DETERMINING DAILY GROWTH RATES OF LARVAL COLORADO PIKEMINNOWAND RAZORBACK SUCKER IN THE SAN JUAN RIVER

FISCAL YEAR 2018 SCOPE OF WORK

SUBMITTED TO THE SAN JUAN RIVER BASIN RECOVERY IMPLEMENTATION PROGRAM

FROM

AMERICAN SOUTHWEST ICHTHYOLOGICAL RESEARCHERS, L.L.C. (*ASIR*)
800 ENCINO PLACE NE
ALBUQUERQUE, NEW MEXICO 87102-2606
505.247.9337 (VOICE) 505.247.2522 (FACSIMILE)

DETERMINING AGE AND GROWTH AND SPAWN DATES OF LARVAL COLORADO PIKEMINNOW AND RAZORBACK SUCKER IN THE SAN JUAN RIVER AND ASSOCIATIONS WITH ABIOTIC FACTORS

FISCAL YEAR 2018 PROJECT PROPOSAL

Principal Investigators: Michael A. Farrington and Stephani Clark-Barkalow
American Southwest Ichthyological Researchers, L.L.C. (*ASIR*)
800 Encino Place NE
Albuquerque, New Mexico 87102-2606
505.247.9337 (voice) 505.247.2522 (facsimile)
mafarrington@gmail.com; sclarkbark@gmail.com

Introduction

Colorado Pikeminnow *Ptychocheilus lucius* and Razorback Sucker *Xyrauchen texanus* are endemic to the Colorado River Basin including the San Juan River. Both species are federally endangered and are protected under the Endangered Species Act of 1973.

Colorado Pikeminnow is the largest North American member of the family Cyprinidae. Though once prevalent throughout the Colorado River Basin, population declines have been attributed to stream alteration, flow modifications, and competition with, and predation by, nonnative fishes. Colorado Pikeminnow was listed as a federally endangered species in 1967.

Razorback Sucker is one of three members of the family Catostomidae that is endemic to the Colorado River basin. The decline of Razorback Sucker and other native fishes in the Colorado River Basin has been attributed to flow modifications, instream barriers, changes to the thermal regime and channel simplification. In addition, the introduction of non-native fishes may have altered predation dynamics and competition for habitat and resources. Razorback Sucker was listed as an endangered species in 1991.

The San Juan River Basin Recovery Implementation Program (SJRRIP) was established in 1991 with the dual goals of conserving endangered fish in the San Juan River while proceeding with water development. Signatories to the program included the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, U.S. Bureau of Land Management, U.S. Bureau of Indian Affairs, states of New Mexico and Colorado, Jicarilla-Apache Nation, Ute Mountain Ute, Southern Ute, and Navajo Nation Indian tribes.

The San Juan River is the second largest and downstream-most major tributary in the Upper Colorado River Basin. From its origins in the San Juan Mountains of Colorado, it flows about 30 river miles to the New Mexico border, then 200 river miles through New Mexico to near Four Corners (New Mexico, Colorado, Utah, Arizona) where it exits the state. It flows about 120 river miles through Utah from the Four Corners Bridge (U.S. Highway 160) and empties into Lake Powell. The size, location, and ichthyofaunal community of the San Juan River make it an important component of Upper Colorado River basin fish recovery and conservation efforts.

Spawning of Colorado Pikeminnow occurs 4–6 weeks after spring high flows (Bestgen et al. 2006) when temperatures are 18–23°C. Adults are capable of long migrations to spawning areas. Spawning typically occurs over cobble or gravel bars. In the San Juan River, spawning by Colorado Pikeminnow was first documented in 1995, with very few larvae collected between 1995 and 2013. The majority (92%) of

Colorado Pikeminnow collected in the San Juan River were collected in 2014 (n =312) and 2016 (n = 548).

Spawning of Razorback Sucker has been associated with the ascending limb of the spring hydrograph, peak spring discharge, and warming river temperatures. Adults congregate in riffles with cobble, gravel, and sand substrates. Spawning of Razorback Sucker coincides with spawning of other native catostomids. Hybridization between Flannelmouth Sucker and Razorback Sucker has been documented where these two species co-occur (Tyus and Karp 1990; Douglas and Marsh 1998). In the San Juan River, spawning by Razorback Sucker was first documented in 1998 (Farrington et al. 2013). Successful spawning of this species has occurred in each of the last 19 years (1998 – 2016).

While considerable work has been done correlating temperature to growth rates, and developing basin specific (i.e. Green River) growth rates for both Colorado Pikeminnow (Schaugaard 1997; Bestgen et al. 2006) and Razorback Sucker (Muth et al.1998; Bestgen et al., 2002; Bestgen 2008; Bestgen et al. 2011) this type of analysis has not been performed for the San Juan River Basin. Previous attempts to apply out-of-basin growth rates and back-calculated dates of hatching and spawning have proven to be a poor fit for San Juan River larval Razorback Sucker. For example, back-calculated spawning dates of Razorback Suckers collected in 2013 begin on December 23, 2012. Mean temperatures recorded at Mexican Hat, Utah between 23 and 31 December 2012 range between 0 and 0.5^{o}C, so we assume that Razorback Suckers were not spawning during December 2012 based on these temperatures. This is a pervasive problem (specimens from 2002 also have back-calculated spawning dates in December of the previous year) observed when using the growth curve developed for use in the Green River. This poor fit has necessitated excluding metalarval and juvenile specimens from back-calculating efforts, as these older life stages suggest spawning by adult Razorback Sucker during periods when abiotic conditions (i.e. temperature) are not suitable. Therefore we know that applying a constant linear growth rate, derived from the Green River, results in the poor fit we observe in the San Juan River. We hypothesize that growth rates are likely non-linear and influenced by temperature. Currently, San Juan River growth rates for both larval Razorback Sucker and Colorado Pikeminnow are unknown, as are the back-calculated spawning dates that rely on growth rate data.

Objectives:

The objectives of this proposed effort are captured under the SJRRIP Long-Range Plan (2016). Specific Actions listed are as follows:

- Action 4.4.1 Describe life history parameters of wild CPM and RBS.
- Action 4.5.1 Annually identify potential project/activities/questions/information needs.
- Action 4.5.2 Implement project/activities necessary to obtain needed information.
- Action 5.2.2 Ensure new information is identified and developed, as necessary to achieve Program goals and Assess Progress Towards Recovery.

Specific objectives are to:

1. Determine daily growth rates of Colorado Pikeminnow and Razorback Sucker.
2. Using San Juan specific growth rates, determine spawning dates for Colorado Pikeminnow and Razorback Sucker.
3. Investigate relationship between fish length and daily age.

4. Investigate relationship between spawning dates of larval Colorado Pikeminnow and Razorback Sucker and Growing-Degree Days (GDD).
5. Investigate relationship between spawning dates and water temperature.
6. Investigate relationship between spawning dates and river discharge.

Objectives 5 and 6 encompass a long-standing research question within the SJRRIP Monitoring Program's Larval Colorado Pikeminnow and Razorback Sucker monitoring survey. This study seeks to "*Determine the spawning periodicity of Colorado Pikeminnow and Razorback Sucker and examine potential correlations with temperature and discharge*".

Study Area:

The study area from which the material to be examined was collected is a 145-mile reach of the San Juan River between Shiprock, New Mexico (RM 147.9) and the Clay Hills Crossing boat landing in Utah (RM 2.9), just upstream of Lake Powell. Suitable specimens for analysis were collected between 2009 and 2017 (Table 1).

Methods:

Laboratory Work:
The proposed study will begin with a null model as follows:

Assumptions for larvae:
a) The first otolith increment forms on the hatch date.
b) Otolith increments are deposited daily post-hatching date.
c) For Razorback Suckers only, specimens examined are not hybrids.

Laboratory studies have confirmed that Colorado Pikeminnow (Bestgen and Bundy 1998) and Razorback Sucker (Bundy and Bestgen 2001) form first otolith increment on the hatch date and deposit daily increments post-hatch.

Assumption for larval age and growth:
a) Larval Colorado Pikeminnow average 5.5 mm total length (TL) at hatching (Bestgen and Williams 1994).
b) Larval Razorback Sucker average 8.0 mm TL at time of hatching (Snyder and Muth 2004).
c) Growth rates will be positively correlated with increasing river temperatures.

Validity of the assumption that growth rates are positively correlated with increasing river temperature will be tested using Pearson's correlation coefficient. Other assumptions will be tested through a thorough examination of pertinent scientific literature. Potential San Juan River hybrid Razorback Sucker were labeled as such during annual processing of samples (W. Howard Brandenburg, pers. comm.) and will not be used for growth rate analysis.

The results from the proposed study will provide previously unknown information about the early life history of larval Colorado Pikeminnow and Razorback Sucker in the San Juan River including daily growth rates that can be used to back-calculate both hatching and spawning dates specific to the San Juan River. In the future, these data could easily be obtained on an annual basis and used to generate a long-term model that could be correlated with other environmental factors and would be of considerable value to resource managers.

Age and growth

Otolith removal and examination will follow the procedures outlined by Secor et al. (1991) and Stevenson and Campana (1992). Sagittal and lapillar otoliths will be dissected from the inner ears of selected specimens and mounted on a glass microscope slide labeled with associated field collection information using Crystalbond 509 thermoplastic cement and a cover slip. Otoliths will be viewed under a Zeiss Axioskop 2 MAT 100-1,000X compound microscope using oil immersion lenses. Images of otoliths (including images along the z-axis) will be captured electronically with a digital camera for archival purposes. The age (in days) of each fish will be determined, independently, by two readers counting the number of putative daily rings from the primordium to the outer edge of the rostrum. Disagreements between readers will be reconciled during a joint reading.

Specimens used for this study are those collected as part of San Juan River larval Colorado Pikeminnow and Razorback Sucker monitoring project being conducted for the SJRRIP. A minimum of 500 Razorback Sucker and 500 Colorado Pikeminnow larvae will be examined for the period between 2009 and 2017 (Table 1). Prior to 2009 fish were fixed in a 10% solution of formalin and cannot be used for otolith examination. Razorback Suckers specimens examined will be representative of the temporal and spatial attributes associated with capture of larvae. Equal sample sizes will be selected for each year and specimens will be selected from across the sample area and period. Care will be made to select larvae representative of the different mesohabitats sampled. Because Colorado Pikeminnow were only captured in high numbers in 2014 and 2016, all specimens collected during years without adequate samples will be included in analysis. A subset of specimens from 2014 and 2016 will be selected to provide spatial representation across the river miles sampled and temporal representation of the sampling period each year.

Specimens of both species captured in isolated pool habitats will be excluded from analysis as elevated water temperatures often associated with isolated pools may skew larval growth rates and are not representative riverine and freely accessible habitat growth rates.

Daily growth rates between hatching and date of capture for larval Colorado Pikeminnow and Razorback Sucker will be estimated by subtracting mean TL at hatching (Colorado Pikeminnow: 5.5 mm TL; Bestgen and Williams 1994; Razorback Sucker: 8.0 mm; Snyder and Muth 2004) from TL at capture and dividing by the age of the specimen (in days) as determined by otolith examination.

Year	# of Razorback Sucker available	Size range TL mm	# of Colorado Pikeminnow available	Size range TL mm
2009	272	10.1 – 30.2	1	25.2
2010	1,251	9.4 – 30.0	5	12.6 – 21.4
2011	1,065	8.6 – 34.2	29	10.0 – 21.3
2012	1,778	8.0 – 31.8	0	NA
2013	979	9.5 – 49.4	12	14.1 – 28.7
2014	612	8.8 – 35.3	312	8.5 – 20.8
2015	1,205	8.8 – 26.0	24	8.6 – 9.7
2016	824	9.3 – 48.4	548	8.8 – 14.7
2017	To be determined			

Table 1. Razorback Sucker and Colorado Pikeminnow larvae available for growth rate analysis.

Degree Day Information

Assessment of Colorado Pikeminnow and Razorback Sucker growth rates in the San Juan River will be made using degree-day metrics. Correlation between rates of growth and environmental temperatures are well established in ectotherms. Degree-days, the thermal integral used to measure the accumulation of thermal units over a given period, are a reliable predictor of growth and development of larval fishes and have been used to predict embryonic developmental rate of White Sucker, *Catostomus commersonii* (Hamel et al. 1997). Degree-days will be calculated using average daily water temperature obtained at the USGS gage near Bluff, UT (#09379500) using the equation:

$$\int GDD = T_{avg} - T_{base}$$

where T_{avg} is the mean daily water temperature and T_{base} is the temperature below which spawning is not likely to occur. Colorado Pikeminnow and Razorback Sucker spawn at different temperatures, thus T_{base} will be species specific. For Colorado Pikeminnow, $T_{base} = 18°C$ (USFWS 2002a) and for Razorback Sucker, $T_{base} = 14°C$ (USFWS 2002b).

Statistical analyses

Length-age relationships will be compared using a growth curve analysis. Gompertz, logistic, and von Bertalanffy growth curves will be fitted to the datasets to investigate the relationship between age and length (TL). Model selection will be performed using Akaike information criterion (AIC). The selected models will be used to predict age from length of specimens collected during larval surveys and better refine spawn dates of these species.

A multiple linear regression will be used to evaluate significance of variables such as GDD, month, length, discharge, and reach on growth rates of Colorado Pikeminnow and Razorback Suckers in the San Juan River. Model selection will be performed with AIC. Significant variables can be used to fine-tune growth curves. The newly selected models will be used to post-process existing Razorback Sucker (1999–2016) and Colorado Pikeminnow (2003–2016) data sets to generate San Juan River specific hatching and spawning dates. Newly calculated hatching and spawning dates will be compared to dates previously calculated.

Management implications

Current growth rate calculations are performed using growth models calculated from fishes in the Green River. These growth models are a poor fit when used in the San Juan River and produce unfeasible hatch and spawn dates (e.g. spawning in December of previous year). Thus, by using the current Green River growth rate models, key parameters of the life history of San Juan River Colorado Pikeminnow and Razorback Sucker are unknown. Having baseline data regarding larval fish growth, spawning periodicity, and hatching dates for larvae has been used to benefit recovery of endangered species within the Green River Basin, and has helped guide Flaming Gorge dam operations (LaGory et al. 2012, and Bestgen et al. 2011)

This SOW seeks to create a San Juan specific growth model for each species, which will result in accurate determination of hatching and spawning periodicity. This information may used to guide future management actions related to water temperature, flow recommendations and flow releases from Navajo

Dam. It can be used for timing inundation of restored habitats (i.e. RERI Phase III) to maximize retention, growth and survival of endangered fish larvae. Knowledge of spawning periodicity can be used to minimize the impacts of electrofishing during peak spawning activity by Razorback Sucker and Colorado Pikeminnow. Additionally, this SOW seeks to evaluate the impacts of water temperature and other variables on growth rates of larval fishes. Accurate spawning periodicity and knowledge of factors impacting larval growth will help guide management activities to protect early life stages of these species.

Literature Cited

Cesaraccio, C., D. Spano, P. Duce, and R. L. Synder. 2001. An improved model for determining degree-day values from daily temperature data. International Journal of Biometeorology 45:161–169.

Bestgen, K. R., G. B. Haines, and A. A. Hill. 2011. Synthesis of flood plain wetland information: Timing of Razorback Sucker reproduction in the Green River, Utah, related to stream flow, water temperature, and flood wetland availability. Final report. Colorado River Recovery Implementation Program, Denver. Larval Fish Laboratory Contribution 163. 190 pp.

Bestgen, K. R., 2008. Effects of water temperature on growth of razorback sucker larvae. Western North American Naturalist 68:15–20.

Bestgen, K.R., D.W. Beyers, J.A. Rice, and G.B. Haines. 2006. Factors affecting recruitment of young Colorado Pikeminnow: synthesis of predation experiments, field studies, and individual-base modeling. Transactions of the American Fisheries Society 135: 1722–1742.

Bestgen, K. R., G. B. Haines, R. Brunson, T. Chart, M. A. Trammell, R. T. Muth, G. Birchell, K. Christopherson, and J. M. Bundy. 2002. Status of wild Razorback Sucker in the Green River Basin, Utah and Colorado, determined from basin wide monitoring and other sampling programs. Final report. Colorado River Recovery Implementation Program Project No. 22D.

Bestgen, K.R. and J.M. Bundy. 1998. Environmental factors affect daily increment deposition and otolith growth in young Colorado Squawfish. Transactions of the American Fisheries Society 127: 105-117.

Bestgen, K.R. and M.A. Williams. 1994. Effects of fluctuating and constant temperatures on early development and survival of Colorado Squawfish. Transactions of the American Fisheries Society 123: 574–579.

Bundy, J.M., and K.R. Bestgen. 2001. Confirmation of daily increment deposition in otoliths of young Razorback Suckers. The Southwestern Naturalist 46: 34-40.

Douglas, M. E. and P. C. Marsh. 1998. Population and survival estimates of *Catostomus latipinnis* in Northern Grand Canyon, with distribution and abundance of hybrids with *Xyrauchen texanus*. Copeia 1998:915–925.

Farrington, M.A., W. H. Brandenburg, and S. P. Platania. 2013. Colorado Pikeminnow and Razorback Sucker larval fish survey in the San Juan River during 2012. Annual Report. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, NM. 52 pp.

Hamel, P., P. Magnan, M. Lapointe, and P. East. 1997. Timing of spawning and assessment of a degree-day model to predict the in situ embryonic developmental rate of white sucker, *Catostomus commersoni*. Canadian Journal of Fisheries and Aquatic Sciences 54:2040–2048.

LaGory, K., T. Chart, K. Bestgen, J. Wilhite, S. Capron, D. Speas, H. Hermansen, K. McAbee, J. Mohrman, M. Trammell, and B. Albrecht 2012. Study plan to examine the effects of using larval Razorback Sucker occurrence in the Green River as a trigger for Flaming Gorge dam peak releases. Final report. Colorado River Recovery Implementation Program.

Muth, R. T., G. B. Haines, S. M. Meismer, E. J. Wick, T. E. Chart, D. E. Snyder, and J. M. Bundy 1998. Reproduction and early life history of razorback sucker in the Green River, Utah and Colorado, 1992–1996. Final Report of Colorado State University Larval Fish Laboratory to Upper Colorado River Endangered Fish Recovery Program, Denver, CO.

San Juan River Basin Recovery Implementation Program. 2016. Long-range plan. San Juan River Basin Recovery Implementation Program, USFWS, Albuquerque, New Mexico. 70 pp.

Schaugaard, C.J. 1997. The effects of temperature regime and food availability on growth rates on young-of-the-year Colorado Squawfish (Ptychocheilus lucius) in the Green River, Utah. Master's thesis. Utah State University, Logan, UT.

Secor, D.H. Dean, J.M. and E.H. Laban. 1991. Otolith Removal and Preparation for Microstructural Examination: A Users Manual. Technical Publication 1991–01. Belle W. Baruch Institute, University of South Carolina and Electric Power Research Institute.

Snyder, D. E. and R. T. Muth. 2004. Catostomid fish larvae and early juveniles of the upper Colorado River Basin-morphological descriptions, comparisons, and computer-interactive key. Colorado Division of Wildlife Technical Publication No. 42.

Stevenson, D.K. and S.E. Campana, editors. 1992. Otolith microstructure examination and analysis. Canadian Special Publication of Fisheries and Aquatic Sciences 117: 130 pp.

Tyus, H. M. and C. A. Karp. 1990. Spawning and movements of razorback sucker, *Xyrauchen texanus*, in the Green River Basin of Colorado and Utah. The Southwestern Naturalist 35:427–433.

U.S. Fish and Wildlife Service. 2002a. Colorado pikeminnow (Ptychocheilus lucius) Recovery Goals: amendment and supplement to the Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

U.S. Fish and Wildlife Service. 2002b. Razorback sucker (Xyrauchen texanus) Recovery Goals: amendment and supplement to the Razorback Sucker Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

von Bertalanffy, L. 1938. A quantitative theory of organic growth (Inquiries on Growth Laws II). Human Biology 10:181–213.

2018 BUDGET: DETERMINING DAILY GROWTH RATES OF LARVAL COLORADO PIKEMINNOW AND RAZORBACK SUCKER

Based on examination of 1,000 larval specimens
(500 larval Colorado Pikeminnow and 500 larval Razorback Sucker)

Personnel

Laboratory Work

Fisheries Biologist I (110 staff days x 8 hr/day x $57.18).....$ 50,318
Tasks: Material examination/selection, developmental staging, otolith extraction, mounting, aging, photographing, accessioning, data entry, query and review, database development

Office Work (Report Development)
Fisheries Biologist I (40 staff days x 8 hr/day x $57.18).....$ 18,298
Tasks: Data analysis, draft report preparation, post-review redraft and submission, development and submission of formal responses to reviewer comments, meeting development of study presentation for and attendance at annual meetings (Feb and May)

Project Participation
Senior Fisheries Biologist (5 staff days x 8 hr/day x $96.77).....$ 3,871
Tasks: Project coordination, project and data review, data management, report review
Personnel (Laboratory, Office, Oversight): Subtotal .....$ 72,487

Materials and Supplies (open market items)

Microscope maintenance (under-lit bulbs, lens cleaning wipes).....$ 85
Otolith extraction and mounting materials
(insect pins, slides, slide covers, slide storage, Crystalbond™ and solvent) .....$ 1,570
Materials and Supplies: Subtotal .....$ 1,655

Travel and Per Diem

SJRBRIP Meetings

Travel (drive with others).....$ 0
Per Diem - 3 days per trip x 1 staff ($51/day GSA M&IE rate) x 2 trips.....$ 306
Per Diem - 2 hotel days per trip x 1 staff ($91/night GSA lodging rate) x 2 trips.....$ 364
Travel and Per Diem: Subtotal .....$ 670

2018 Project Totals

Personnel: .....$ 72,487

Materials and Supplies: .....$ 1,655
Travel and Per Diem .....$ 670

2018 Scope of Work Total: .....$ 74,812