

Upper Colorado River Recovery Implementation Program- *Floodplain Inundation and Entrainment Studies*

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Executive Summary

Flood plain wetlands are presumed important habitat for early life stages of razorback sucker in the middle Green River, Utah, because they are warm, food-rich, and may promote higher survival of larvae and recruitment to juvenile and adult life stages. Flow recommendations were developed to provide for river flows needed for entrainment of early life stages of razorback sucker from the main stem Green River in spring into flood plain wetlands. However, it is not precisely known if flood plain connectivity and flow timing, magnitude, and duration, as outlined in flow recommendations, is adequate for entrainment of razorback sucker larvae into target wetlands. Information to guide management of Green River flood plain wetlands for razorback sucker is extensive but a single synthesis of that information does not exist. A synthesis would be useful to integrate biological and physical information that will assist managers in efforts to increase recruitment of early life history stages of razorback sucker and, ultimately, recover the species. This project proposal is designed to fill those information needs.

Eight different, but overlapping information needs were identified in the request for proposals and those are paraphrased below.

- Information need 1.** Flow and stage at which floodplains with levee breaches become sufficiently inundated to provide nursery habitat for razorback suckers.
- Information need 2.** Frequency of flood plain inundation relative to the hydrologic cycle.
- Information need 3.** Area, depth, volume, and persistence of floodplain depression habitat after peak flows recede and relationship with peak flow magnitude.
- Information need 4.** Rates of sediment deposition and erosion in breaches and floodplains.
- Information need 5.** Entrainment and retention of larvae in floodplain nursery habitats as a function of physical characteristics and timing of drift.
- Information need 6.** Temporal relationships between drifting larvae and hydrology during the runoff period with a focus on the peak flow characteristics needed to entrain larvae.
- Information need 7.** The area of terrace and depression floodplains inundated at different flows.
- Information need 8.** What is the optimal combination of flow magnitude and duration to maximize entrainment of razorback sucker larvae.

This proposal presents a plan to fill those information needs. Information will be gathered and synthesized from available peer-reviewed literature and technical reports, and original data will be gathered from the sources needed. It is anticipated that original data analyses will include simulations to assess entrainment rates of larvae into flood plain wetlands under different hydrologic regimes, focusing on flow frequency, magnitude, and duration in relation to timing of reproduction of razorback suckers. The report is expected to contain a synthesis of available information on flood plain connection and inundation related to flow frequency, magnitude, and duration, with a goal of maximizing entrainment of early life stages of razorback sucker larvae. The report will be useful to evaluate effectiveness of existing flow and temperature recommendations, and will identify possible strategies to enhance of those recommendations for flood plain wetland habitat management and for conservation and recovery of razorback sucker in the middle Green River, Utah. I also present investigator qualifications, anticipated collaborations with other scientists, a schedule for work, and expected report outcomes.

Introduction

Razorback sucker, *Xyrauchen texanus*, is a relatively long-lived member of the family Catostomidae (Minckley 1983; McCarthy and Minckley 1986; Bestgen 1990; Minkley et al. 1991; Bestgen et al. 2002; Arizona Game and Fish Department 2002). Endemic razorback sucker was formerly widespread throughout warmwater reaches of the Colorado River Basin but its current range is much reduced due to negative effects of physical habitat alteration and introduction and proliferation of non-native fishes. Due to declines in distribution and abundance of razorback sucker, the species was federally listed as endangered in 1991 (U.S. Fish and Wildlife Service 1991). Substantial populations (e.g., > a couple hundred individuals) of razorback sucker in the lower Colorado River Basin are presently restricted to Lake Mohave Reservoir and Lake Mead Reservoir (Bestgen et al. 2002, Marsh et al. 2003). Larger populations in the Green and Colorado rivers in the Upper Colorado River Basin also exist, a result of stocked hatchery fish (Bestgen et al. 2002).

Flood plain wetlands are presumed important habitat for early life stages of razorback sucker (Bestgen 1990; Tyus and Karp 1990; Wydoski and Wick 1998; Muth et al. 1998; Lentsch et al. 1996; Modde 1996 et al. 1996; Modde et al. 2001; Bestgen in press). Reproduction by razorback suckers in the middle Green River occurs before or during the ascending limb of the spring hydrograph when water temperatures are 10–18°C; presence of razorback sucker larvae in the system during rising flows offers the opportunity for their entrainment into flood plain habitats that are warm, food-rich and may promote higher survival of larvae and recruitment to juvenile and adult life stages (Modde 1996; Muth et al. 1998; Bestgen et al. 2002; Bestgen in press).

Study Area

The Green River study area is near the town of Vernal in northeastern Utah (Figure 1, page 15). Flow of the Green River is partially controlled by Flaming Gorge Dam, located near the Utah-Wyoming border. Green River flow is supplemented by tributary flow, particularly that from the Yampa River, which is confluent with the Green River in upstream Dinosaur National Monument. The Green River downstream of the Yampa River is designated critical habitat for recovery of the razorback sucker (USFWS 1991, USFWS 2002). The flow pattern of the Green River near Jensen, Utah, is dominated by a large spring peak generated from snowmelt runoff in the headwaters of the Green and Yampa rivers, and has a relatively low base flow during the rest of the year. The middle Green River between Split Mountain (River Kilometer (RKM) 513) and the confluence of the White River (RKM 396) is an alluvial reach with many well-developed flood plain areas thought important for survival of larvae and recruitment, as well as razorback sucker spawning areas. The two known spawning bars in this reach are at RKM 500.9 (Razorback Bar) and RKM 494.8 (Escalante Spawning Bar). Over the course of the study, five flood plain sites were sampled. Flood plain sites ranged from upstream Thunder Ranch (RKMM 491.7), downstream to Leota wetland number 7 (L-7, RKM 414.9) on the Ouray National Wildlife Refuge.

Proposal Justification

Two main management actions initiated by the Upper Colorado River Basin Endangered Fishes Recovery Program (Program) are responsive to the need to increase flood plain wetland habitat availability for early life stages of razorback sucker. The first was a program to identify key flood plain wetlands of the Upper Colorado River Basin (Irving and Burdick 1995). High priority areas (e.g. depression wetlands) identified were downstream of known or suspected razorback sucker spawning areas in the middle Green River, located at Razorback Bar (RKM 500.9), and Escalante Spawning Bar (RKM 494.8), which may enhance entrainment of drifting larvae into flood plain wetlands (Karp and Tyus 1990; Modde et al. 1996; Muth et al. 2000, Bestgen et al. 2002, Valdez and Nelson 2004). Upon identifying high priority flood plain areas, efforts were made to increase river connection and functioning of flood plain habitats via removal of levees (Birchell et al. 2002). Eight flood plain levees were breached in 1997 and 1998.

A second main management action to increase flood plain wetland habitat availability for early life stages of razorback sucker was to implement flow recommendations to enhance river-flood plain connections in the Middle Green River, Utah (Muth et al. 2000). This was needed because spring discharge levels of the Green River have been reduced due to impoundment and storage of flows in Flaming Gorge Reservoir. Specifically, recommendations implemented were designed to match spring peak and post-peak flow of the mostly unregulated Yampa River with releases from Flaming Gorge Dam, to increase the frequency and duration of flood plain wetland connections. Recommendations sought to increase those connections mainly in average, moderately wet, or wet hydrologic conditions (Muth et al. 2000) because flows in moderately dry or dry years are usually insufficient to achieve substantial river-flood plain connections.

Flow recommendations list uncertainties regarding the response of native fishes to certain flow and temperature regimes (Muth et al. 2000). Because provision of flood plain habitat to benefit native fishes is mainly an hypothesis, research and monitoring is ongoing to test that hypothesis. Some user groups have questioned the need for increased flows or suitability of release durations to link the Green River with flood plain wetlands, especially in average flow years. Recommendations in average hydrologic conditions, which occur on average in about 4 of every 10 years (40% of the time), call for flows in Reach 2 of the middle Green River near Jensen, Utah, to reach $\geq 527 \text{ m}^3/\text{sec}$ ($18,600 \text{ ft}^3/\text{sec}$) in 1 of 2 average flow years, and that flow should be maintained for at least 2 weeks in 1 of every 4 years. No recommendations were made for the upper limit of any peak flow under any hydrologic condition because a greater extent of flood plain inundation was viewed as beneficial to native fishes. The average hydrologic condition recommendations were questioned mainly because lowering or removal of levees may enhance riverine connections sufficiently without the need for Flaming Gorge Dam flows of the magnitude or duration forwarded in recommendations.

Information to guide management of Green River flood plain wetlands for razorback sucker recruitment is extensive but a single synthesis of that information does not exist. A synthesis would be useful to integrate biological and physical information that will assist managers in efforts to increase recruitment of early life history stages of razorback sucker and, ultimately, recover the species. The Funding Opportunity Announcement listed eight specific hypotheses or information needs that need to be addressed by the synthesis report. Below, I list those eight items and outline a plan to fulfill those needs.

Proposal Elements

Information need 1. Flow and stage at which floodplains with levee breaches become sufficiently inundated to provide nursery habitat for razorback suckers; and

Information need 7, The area of terrace and depression floodplains inundated at different flows.

Information to understand flow and river stage needed to inundate levee breaches and their respective flood plain is contained in a number of sources and will be summarized for managed wetlands in the middle Green River (Muth et al. 2000; Valdez and Nelson 2004, Tetra Tech 2005, Hedrick et al. 2008, observations of investigators). Variation in floodability at a given river stage has been documented (Hedrick et al. 2008), and will be described and prescriptions for management of factors affecting floodability (e.g., breach sedimentation) will be reported. River stage needed to flood wetlands other than those with breaches, including terraces and depression wetlands, will also be assessed to the extent possible and as resources permit and will include estimates of area, depth, and volume, and how those spatial parameters vary with different peak and post-peak flows.

Information need 2. Frequency of flood plain inundation relative to the hydrologic cycle.

Frequency of flood plain inundation is dependent on a number of factors, particularly breach and flood plain elevation and river stage (elevation). Thus, river stage needed to effect flood plain inundation is site specific and will be a primary factor in assessing flood plain inundation frequency. Relationships will be developed that describe connections of flow to flood plain areas and the stage needed to flood wetlands under various hydrologic regimes. Degree of inundation of flood plain wetlands and the amount of flow that enters each will vary with river stage, even within the various wet, moderately wet, and average hydrologic conditions described by Muth et al. (2000). Thus, it will be most useful to describe inundation and flow volume passing into flood plain wetlands as a discrete function of flow level, in addition to the broader hydrologic condition categories. If possible, functional statistical relationships will be developed that predict inundation as a function of river stage. Much of the information needed is in Muth et al. (2000), Tetra Tech (2005), and Hedrick et al. (2008).

However, simply filling a flood plain wetland with water is likely not sufficient to effect recruitment of razorback suckers to contribute to recovery, because natural recruitment is dependent upon entrainment of sufficient numbers of razorback sucker larvae from the river. Entrainment rates of buoyant beads and larvae vary directly as a function of volume of flow into or through wetlands (Hedrick et al. 2008). Wetlands with a single breach opening (e.g., Stirrup, Stewart Lake when outlet is closed, Leota wetland 7 [L-7] when the inlet is not functional), once full, entrain few drifting particles, because water flows into the connected wetland only when river stage is rising and water drains when river stage is falling. Although some entrainment likely occurs in single breach wetlands when flows pulse up and down in the spring runoff period, the amount of flow and particles entrained is low when wetlands are mostly filled (Hedrick et al. 2008). A different situation occurs, of course, when river stage is sufficient to overtop levees

(e.g., High hydrologic flow condition in Flow Recommendations, Muth et al. 2000) , because flow is not constrained from entering the flood plain in just one area.

In contrast to wetlands with a single breach, wetlands with at least one inlet breach and one outlet breach (e.g., Thunder Ranch, Stewart Lake with outlet open, Bonanza) continue to entrain drifting particles when connected to the river regardless of flow level and regardless of whether flows are on the ascending or descending limb of the hydrograph (Hedrick et al. 2008). In flow-through wetlands, amount of flow and particles entrained increases at a faster rate than river stage increases, which makes entrainment much more efficient at higher flows (Hedrick et al. 2008). These factors will be accounted for when considering flows, entrainment rates of larvae, and the potential value of a particular wetland with a particular breach configuration for recruitment and recovery of razorback sucker. Site visits in spring during peak flows may also be considered, if the budget allows.

Information need 3. Area, depth, volume, and persistence of floodplain depression habitat after peak flows recede and relationship with peak flow magnitude.

Area, depth, volume, and persistence of flood plain depression habitat are expected to vary depending on whether a specific habitat was inundated during peak flow, duration of river connection, and ultimately, what river stage is during summer base flows. This is true because most depression wetlands likely communicate to some extent with the river via subterranean flow.

Spatial characteristics of wetlands, their persistence, and water quality will also likely be affected by summer water temperatures, which clearly play a role in understanding if a particular wetland is suitable for rearing razorback suckers. An additional factor to consider is the effect of winter conditions on survival of razorback suckers entrained into the wetland the previous spring. If razorback suckers entrained in spring grow and survive through summer, only to die in winter because post-river-connection conditions are not suitable, then little has been gained.

Post-peak spatial characteristics of wetlands, their persistence, and water quality will be assessed from aerial photographs, reports (Birchell et al. 2002, Christopherson et al. 2004, Modde and Haines 2005, Tetra Tech 2005, other surveys), and observations from investigators familiar with these wetlands (T. Modde and B. Haines, U. S. Fish and Wildlife Service, Vernal, Ouray National Wildlife Refuge personnel, K. Christopherson and T. Hedrick, Utah Division of Wildlife Resources). The author maintains good working relationships with those investigators working in the area, which will promote such interactions. Site visits may also be attempted to better understand spatial dynamics of wetlands in post-peak flow periods, if the budget allows.

Information need 4. Rates of sediment deposition and erosion in breaches and floodplains.

The flood plain is a depositional environment by definition (i.e., flood plain do not typically scour), because as water flows out of the channel, velocity decreases, and suspended load is deposited. The nature of meandering river systems is such that flood plain depressions are largely left abandoned on the river terrace on inside meander bends, with channel scouring and lateral migration occurring on the outside of meander bends. Once abandoned by the river channel, flood plain wetlands typically increase in distance from the river as channel migration proceeds, and wetlands are inundated only when river flows are sufficient to allow it. Areas near

river margins at high flows (breach entrances) are also usually depositional environments because as high spring flows recede, nearshore areas become slack water and sediment in suspension or moving as bed load is deposited. Thus, sediment deposition and erosion rates in breaches and flood plain wetlands is largely a function of the amount of flow entrained into the breach and wetland.

Rates of sediment deposition in flood plain wetlands should be straightforward and based largely on the amount of water entrained on an annual basis and the suspended sediment concentration present in those river flows. Sediment concentrations vary with river stage, basin runoff source, time relative to hydrograph position (ascending flows typically have more suspended load than descending flows) and other factors and data should be available from various U.S. Geological Survey flow gauge records and reports. It is anticipated that flow-through wetlands will have higher deposition rates because of the larger amount of water flowing through them on an annual basis, which has consequences for wetland sedimentation and filling over time. Single breach wetlands will have less sediment deposition and longer life, but have the aforementioned disadvantages of potentially lower entrainment rates.

Sediment deposition in the wetland breach and in the wetland will also occur as a result of breach downcutting during initial inundation, and potential for bedload movement into the breach. Most deposition occurs close to the breach because flow velocity declines quickly away from the breach. Bedload movement rates relative to flow velocity in breaches can be estimated, if the source sediment (sand) is proximal to the breach.

Estimation of sedimentation rates in breaches is less straightforward. This is because near shore sedimentation rates may be affected by breach entrainment flow magnitude as well as river flow stage, breach position relative to the river thalweg (e.g., inside or outside meander bend, most are on inside, again by definition of where wetlands occur), bed load deposition, propensity for vegetative growth in breaches and the species involved, potential sediment deposition from aeolian sources, and many other factors. Available literature, observations of investigators during pre-runoff and post-runoff periods, and possibly, site visits, may yield information on the most important factors affecting sediment deposition rates. Consultation with, and possible site visits by, a knowledgeable fluvial geomorphologist (e.g., Dr. Ellen Wohl, Colorado State University) will also assist with this aspect, if resources allow. This is an important aspect of the study. However, sedimentation issues are largely management ones (e.g., excavate flood plain or breaches if filling), which can be investigated more fully after the main results of this study synthesis are available. Thus, sedimentation issues will receive less attention, and the main issue, resolving appropriate flow magnitude and duration regimes to maximize entrainment of razorback sucker larvae, will receive the most attention.

Information need 5. Entrainment and retention of larvae in floodplain nursery habitats as a function of physical characteristics and timing of drift.

Entrainment and retention of razorback sucker larvae in a flood plain nursery is a complex function of timing of reproduction, timing and magnitude of flows needed to inundate the flood plain, position of production areas of larvae relative to the side of the river the wetland is on (e.g., beads and larvae released at Razorback Bar remain on river right for substantial distances downstream), characteristics of wetland inlets and outlets (flow through wetlands entrain more beads and larvae than single inlet wetlands), wetland flow entrainment rates, wetland elevation relative to flow stage when larvae are available, and many other factors. Much of the information

for assessing this aspect of the request is contained in Hedrick et al. (2008), results and conclusions for which the author of this proposal played a major role in formulating. The author is also very familiar with timing of reproduction of razorback sucker relative to flow and temperature regimes of the Green River. This comes from studies conducted in the Green River since 1992, where light trap samples are used to assess availability of razorback sucker larvae in nearshore areas of the Green River. The author has also conducted studies to age larvae and develop relationships of timing of spawning and hatching of razorback sucker in the Green River (Bestgen 1990, Muth et al. 1998, Muth et al. 2000, Bundy and Bestgen 2001, Bestgen et al. 2002, annual project reports for Recovery Program project 22f, Assessment of endangered fish reproduction in relation to Flaming Gorge flow and temperature recommendations). The insights of the author with regard to these relationships are essential to the success of this study, and include aspects of aging of larvae, which are still ongoing under project 22f.

It should be clarified that there is little information available to understand patterns of drift of razorback sucker larvae in the Green River, which is unlike what the request suggests. Only a few such drift samples were collected early in monitoring studies (e.g., 1992 and 1993, Muth et al. 1998), in addition to some drift sample data collected in the study by Hedrick et al. (2008), which was mostly (except for a single day in 2004) a consequence of releases of hatchery-produced larvae. Data that is available consists of captures of fish in light traps set in low-velocity near shore environments of the Green River (e.g., inlet of Cliff Creek, etc.), which may indicate the timing of availability of larvae to entrain, but nothing about timing or patterns of dispersal. That is why the aging information for early life stages of razorback sucker is critical, as it provides information on timing of hatching and potentially, drift, of larvae in the system.

Timing of reproduction of razorback sucker and availability larvae in the Green River for entrainment will be estimated from light trap captures of fish across a set of years. Size and age information will allow estimation of hatching dates, which when calibrated with water temperature dependent rates of development, will allow prediction of timing of emergence of larvae. Density of larvae will be estimated from limited drift data and will also include a hypothetical range of values that might be achieved with a larger population of adult razorback suckers in the Green River. We can also use drift rates of larvae of Colorado pikeminnow *Ptychocheilus lucius* to put some upper bounds on drift density (Bestgen et al. 1998, Bestgen et al. 2006). Entrainment rates for individual breaches and wetlands estimated by Hedrick et al. (2008) will be used to understand advection rates of larvae into breaches and wetlands. Those entrainment rates will correct for declining density of razorback sucker larvae as they proceed downstream (estimated by surrogate bead captures), again accounting for differences in entrainment into breaches that depend on flow level, breach configuration, assumptions about spawning areas and their proximity to wetlands, flow into wetlands, and connection duration.

A main analysis technique (the objective of Information Need # 8) will be to assume combinations of different rates of drift, with different temporal availability of larvae, under different flow timing, magnitude, and duration conditions. It would also be possible to simulate entrainment rates, with varying flow magnitudes and durations, assuming that Yampa River flow peaks were well before Green River flow peaks. Simulating flow entrainment rates into breaches (and subsequent entrainment rates of larvae) at different flow magnitudes and durations of the Green River, and overlaying different razorback sucker reproduction periodicities and abundances of larvae, will ultimately allow answering the main question of interest in this study, under which

combination of flow level, magnitude, and duration is entrainment of razorback sucker larvae into managed flood plain wetlands maximized.

Retention of larvae in wetlands will be difficult to estimate because no empirical data exists to describe entrainment rates of larvae out of wetlands. I assume larvae will be actively swimming and once entrained, will swim to maintain position within a wetland. In other words, it is assumed that once a larva is entrained into a wetland, it will stay there. It is relatively intuitive that a flow through wetland will act as a filter for razorback sucker larvae and retain them, because larvae will be a long distance from inlet or outlet breaches in such instances and will have a low likelihood of exiting those favorable habitats. For single breach wetlands, it may be possible to estimate an index of retention for larvae entrained, based on potential distance of entrainment into the wetland. It is also intuitive that a larva will have a better chance of remaining in a single breach wetland if it is carried well into the wetland while it is filling, compared to a larvae deposited near the wetland mouth, where water may drain back to the river if river stage drops. Thus, the index could also be based on availability of the larvae relative to when the wetland is filling. For example, in the early season when the wetland is just filling, a higher proportion of larvae might be retained than if a larva drifted by an already full wetland at peak flow.

Although the author can not claim true cost-sharing aspects of this proposal, this study will be supported by other ongoing investigations. These include gathering additional information under project 22f, including the aging of larvae that is ongoing from past years of sampling. That information is essential for developing relationships of availability of larvae for entrainment relative to flow and temperature regimes.

Information need 6. Temporal relationships between drifting larvae and hydrology during the runoff period with a focus on the peak flow characteristics needed to entrain larvae.

Aspects of the temporal relationships between drifting larvae and hydrology have been discussed under **Information need 5**. The main project focus here would be to understand reproduction, a temperature driven process and how that relates to hydrology (e.g., magnitude, duration, etc.), regimes and processes which are not always consistent. These relationships can be described with data collected from project 22f, which again, the author has high familiarity. Aging of larvae will allow estimation of hatching and emergence dates for the reproductive period. The expected outcome is prediction of timing of spawning based on flow and temperature relationships, which will be useful to estimate entrainment rates.

The reality of the situation is that most larvae in most years appear to be available during peak or post-peak periods (Muth et al. 2000, Bestgen et al. 2002, annual reports under 22f), so already changes to the flow patterns might be hypothesized if entrainment is to be maximized. This likely occurred historically as well but was less problematic because the Green River peaked after the Yampa River, which provided a high and long peak. Now we have a moderately high and shorter duration peak, which may limit temporal entrainment opportunities for razorback sucker larvae in the middle Green River.

Information need 7. The area of terrace and depression floodplains inundated at different flows. See **Information Need 1**.

Information need 8. What is the optimal combination of flow magnitude and duration to maximize entrainment of razorback sucker larvae. See **Information need 6.**

Investigator Qualifications and Approach

The author has extensive experience with razorback sucker ecology and the system, beginning with a status review completed in 1990, and many other investigations followed since that time (see bolded publications and technical reports below). He can also claim an excellent record of productivity and a good record for timeliness for other Recovery Program products as well (see list of reports and publications that are relevant to this project, placed in bold in the Literature Cited section). The author has already provided clues, backed with data, to many of the questions posed in the request, and the author also has the highest level of knowledge of critical data needed for this project, so probability of success in fulfilling project objectives and goals is high. The author can also demonstrate good working relationships with the key players needed to make this project a success, or can recruit such to ensure success because he is generally well-respected and productive. The author is also interested in providing the best possible product to meet the needs of the Recovery Program and will be flexible with project objectives and goals.

I anticipate working extensively with many other colleagues to accomplish this work. These include personnel from the U. S. Fish and Wildlife Service, Vernal Office (Dr. Tim Modde and Bruce Haines), the Utah Division of Wildlife Resources (Trina Hedrick and Kevin Christopherson), the Ouray National Wildlife Refuge, U. S. Geological Survey sediment study scientists, Dr. Ellen Wohl, fluvial geomorphologist, Colorado State University, Argonne National Lab scientists (Drs. John Hayse and Kirk LaGory), Recovery Program staff, members of the Biology Committee, and others. It would have been most correct to include them in the proposal as co-authors but time did not allow for that.

Expected Products

A draft report, in Recovery Program format, will be available for review one year from the date of initiation of the work (suggested date of March 2009). The report is expected to contain a synthesis of available information on flood plain connection and inundation related to flow frequency, magnitude, and duration, with a goal of maximizing entrainment of early life stages of razorback sucker larvae. The report will be useful to evaluate effectiveness of existing flow and temperature recommendations (Muth et al. 2000), and will identify possible strategies to enhance effectiveness of those recommendations for flood plain wetland habitat management and for conservation and recovery of razorback sucker in the middle Green River, Utah.

Work Schedule

The schedule assumes a start date of 15 April, 2008, and assumes that one year beyond the start date of the project will be available to complete the report.

Objective 1. Gather and assimilate available literature and data sets. These include peer-reviewed literature, technical reports, data for project 22f, entrainment data, sediment and flow data, and anything else deemed useful to the process. 15 April to 15 July 2008.

Objective 2. Complete assembling data and analysis for Information Needs 1, 2, 3 and 7. 15 July to 30 September, 2008.

Objective 3. Complete assembling data and analysis for Information Needs 5, 6, and 8. 30 September to 31 December, 2008.

Objective 4. Attend Biology Committee meeting in November or December 2008.

Objective 5. Complete assembling data and analysis for Information Need 4. January, 2009.

Objective 6. Prepare final report. 1 February to 15 April 2009.

The author commits to attending a Biology Committee meeting at the approximate midpoint of the project (Objective 4) to brief the committee on progress to meet project objectives. The author also thought it would be useful to commit to another meeting to present the final product and answer questions related to findings.

Literature Cited and relevant work by the author (Bold)

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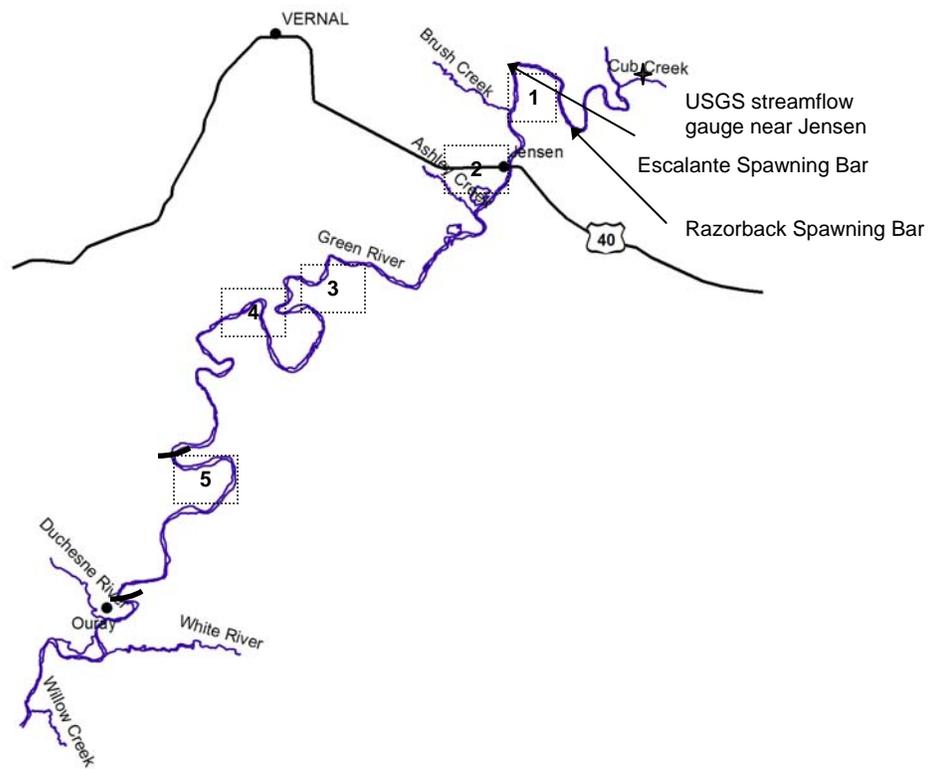


Figure 1. Green River study area from just below the Split Mountain boat ramp to Willow Creek. 1 = Thunder Ranch; 2 = Stewart Lake; 3 = Bonanza Bridge; 4 = The Stirrup; 5 = Leota L7. Map courtesy Bureau of Land Management, Vernal office.

Budget Narrative

Budget narrative for project entitled “Upper Colorado River Recovery Implementation Program-*Floodplain Inundation and Entrainment Studies*”

Below is a table that identifies budget information requested in the Announcement. This budget was constructed in accordance with the guidelines forwarded in the Announcement. If the Recovery Program requires more definitive answers to some hypotheses described in this study (e.g., sedimentation issues, more original data), consideration should be given to providing additional funding to accomplish those aspects.

Fringe rates are 22.8% for the Principal Investigator, 14.3% for technicians.

Mileage rates are \$0.58/mile

Overhead rate of 17.5% is the CESU rate

Per diem is \$35.00/day

Item	Units	Cost/unit		Total cost
<u>Salaries</u>				
Principal investigator, Bestgen, (months)	4.4	7415		\$32,626
Technician, persons not determined (days)	97.5	13.5		\$1,316
Federally Approved Fringe Rate (22.8% for PI, 14.3% for Technician)				\$7,627
			subtotal	\$41,569
<u>Travel</u>				
(2 trips to Grand Junction, CO, Bio Comm. Mtg., for principal investigator)				
Per diem (d)	4	35		\$140
Mileage (miles), 2 trips @ 598 miles each x 0.58/mile	1196	0.58		\$694
Motel (nights), 1 night/trip	2	75		\$150
			subtotal	\$984
			subtotal	\$42,553
Overhead (17.5% under CESU)				\$7,447
			TOTAL	\$50,000