138.6	na	138,602	813
2003	Larval seine Light traps	141.5 – 2.9	138.6	na	112,842	472
2004	Larval seine	141.5 – 2.9	138.6	na	160,292	41
2005	Larval seine	141.5 – 2.9	138.6	na	109,368	19
2006	Larval seine	141.5 – 2.9	138.6	na	50,616	202
2007	Larval seine	141.5 – 2.9	138.6	na	53,084	200
2008	Larval seine	141.5 – 2.9	138.6	na	40,855	126
2009	Larval seine	141.5 – 2.9	138.6	na	72,404	272
2010	Larval seine	141.5 – 2.9	138.6	na	70,610	1,251
2011	Larval seine	141.5 – 2.9	138.6	na	28,258	1,065
2012	Larval seine	147.9 – 2.9	145.0	+ 4.6%	29,384	1,778
2013	Larval seine	147.9 – 2.9	145.0	na	25,842	979
2014	Larval seine	147.9 – 2.9	145.0	na	20,508	612
2015	Larval seine	147.9 – 2.9	145.0	na	17,787	1,205
2016	Larval seine	147.9 – 2.9	145.0	na	12,973	824

Colorado Pikeminnow project history:

Beginning in spring 1995, personnel from the Division of Fishes, Museum of Southwestern Biology (MSB), at the University of New Mexico assumed responsibility for the San Juan River larval fish passive drift-netting study. This project, formerly conducted by the Utah Division of Wildlife Resources, continued through 2001 with only minor changes in sampling protocol. Between 1995 and 2001, a total of four larval Colorado Pikeminnow were collected using this sampling method at two different collecting locations (Table 2).

The limited number of wild adult Colorado Pikeminnow (versus stocked individuals) in the San Juan River was reflected in the extremely low catch rate of larval Colorado Pikeminnow. Numerous adult and sub-adult Colorado Pikeminnow have now been stocked into the San Juan River in an effort to augment the diminished wild population. The Colorado Pikeminnow augmentation plan (phase II) calls for continued stocking efforts in the San Juan River through 2020. The San Juan River Basin Biology Committee expects, as was documented with stocked Razorback Sucker, that reproduction among stocked Colorado Pikeminnow will occur and can be documented through the sampling of larval fish.

As the number of adult (reproductively mature) Colorado Pikeminnow in the San Juan River increases (due to both stocking and recruitment), so does the probability of elevated levels of spawning by this species. The San Juan River Basin Biology Committee began exploring the possibility of expanding the sampling effort for larval Colorado Pikeminnow in fiscal year 2003. One means of accomplishing this task was to include an additional sampling site (increasing from two to three sites) for the passive drift-netting study. Another suggestion was to perform targeted sampling for Colorado Pikeminnow similar to that performed for larval Razorback Sucker. In the case of the latter sampling effort, discussion regarding sampling that would target larval Colorado Pikeminnow centered around expanding the duration of the current larval Razorback Sucker survey (April-June) or development of a discrete (new) project. These and other items were considered and evaluated during the February 2002 San Juan River Basin Biology Committee meeting. The Committee recommended the immediate expansion of the larval Razorback Sucker survey (April-June) to include the months of July, August, and September with seining efforts to target larval Colorado Pikeminnow.

Beginning in July of 2002, using funds from FY 2002 that had been appropriated for use at the two larval drift-netting stations, Museum of Southwestern Biology (MSB) personnel began an active sampling regime that mirrored the sampling protocol successfully used in the larval Razorback Sucker survey. The results from the temporal expansion of the larval surveys have produced 936 wild larval Colorado Pikeminnow to date. The majority of those larvae were collected in 2014 (n= 312) and 2016 (n= 548). Larval Colorado Pikeminnow were collected in surveys during 2004, 2007, 2009, 2010, 2011, 2013, 2014, 2015 and 2016 at 97 discrete sites, within the study area. Between 1995 and 2016 the combined sampling methodologies (passive and active) resulted in the collection of 940 larval Colorado Pikeminnow. Back-calculated spawning dates, based on those 940 individual larvae, range from 23 May to 18 July (Table 2) and are generally associated with the descending limb of spring run-off and mean river temperatures >18^{o}C.

Over 1,000,000 fish have been collected between 1995 and 2016 under the larval Colorado Pikeminnow survey. Of those, over 900,000 fish were collected after 2001 when the sampling protocol switched from passive to active sampling (2002).

Table 2. Summary of larval and YOY Colorado Pikeminnow collected in the San Juan River during larval drift-netting/larval seining (1995-2016) and back-calculated dates of spawning.

Year	*Sample Method*	*Study Area (River Miles)*	*N=*	*Length mm TL.*	*Collection Date*	*Spawning Date*
1995	Drift Netting	127.5, 53.3	2	9.0, 9.2	02, 03 Aug	15, 17 Jul
1996	Drift Netting	127.5, 53.3	1	8.6	02 Aug	18 Jul
2001	Drift Netting	127.5, 53.3	1	8.5	01 Aug	17 Jul
2004	Larval Seine	141.5 – 2.9	2	14.2, 18.1	22, 26 Jul	24, 25 Jun
2007	Larval Seine	141.5 – 2.9	3	14.9-17.5	25 Jul	27 Jun
2009	Larval Seine	141.5 – 2.9	1	25.2	27 Jul	10 Jun
2010	Larval Seine	141.5 – 2.9	5	12.6–21.4	20-23 Jul	15–27 Jun
2011	Larval Seine	141.5 – 2.9	29	10.0–21.3	20, 21 Jul, 10,11 Aug	23 Jun–6 Jul
2013	Larval Seine	147.9 – 2.9	12	14.1–28.7	17–30 Jul	23 May–3 Jul
2014	Larval Seine	147.9 – 2.9	312	8.5–20.8	13–28 Jul	15 Jun–2 Jul
2015	Larval Seine	147.9 – 2.9	24	8.6–9.7	28–30 Jul	10–14 Jul
2016	Larval Seine	147.9 – 2.9	548	8.8–14.7	24–28 Jul	29 Jun–12 Jul

Project Modifications:

There have been numerous modifications to the field methodology of the larval fish survey over time as well as changes in reporting priorities, protocol, and format. The extent of the study area and aspects of the longitudinal sampling have been modified to improve spatial comparisons. The study area was expanded in 1999, 2001, and 2012 by a total of 70.8 river miles (nearly double the length of the original study area) to include most of Reach 5 (Shiprock, New Mexico) through Reach 1 (Clay Hills Crossing, Utah; a total of 145.0 miles of critical habitat sampled). Beginning in 2003, the entire study area was sampled in single uninterrupted trips (10–12 field days per trip) rather than in two temporally discrete sections as done in previous years (1998 – 2002). Because of the increasing numbers of larval Razorback Sucker collected (as well as detailed information regarding the native fish community), the SJRBRIP Biology Committee voted to elevate the larval fish surveys from an “experimental” project to a monitoring program. This change allowed for comparisons of catch per unit effort (CPUE) data with the programs monitoring activities (i.e., small bodied fish, sub-adult and adult, habitat, etc.).

Conducting the larval Razorback Sucker and Colorado Pikeminnow surveys under this new protocol not only provided discrete reach information but also provided greater temporal resolution in respect to the longitudinal distribution of Razorback Sucker larvae and the ability to correlate potential environmental cues required by Razorback Sucker for spawning. These same advantages also apply to Colorado Pikeminnow. Disadvantages to this top to bottom approach were that the duration of the monthly sampling trips (10–12 field days) made them more subject to abiotic fluctuations (floods, flow spikes). Large flood events reduce sampling efficiency as many low velocity habitats become flooded by rising water levels thereby transporting larval and early juvenile fish downstream. In addition, large flood events have necessitated premature termination of some survey runs, reducing the temporal resolution of the single-continuous pass effort. Annually, at least one trip (an average) had to be cut short due to large flood events or low water events in the lower canyon. The abbreviated trips were subsequently resumed once conditions improved (usually 1–2 weeks later). Additional costs were incurred because of the need to return to the field to complete the sampling effort for that month.

To reduce the variability of abiotic conditions as well as gain even greater temporal resolution of the longitudinal distribution of Razorback Sucker larvae, the protocol was modified to survey the upper and lower halves of the study area simultaneously. This effort began in 2007 and utilized two fully equipped and autonomous crews (Table 3). In 2008, additional participation of our staff with other SJRBRIP projects made the new simultaneous sampling effort a necessity so that our staff could meet obligations to assist the other researchers with their work. Beginning in 2011, the September sampling trip was discontinued. The Biology Committee felt that the September survey did not provide enough data with respect to endangered fishes to warrant continuation.

The study area expanded 6.4 miles upstream in 2012. The expansion of the study area was a result of captures of larval Razorback Sucker at the top of the previous study area (river mile 141.5). Collections in 2012, 2013, 2014, and 2015 documented larval Razorback Sucker in this newly expanded area.

Beginning in 2017, larval fish sampling was expanded to include the San Juan River between Farmington and Shiprock, NM (river miles 180 – 148). This expanded effort targets the collection of Razorback Sucker only, and is considered to be independent of the work proposed in this SOW.

In 2013 a new analysis of Colorado Pikeminnow and Razorback Sucker trend data was developed using mixture models (White, 1978; Welsh et al., 1996; Fletcher et al., 2005; Martin et al., 2005.). Mixture models can be particularly effective at modeling ecological data with multiple zeros to estimate occurrence and abundance separately (e.g., combining a binomial distribution with a lognormal distribution). Data collection for this new approach meant each seine haul was preserved independently along with physical descriptors of each haul. Beginning in 2014, the mixture model analysis was expanded to include annual trends for many of the common species collected.

Table 3. Summary of annual projects and project modifications of the larval fish surveys from 1997 to 2016.

Year	*Sampling method*	*Study area (River Miles)*	*Specimens collected*	*Field modification*	*Laboratory modification*

1997	Light Trap Drift-nets	99 – 75	297		
1998	Larval Seine Light Trap Drift-nets	127.5 – 53.3	13,608	study area expanded; active sampling	
1999	Larval Seine Light Trap Drift-nets	127.5 – 2.9	20,711	study area expanded; upper-lower reaches sampled separately; nonsynchronous	
2000	Larval Seine Light Trap Drift-nets	127.5 – 2.9	13,549		
2001	Larval Seine Light Trap Drift-nets	141.5 – 2.9	95,629	study area expanded; upper-lower reaches sampled separately; nonsynchronous	
2002	Larval Seine Light Trap	141.5 – 2.9	138,602	study period expanded to September. Drift-nets no longer used.	
2003	Larval Seine Light Trap	141.5 – 2.9	112,842	upper-lower reaches sampled monthly in one uninterrupted trip (11-12 day runs)	CPUE data used for integration in reporting
2004	Larval Seine	141.5 – 2.9	160,292		Reports merged, trend data reported
2005	Larval Seine	141.5 – 2.9	109,368		
2006	Larval Seine	141.5 – 2.9	50,616		
2007	Larval Seine	141.5 – 2.9	53,084	Two rafts-two crews; upper-lower reaches samples synchronous	Analyzed catch with habitat data
2008	Larval Seine	141.5 – 2.9	40,855		
2009	Larval Seine	141.5 – 2.9	72,404	Specimens preserved in 95% ethanol	
2010	Larval Seine	141.5 – 2.9	70,610		
2011	Larval Seine	141.5 – 2.9	28,258	September survey dropped from the monitoring	
2012	Larval Seine	147.9 – 2.9	29,384	Study area expanded	
2013	Larval Seine	147.9 – 2.9	25,842	Individual seine hauls preserved independently	Mixture Model analysis used for trend data

2014	Larval Seine	147.9 – 2.9	20,508		Mixture Model analysis used for several common species
2015	Larval Seine	147.9 – 2.9	17,787		Multiple covariates used in all mixture models
2016	Larval Seine	147.9 – 2.9	12,973		Additional covariates used in CPM mixture models

Objectives:

This work is being conducted as required by the San Juan River Basin Recovery Implementation Program Monitoring Plan and Protocol (2012). The objectives of this specific monitoring effort are identified and listed below. Where applicable, these objectives are related to the specific tasks listed in the 2016 Long Range Plan set forth by the San Juan River Basin Recovery Implementation Program (SJRBRIP).

1) Conduct larval fish sampling to determine if (Colorado Pikeminnow and Razorback Sucker) reproduction is occurring, locate spawning and nursery areas, and gauge the extent of annual reproduction. (Task 4.1.2.1)

2) Determine the spawning periodicity of Colorado Pikeminnow and Razorback Sucker (utilizing back-calculated spawning and hatching formulas) between mid-April and August and examine potential correlations with temperature and discharge.

3) Document and quantify reproduction, survival, and recruitment. (Task 4.4.1.1).

4) Document and track trends in the use of specific mesohabitat types by larval Colorado Pikeminnow and Razorback Sucker. (Task 4.2.3.2).

5) Analyze and evaluate monitoring data and produce Annual Fish Monitoring Reports to ensure that the best sampling design and strategies are employed. (Task 4.1.1.2)

6) Provide detailed analysis of data collected to determine progress towards endangered species recovery in the San Juan River. (Task 5.1.1.3)

7) Identify principal river reaches and habitats used by various life stages of endangered fish. (Task 4.2.4.1)

8) Deposit, process, and secure San Juan River fish specimens, field notes, and associated data at an organized permanent repository. (Task 4.1.2.5)

9) Provide annual updates on the rate of opercular deformities found in Razorback Sucker. (Task 4.1.7.2)

10) Monitor TNC's restoration sites for the presence of endangered species, and compare species composition and relative abundance of fishes captured in restoration sites to nearby control sites. (Task 4.3.2.1)

Hypotheses:

When possible, the following hypotheses from the 2012 SJRRIP Monitoring Plan and Protocol will be annually evaluated. Exceptions are noted below in italics.

1) Densities of larval fishes will be influenced by specific mesohabitat types.

2) Relative abundance of larval fishes will be highest in mesohabitat types that contain cover, inundated vegetation and submerged debris which provides protection from aquatic and avian predators.

Previous attempts to evaluate the effect of cover type on larval fish density have proven problematic. Even at the small scale (ca. 5–15 m^2) of the individual mesohabitats being sampled, cover type is rarely distributed throughout site. Therefore it is not possible to say with certainty that cover type is resulting in increased abundance of fish.

3) Elevated spring discharge increases relative reproduction of native fishes, as determined by annual relative abundance and distribution of native larval fishes.

4) Elevated spring discharge decreases reproductive success of non-native fishes, as determined by annual relative abundance and distribution of non-native larval fishes.

5) Modification of physical attributes of San Juan River by natural flow regime mimicry, mechanical creation of nursery habitats and decreased entrainment of adults into irrigation canals will result in increased relative abundance, expanded distribution, and multiple ontogenetic life stages of larval Colorado Pikeminnow and Razorback Sucker.

Attributing an increase in abundance, distribution, or presence of multiple ontogenetic stages to any one of the factors listed in Hypothesis 5 is difficult or not possible. A variety of management actions preclude the ability to specifically attribute a response in the fish community to any of the factors listed in Hypothesis 5. For example, the stocking of thousands of adult Razorback Sucker, and hundreds of thousands of juvenile Pikeminnow annually could result in increases in abundance, distribution, or the presence of multiple ontogenetic stages. Monitoring of mechanically created habitats is ongoing, and details pertaining to that effort are listed within the methods section of this document.

6) Modification of biological attributes of San Juan River fish community (non-native removal and native fish stocking) will result in increased relative abundance, expanded distribution, and multiple ontogenetic life stages of larval Colorado Pikeminnow and Razorback Sucker.

See comments regarding Hypothesis 5.

Study Area:

The study area encompasses the San Juan River between Shiprock, New Mexico (RM 147.9) and the Clay Hills Crossing boat landing (RM 2.9) just above Lake Powell in Utah (145.0 river miles). As in all post 1999 sampling efforts, the study will include making collections in reaches of the San Juan River under the jurisdiction of the National Park Service.

Methods:

Field Work:

Sampling for Colorado Pikeminnow and Razorback Sucker larvae will be conducted in the San Juan River between RM 147.9 and RM 2.9 from mid-April through early August using sampling techniques that will provide sufficient numbers of fish necessary to meet study objectives 1–7, 9 and 10. Access to the river will be gained through the use of inflatable rafts equipped with all of the necessary equipment and provisions needed for trips of up to seven days. A day and a half is added before and after each field survey for field preparation, gear maintenance, and clean up. The study area will be divided into an "upper" section (Shiprock, NM, to Sand Island, UT) and a "lower" section (Sand Island, UT, to Clay Hills crossing, UT). Separate field crews will launch simultaneously in each of the two sections and proceed through their designated study area. The vehicle and raft trailer used by the field crew working in the upper section will be left at the Shiprock launch site and subsequently be shuttled to the Sand Island BLM ranger station, UT. The vehicle shuttle (with trailer) for the upper reach sampling effort was typically performed en gratis by personnel from the Farmington Office of the Bureau of Indian Affairs Office. Between 2008 and 2010, personnel from the N.M. Fishery Resources Office stationed in Farmington performed this service. Beginning in 2011, ASIR personnel shuttled vehicles for the upper end crew. At this time, there is no charge for this service.

The sampling crew for the lower reach will launch from, and store their vehicle and raft trailer at Sand Island, UT, where a commercial shuttle will take the vehicle to Clay Hills crossing, UT. The cost for this service is included under the travel and per diem section of our budget.

Because crews sampling the lower section of the study area will be in a high use recreational area, advance reservations are required. All trips for 2018 must be scheduled by late January 2018 and submitted to the Bureau of Land Management (BLM) Office at Monticello, Utah. Designated camping permits for our lower reach sampling crews will be obtained and must be strictly adhered to in addition to other BLM- San Juan River Recreation Area regulations (i.e., low impact and pack-out policies). Low flow conditions often prevalent during the study period make several sections of the river more difficult to navigate (especially in the lower reach). Our field crews are required to render assistance to boaters stuck in rapids or otherwise in distress and report all such encounters to the appropriate BLM personnel.

Sampling efforts for larval fish will be concentrated in low velocity habitats and employ small mesh seines (1 m x 1 m x 0.8mm) to collect fish. Individual seine hauls will be preserved independently at each site. Habitat designations will also be recorded by seine haul. Retained specimens will be placed in Whirl-paks containing 10% formalin and a tag inscribed with unique alphanumeric code that is also recorded on the field data sheet. For each sample site, the lengths (to 0.1 m) of each seine haul and total number of hauls will be measures and recorded. Capture densities for seine samples will be reported as the number of fish per 100 m^2.

Native species large enough to be positively identified will be measured (standard length) and returned to the river. Post-larval endangered fish species collected during this study will be photographed, a small portion of tissue from the caudal fin clipped and retained in 95% ethanol (in the case of potential Razorback Sucker hybrids) and scanned with a FS2001 PIT tag reader for the presence of a PIT tag. Specimens of sufficient size but lacking a PIT tag will be injected with a tag following the protocols established by the program (Davis 2010). All PIT tag information will be recorded in the field data sheet and subsequently forwarded to the SJRBRIP for integration in the program's PIT tag database.

For each sampling locality, river mile will be determined to the nearest tenth of a mile using the SJRBRIP 2009 Standardized Map Set. Universal Transverse Mercator (UTM) coordinates and zone will be determined with a Garmin Navigation Geographic Positioning System Instrument for each sampling locality. Mesohabitat type, length, maximum and minimum depths, water clarity (determined with a Secchi disc), and substrata will be recorded for each sampling locality. A minimum of one digital photo will also be taken of each specific habitat sampled.

Each of the six River Ecosystem Restoration Initiative (RERI) sites located between river miles 132.2 and 127.2 will be the subject of repeated monthly monitoring. The goal of these collections is to detect the presence of endangered species, and compare species composition and relative abundance of fishes captured in restoration sites to nearby control sites. If a site cannot be effectively sampled (e.g. too deep or swift), photos will be taken, habitat conditions noted, and no collection made.

All collections that contain Razorback Sucker will be examined for frequency and severity of opercular deformities. The opercula are not fully developed until at least the post-flexion mesolarval stage of development. Because of this, only Razorback Sucker greater than 15 mm TL (the size at which the opercula should be fully developed) will be examined for opercular deformities. Individuals will be examined on both the left and right sides. Severity of shortening will be assessed and rated as level 0 (no opercular deformity), level 1 (slight shortening), or level 2 (severe shortening). Annual rates of opercular deformities will be plotted and compared to the long-term data set (1999-present).

Field Work, Safety:

Personnel participating in fieldwork are required to successfully complete an International Rescue Instructors Association (IRIA) level 2 swiftwater rescue class and American Red Cross CPR/AED training. Type III personal flotation devices (PFD's) will be worn by sampling personnel at all times while working. As PFD's lose flotation capacity due to UV exposure, compression of material, and oil and grit impregnation, and since each crewmember's PFD will be used for approximately 45 days per season, the PFD's will be annually replaced. Simms Guideweight Gore-Tex waders and boots will be issued to all personnel along with 3 mm neoprene gloves (necessary in April and May). In addition to personal camping gear and rain suits, all personnel will be required to provide and use wide brimmed hats, sunscreen, and sunglasses (provided at no cost to the program).

All rafts used for this project will carry an extensively stocked first aid kit replete with items necessary for most minor medical situation. Additionally, the first aid kit will contain a suite of items (i.e., splints, neck braces, butterfly stitches, snakebite kits) needed to address more serious medical conditions. Because ethanol is used in the preservation of specimens, several vials of eyewash solution will be incorporated into each first aid kit. First aid kits will be inventoried after each sampling trip and used and/or expired items replaced. In the upper reach of the study area, personal cell phones and PDA's will be used (at no cost to the program) to contact outside parties should a medical situation arise. In the lower study area reach (canyon bound; where cell phones do not have service) a Iridium 9505-satellite phone will be provided for sampling crews.

Both sampling crews will be equipped with SPOT Satellite GPS Messenger units to be used in case of an emergency.

All preservation fluids will be transported in heavy-duty LPDE carboys. Extensive exposure to UV light makes the carboys susceptible to decomposition and cracking and requires that they be inspected monthly and not used for more than two years. Safety rope throw bags will be similarly inspected and retired from use accordingly. Rafts will be equipped with raft recovery (Z-line) kits, and repair kits, extra oars and oar blades, and two spare hand pumps to help ensure that crews do not become stranded due to raft damage. BLM regulations also mandate that a extra PDF and emergency whistle be carried by all boaters.

Laboratory Work:

Samples will be returned to the lab immediately after each field trip is completed and processed following a multi-step procedure. To maintain the larval fish in good condition (necessary to ensure accurate identification) the samples must be transferred from whirl-packs to glass jars and the field fluids replaced with new preservation fluids. Cyprinid and catostomid larvae are extremely small and transparent especially at early developmental stages. To minimize the potential loss of fish in individual seine hauls, it is best to retain the entire contents of each seine haul. A negative result of this technique is that, in addition to larval fish, whirl-pack samples usually contain considerable debris, detritus, and silt. Another important step in processing of individual samples is to separate fish from the detritus. This necessary portion of the process is labor intensive and can be quite tedious. During this process initial sorting of fish based on age class (age 0 [larvae] and age 1+) occurs. Samples that contain a large number of larval fish, especially proto or mesolarvae, often must be sorted twice to ensure all larvae are located within a sample.

After the fish are separated from the debris, personnel with San Juan River Basin larval fish identification expertise will identify individual specimens to species. Stereomicroscopes equipped with transmitted light bases (light and dark field) and polarized filters (that enhance the delineation of myomeres, pterygiophores, and fin rays) will be used to assist with the identifications. Larval fish keys are referenced to assist in species specific determinations (e.g., Contributions to a guide to the cypriniform fish larvae of the Upper Colorado River System [Snyder 1981], Catostomid fish larvae and early juveniles of the Upper Colorado River basin, Morphological descriptions, comparisons, and computer interactive key [Snyder and Muth 2004], and Identifications of larval fishes of the Great Lakes Basin [Auer 1982]). Age-0 specimens will be separated from age-1+ specimens using published literature on growth and development (Snyder 1981, Snyder and Muth 2004).

Age classes will be enumerated, measured (minimum and maximum size [mm standard length] for each species at each site), and catalogued in the Division of Fishes of the Museum of Southwestern Biology (MSB) at the University of New Mexico (UNM). Both total length (TL) and standard length (SL) of Colorado Pikeminnow and Razorback Sucker will be obtained using electronic calipers and stereomicroscope mounted micrometers. The ontogenetic stage of Colorado Pikeminnow and Razorback Sucker obtained in this study shall be determined based on the definitions provided by Snyder (1981).

Quality Assurance and Quality Control:

The qualifications of the investigators include extensive experience working on large data sets from multiple river systems over several decades. This experience has resulted in the implementation of numerous protocols that assure the quality of the finished data files. The field sampling crew has been kept constant, which ensures that the collection of the raw data is standardized between trips and that errors are minimized. Field notes and raw data sheets will be checked for any errors prior to being entered into spreadsheet data files. Any errors will be corrected by crossing out the original data and writing the correct data on the sheet in pencil (all corrections will include the initials of the person making them). All data will be entered into spreadsheet templates designed for the particular type of data being entered (i.e., site locality and physical conditions data, sample size and habitat data, fish species and age-class data). These template files are customized using drop-down lists to facilitate more efficient data entry while also assuring that the correct values are entered (i.e., eliminates typographical errors) within each field. After all data is imported into the main database, all data values will be checked. Data checking will include cross-referencing the field notes and raw data sheets with the values entered into the main database. Upon completion of the quality assurance and quality control steps listed above, the data will then be analyzed and tabulated. All the computed results will be examined and cross-checked with the original data files. Outlying values will be identified by using advanced sorting features on multiple data fields. Missing or incorrect data will be identified by using advanced sorting features and by running multiple queries written for this purpose. Checking the cross-tabulation of data will ensure that the sum of values is in agreement with the individual values (e.g., total number is equal to the sum of the total number of each age-class). Any corrections to the data will be made directly to individual tables within the main database.

Analysis:

Modeling ecological data with multiple zeros can be particularly effective when using mixture models (e.g., combining a binomial distribution with a lognormal distribution) to estimate occurrence and abundance separately (White, 1978; Welsh et al., 1996; Fletcher et al., 2005; Martin et al., 2005). Long-term Razorback Sucker (1999–2016) and Colorado Pikeminnow (2003–2016) sampling-site density data will be analyzed using PROC NLMIXED (SAS, 2015), a numerical optimization procedure, by fitting a mixture model using the methods outlined in White (1978). Covariates specific to Razorback Sucker and Colorado Pikeminnow mixture models are listed in Tables 4 and 5 of this proposal. Logistic regression will be used to model the probability a site was occupied, and the lognormal model will be used to model the distribution of abundance given that the site is occupied. Models provide four parameter estimates for each year (δ = probability of occurrence, μ = mean of the lognormal distribution, σ = standard deviation of the lognormal distribution, and $E(x)$ = estimated density). Model parameter estimates will be annual plotted and compared to the long-term data set to address Objectives 1 and 3–7 of this proposal.

Additional samples (i.e. each seine haul preserved individually) were taken between 2013 and 2016 to increase the overall sample size and provide supplemental information on habitats (i.e., habitat type, habitat location, and cover type) in order to address Objective 4 and 7 of this proposal. Field sampling efforts occurred in nine habitat types (backwater [BW], cobble shoal [CS], eddy [ED], embayment [EM], pool [PO], pocketwater [PW], run [RU], sand shoal [SS], and slackwater [SW]). These habitat designations follow those used by the SJRBRIP as defined in Bliesner et al. (2008). Additionally, four categories were assigned to habitat depending on where the sample was taken. Shoreline (SH) indicates all samples taken along the land-water interface, open-water (OP) indicates samples taken away from the shoreline, and mouth (MO) or terminus (TR) indicates samples taken from those locations within a backwater or embayment.

Habitat-specific density data (i.e., providing information on habitat type, habitat location, and cover type) have only been available since 2013. These data provide information on the specific habitat features used by Razorback Sucker and Colorado Pikeminnow. Habitat-specific density data are also analyzed using PROC NLMIXED (SAS, 2015), using the same methods outlined previously, to assess differences among models. A simplified list of five habitats (BW, EM, RU, LV [combining CS, PW, SS, and SW], and NZV [combining ED and PO]) is used for the purpose of statistical analysis since several habitats shared nearly identical low velocity (LV) or near zero velocity (NZV) conditions. General linear models will be used to incorporate covariates to model δ, μ, and σ. Covariates considered to model habitat-specific density data are year, reach, habitat type, and habitat location. Random effects models are used with the joint binomial and lognormal likelihood to provide random errors for the Site*Year combinations. Bivariate normal errors with mean zero and covariance are assumed for each Site*Year combination. A random error will be added to the logit of the binomial parameter δ, and a second random error was added to the log of the μ lognormal parameter. Adaptive Gaussian quadrature as described in Pinheiro and Bates (1995) is used to integrate out these random effects in fitting the model using the SAS NLMIXED procedure. Goodness-of-fit statistics (logLike and AIC_C) are generated to assess the relative fit of data to various models. The approach used to analyze habitat data between 2013 and 2016 and scheduled for use in 2017, will be used in 2018 in order to further elucidate fish and habitat relationships and fulfill Objectives 4, 6 and 7 of this proposal.

The results in the annual report will pertain almost exclusively to age-0 fish (i.e., age-1+ are not “larval fish” and are not the focus of this effort, they are not included in analysis). The exception to this will be age-1+ augmented Colorado Pikeminnow. Capture data for all Colorado Pikeminnow is analyzed and trend data reported. The number of all other fish age-1+ collected during the study will be presented as an Appendix.

Hatching dates of Razorback Sucker larvae will be calculated by subtracting the average length of larvae at hatching (8.0 mm TL) from the total length at capture (for proto- and mesolarvae) divided by 0.3 mm (Bestgen et al. 2002), which is the average daily growth rate of wild larvae observed by Muth et al. (1998). Spawning dates for Razorback Sucker will then be calculated once hatching dates have been established using the negative exponential equation $y=1440.3e^{-0.109x}$ (Bestgen et al. 2011) where y is the temperature dependent incubation time (in hours), e is the base of the natural logarithm, and x is the mean daily temperature on the hatching date.

Hatching dates for larval Colorado Pikeminnow will be calculated using the formula: $A=-76.7105+17.4949(L)-1.0555(L)^2+0.0221(L)^3$ for larvae <22 mm, where A= post-hatch age in days, and L= length (mm TL). For larvae 22-47 mm TL the formula $A=-26.6421+2.7798L$ will be used. Both hatching date formulas are taken from Nesler et al. (1998).

Spawning dates for larval Colorado Pikeminnow will be estimated by adding five days to the post-hatch ages to account for incubation time at 20 – 22 ^{o}C (Nesler et al. 1988). Hatching and spawning dates for both endangered species will then be compared with the discharge and temperature data during that period within the study area in order to fulfill Objective 2 of this proposal.

This study will be initiated prior to spring runoff and completed during mid-summer (late July or early August). Daily mean discharge and temperature (mean, maximum, and minimum) during the study period is acquired from U.S. Geological Survey Gauge (# 09379500) near Bluff, Utah and Four Corners Bridge (#09371010).

Table 4. Covariates used in mixture models for Razorback Sucker.

Covariate	**Description**
Year	The calendar year in which the larval survey took place.
Reach	Each of the 5 geomorphic reaches (5–1) within the study area.
Mean March, April and May temperature.	Daily mean temperature data was taken from USGS gage #09379500 near Bluff, Utah.
Mean March, April and May discharge.	Daily mean discharge data (cfs) was taken from USGS gage #09379500 near Bluff, Utah.
Annual # stocked.	The number of Razorback Sucker stocked within a calendar year. Fish stocked in a given year were used as a covariate for larval captures during the following larval survey year (i.e. 1+ overwinter periods).
Cumulative # stocked	The number of Razorback Sucker stocked during the time period between 1998 and the year prior to the larval survey year. (e.g. 5,000 fish stocked between 1998–2000 would be used as a covariate for 2001 larval capture data).
Fall monitoring captures.	All fall monitoring captures of adult Razorback Sucker. Fish collected during a given year were used as a covariate for larval captures during the following larval survey year (i.e. 1+ overwinter periods).

Table 5. Covariates used in mixture models for Colorado Pikeminnow.

Covariate	**Description**
Year	The calendar year in which the larval survey took place.
Reach	Each of the 5 geomorphic reaches (5–1) within the study area.
Mean June and July temperature.	Daily mean temperature data was taken from USGS gage #09379500 near Bluff, Utah.
Mean June and July discharge.	Daily mean discharge data (cfs) was taken from USGS gage #09379500 near Bluff, Utah.
Cumulative # stocked	The number of age-0 Colorado Pikeminnow stocked during the time period between 1998 and five years prior to the larval survey year. (e.g. 100,000 fish stocked in 2000 would be used as a covariate for 2005 larval capture data).
Fall monitoring captures 400+ mm TL.	All fall monitoring captures of Colorado Pikeminnow greater than 400 mm TL. Fish collected during a given year were used as a covariate for larval captures during the following larval survey year (i.e. 1+ overwinter periods).

Reporting and Permitting:

Beginning in 2004, data from the two San Juan River larval fish surveys (Razorback Sucker and Colorado Pikeminnow) were analyzed collectively and presented in a single report. This created a whole picture of the reproductive activities of the entire ichthyofaunal community in the San Juan River using the same criterion used as the other monitoring programs. The report will be disseminated as outlined by the program office.

In addition to the annual report of the study provided to the SJRBRIP, reports summarizing fish collecting activities and specimens captured are also required annually under scientific collection permits provided by the U.S. Fish and Wildlife Service, New Mexico Department of Game and Fish, Navajo Nation, and state of Utah. The aforementioned reports include (at a minimum) site localities, GPS coordinates, and fish collected. An annual report of activities is a BLM (Monticello Field Office) requirement under our access permit to the San Juan River below San Island (Bluff, UT) and designated camps in the lower reaches of the river. Annual Mussel-free permits will also be acquired by all trip leaders for use in Utah and Glen Canyon National Park.

Meetings:

Researchers are required to attend four meetings annually and report on annual monitoring projects. The two pre-set annual meetings (February and May) require researchers present PowerPoint presentations outlining the results and that years findings. Each meeting lasts about three days (which includes travel time).

Products:

A draft report of the 2018 larval Razorback Sucker and Colorado Pikeminnow sampling activities will be prepared and distributed to the San Juan River Basin Biology Committee for review by 31 March 2019. Upon receipt of written comments, that report will be finalized and disseminated to members of the San Juan River Basin Biology Committee by 30 June 2019 in order to meet Objective 5 of this proposal. Electronic copies of the 2018 collection data will be transferred to the San Juan River database manager. Fish collected from this study will be curated in the Division of Fishes, Museum of Southwestern Biology (MSB), Department of Biology, at the University of New Mexico under a MSB contract with the SJRBRIP in order to fulfill Objective 8 of this proposal. Original field notes will be retained in the Division of Fishes and collection information electronically stored in a permanent MSB database program. These data and any maps generated from them will be available to the San Juan River Basin Biology Committee via hard-copy reports and electronically.

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2018 BUDGET: SAN JUAN RIVER LARVAL ENDANGERED FISH MONITORING

Based on five sampling trips per year

Personnel

Field Data Collection

Upper Reach (two staff, one raft) Shiprock to Sand Island - RM 148.0 - 76.0

Fisheries Biologist I (1 staff x 5 trips x 10 days x 8 hrs/day): ....$ 22,872

Fisheries Technician (1 staff x 5 trips x 10 days x 8 hrs/day): ....$ 14,076

Lower Reach (two staff, one raft) Sand Island to Clay Hills - RM 76.0 - 2.9

Fisheries Biologist I (1 staff x 5 trips x 10 days x 8 hrs/day): ....$ 22,872

Fisheries Technician (1 staff x 5 trips x 10 days x 8 hrs/day): ....$ 14,076

Lab Work

Upper and Lower Reach Samples Combined

Fisheries Biologist I (120 staff days/sampling year): ....$ 54,893
Tasks: Laboratory identification, developmental staging, specialized endangered fish processing, data entry, data query and review, database development

Fisheries Technician (120 staff days/sampling year): ....$ 33,782
Tasks**:** Post-trip sample processing, juvenile identification, excise, mount and examine sub-sample of otoliths, post-identification – processing, measures, review of counts

Office Work (Report Development)

Fisheries Biologist I (70 staff days year): ....$ 32,021
Tasks: Data analysis, draft report preparation, post-review redraft and submission, development and submission of formal responses to reviewer comments, development of presentation of study for annual meetings, annual reporting related to state and tribal permitting of sampling activities

Senior Biostatistician (10 staff days year): ....$ 14,075
Tasks: Mixture model development and analysis.

Project Oversight

Senior Fisheries Biologist (10 staff days year): ....$ 7,742
Tasks: Project coordination, project and data review, data management, report review

Personnel (Field, Lab, Office, Oversight): .... Subtotal $ 216,409

SJRBRIP Meetings

Four meetings/year required; 2 days/meeting

Fisheries Biologist I (8 staff days/year): ....$ 3,660

Senior Fisheries Biologist (8 staff days/year): ....$ 6,193

Personnel (Meetings): .... Subtotal $ 9,853

Personnel: .... Total $ 226,262

Materials and Supplies

Safety dedicated first aid gear (open market items):	$	1,893
Raft and rafting associated gear (open market items):	$	1,534
Fish Sampling and associated electronic recording gear (open market items):	$	1,335
Materials and Supplies: ... Total	**$**	**4,762**

Travel and Per Diem

Field Data Collection

Shiprock to Clay Hills (five trips) - RM 148.0 - 2.9 (Using two rafts & two crews)

Travel - 4 x 4 pickup truck and raft trailer (1,380 miles x $ 0.54/mile x 5 trips):	$	3,726
Per Diem - 6 field days per trip x 4 staff ($51/day GSA M&IE rate) x 5 trips:	$	6,120
Per Diem - 1 hotel day per trip x 4 staff ($91/night GSA lodging rate) x 5 trips:	$	1,820
Truck and Trailer Shuttle from Sand Island to Clay Hills x 5:	$	1,800
Travel and Per Diem (Field): ... Subtotal	**$**	**13,466**

SJRBRIP Meetings

Travel (one vehicle at 430 miles r.t. x 4 trips x $ 0.54/mile):	$	929
Per Diem (2 GSA lodging + 3 M&IE per diem days/meeting x 4 meetings x 2 staff):	$	2,680
Travel and Per Diem (Meetings): ... Subtotal	**$**	**3,609**
Travel and Per Diem: ... Total	**$**	**17,075**

2018 Project Totals

Personnel: ... Total	**$**	**226,262**
Materials and Supplies: ... Total	**$**	**4,762**
Travel and Per Diem ... Total	**$**	**17,075**
2018 Scope of Work: ... GRAND TOTAL	**$**	**248,099**

Projected Out-year funding (Adjusted by 3% annually)

FY 2019	**$ 255,542**
FY 2020	**$ 263,208**
FY 2021	**$ 271,104**