Notes

Detecting Razorback Suckers Using Passive Integrated Transponder Tag Antennas in the Green River, Utah

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Abstract

In order to increase detections of razorback suckers *Xyrauchen texanus* tagged with passive integrated transponders in the upper Colorado River basin, we deployed two passive instream flat-plate antennas (33 × 68 cm) at a razorback sucker spawning location in the Green River, Utah, during spring of 2012 and 2013. Over the course of 29 d in 2012 and 90 d in 2013, the antennas detected 569 razorback suckers, 19 Colorado pikeminnow *Ptychocheilus lucius*, 16 flannelmouth suckers *Catostomus latipinnis*, and 1 bluehead sucker *Catostomus discobolus*. Despite extensive sampling via boat electrofishing (rafts and hard-bottom boats) and netting (fyke, trammel, and gill) in wetlands that occurred from the 1990s to present in the upper Colorado River basin, a large number of tagged razorback suckers and Colorado pikeminnow, including a fish released in 1996, were detected for the first time by our antennas. Our data indicate that the detectability of razorback suckers, and precision and accuracy of survival and population estimates might be increased significantly with the addition of data gathered by passive instream flat-plate antennas in the Green River.

Keywords: razorback sucker; colorado pikeminnow; PIT tag; antenna; spawn; Green River; Utah

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Introduction

The razorback sucker *Xyrauchen texanus* is a large-bodied catostomid endemic to the Colorado River basin; it is listed as endangered under the Endangered Species Act (ESA 1973, as amended) by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 1991). Factors contributing to their decline include negative effects from dams (population fragmentation, altered hydrography, thermal regime; Carlson and Muth 1993) and predation by nonnative fishes (Bestgen 1990; Minckley et al. 1991). In the upper Colorado River basin (UCRB) in the early 1990s, Modde et al. (1996) estimated the population to be as low as 500 individuals. The U.S. Fish and Wildlife Service collected brood stock from the wild and began stocking razorback suckers in 1981 (Johnson 1985).

The U.S. Fish and Wildlife Service and other collaborators drafted an official recovery plan (U.S. Fish and Wildlife Service 1998) in 1998 that included a stocking program to assist recovery of the razorback sucker. Since 1995, the U.S. Fish and Wildlife Service has stocked more than 200,000 razorback suckers into the UCRB (Zelasko et al. 2010; K. Schnoor, U.S. Fish and Wildlife Service, personal communication). An increase in razorback sucker larvae captured during light trap monitoring was recorded during the last decade by Bestgen et al. (2011), likely as a result of successful spawning by stocked individuals. Nevertheless, razorback sucker capture and recapture data in the UCRB through projects not targeted at studying razorback sucker (e.g., nonnative fish removal and Colorado pikeminnow *Ptychocheilus lucius* population estimates) were not sufficient to produce precise and accurate population and survival estimates using mark–recapture models, and researchers identified the need to obtain more recaptures to increase precision and accuracy of population and survival estimates to aid recovery and

management of the species (Bestgen et al. 2012). Low sample sizes are directly correlated with decreased precision and accuracy (Otis et al. 1978). Our study addressed this need of increasing recapture rates of razorback suckers.

Razorback suckers in the middle Green River were known to congregate and spawn on a gravel bar near Jensen, Utah, known as ''Razorback Bar,'' which has also been referred to as the Escalante (Modde et al. 1996) or Jensen (Tyus and Karp 1990) spawning site. This site had potential to attract many fish that could be recaptured with minimal effort. A radiotelemetry study examined razorback sucker use of Razorback Bar (Modde et al. 2005), but such research required scientists to use electrofishing equipment to capture the species during its spawning season. This sampling technique was thought to potentially discourage razorback suckers from spawning. In order to sample the species while congregated at Razorback Bar, with the intent to increase razorback sucker detections, but not discourage spawning, we used an alternative method.

A passive instream flat-plate antenna (PIA) detects fish that are tagged with passive integrated transponder tags (PIT; hereafter, all references to tags refer to this type of tag) when tags are within a certain distance of the PIA. This technology allows tagged fish to be detected without being handled. Webber et al. (2012) successfully sampled bluehead suckers *Catostomus discobolus* in the Weber River, Utah, using PIAs, documenting 58 of 98 tagged fish during a 6-mo period by placing PIAs in an area with a known high concentration of tagged fish. Similarly, since Razorback Bar supported high concentrations of razorback suckers during the spring (Modde et al. 2005), we hypothesized that PIAs could be used effectively to detect them without using electrofishing equipment.

In the UCRB, researchers tagged razorback suckers prior to stocking. In 2012 and 2013 in the middle Green River near Razorback Bar, researchers handled 858 adult razorback suckers, of which 63 were not tagged (7.3%; U.S. Fish and Wildlife Service, unpublished data). A small percentage of stocked razorback suckers likely lose their tags, as seen with similar species ($<$ 3%; Ward and David 2006; Ward et al. 2008). Most razorback suckers present at Razorback Bar would be tagged since little natural recruitment has been documented in recent years (Webber 2013). Although our focus was detecting razorback suckers, there was the potential to detect other tagged fishes, including Colorado pikeminnow, another endangered fish endemic to the Colorado River basin. In contrast to razorback suckers, in the UCRB Colorado pikeminnow are not stocked, but are wild-produced fish and are tagged only when captured in the wild.

The objectives of this study were 1) to determine if PIAs could detect tagged razorback suckers at Razorback Bar, and if so 2) to use these data to better understand the razorback sucker spawning population at Razorback Bar and provide the data to researchers to increase precision and accuracy of future survival estimates, as recommended in Bestgen et al. (2012).

Methods

Razorback Bar is located at approximately river kilometer 504 of the Green River (distance upstream of the confluence with the Colorado River) along the eastern channel as the river flows around a large island. We deployed two PIAs (33 $\times$ 68 cm) approximately 100 m apart at Razorback Bar on 30 March 2012. Each PIA was connected to a Biomark FS2001F-ISO reader powered by one 12 V deep-cycle battery, which was housed in a secured streamside box. A tag had to be within approximately 30 cm of a PIA to be detected, and each of the cords from the reader to the PIA measured 15 m. The spawning area at Razorback Bar during the study consisted of approximately 2 ha. We secured each PIA with four 60-cm rebar stakes. We buried the cable from the reader to the PIA approximately 15 cm deep, and secured the cable to a 60-cm stake every 1.5 m. On 30 March 2012, the PIAs were secured on dry ground in gravel where we expected the razorback suckers to spawn after water levels increased, and water levels needed to rise 15 cm to inundate them. We programmed the readers to record the time and date of each detection and exclude the same fish from being detected more than once within a 10-s period. We replaced the batteries every 7 d.

We used knowledge gained from previous studies of reproductive ecology of razorback suckers to determine timing for deploying PIAs in the Green River. Razorback suckers spawn in the Green River during the ascending limb of the hydrograph, usually from late April to early June (Tyus 1987; Tyus and Karp 1990; Modde and Irving 1998); however, 2012 was a drought year, which resulted in lower than average peak flows. During April 2012, the PIAs were inundated only twice by a few centimeters, and by early May we suspected razorback suckers were spawning. We relocated the PIAs into the water at a depth of approximately 60 cm on 7 May 2012 and began detecting tags that day. We removed the readers as flows increased on 21 May to prevent equipment loss due to high-water conditions. We reinstalled them on 25 May after flows receded. Detections continued from 25 May to 1 June 2012. We did not detect fish from 2 June to 7 June 2012, and removed the equipment 7 June. The PIAs were operational for a total of 29 d in 2012.

On 3 April 2013, we deployed two PIAs on Razorback Bar at the same location as in 2012. Methods of installation were the same except we installed solar panels to continuously power the batteries and we built a 2-m-tall platform to hold the battery, solar panel, and reader of the downstream PIA using metal fence posts and plywood to keep the system above high water. The two PIAs functioned continuously from 3 April to 1 July 2013.

Results

We detected 59 unique tags on the PIAs in 2012, and 553 in 2013. Researchers in the UCRB typically report data from tagged fish to a database managed by the U.S. Fish and Wildlife Service. From a database query, we discovered that 569 fish were razorback suckers, 19 were

Colorado pikeminnow, 15 were flannelmouth suckers *Catostomus latipinnis*, one was a bluehead sucker, and eight were found in the database, but did not have information on species (Data S1, Data S2, Data S3, Data S4, *Supplemental Materials*).

Tag history provided information on fish detection across years, fish age or year of initial tagging, whether they had been handled by researchers since tagging, and movement history. Of the 59 fish detected by the PIAs in 2012, only three razorback suckers were detected again by the PIAs in 2013. The oldest razorback sucker detected at Razorback Bar was 15 y old, and the youngest were 3-y-old fish that were stocked in 2011and detected in 2013. Researchers recaptured forty razorback suckers using electrofishing equipment one time in between stocking and detection on a PIA, but for the remaining 529 razorback suckers (93%), detection by a PIA was the first time they were detected since being stocked. The farthest distance from Razorback Bar that a razorback sucker was stocked was at river kilometer 193, which represents an upstream movement of 311 km. Most razorback suckers (468) were detected by a PIA during only 1 d of the study; however, one razorback sucker was documented during 6 d spanning a 13-d period. The 19 Colorado pikeminnow detected at the PIAs were initially tagged between 1996 and 2013. Fifteen Colorado pikeminnow were tagged in the Green River and one moved upstream 168.3 km. Three were tagged in the Yampa River and one moved downstream 202.3 km. One was tagged 22 km up the White River and traveled 130 km to Razorback Bar.

Discussion

We accomplished our first objective of detecting razorback suckers at Razorback Bar using PIAs. Our results indicate that the use of PIAs can greatly increase the rates of detection over active sampling alone for razorback suckers at Razorback Bar. Moreover, we could have detected more razorback suckers potentially with more PIAs or a more robust antenna system. We detected most razorback suckers on Razorback Bar during only 1 d in this study. However, Modde et al. (2005) reported razorback suckers staying near Razorback Bar for several weeks at a time during the spring. The PIAs covered a small area, and it is likely that some tagged razorback suckers visited Razorback Bar but were not detected.

We believe that the razorback suckers detected in this study were congregated to spawn, but we could not verify spawning status because we did not capture any individuals. Females become sexually mature when 3–4 y old (McAda and Wydoski 1980; Minckley 1983). The majority of the razorback suckers detected in this study were $\geq$ 4 y old, and they were detected during the spawning season at a location where previous investigators have documented spawning fish.

We believe the PIAs functioned until the end of the spawning season. It appears that the razorback suckers left Razorback Bar in early June in 2012 and mid-June in 2013. In 2012, the last detection occurred on 1 June, and we kept the PIAs functioning on Razorback Bar until 7 June without any additional detection. In 2013, the last detection occurred on 15 June, and we kept the PIAs functioning until 1 July without any additional detection.

In 2013, we built a platform to hold the battery and reader so high water would not damage the equipment. This platform, however, might not be stable enough to secure the equipment against large drifting debris. Longer cords would allow the readers to be above high water, but longer cords also decrease the read range of the antennas. For future studies at Razorback Bar, researchers should consider using a more robust antenna system.

Survival rate estimates on razorback suckers in the UCRB might have been underestimated in recent years, and could have benefitted from additional passive detections from PIAs. First-year survival for stocked razorback sucker in the UCRB was estimated at 5% (Zelasko et al. 2010). This estimated rate was derived with active capture data, but passive detection data (i.e., data gathered by PIAs) were not available for the analysis. In this study, 93% of razorback suckers had not been detected by researchers since they were stocked up to 13 y prior to our study. Schooley et al. (2008) used trammel netting and electrofishing to generate survival rates of 9% or less on razorback suckers in the lower Colorado River, but these rates increased to 39% with the addition of recapture data from PIAs. Adding passive detection data to active sampling data has several benefits. Fish captured using active sampling may be released harmed, and survival of these fish may be poorer than fish that are detected using passive sampling (i.e., they are not handled), thus making future capture probability poorer. Actively sampled fish may learn to avoid the nets or electrofishing equipment they were captured with, and will thus be less likely to be recaptured. Using PIAs may allow researchers to detect tagged fish that otherwise would be more difficult to capture using active sampling methods. Other studies have also produced higher survival rates when passive detections were included with active sampling data (Hewitt et al. 2010; Webber et al. 2012). Researchers should consider known areas with high concentrations of razorback suckers, such as tributary confluences or a recently discovered spawning location in the lower White River (Webber et al. 2013), as locations where PIAs could be used to increase detections. We encourage researchers, especially in the UCRB, to develop tools and techniques to collect and use more passive recapture data for recovery of endangered fishes, especially razorback sucker and Colorado pikeminnow.

Supplemental Material

Please note: The *Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Reference S1. Bestgen KR. 1990. Status review of the razorback sucker, *Xyrauchen texanus*. Colorado State University, Larval Fish Laboratory Contribution 44, Fort Collins.

Found at DOI: http://dx.doi.org/10.3996/122012-JFWM-104.S1 (870 KB PDF).

Reference S2. Bestgen KR, Haines GB, Hill AA. 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 plain wetland availability. Colorado State University, Larval Fish Laboratory Contribution 163, Fort Collins.

Found at DOI: http://dx.doi.org/10.3996/122012-JFWM-104.S2; also available at http://www.coloradoriverrecovery.org/documents-publications/technical-reports/hab/Bestgenetal.2011FloodPlainSynthesisFinalReport.pdf (1437 KB PDF).

Reference S3. Bestgen KR, Zelasko KA, White GC. 2012. Monitoring reproduction, recruitment and population status of razorback suckers in the upper Colorado River basin. Report to the Upper Colorado River Endangered Fish Recovery Program. Larval Fish Laboratory Contribution 170, Colorado State University, Fort Collins.

Found at DOI: http://dx.doi.org/10.3996/122012-JFWM-104.S3; also available at http://www.coloradoriverrecovery.org/documents-publications/technical-reports/rsch/BestgenetalProject159RZBMonitoringOctober2012Final.pdf (802 KB PDF).

Reference S4. McAda CW, Wydoski RS. 1980. The razorback sucker, *Xyrauchen texanus*, in the upper Colorado River basin, 1974–76. U.S. Fish and Wildlife Service Technical Papers 99, Washington, D.C.

Found at DOI: http://dx.doi.org/10.3996/122012-JFWM-104.S4; also available at http://www.nativefishlab.net/library/textpdf/15245.pdf (773 KB PDF)

Reference S5. Schooley JD, Kesner BR, Campbell JR, Barkstedt JM, Marsh PM. 2008. Survival of razorback sucker in the lower Colorado River, Final Report. Agreement Number 06-FC-30-0002. Arizona State University, Tempe.

Found at DOI: http://dx.doi.org/10.3996/122012-JFWM-104.S5 (1491 KB PDF).

Reference S6. U.S. Fish and Wildlife Service. 1998. Razorback sucker (*Xyrauchen texanus*) recovery plan. U.S. Fish and Wildlife Service, Region 6, Denver, Colorado.

Found at DOI: http://dx.doi.org/10.3996/122012-JFWM-104.S6 (736 KB PDF)

Data S1. Spreadsheet containing raw data of all passive integrated transponder tag numbers obtained by passive instream flat-plate antennas at the Razorback Bar spawning location in the Green River, Utah, during 2012. Sheet 1 column A is date, column B is time, and column C is tag number; sheet 2 column A is date, column B is time, and column C is tag number.

Found at DOI: http://dx.doi.org/10.3996/122012-JFWM-104.S7 (18 KB XLSX)

Data S2. Spreadsheet used to obtain demographics for razorback sucker *Xyrauchen texanus* and Colorado pikeminnow *Ptychocheilus lucius* based off detections from fish encountered on passive integrated transponder tag antennas at the Razorback Bar spawning location in the Green River, Utah, during 2012. Sheet 1 column A is date, column B is time, column C is tag number, and column D is number of days detected at Razorback Bar during the study. Sheet 2 column A is date, column B is time, and column C is tag number; the remaining columns are manipulations of columns A–C to obtain demographic data. Sheets labeled ''stocking event,'' ''river captures,'' ''tag distribution without data,'' and ''capture history'' are data from a query from the database managed by the U.S. Fish and Wildlife Service used to gather demographic data.

Found at DOI: http://dx.doi.org/10.3996/122012-JFWM-104.S8 (39 KB XLSX)

Data S3. Spreadsheet containing raw data of all passive integrated transponder tag numbers obtained by passive instream flat-plate antennas at the Razorback Bar spawning location in the Green River, Utah, during 2013. Sheet labeled ''upper antenna'' has columns of date, time, tag number, and species. Sheet labeled ''lower antenna'' has all data gathered by two antennas, then organized to make a query to obtain demographics of fishes detected. Sheet labeled ''Baeser Fish'' is a list of razorback suckers detected from the Razorback Bar antenna study, which originated from a wetland on the Green River known as Baeser Bend. Sheet labeled ''2012 and 2013 matches'' is a list of tag numbers detected in 2012 and 2013 at Razorback Bar. Sheet 1 column A is each individual tag number detected, column B is date and time, column C is number of times each tag number was detected in this study, and column D is number of days each tag number was detected in this study.

Found at DOI: http://dx.doi.org/10.3996/122012-JFWM-104.S9 (188 KB XLSX)

Data S4. Spreadsheet used to obtain demographics for razorback sucker *Xyrauchen texanus* and Colorado pikeminnow *Ptychocheilus lucius* based off detections from fish encountered on passive integrated transponder tag antennas at the Razorback Bar spawning location in the Green River, Utah, during 2013. Sheet 1 column A is the list of tag numbers sent to the database manager who manages tag information for the Upper Colorado River Endangered Fish Recovery Program. Sheet labeled ''query column A'' is the same list from Sheet 1 column A manipulated by the database manager. Sheet labeled ''CS river capture'' records is a list of Colorado pikeminnow detected at the antennas during the study, and the encounter history of these fish from previous investigators. Sheet labeled ''RZ stock records'' is a list of razorback suckers detected on the antennas during this study and their associated stocking information. Sheet labeled ''graphs'' is information organized to construct a graph to show ages of fish detected at Razorback Bar. Sheet labeled ''RZ capture data'' is a list of razorback suckers that were detected between stocking and detection by antennas in this study, and their associated handling records. Sheet labeled ''distribution records'' is a sheet with tag numbers representing tags that were detected on the antennas in this study and have a record of being distributed to researchers, but have no other information available in the database.

Sheet 2 is a list of individual tag numbers detected by the antennas during the study. Sheet labeled "RZ wetlands" is a list of razorback suckers stocked into wetlands near the Green River that were detected by the antennas during this study.

Found at DOI: http://dx.doi.org/10.3996/122012-JFWM-104.S10 (113 KB XLSX)

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References

Bestgen KR. 1990. Status review of the razorback sucker, *Xyrauchen texanus*. Colorado State University, Larval Fish Laboratory Contribution 44, Fort Collins (see *Supplemental Material*, Reference S1, http://dx.doi.org/10.3996/122012-JFWM-104.S1).

Bestgen KR, Haines GB, Hill AA. 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 plain wetland availability. Colorado State University, Larval Fish Laboratory Contribution 163, Fort Collins (see *Supplemental Material*, Reference S2, http://dx.doi.org/10.3996/122012-JFWM-104.S2); also available: http://www.coloradoriverrecovery.org/documents-publications/technical-reports/hab/Bestgenetal.2011FloodPlainSynthesisFinalReport.pdf (March 2014).

Bestgen KR, Zelasko KA, White GC. 2012. Monitoring reproduction, recruitment and population status of razorback suckers in the upper Colorado River Basin. Report to the Upper Colorado River Endangered Fish Recovery Program. Larval Fish Laboratory Contribution 170, Colorado State University, Fort Collins (see *Supplemental Material*, Reference S3, http://dx.doi.org/10.3996/122012-JFWM-104.S3); also available: http://www.coloradoriverrecovery.org/documents-publications/technical-reports/rsch/BestgenetalProject159RZBMonitoringOctober2012Final.pdf (March 2014).

Carlson CA, Muth RT. 1993. Endangered species management. Chapter 15, pp. 355–381 in Kohler CC, Hubert WA, editors. Inland fisheries management. Bethesda, Maryland: American Fisheries Society.

[ESA] U.S. Endangered Species Act of 1973, as amended, Pub. L. No. 93-205, 87 Stat. 884 (Dec. 28, 1973). available at: http://www.fws.gov/endangered/esa-library/pdf/ESAall.pdf.

Hewitt DA, Janney EC, Hayes BS, Shively RS. 2010. Improving inferences from fisheries capture–recapture studies through remote detection of PIT tags. Fisheries 35(5):15.

Johnson JE. 1985. Reintroducing the natives: razorback sucker. Proceedings of the Desert Fishes Council 13–15:73–79.

McAda CW, Wydoski RS. 1980. The razorback sucker, *Xyrauchen texanus*, in the upper Colorado River basin, 1974–76. U.S. Fish and Wildlife Service Technical Papers 99, Washington, D.C. (see *Supplemental Material*, Reference S4, http://dx.doi.org/10.3996/122012-JFWM-104.S4); also available: http://www.nativefishlab.net/library/textpdf/15245.pdf (March 2014).

Minckley WL. 1983. Status of the razorback sucker, *Xyrauchen texanus*, in the lower Colorado River basin. Southwestern Naturalist 28:165–187.

Minckley WL, Marsh PC, Brooks JE, Johnson JE, Jensen BL. 1991. Management toward recovery of the razorback sucker. Chapter 17, pp. 303–357 in Minckley WL, Deacon JE, editors. Battle against extinction: native fish management in the American west. Tucson, Arizona: University of Arizona Press.

Modde T, Bowen ZH, Kitcheyan DC. 2005. Spatial and temporal use of a spawning site in the middle Green River by wild and hatchery-reared razorback suckers. Transactions of the American Fisheries Society 134:937–944.

Modde T, Burnham KP, Wick EJ. 1996. Population status of the razorback sucker in the middle Green River. Conservation Biology 10:110–119.

Modde T, Irving DB. 1998. Use of multiple spawning sites and seasonal movements of razorback sucker in the Green River, Utah. North American Journal of Fisheries Management 18:318–326.

Otis DL, Burnham KP, White GC, Anderson DR. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monographs 62.

Schooley JD, Kesner BR, Campbell JR, Barkstedt JM, Marsh PM. 2008. Survival of razorback sucker in the lower Colorado River, Final Report. Agreement Number 06-FC-30-0002. Arizona State University, Tempe (see *Supplemental Material*, Reference S5, http://dx.doi.org/10.3996/122012-JFWM-104.S5).

Tyus HM. 1987. Distribution, reproduction and habitat use of the razorback sucker in the Green River, Utah, 1979–1986. Transactions of the American Fisheries Society 116:111–116.

Tyus HM, Karp CA. 1990. Spawning and movements of razorback sucker, *Xyrauchen texanus*, in the Green River basin of Colorado and Utah. Southwestern Naturalist 35:427–433.

U.S. Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants: the razorback sucker (*Xyrauchen texanus*) determined to be an endangered species. Federal Register 56:54957–54967.

U.S. Fish and Wildlife Service. 1998. Razorback sucker (*Xyrauchen texanus*) recovery plan: U.S. Fish and Wildlife Service, Region 6, Denver, Colorado (see *Supplemental Material*, Reference S6, http://dx.doi.org/10.3996/122012-JFWM-104.S6).

Ward DL, Childs MR, Persons WR. 2008. PIT tag retention and tag induced mortality in juvenile bonytail and Gila chub. Fisheries Management and Ecology 15:159–161.

Ward DL, David J. 2006. Evaluation of PIT tag loss and tag-induced mortality in bluehead sucker (*Catostomus discobolus*). Arizona–Nevada Academy of Science 38:74–76.

Webber PA. 2013. Juvenile razorback suckers documented in wetlands in the Green River, Utah. Southwestern Naturalist 58:368–369.

Webber PA, Bestgen KR, Haines GB. 2013. Tributary spawning by endangered Colorado River basin fishes in the White River. North American Journal of Fisheries Management 33:1166–1171.

Webber PA, Thompson PD, Budy P. 2012. Status and structure of two populations of bluehead suckers (*Catostomus discobolus*) in the Weber River, Utah. Southwestern Naturalist 57:267–276.

Zelasko KA, Bestgen KR, White GC. 2010. Survival rates and movement of hatchery-reared razorback suckers in the upper Colorado River Basin, Utah and Colorado. Transactions of the American Fisheries Society 139: 1478–1499.