# San Juan River Larval Razorback Sucker and Colorado Pikeminnow Monitoring

## Fiscal Year 2022 Scope of Work

**Submitted to the U.S. Bureau of Reclamation**

**Submitted by**

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**Contract # GS-10F-0249X-140R4018F0037**

**1 October 2021 - 30 September 2022**

# SAN JUAN RIVER LARVAL RAZORBACK SUCKER AND COLORADO PIKEMINNOW MONITORING FISCAL YEAR 2022 PROJECT PROPOSAL

## Project history

Surveys conducted in late 1980s documented small resident populations of Colorado Pikeminnow and Razorback Sucker in the San Juan River and the San Juan River arm of Lake Powell (Platania et al. 1991). Beginning in the mid-1990s, populations of these two species were augmented with annual hatchery stocking under the auspices of the San Juan River Basin Recovery Implementation Program (SJRRIP). Currently, populations of Colorado Pikeminnow and Razorback Sucker persist in the lowermost 180 river miles of the San Juan River (between the Animas River confluence and the inlet of Lake Powell Reservoir). Annual investigations into the early life history of Colorado Pikeminnow began in 1991 when passive drift-netting for larval and young-of-year (YOY) fish was initiated in the San Juan River. The primary objectives of the passive drift-netting study were to 1) determine the temporal distribution of San Juan River ichthyoplankton in relation to the hydrograph, 2) provide comparative analysis of the reproductive success of San Juan River fishes, 3) attempt to characterize downstream movement of ichthyoplankton, and 4) attempt to validate the presumed spawning period of Colorado Pikeminnow.

Two stationary sites were used for the drift-net surveys. The upstream site was located 4.6 miles upstream of the Mancos River confluence in New Mexico. A second site was established in Mexican Hat, UT. Over 70 river miles separated the two field stations. Results from eleven years of drift-net surveys (1991–2001) resulted in the collection of 11 larval Colorado Pikeminnow (Table 1) as well as information regarding the ichthyofaunal community of the San Juan River during the presumed spawning period of Colorado Pikeminnow (Platania et al. 2000, 2002).

In 1994, personnel from the U.S. Fish and Wildlife Service Colorado River Fishery Project (CRFP; Grand Junction, Colorado) stocked the first series of Razorback Sucker (n=672) in the San Juan River. Those fish, whose mean length and mass at the time of stocking were about 400 mm TL and 710 g, respectively, were released between Hogback, New Mexico and Bluff, Utah. In their 1995 report of activities, Ryden and Pfeifer (1996) suggested that most experimentally stocked 1994 San Juan River Razorback Sucker would achieve sexual maturity by 1996 thereby providing the potential for spawning during 1997–1998. The success of the experimental stocking study resulted in the development of a full-scale augmentation program for Razorback Sucker in the San Juan River.

At the November 1996 SJRRIP Biology Committee integration meeting, it was suggested that the Colorado Pikeminnow, larval fish drift study be expanded to document spawning of Razorback Sucker. However, because reproduction by Razorback Sucker (March-May) occurred considerably earlier than Colorado Pikeminnow (June-July), separate investigations of spawning periodicity and magnitude were deemed necessary. The initial attempt to document reproduction by Razorback Sucker stocked in the San Juan River took place in 1997. Low velocity monitoring sites were established in numerous locations adjacent to U.S. Hwy 163 and Utah State Hwy 262 (which parallels the San Juan River between Aneth and Bluff, UT) that appeared suitable for sampling with light-traps. Light-traps were set nightly in low-velocity habitats between Aneth and Mexican Hat from late March through mid-June 1997. 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 and larval Razorback Sucker was not present. While there were probably several variables that accounted for the poor light-trap catch rate, a principal factor was limited access to suitable habitats. A primary result of the 1997 study was the realization that being bound to specific collecting sites was an inefficient means of collecting the large number of larval fish necessary to document reproduction of a rare species.

In 1998, the Razorback Sucker larval fish sampling technique was modified to allow for collections over a larger portion of the San Juan River and capture of a considerably larger number of larval fish. Navigation of the river by use of an inflatable raft provided the opportunity to sample habitats that were formerly either inaccessible or unobservable under the constraints of the 1997 sampling protocol. The primary collecting method was sampling low-velocity habitats with a fine mesh seine (0.8 mm mesh). The seining technique yielded over 13,000 specimens between river miles 127.5 and 53.3 with most these individuals (n=9,960) being larval catostomids. Included in the 1998 larval fish catch were two larval Razorback Suckers (Table 2). The success of this project became evident as documentation of reproduction by Razorback Sucker continued in successive years. Between 1998 and 2020 there have been both spatial and temporal expansions upon this project but sampling methodology has remained relatively consistent.

The most significant change to the larval Razorback Sucker survey was the incorporation of the spawning periodicity of Colorado Pikeminnow using the same methodology. Beginning in July 2002, personnel began an active sampling regime that mirrored the sampling protocol successfully used to document reproduction by Razorback Sucker. This temporal expansion of the larval fish survey resulted in the monitoring of reproduction by the entire ichthyofaunal community.

Following the 2002 expansion of the San Juan River larval fish survey to actively sample for larval Colorado Pikeminnow, 1,734 individuals have been collected. Over 95% (n = 1,682) of all larval Colorado Pikeminnow has been collected since 2014 (Table 1). Back-calculated spawning dates, based on Colorado Pikeminnow larvae, range from 30 June to 3 August and are associated with the descending limb of spring runoff and mean river temperatures typically above 18°C.

The results of the investigation into the early life history of Colorado Pikeminnow and Razorback Sucker is a foundation of work detailing the spawning periodicity of the entire ichthyofaunal community of the San Juan River. For the endangered fishes, catch data elucidates potential spawning areas, distribution, and displacement of propagules in the system and back-calculated spawning and hatching dates. The long-term data set (22 years) can track trends of the entire ichthyofaunal community by year, month, and river reach. The larval survey is also able to detect spawning by the rarest of the San Juan River fishes; Colorado Pikeminnow and Roundtail Chub, *Gila robusta*.

To date larval fish monitoring has collected and identified 13,139 larval or age-0 juvenile Razorback Sucker and documented reproduction by Razorback Sucker for 23 consecutive years (Table 2). Back-calculated hatching dates derived from individual Razorback Sucker larvae indicates spawning occurs prior to spring run-off often including the ascending limb of the spring hydrograph, and can persist into early summer (Farrington et al. 2017). Mean water temperatures during this period among all years ranged between 7.7–26.5°C. This minimum, maximum and subsequent range of temperatures at which successful spawning by Razorback Sucker has been documented is outside of the temperature range typically reported for this species (Bozek et al. 1990; Tyus and Karp, 1990; Muth et al. 1998; Bestgen et al. 2011)

Table 1. Summary of larval and YOY Colorado Pikeminnow collected in the San Juan River during larval drift-netting/larval seining (1991-2020) and back-calculated dates of spawning.

| *Year* | *Sample Method* | *Study Area (River Miles)* | *N=* | *Length TL* | *Collection Date* | *Spawning Date* |
|---|---|---|---|---|---|---|
| 1991-2001 | Drift Netting | 127.5, 53.3 | 11 | 8.5–9.2 | 26 Jul–03 Aug | 15-18 Jul |
| 2004 | Larval Seine | 141.5 – 2.9 | 2 | 14.2, 18.1 | 22, 26 Jul | 4, 10 Jul |
| 2007 | Larval Seine | 141.5 – 2.9 | 3 | 14.3-16.2 | 25, 27 Jul | 8–13 Jul |
| 2009 | Larval Seine | 141.5 – 2.9 | 1 | 25.2 | 27 Jul | 13 Jul |
| 2010 | Larval Seine | 141.5 – 2.9 | 5 | 12.6–21.4 | 20-23 Jul | 2–6 Jul |
| 2011 | Larval Seine | 141.5 – 2.9 | 29 | 10.0–21.3 | 20, 21 Jul, 10,11 Aug | 2–27 Jul |
| 2013 | Larval Seine | 147.9 – 2.9 | 12 | 14.1–28.7 | 17–30 Jul | 1–16 Jul |
| 2014 | Larval Seine | 147.9 – 2.9 | 312 | 8.5–20.8 | 13–28 Jul | 17 Jun–5 Jul |
| 2015 | Larval Seine | 147.9 – 2.9 | 24 | 8.6–9.7 | 28–30 Jul | 11–14 Jul |
| 2016 | Larval Seine | 147.9 – 2.9 | 548 | 8.8–14.7 | 24–28 Jul | 30 Jun–12 Jul |
| 2017 | Larval Seine | 180.6 – 2.9 | 174 | 9.0–21.5 | 23 Jul–16 Aug | 16 Jun–17 Jul |
| 2018 | Larval Seine | 180.6 – -17.0* | 54 | 9.3–25.3 | 7–26 Jul | 4–28 Jun |
| 2019 | Larval Seine | 180.6 – -19.0* | 300 | 8.9–37.0 | 17 Jul–19 Aug | 30 Jun–3 Aug |
| 2020 | Larval Seine | 188.3 – -17.0* | 270 | 9.2–37.0 | 12 Jul–12 Aug | 14 Jun–12 Jul |

* RM 17.0 is equivalent to Lake Mile 38 in the San Juan arm of Lake Powell.
** RM 19.0 is equivalent to Lake Mile 36 in the San Juan arm of Lake Powell.

Table 2. Summary of larval and YOY of Razorback Sucker collected in the San Juan River (1998 – 2020) and back-calculated dates of spawning.

| *Year* | *Sample Method* | *Study Area (River Miles)* | *N=* | *Length TL* | *Collection Date* | *Spawning Date* |
|---|---|---|---|---|---|---|
| 1998 | Larval seine<br>Light traps | 127.5 – 53.3 | 2 | 12.1, 12.7 | 21, 22 May | NA |
| 1999 | Larval seine<br>Light traps | 127.5 – 2.9 | 7 | 10.2–18.6 | 4 May–14 Jun | 9 Apr–14 May |
| 2000 | Larval seine<br>Light traps | 127.5 – 2.9 | 129 | 9.3–16.2 | 9 May–2 Jun | 4 Apr–14 May |
| 2001 | Larval seine<br>Light traps | 141.5 – 2.9 | 50 | 10.1–28.8 | 16 May–14 Jun | 7 Apr–8 May |
| 2002 | Larval seine<br>Light traps | 141.5 – 2.9 | 813 | 9.7–62.4 | 29 Apr–12 Jul | 27 Mar–13 May |
| 2003 | Larval seine<br>Light traps | 141.5 – 2.9 | 472 | 9.2–37.3 | 16 May–18 Jun | 18 Mar–12 May |
| 2004 | Larval Seine | 147.9 – 2.9 | 41 | 8.7–25.9 | 15 May–15 Jun | 17 Apr–2 Jun |
| 2005 | Larval Seine | 147.9 – 2.9 | 19 | 10.8–25.3 | 14 May–3 Aug | 16 Apr–26 Jun |
| 2006 | Larval Seine | 147.9 – 2.9 | 202 | 8.9–22.5 | 23 Apr–30 May | 2 Apr–16 May |
| 2007 | Larval Seine | 147.9 – 2.9 | 200 | 6.7–31.9 | 19 Apr–26 Jul | 22 Mar–11 Jun |
| 2008 | Larval Seine | 147.9 – 2.9 | 126 | 8.3–18.7 | 21 May–21 Jun | 15 Apr–31 May |
| 2009 | Larval Seine | 147.9 – 2.9 | 272 | 10.1–30.2 | 19 May–19 Jun | 27 Mar–28 May |
| 2010 | Larval Seine | 147.9 – 2.9 | 1,251 | 9.4–30.0 | 17 May–20 Jul | 13 Apr–4 Jun |
| 2011 | Larval Seine | 147.9 – 2.9 | 1,065 | 8.6–34.2 | 16 May–19 Jul | 21 Mar–27 May |
| 2012 | Larval Seine | 147.9 – 2.9 | 1,778 | 6.1–31.8 | 14 May–14 Jun | 20 Mar–30 May |
| 2013 | Larval Seine | 147.9 – 2.9 | 979 | 9.5–70.0 | 17 May–18 Jul | 23 Mar–2 Jun |
| 2014 | Larval Seine | 147.9 – 2.9 | 612 | 8.8–57.6 | 22 Apr–17 Jul | 19 Mar–30 Jun |

Table 2 (cont.). Summary of larval and YOY of Razorback Sucker (Xyrtex) collected in the San Juan River (1998 – 2020) and back-calculated dates of spawning.

| *Year* | *Sample Method* | *Study Area (River Miles)* | *N=* | *Length TL* | *Collection Date* | *Spawning Date* |
|---|---|---|---|---|---|---|
| 2015 | Larval Seine | 141.5 – 2.9 | 1,205 | 9.6–22.4 | 19 Apr–21 May | 19 Mar–4 May |
| 2016 | Larval Seine | 141.5 – 2.9 | 824 | 9.3–48.4 | 21 Apr–25 Jul | 19 Mar–30 Jun |
| 2017 | Larval Seine | 180.6 – 2.9 | 360 | 9.2–43.0 | 20 Apr–26 Jul | 23 Mar–9 Jun |
| 2018 | Larval Seine | 180.6 – -17.0* | 1,833 | 8.2–102.2 | 23 Apr–26 Jul | 3 Mar–22 Jun |
| 2019 | Larval Seine | 180.6 – -19.0** | 722 | 9.1–37.9 | 25 Apr–1 Aug | 19 Mar–19 Jul |
| 2020 | Larval Seine | 188.3 – -17.0** | 177 | 9.2–48.0 | 19 May–31 Jul | 11 April–6 Jun |

* RM 17.0 is equivalent to Lake Mile 38 in the San Juan arm of Lake Powell.
** RM 19.0 is equivalent to Lake Mile 36 in the San Juan arm of Lake Powell.

**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 (Table 3). 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, 2012 and 2017 by a total of 103.5 river miles (over double the length of the original study area) to include Reach 6 through Reach 1 (Farmington, NM to Clay Hills Crossing, UT). The expansions of the study area were a result of captures of larval Razorback Sucker at the top of the previous study area boundary. Within two years (and often the following year) of each study area expansion, larval Razorback Sucker was documented in the newly expanded study area. The most recent expansion occurred in 2018 when larval fish sampling was expanded downstream of the Paiute Farms waterfall (RM -1.0) to include riverine habitat in the San Juan arm of Lake Powell. Larval Razorback Sucker larvae were collected downstream of the waterfall in 2018 and 2019. Sampling done downstream within the “Expanded Study Area” (RM 168.4–180.6, Waterflow, NM to Farmington, NM) is considered to be independent of the work proposed in this SOW with discrete sampling dates, SOW, and budget submitted to the SJRRIP each fiscal year.

Beginning in 2003, the entire study area (excluded the aforementioned Expanded Study Area and Paiute Farms waterfall reach) 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 SJRRIP 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 Colorado Pikeminnow and 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). 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.

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.

**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 (SJRRIP).

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)

Table 3. Summary of annual projects and project modifications of the larval fish surveys from 1997 to 2020.

| *Year* | *Sampling method* | *Study area (River Miles)* | *Specimens collected* | *Field modification* | *Laboratory modification* |
|---|---|---|---|---|---|
| 1997 | Light Trap<br>Drift-nets | 99 – 75 | 297 | | |
| 1998 | Larval Seine<br>Light Trap<br>Drift-nets | 127.5 – 53.3 | 13,608 | study area expanded; active sampling | |
| 1999 | Larval Seine<br>Light Trap<br>Drift-nets | 127.5 – 2.9 | 20,711 | study area expanded; upper-lower reaches sampled separately; nonsynchronous | |
| 2000 | Larval Seine<br>Light Trap<br>Drift-nets | 127.5 – 2.9 | 13,549 | | |
| 2001 | Larval Seine<br>Light Trap<br>Drift-nets | 141.5 – 2.9 | 95,629 | study area expanded; upper-lower reaches sampled separately; nonsynchronous | |
| 2002 | Larval Seine<br>Light Trap | 141.5 – 2.9 | 138,602 | study period expanded to September. Drift-nets no longer used. | |
| 2003 | Larval Seine<br>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 | | |

Table 3 (cont). Summary of annual projects and project modifications of the larval fish surveys from 1997 to 2020.

| *Year* | *Sampling method* | *Study area (River Miles)* | *Specimens collected* | *Field modification* | *Laboratory modification* |
|---|---|---|---|---|---|
| 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 |
| 2017 | Larval Seine | 180.6 – 2.9 | 31,587 | Study Area expanded | |
| 2018 | Larval Seine | 180.6 – -17.0* | 44,611 | Study Area expanded downstream to include riverine habitat below the waterfall. | Fall monitoring covariate changed from raw numbers to CPUE |
| 2019 | Larval Seine | 180.6 – -19.0** | 30,395 | | |
| 2020 | Larval Seine | 188.3 – -17.0** | 47,655 | | |

* RM 17.0 is equivalent to Lake Mile 38 in the San Juan arm of Lake Powell.
** RM 19.0 is equivalent to Lake Mile 36 in the San Juan arm of Lake Powell.

## 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 for this SOW 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 to meet the study objectives of this SOW 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, clean up and specimen deposition. 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 without cost 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 (there is no cost 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 2022 must be scheduled by late January 2022 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 95% ethanol (EtOH) 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% EtOH (in the case of potential Razorback Sucker hybrids) and scanned with a 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 SJRRIP 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 most current SJRRIP 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 phase I 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. Beginning in 2011, ASIR researchers defined 15 monitoring sites located in lateral washes and canyons throughout the study area to assess persistence of backwater habitats. Monitoring sites will be visited in each survey. If suitable nursery habitat exists at the time of visitation they will be sampled. If the sites are dry or contain isolated pools, photographs will be taken and field notes written detailing condition of the habitat. Conditions of all monitoring sites and RERI restoration sites will then be related back to discharge at time of visitation.

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 60 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 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) an 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, 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 all boaters carry an extra PDF and emergency whistle.

*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 is 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–present) and Colorado Pikeminnow (2003–present) sampling-site density data will be analyzed using PROC NLMIXED (SAS, 2018), 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 ($\delta$ = probability of occurrence, $\mu$ = mean of the lognormal distribution, $\sigma$ = 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 2020 to increase the overall sample size and provide supplemental information on habitats (i.e., habitat type and habitat location) to address Objectives 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 SJRRIP 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 and habitat location) 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, 2018), 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 $\delta$, $\mu$, and $\sigma$. 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 $\delta$, and a second random error was added to the log of the $\mu$ 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 2020, and scheduled for use in 2021, will be used in 2022 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 are 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 were calculated using the formula age = SL – 7.1058 + 0.0003($Q$) + 0.0061($RM$) – 0.0408($T$)/ 0.2463, where SL is the standard length in millimeters, $Q$ is mean April discharge, $RM$ is river mile and $T$ is the temperature on the collection date (Clark-Barkalow et al. 2019). 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 were calculated for larval Colorado Pikeminnow using the formula age = $0.0086SL^3 – 0.3781SL^2 – 30.7930$, where SL is the standard length in millimeters. Spawning dates are calculated by calculating the incubation time using the formula days = $315.42e^{-0.05(T\ hatch)}$ where T hatch is the temperature on the hatch date and $e$ is the base of the natural logarithm; spawning date is then the age at hatch – the incubation time (Clark-Barkalow et al. 2019). 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. |
| Cumulative # stocked | The number of Razorback Sucker stocked during the period between 1998 and the year prior to the larval survey year. (e.g., 70,000 fish stocked between 1998 and 2020 would be used as a covariate for 2021 larval capture data). |
| Fall monitoring captures. | # of adult Razorback Sucker collected per hour of electrofishing effort. 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 occurred. |
| 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 period between 1998 and five years prior to the larval survey year. (e.g., 100,000 fish stocked in 2016 would be used as a covariate for 2021 larval capture data). |
| Fall monitoring captures 400+ mm TL. | # of Colorado Pikeminnow greater than 400 mm TL collected per hour of electrofishing effort. 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 single picture of the reproductive activities of the entire ichthyofaunal community in the San Juan River employing the same criterion as 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 SJRRIP, 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 Department of Fish and Wildlife, and Utah Division of Wildlife Resources. The aforementioned reports include (at a minimum) site localities, GPS coordinates, fish collected and deposition history of retained specimens. 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 are also acquired by all trip leaders for use in the Utah portion of the San Juan River and Glen Canyon National Park.

*Deliverables*

*Meetings*

In addition to participating in multiple conference calls, researchers are required to attend three 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 2022 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 2023. 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 2023 to meet Objective 5 of this proposal. Electronic copies of the 2022 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 SJRRIP 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 electronically and via hard-copy reports.

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**2022 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 148.0–76.4*
Fisheries Biologist I (1 staff x 5 trips x 10 days x 8 hr/day at $65.80/hr) ................. $ 26,320.00
Fisheries Technician (1 staff x 5 trips x 10 days x 8 hr/day at $40.49/hr)................. $ 16,196.00

*Lower Reach (two staff, one raft) Sand Island to Clay Hills; RM 76.4–2.9*
Fisheries Biologist I (1 staff x 5 trips x 10 days x 8 hr/day at $65.80/hr) ................. $ 26,320.00
Fisheries Technician (1 staff x 5 trips x 10 days x 8 hr/day at $40.49/hr)................. $ 16,196.00

Lab Work

*Upper and Lower Reach Samples Combined*
Fisheries Biologist II (120 staff days/sampling year x 8 hr/day at $80.98/hr) .......... $ 77,740.80
Tasks Laboratory identification, developmental staging,
specialized endangered fish processing, data entry, data query
and review, database development

Fisheries Technician (60 staff days/sampling year x 8 hr/day at $40.49/hr)............. $ 19,435.20
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 (50 staff days year x 8 hr/day at $65.80/hr) ............................. $ 26,320.00
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 (5 staff days year x 8 hr/day at $202.44/hr )........................... $ 8,097.60
Tasks Mixture model development and analysis.

Project Oversight

Senior Fisheries Biologist (6 staff days year x 8 hr/day at $111.34/hr) .................... $ 5,344.32
Tasks Project coordination, project and data review, data
management, report review, permitting review

SJRRIP Meetings

*Three meetings/year required; 2 days/meeting*

| | | |
|---|---|---|
| Fisheries Biologist I (6 staff days/year x 8 hr/day at $65.80/hr) | $ | 3,158.40 |
| Senior Fisheries Biologist (6 staff days/year x 8 hr/day at $111.34/hr) | $ | 5,344.32 |
| **Personnel ... Subtotal** | **$** | **230,472.64** |
| **Personnel ... GSA General and Administrative Fee (IFF)*** | **$** | **1,728.54** |
| **Personnel ... Total** | **$** | **232.201.18** |

***** The Industrial Funding Fee is a fixed (0.75%) cost to cover the General Services Administration's cost of operating the Federal Supply Schedules (FSS) program.

**Materials and Supplies**

| | | |
|---|---|---|
| Safety dedicated first aid gear (open market items and includes PFD's) | $ | 2,131.00 |
| Camping and rafting associated gear (open market items) | $ | 1,726.00 |
| Fish Sampling and associated electronic recording gear (open market items) | $ | 1,416.00 |
| **Materials and Supplies ... Total** | **$** | **5273.00** |

**Travel and Per Diem (published GSA rates at the time of travel will be used)**

Field Data Collection

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

| | | |
|---|---|---|
| Travel - Albuquerque, NM to Clay Hills, UT (742 miles x $ 0.56/mile x 5 trips) | $ | 2,077.60 |
| Travel - Albuquerque, NM to Bluff, UT (576 miles x $ 0.56/mile x 5 trips) | $ | 1,612.80 |
| Per Diem - 6 field days per trip x 4 staff ($55/day GSA M&IE rate) x 5 trips | $ | 6,600.00 |
| Per Diem - 1 hotel day per trip x 4 staff ($96/night GSA lodging rate) x 5 trips | $ | 1,920.00 |
| Per Diem - 1 hotel day per trip x 4 staff ($55/day GSA M&IE rate) x 5 trips | $ | 1,100.00 |
| Truck and Trailer Shuttle from Bluff to Clay Hills x 5 at $220.00 per trip | $ | 1,100.00 |
| **Travel and Per Diem (Field) ... Subtotal** | **$** | **14,410.40** |

SJRRIP Meetings

| | | |
|---|---|---|
| Travel (one vehicle at 430 miles r.t. x 3 trips x $ 0.56/mile) | $ | 722.40 |
| Per Diem (Durango CO.) | | |
| (3 meetings x 2 staff x GSA lodging $102/night x 2) | $ | 1,224.00 |
| (3 meetings x 2 staff x M&IE rate $71/day x 3) | $ | 852.00 |
| **Travel and Per Diem (Meetings) ... Subtotal** | **$** | **2,798.40** |
| **Travel and Per Diem ... Total** | **$** | **17,208.80** |

**2022 Project Totals**

| | | | |
|---|---|---|---|
| **Personnel** | **Total** | **$** | **232,201.18** |
| **Materials and Supplies** | **Total** | **$** | **5,273.00** |
| **Travel and Per Diem** | **Total** | **$** | **17,208.80** |
| | | | |
| **2022 Scope of Work** | **GRAND TOTAL** | **$** | **254.682.98** |

**Response to reviewer's comments.**

**PO:** Provides an annual indication of whether spawning efforts were successful in producing larvae and whether those larvae recruit through each phase. Annually assesses the environmental variables related to larval CPUE. These data are also needed for other investigations (e.g., Nb estimates).

**Response:** Thank you for taking time to review this document.