AN AUGMENTATION PLAN FOR RAZORBACK SUCKER IN THE SAN JUAN RIVER

An addendum to the ***Five-Year Augmentation Plan For Razorback Sucker In The San Juan River*** (Ryden 1997)

Final Report

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EXECUTIVE SUMMARY

Razorback sucker, a federally-listed endangered fish species, is a scientifically-documented member of the San Juan River fish community. The dearth of razorback sucker collections before 1994, made gathering basic scientific information on this species in the San Juan River impossible. A successful experimental stocking program for razorback sucker (1994-1996) led to the initiation of a five-year augmentation effort (1997-2001). However, difficulties in obtaining enough razorback sucker to stock from outside sources and the lack of hatchery and grow-out facilities owned by the San Juan River Recovery Implementation Program (SJRIP) led to large stocking shortfalls during the five-year augmentation effort.

Between 1994 and 2001, only 6,836 razorback sucker were stocked into the San Juan River. Despite the small number of stocked fish, many stocked razorback sucker recruited to adulthood and successful spawning by these fish has been recorded for five consecutive years (1998-2002). During this same general time-frame (1997-2001), the SJRIP acquired the use of or built roughly 25.69 surface acres of grow-out ponds (9 individual ponds) in order to facilitate the production of larger numbers of razorback sucker for future augmentation efforts.

This augmentation plan, an addendum to the ***Five-Year Augmentation Plan For Razorback Sucker In The San Juan River*** (Ryden 1997), calls for the stocking of 11,400 age-2 ($\geq$ 300 mm TL) razorback sucker annually for a period of eight years (2004-2011). If survival curves assumed in this plan are correct, then the stocking of these 91,200 razorback sucker over the specified eight-year period should lead to a window of eight consecutive years (2007-2014) during which stocked fish contribute > 5,800 adult fish (i.e., age-4+; $\geq$ 400 mm TL) to the San Juan River razorback sucker population. It is assumed

that if this number of adult razorback sucker can be established in the San Juan River, that natural recruitment will become sufficient to sustain the razorback sucker population once stocking is discontinued.

The figure of 5,800 razorback sucker is considered to be the Minimum Viable Population (MVP) for razorback sucker. The SJRIP Biology Committee agreed that > 5,800 adult razorback sucker should be the target number for this razorback sucker augmentation plan. This target number also matches the demographic criteria set forth for the delisting of razorback sucker under the ***Razorback Sucker (Xyrauchen texanus) Recovery Goals: amendment and supplement to the Razorback Sucker Recovery Plan*** (USFWS 2002).

All razorback sucker to be stocked will be individually marked with Passive integrated Transponder (PIT) tags before their release into the wild. All fish will be stocked at river mile 158.6, immediately downstream of the Hogback Diversion. This location is the upstream limit of federally-designated Critical Habitat for razorback sucker. No new follow-up monitoring is planned in association with this augmentation effort. The monitoring programs that the SJRIP currently has in place should be sufficient to track general population trends until razorback sucker become much more abundant. However, it is recommended that as early as calendar year 2006, the SJRIP consider initiating an intensive, riverwide, mark-recapture study to obtain high-precision point estimates to determine the number of adult razorback sucker present in the San Juan River. It is also recommended that mechanical removal of all nonnative fishes encountered during research and monitoring trips continue, in support of razorback sucker augmentation efforts.

As with all management- and recovery-related activities undertaken by the SJRIP, this augmentation plan addendum is subject to adaptive management and can be updated as new information becomes available.

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INTRODUCTION

The razorback sucker (Xyrauchen texanus) is one of several native fishes that was formerly much more common and widespread throughout warmwater reaches of the Colorado River basin, primarily in the mainstem and large tributaries from Wyoming to Mexico (Burdick 1992). Razorback sucker is a scientifically-documented member of the historic San Juan River fish community (Platania 1990). Scientific collections of this species in the San Juan River before 1994 were extremely sparse. However, anectdotal reports place the upstream distribution of razorback sucker in the San Juan River near the Colorado-New Mexico state line (i.e., about three miles downstream of the town of Rosa, NM, a site now inundated by Navajo Reservoir; Koster 1960) and in the Animas River upstream to at least the town of Cedar Hill, NM (L. Ahlm pers. comm. *in* Ryden 1997) and more likely as far upstream as Durango, CO (Jordan 1891). Extremely low numbers of adult wild fish and the apparent long-term lack of recruitment led to the razorback sucker being listed as an Endangered Species on 22 November 1991 (U. S. Fish and Wildlife Service {USFWS} 1991). This species is also protected by state laws in Arizona, California, Colorado, Nevada, Utah, and by the Navajo Nation (Ryden 1997).

The lack of razorback sucker collections in the San Juan River prior to 1994 made obtaining basic life-history information on this species impossible. An experimental stocking study was begun in 1994 (following ***An Experimental Stocking Plan For Razorback Sucker In The San Juan River***; Ryden and Pfeifer 1994). Between 1994 and 1996, a total of 940 razorback sucker were stocked to assess dispersal, survival, and habitat use and preference of this species in the San Juan River. Based on the relative success of these limited experimental stockings, the San Juan River Recovery Implementation Program (SJRIP) initiated a five-year augmentation program for razorback sucker in the San Juan River in 1997.

The ***Five-Year Augmentation Plan For Razorback Sucker In The San Juan River*** (Ryden 1997) called for the stocking of 73,482 razorback sucker over a five-year period (1997-2001) to establish a target population of 15,900 adult fish from river mile (RM) 158.6-0.0 (i.e., 100 fish per mile). However, only 5,896 razorback sucker were stocked between 1997 and 2001. This was a 67,586 fish shortfall over the five-year period 1997-2001.

This shortfall was a direct result of an inability to obtain sufficient numbers of razorback sucker from outside sources to meet SJRIP stocking target numbers, combined with a lack of hatchery and grow-out facilities from which the SJRIP could make up shortfalls. In order to address these deficiencies, The SJRIP either acquired the use of or constructed approximately 25 surface acres of grow-out ponds between 1997 and 2001 (roughly 16 surface acres of these ponds were not completed until fall 2001). These grow-out ponds are stocked with young razorback sucker in the spring of each year, in order to establish multiple year-class populations of razorback sucker in each pond from which appropriately-sized fish can be harvested in the fall of each year for augmentation efforts.

Despite the limited number of razorback sucker stocked during the two previous stocking efforts (1994-1996 and 1997-2001), the positive results observed attest to the fact that the razorback sucker augmentation effort in the San Juan River has not only been much more successful than was thought probable prior to its inception, it has been ***THE*** most successful riverine reintroduction effort implemented for this species to date. Numerous stocked fish have survived to adulthood and successful spawning by these adults has been documented. Aggregations of mature (presumably spawning) razorback sucker were identified via electrofishing recaptures and radio telemetry in the spring of 1997, 1999, and 2001 at RM 100.2, just downstream of Aneth, Utah (Ryden 2000a, 2000b, 2001). In addition, larval razorback sucker have been collected in the San Juan River for five consecutive years (1998-2002), from

RM 124.8 downstream to Lake Powell (S. Platania pers. comm., S. Platania unpublished data).

With the acquisition of roughly 25 surface acres of grow-out ponds, the SJRIP now stands in a position where it can realistically expect to meet stocking target numbers and therefore fulfill overall augmentation plan goals. This addendum to the 1997 augmentation plan was produced to update plan goals and objectives, incorporate the latest scientific information (e.g., survival curves, size at adulthood), and to provide direction for the SJRIP's razorback sucker augmentation effort under both the updated SJRIP Long Range Plan (LRP; SJRIP 2002) and the recently-published ***Razorback Sucker (Xyrauchen texanus) Recovery Goals: amendment and supplement to the Razorback Sucker Recovery Plan*** (hereafter referred to as the "Recovery Goals"; USFWS 2002).

Relationship to Recovery Program

One of the two purposes of the SJRIP is to protect and recover endangered fishes in the San Juan River subbasin, including razorback sucker and Colorado pikeminnow. In the SJRIP Program Document, Item 3.2.2.2.b under RESEARCH AND RECOVERY ELEMENTS AND RECOVERY PROGRAM IMPLEMENTATION specifically identifies augmenting populations of razorback sucker as a suitable course of action for recovery of this species (SJRIP 1995a). The original SJRIP LRP identified augmenting populations of razorback sucker by stocking as an activity for recovery of this species in the San Juan River (SJRIP 1995b). Specifically, Item 5.3.8.2 of that document identified the need to develop an augmentation plan for razorback sucker (SJRIP 1995b). In the updated SJRIP LRP (SJRIP 2002): Item 4.1.2 identifies the need to continue augmentation of razorback sucker in accordance with the augmentation plan; Item 4.1.3 identifies the

need to determine key razorback sucker habitats and limiting factors; and Item 4.1.6 identifies the need to continue reducing numbers of nonnative fishes in the San Juan River in order to facilitate the success of the razorback sucker augmentation effort.

Once augmentation begins, all stocked razorback sucker and their progeny will be afforded the same protection as wild fish under the Endangered Species Act.

AUGMENTATION PLAN

Given the positive results observed with the few razorback sucker stocked between 1994 and 2001, the SJRIP Biology Committee (BC) decided to extend the 1997-2001 augmentation effort for this species. This addendum to the 1997 augmentation plan (Ryden 1997) discusses where the two plans are the same and where differences between the two plans exist.

All razorback sucker stocked as part of this continued augmentation effort will be individually-marked with a unique PIT tag before release into the wild. PIT tags are highly-reliable, passive markers with excellent long-term retention when used on razorback sucker (Burdick and Hamman 1993; D. Ryden unpublished data). Fish will be evaluated, prior to stocking, for pathogens and parasites that are currently on USFWS fish health forms. Transport and stocking of razorback sucker will conform to existing USFWS guidelines and protocols (e.g., Williamson 1991).

Goal and Objective

Goal

The goal of this eight-year augmentation plan addendum is to establish a multiple year-class population of razorback sucker in the San Juan River between the Hogback Diversion (RM 158.6) and Lake Powell (RM 0.0). It is hoped that if this goal is attained, this multiple year-class population of razorback sucker will become self-sustaining, such that the criteria set forth in the Recovery Goals (USFWS 2002) can be met and this species can achieve recovery in the San Juan River.

In general terms, a self-sustaining population can be defined as a population containing a stable number of successfully-reproducing adult fish that contribute sufficient numbers of young to maintain the adult population via recruitment over an extended period of time and a variety of environmental conditions (D. Propst pers. comm.). Specific numbers of fish composing any given life-stage within a self-sustaining population will vary over time depending upon the long-term conditions that determine carrying capacity for a given species in any river system.

Objective

The objective of this augmentation plan addendum is to stock sufficient numbers of razorback sucker into the San Juan River to: 1) establish a multiple year-class population of razorback sucker in the San Juan River

between the Hogback Diversion (RM 158.6) and Lake Powell (RM 0.0); and 2) establish numbers of razorback sucker in the San Juan River that meet or exceed the target numbers specified in this augmentation plan and the demographic criteria for downlisting specified in the Recovery Goals (USFWS 2002).

Risks

Risk assessments (both genetic and ecological) pertinent to continued augmentation efforts were performed in previous razorback sucker stocking plans (Ryden and Pfeifer 1994, Ryden 1997) and in the ***Genetics Management Plan For The Endangered Fishes Of The San Juan River***, hereafter referred to as the GMP (Crist and Ryden 2003).

Source Of Fish

Appropriate stocks of razorback sucker, identified in previous razorback sucker stocking plans (Ryden and Pfeifer 1994, Ryden 1997) and in the GMP (Crist and Ryden 2003), will be used during this augmentation effort.

Size Of Fish To Stock

Because of very low post-stocking recapture rates (i.e., poor survival) observed among small size-class razorback sucker (< 300 mm TL) stocked into the San Juan River between 1994 and 2000 (Ryden 2000a, 2000b, 2001), the SJRIP BC agreed to only stock razorback sucker ≥ 300 mm TL during future augmentation efforts (SJRIP Biology Committee pers. comm., 6 February 2001). This same size-class of razorback sucker is specified for use in the ***Stocking Plan For Endangered Colorado River Fish Species In Colorado*** (Nesler 2001) and the ***State Of Utah Stocking Plan For Endangered Fish Species Of The Upper Colorado River Basin*** (Hudson 2001). Both of these plans assume that artificially-produced razorback sucker will reach ≥ 300 mm TL at age-2+ (i.e., after three growing seasons).

However, it has been documented that many razorback sucker stocked into the SJRIP's grow-out ponds (located on Navajo Indian Irrigation Project {NIIP} lands southwest of Farmington, NM) as larvae in the spring will grow to ≥ 300 mm TL by fall of the year they are age-1 (i.e., after two full growing seasons), with the vast majority being ≥ 300 mm TL by fall of the year they are age-2 (i.e., after three full growing seasons). Age-1 razorback sucker harvested from NIIP ponds in the fall had a mean TL = 374 mm (range = 280-450 mm TL, n = 429). Age-2 razorback sucker harvested from NIIP ponds in the fall had a much higher percentage of fish ≥ 300 mm TL (mean TL = 460 mm, range = 288-539 mm TL, n = 152). By fall of the year they were age-3, all razorback sucker harvested from NIIP ponds were > 300 mm TL (mean TL = 482 mm, range = 460-523 mm TL, n = 8). This rapid growth observed among pond-reared razorback sucker is not unusual (e.g., Osmundson and Kaeding 1989, Bestgen 1990).

So, razorback sucker harvested from the NIIP ponds at 300 mm TL are documented to be either age-1 or age-2 fish, with all age-3+ fish being > 300

mm TL. For the purpose of this addendum and to stay consistent with UCRB stocking plans (Hudson 2001, Nesler 2001), this plan will assume that fish stocked at ≥ 300 mm TL are age-2+ fish.

, Guideline: For the purposes of this augmentation plan addendum, pond-reared razorback sucker that are ≥ 300 mm TL will be assumed to be age-2+ fish.

Numbers Of Fish To Stock

Background

The historical ratio of razorback sucker to other native fish species in any of the UCRB rivers is unknown. It is known that razorback sucker were historically much more abundant and widespread than they are today (e.g., Minckley 1983, Burdick 1992, Modde et al. 1996). Unfortunately, no historic data exists that would allow for an estimate of actual abundance (e.g., numbers of adult fish per mile) before this species began its precipitous decline. Therefore, establishing a realistic numeric goal of an augmentation effort aimed at reestablishing a somewhat "natural population" of this species is difficult at best.

In the UCRB, the largest extant population of wild adult razorback sucker are found in the Green and Yampa rivers (Holden and Wick 1982, Lanigan and Tyus 1989). Using the computer program CAPTURE, Lanigan and Tyus (1989) estimated that there were 948 adult razorback sucker (95% confidence interval {CI} = 758-1,138) in the middle Green River, from approximately RM 345-175

(about 170 RM). This averages out to 5.6 adult fish/mi. (95% CI = 4.5-6.7 fish/mi.). Using the Lincoln-Petersen method, Modde et al. (1996) later estimated this same population of adult razorback sucker in the middle Green River to be composed of 524 fish (95% CI = 351-696). However, Modde et al. (1996) did not specify over how many RM this population of 524 adult fish occurred, so extrapolating an adult fish/mi. value from their population estimates was not possible. Most recently, the population of wild adult razorback sucker in the middle Green River was estimated at about 100 fish (Bestgen et al. 2002) from approximately RM 320-248 (about 72 RM). This averages out to only about 1.4 adult fish/mi. Regression analysis of abundance estimates as a function of time that were available for this population of razorback sucker between 1990 and 1999 detected significant declines in abundance from about 500 animals in 1990 to about 100 animals in 1998 and 1999 (Bestgen et al. 2002).

Since 1974, the number of razorback sucker that have been collected in the Colorado River has decreased dramatically (USFWS 2002). Only 25 adult razorback sucker were captured from riverine habitats in the Colorado River between 1980 and 1990 (Valdez et al. 1982, Burdick and Bonar 1997). Only seven adult razorback sucker have been captured from riverine habitats since 1990 (Osmundson and Kaeding 1991, Burdick 1992, Burdick and Bonar 1997). Conversely, over a hundred razorback sucker have been collected in the Colorado River subbasin from lentic habitats (mostly abandoned gravel pit ponds) since the late 1970's, but genetic analysis indicates that most of these fish are probably progeny of a few wild adult razorback sucker that entered these off-channel habitats during spring flood events and subsequently became trapped (Burdick and Bonar 1997).

The last adult razorback sucker collected in the Gunnison River was captured in 1981 (Burdick and Bonar 1997). This species is now thought to be extirpated from the Gunnison River (Burdick and Bonar 1997).

Schnabel multiple-census population estimates (following Van den Avyle 1993) done for all life-stages of razorback sucker recaptured from the San Juan River between 1994 and 2000 indicated that there were approximately 268 razorback sucker occupying the river from RM 158.6-2.9 (155.7 total RM) in October 2000 (Ryden 2001a). This averages out to only 1.7 fish/mi., not all of which were adults.

Razorback sucker stocking plans currently in place for the UCRB (Hudson 2001, Nesler 2001) are based on establishing a minimum viable population (MVP) of > 5,800 adult razorback sucker in both the Green River and upper Colorado River subbasins, as specified in the Recovery Goals (USFWS 2002). An MVP is defined as a population that is sufficiently abundant and well adapted to its environment for long-term persistence without significant artificial demographic or genetic manipulations (USFWS 2002). Alternately, an MVP can be defined as the smallest isolated population size that has a specified percent chance of remaining extant for a specified period of time in the face of foreseeable demographic, genetic, and environmental stochasticities, plus natural catastrophes (USFWS 2002).

Nesler (2001) specifies that the MVP of > 5,800 adult razorback sucker would be distributed over 150 RM of three reaches in the upper Colorado River subbasin. This averages out to > 38.7 adult fish/mi. Hudson (2001) did not specify a target number of RM for establishing an MVP of 5,800 adult razorback sucker in the Green River subbasin. If an MVP of > 5,800 adult razorback sucker were established in the San Juan River, between Hogback Diversion and Lake Powell (RM 158.6-0.0), it would average out to > 36.6 adult fish per mile.

As can be seen by the data presented above, there is no clear benchmark number available when trying to develop a target number for an augmentation effort. The Green River razorback sucker population, once the most abundant and healthy of all the UCRB populations, appears to be in serious decline and

provides no clear guidance as to what a healthy population size may be, whether using an actual population size or a fish/mi. metric. Thus augmentation plans in the UCRB have switched to trying to achieve an MVP of > 5,800 adult razorback sucker (Hudson 2001, Nesler 2001).

Recovery Goals

Members of the SJRIP BC felt that the target number of 100 adult fish/mi. specified in the 1997 razorback sucker augmentation plan (i.e., 15,900 from RM 158.6-0.0) was too high and that the target of any continued augmentation effort should match the demographic criteria for downlisting of this species, specified in the Recovery Goals.

The Recovery Goals, which update and amend the original ***Razorback Sucker (Xyrauchen texanus) Recovery Plan*** (USFWS 1998) were developed to provide "objective, measurable" criteria to achieve recovery of the razorback sucker in the Colorado River basin, following Section 4(f)(1) of the Endangered Species Act, as amended. In the Recovery Goals, the Colorado River basin is split into two distinct recovery units, the upper Colorado River basin (UCRB) and lower Colorado River basin (LCRB), divided at Glen Canyon Dam near Page, AZ (USFWS 2002). The San Juan River is included as part of the UCRB recovery unit. The Recovery Goals define two sets of criteria (called "demographic criteria" and "recovery factor criteria") that need to be achieved to be able to downlist and delist razorback sucker (USFWS 2002). The following demographic criteria for the downlisting and delisting of razorback sucker in the San Juan River are listed in the Recovery Goals (USFWS 2002):

5.3.1.1.1 Demographic criteria for downlisting in the upper basin recovery unit: upper Colorado River and San Juan River subbasins

1) A self-sustaining population is maintained in **EITHER** the upper Colorado River subbasin or the San Juan River subbasin over a 5-year period, starting with the first point estimate acceptable to the Service (i.e., USFWS), such that for either population:

   a) the trend in adult (age-4+; ≥ 400 mm total length {TL}) point estimates does not decline significantly, and

   b) mean estimated recruitment of age-3 (300-399 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and

   c) each point estimate exceeds 5,800 adults (minimum viable population {MVP}).

5.3.2.1.1 Demographic criteria for delisting in the upper basin recovery unit: upper Colorado River and San Juan River subbasins

1) A self-sustaining population is maintained over a 3-year period beyond downlisting, starting with the first point estimate acceptable to the Service, in **EITHER** the upper Colorado River subbasin or the San Juan River subbasin, such that:

   a) the trend in adult (age-4+; ≥ 400 mm TL) point estimates does not decline significantly, and

   b) mean estimated recruitment of age-3 (300-399 mm TL) naturally produced fish equals or exceeds mean annual adult mortality, and

   c) each point estimate exceeds 5,800 adults (MVP).

In the San Juan River, the downlisting criteria specifies a target number of > 5,800 adult razorback sucker for a consecutive five-year period. The

delisting criteria specifies a target number of > 5,800 adult razorback sucker for three consecutive years beyond and contiguous to, the downlisting period (i.e., a total of eight consecutive years).

, Summary: The Recovery Goals specify a population of > 5,800 adult (age-4+) razorback sucker in the San Juan River for a minimum of eight years as the demographic criteria for delisting of this species in the San Juan River

, Guideline: The SJRIP BC has agreed to adopt the number specified as the demographic criteria for delisting in the Recovery Goals as the target number for this augmentation plan addendum (i.e., > 5,800 adult {age-4+} fish for a minimum of eight years).

What Is An Adult Fish?

The Recovery Goals assume that razorback sucker achieve sexual maturity in riverine environments by no later than age-4, or $\geq$ 400 mm TL (USFWS 2002). McAda and Wydoski (1980) reported that all of the razorback sucker from UCRB riverine habitats they examined had completed from four to nine growing seasons (i.e. were age-3 to age-8) and all were mature. However, the youngest mature female razorback sucker McAda and Wydoski (1980) observed had completed five growing seasons (i.e., was age-4; TL = 510 mm TL). Hamman (1985) reported that hatchery-reared male razorback sucker matured at age-2 (< 350 mm TL), while hatchery-reared females matured at age-3 (> 390 mm TL). Bestgen (1990) stated that age at maturity is apparently habitat specific and based on

differences in food availability, water temperature, and subsequent growth rates.

Male razorback sucker reared in the NIIP grow-out ponds were observed to have tubercles at sizes as small as 338 mm TL (a known age-2 fish; SJRIP database, USFWS unpublished data). Male razorback sucker reared in the NIIP ponds were observed to be ripe (i.e., freely expressing milt) at sizes as small as 420 mm TL (a known age-2 fish; SJRIP database, USFWS unpublished data). By comparison, male razorback sucker reared at the Utah Division of Wildlife Resources' Wahweap ponds (near Page, AZ) were tuberculate and ripe at sizes as small as 388 mm TL (a known age-2 fish; SJRIP database, USFWS unpublished data). There were no recorded observations of gravid female razorback sucker (i.e., freely expressing eggs) being harvested from either the NIIP or Wahweap ponds between 1994 and 2000.

Observations of pond-reared razorback sucker during post-stocking recaptures from the San Juan River showed that male fish often remained tuberculate and ripe throughout much of the year. Tuberculate males were observed as early in the year as 14 March and as late as 22 October (SJRIP database, USFWS unpublished data). Ripe, male razorback sucker were observed as early as 16 March and as late as 2 October (SJRIP database, USFWS unpublished data). The minimum size for a ripe, tuberculate male razorback sucker recaptured from the San Juan River was 376 mm TL (a known age-3 fish; SJRIP database, USFWS unpublished data).

As is observed among many of the large-bodied fish species native to the UCRB, male razorback sucker mature earlier and at smaller sizes than do females (Hamman 1985, pers. obs., D. Osmundson pers. comm.). Female razorback sucker are also, apparently, reproductively active for a much shorter period of time than are males. Only four gravid female razorback sucker have been recaptured from the San Juan River since 1994. These females (ranging in size

from 477-565 mm TL and from age-5 to age-9) were all collected between 16 April and 6 May (SJRIP database, USFWS unpublished data).

- Summary: In the SJRIP's NIIP grow-out ponds male razorback sucker can mature as early as age-2. The youngest mature female razorback sucker recaptured from the San Juan River was age-5. However, other studies show that female razorback sucker reach maturity by age-4.

- Guideline: In order to stay consistent with the Recovery Goals, this augmentation plan addendum will assume that all razorback sucker stocked into the San Juan River will reach adulthood by age-4 ($\geq$ 400 mm TL).

Survival Rates

Very little is known about year-to-year survival of razorback sucker of different age-classes or at different life-stages in the wild. In fact the only published "survival rate" for razorback sucker is not really even a survival rate, but an assumed annual adult mortality rate. Modde et al. (1996) assumed a mean annual adult mortality rate of 0.29 (29%) based on studies of razorback sucker in the middle Green River. Thus, their assumed mean annual adult survival rate would be 0.71 (71%). The only other survival curves available for razorback sucker are those being used in endangered fish stocking plans for the UCRB produced by the states of Colorado (Nesler 2001) and Utah (Hudson 2001). Both of these UCRB stocking plans assume a 0.5 (50%) survival rate at age-2, a 0.6 (60%) survival rate at age-3, and a 0.7 (70%) survival rate for all adult fish (i.e., age-4+), regardless of age. The

assumed mean annual adult mortality rate of 0.3 (30%) used by Nesler (2001) and Hudson (2001) is very close to that reported by Modde et al. (1996).

These survival curves are more conservative (i.e., assume lower survival rates) than those used in the 1997 razorback sucker augmentation plan (Ryden 1997). However, for lack of reliable, published survival data on razorback sucker and in order to maintain consistency between the UCRB and SJRIP augmentation efforts, this augmentation plan addendum will assume that the survival curves used by Nesler (2001) and Hudson (2001) are correct.

, Guideline: The survival curve used for this augmentation plan addendum will assume a 0.5 (50%) survival rate at age-2, a 0.6 (60%) survival rate at age-3, and a 0.7 (70%) survival rate for all adult fish (i.e., age-4+), regardless of age.

Numbers Of Fish To Stock

A wide range of possible numbers of fish to be stocked could be developed (and in reality will likely be used) when trying to figure out how many fish should, or in reality can, be stocked on an annual basis. These numbers are dependent upon many variables, some of which may include: 1) numbers of razorback sucker available to the SJRIP from various sources annually for stocking into grow-out ponds; 2) sizes of razorback sucker available to SJRIP from various sources annually for stocking into grow-out ponds; 3) varying survival rates among year classes of razorback sucker in grow-out ponds due to water chemistry, available space and food resources, predation losses (to birds, tiger salamanders, bullfrogs, aquatic insects, etc.), and stochastic events (e.g., algae blooms, pond freeze-over causing oxygen depletion);

4) varying growth rates among year-classes of fish due to stocking densities, etc.; 5) harvest success; 6) immediate or delayed mortality associated with harvest, PIT-tagging, handling, transport, and stocking; and; 7) variable production rates between grow-out ponds.

For this augmentation plan addendum, a new stocking table was developed to ascertain the number of fish that needed to be stocked to meet the goal of establishing a population of > 5,800 adult (age-4+; ≥ 400 mm TL) razorback sucker in the San Juan River for a minimum of eight years, using the assumed survival curves (following Hudson 2001 and Nesler 2001) discussed earlier.

This augmentation plan has been developed based on an eight-year stocking period (2004-2011). Similar plans for stocking razorback sucker in two sections of the Green River (Hudson 2001) and in three sections of the Gunnison and upper Colorado rivers (Nesler 2001) recommend five- and eight-year stocking periods, respectively. By increasing either the number of razorback sucker to be stocked each year or the number of years in which fish are to be stocked, or both, the SJRIP would be able to achieve a greater safety margin in both reaching and maintaining the target number of > 5,800 adult razorback sucker in the San Juan River. This would help to buffer against years of poor post-stocking survival, spawning conditions, spawning success, and/or recruitment.

Stocking Table

If the rate of recruitment into adulthood and the adult mortality rate exactly match one another on a year-to-year basis, only 5,801 adult razorback sucker would be needed for a minimum of eight years to meet the demographic criteria specified in the Recovery Goals for delisting.

Table 1 is based on the minimum number of razorback sucker (11,400) that would need to be stocked annually to meet a goal of > 5,800 adult fish on an annual basis for a minimum of eight years. This option assumes an eight-year stocking effort, from 2004 to 2011, during which a total of 91,200 razorback sucker $\geq$ 300 mm TL would be stocked. The 2004 start date for stocking is based on allowing razorback sucker in all nine NIIP grow-out ponds (roughly 25 surface acres) to be stocked at $\geq$ age-2, since all nine ponds were stocked with age-0 or older fish in spring 2002.

Under the scenario laid out in Table 1, the target number of > 5,800 adult razorback sucker in the San Juan River could be achieved as early as 2007 (assuming the survival curves assumed in this plan are correct). There would be an eight-year window (from 2007 to 2014) when stocked razorback sucker would contribute > 5,800 adult fish to the total population in the San Juan River (Table 1). Numbers of adult razorback sucker would exceed the > 5,800 fish target by as little as 14 fish in 2007, a 0.2% buffer, and as many as 4,943 fish in 2013, an 85.2% buffer (Table 1).

Under an eight-year stocking scenario (2004-2011), the survivors of all eight years' stockings will have reached adulthood by 2013 (Table 1). Also during 2013, the number of adult razorback sucker in the San Juan River contributed by stocking will have reached its zenith of 10,743 fish (Table 1). Razorback sucker from the first stocking in 2004 will reach adulthood (age-4) and begin spawning in 2006 (Table 1). Young produced in 2006 (by fish stocked in 2004) should begin recruiting into the adult population by 2010. Thus by the time the number of adult razorback sucker in the San Juan River from the 2004-2011 stockings has dropped below 5,800 fish (i.e., in 2015), there should be young recruiting into the adult population that were spawned by adults from six of the eight years' stockings (i.e., 2004-2009; Table 1). Between the

Table 1. Estimated number of stocked razorback sucker surviving in each consecutive calendar year, 2004-2025, based on stocking 11,400 age-2 fish (≥ 300 mm TL) for eight consecutive years (i.e., 2004-2011). Estimated between-year survival rates are 0.5 (50%) at age-2, 0.6 (60%) at age-3, and 0.7 (70%) in all following years.

Calendar Year	Stocking Number:								Total # Of Fish, All Ages	Total # Of Adult Fish: Age-4+
	1 (2004)	2 (2005)	3 (2006)	4 (2007)	5 (2008)	6 (2009)	7 (2010)	8 (2011)		
2004	11,400								11,400	0
2005	5,700	11,400							17,100	0
2006	3,420	5,700	11,400						20,520	3,420
2007	2,394	3,420	5,700	11,400					22,914	5,814
2008	1,676	2,394	3,420	5,700	11,400				24,590	7,490
2009	1,173	1,676	2,394	3,420	5,700	11,400			25,763	8,663
2010	821	1,173	1,676	2,394	3,420	5,700	11,400		26,584	9,484
2011	575	821	1,173	1,676	2,394	3,420	5,700	11,400	27,159	10,059
2012	402	575	821	1,173	1,676	2,394	3,420	5,700	16,161	10,461
2013	282	402	575	821	1,173	1,676	2,394	3,420	10,743	10,743
2014	197	282	402	575	821	1,173	1,676	2,394	7,520	7,520
2015	138	197	282	402	575	821	1,173	1,676	5,264	5,264
2016	97	138	197	282	402	575	821	1,173	3,685	3,685
2017	68	97	138	197	282	402	575	821	2,580	2,580
2018	47	68	97	138	197	282	402	575	1,806	1,806

Table 1. Estimated number of stocked razorback sucker surviving in each consecutive calendar year, 2004-2025, based on stocking 11,400 age-2 fish (≥ 300 mm TL) for eight consecutive years (i.e., 2004-2011). Estimated between-year survival rates are 0.5 (50%) at age-2, 0.6 (60%) at age-3, and 0.7 (70%) in all following years.

Calendar Year	Stocking Number:								Total # Of Fish, All Ages	Total # Of Adult Fish: Age-4+
	1 (2004)	2 (2005)	3 (2006)	4 (2007)	5 (2008)	6 (2009)	7 (2010)	8 (2011)		
2019	33	47	68	97	138	197	282	402	1,264	1,264
2020	23	33	47	68	97	138	197	282	885	885
2021	16	23	33	47	68	97	138	197	619	619
2022	11	16	23	33	47	68	97	138	433	433
2023	8	11	16	23	33	47	68	97	303	303
2024	6	8	11	16	23	33	47	68	212	212
2025	4	6	8	11	16	23	33	47	148	148

number of adults remaining from the 2004-2011 stockings and the progeny of the six stockings (2004-2009), the adult (age-4+) population should be able to maintain itself at or above the level of > 5,800 adult fish.

However, recruitment of progeny from stocked fish that achieve adulthood should not be expected to be at a constant or reliable rate. Like wild razorback sucker observed in the Green River system, spawning and recruitment success among stocked fish and their progeny will be a pulsed phenomena, with certain years providing larger cohorts of young fish while others provide very few, depending upon the environmental variables (e.g., egg viability, instream flows, low-velocity habitat availability, predator load, food availability) and stochastic events during any given year (e.g., Modde et al. 1996, USFWS 2002). This pulsed recruitment phenomena, called a "storage effect" (Gilpin 1993), enables long-lived populations to maintain themselves despite several consecutive years of failed or low reproductive success (USFWS 2002). However, unlike the Colorado River, the San Juan River has the added stochasticity of probable large-scale invasions of striped bass from Lake Powell in years when river flows remain low and clear in the absence of summer monsoonal rainstorms (Ryden 2001b).

Effects Of Stocking Large Numbers Of Razorback Sucker On The San Juan River Native Fish Community

This plan calls for the stocking of 91,200 razorback sucker $\geq$ 300 mm TL over an eight-year period. This represents a very large influx of biomass (and thus, competitive pressure) into the San Juan River. It is almost certain that if these stockings do result in the target number of > 5,800 adult razorback sucker becoming established in the San Juan River, abundance

(and possibly distribution) of other common, large-bodied fish species in the San Juan River will decrease. Which species will be effected and to what degree, is unknown. However, it is anticipated that establishment of > 5,800 adult razorback sucker in the San Juan River will most likely cause some level of reduction in the overall biomass of the sympatric native suckers, due to competition for habitat and food resources (Nesler 2001). However, if vigorous mechanical removal of channel catfish and common carp are successful enough at lowering the overall biomass of these species, it may also reduce the amount of competitive pressure that stocked razorback sucker would place on sympatric native suckers (Nesler 2001). In theory, if populations of channel catfish and common carp could be severely reduced (or extirpated), it would likely allow enough food and habitat resources to become available so that razorback sucker could thrive beyond target numbers specified in this plan, as well as possibly causing an increase in the overall biomass of sympatric native suckers.

Grow-out Ponds

Production Potential

In the UCRB, hatchery and grow-out pond managers have agreed that they should be able to rear approximately 500 lbs. of razorback sucker per surface acre of grow-out pond space per year (M. Baker pers. comm., T. Czapla pers. comm.). For the San Juan River, the value of 500 lbs. per surface acre translates into approximately 754 fish per surface acre of grow-out pond space. This number is based on the average weight (300.89 g; 0.6633377 lbs.)

of a razorback sucker with a mean TL of 300 mm (range = 295-305 mm TL, n = 36) reared in SJRIP grow-out ponds and stocked into the San Juan River between 1994 and 2002 (SJRIP database). Razorback sucker from 295-305 mm TL were used to calculate this mean weight because these fish all fell within the expected TL measurement error range.

In 2001, the SJRIP built approximately sixteen surface acres of new grow-out ponds (referred to as the "6-Pack Ponds"). Together with Hidden Pond (2.83 surface acres) and the two Avocet ponds (East Avocet Pond = 3.52 surface acres; West Avocet Pond = 3.34 surface acres), this brings the total surface acreage of grow-out ponds available to the SJRIP to approximately 25.69 surface acres (in nine separate ponds). The 6-Pack Ponds were filled with water in the fall of 2001 and were stocked with young razorback sucker in April 2002. Razorback sucker stocked into these ponds in 2002 will be harvested and stocked into the San Juan River as age-2+ fish ($\geq$ 300 mm TL) in fall 2004.

Based on an assumed production potential of 754 razorback sucker ($\geq$ 300 mm TL) per surface acre per year and 25.69 surface acres of available grow-out ponds, the SJRIP should be able to potentially produce 19,370 fish ($\geq$ 300 mm TL) per year (Table 2), ***IF***: 1) the production potential of the SJRIP grow-out ponds meets the value (500 lbs. per surface acre per year) anticipated by UCRB hatchery and grow-out pond managers; 2) ponds are properly managed to achieve their full production potential; and, 3) annual production is uniform between ponds and lots of fish stocked into those ponds. ***IF*** this is the case, the SJRIP would be able to meet the annual stocking target of 11,400 razorback sucker $\geq$ 300 mm TL (Table 1) and have, roughly, a 70% overage in production based on the 25.69 surface acres of grow-out ponds currently available (Table 2).

Table 2. Annual production potential for SJRIP grow-out ponds, based on an anticipated potential of 500 lbs. of fish per surface acre (i.e., 754 razorback sucker $\geq$ 300 mm TL per surface acre per year).

Pond Name	Pond Surface Acreage	Potential Production At 500 lbs./acre
East Avocet Pond	3.52 Acres	2,654 fish
West Avocet Pond	3.34 Acres	2,518 fish
Hidden Pond	2.83 Acres	2,134 fish
6-Pack Ponds	~ 16.00 Acres	12,064 fish

Management

In the spring of each year, grow-out ponds will be stocked with appropriate stocks of larval or young razorback sucker, as identified in previous razorback sucker stocking plans (Ryden and Pfeifer 1994, Ryden 1997) and the GMP (Crist and Ryden 2003). The densities at which each grow-out pond should be stocked will vary depending upon a given pond's relative productivity, predator load, and size of young razorback sucker available for stocking. For example, it is known that the two Avocet ponds have more primary productivity (based on standing crop of vegetation) when compared to the newer 6-Pack ponds. However, the two Avocet ponds also have a very heavy predator load (e.g., tiger salamanders), whereas the newer 6-Pack ponds should have virtually no predator load. Detailed records of annual harvest efforts from each individual pond should be kept to help track yearly production on a pond-by-pond basis. Since 1998, grow-out ponds have been stocked at a rate of approximately 10,000-15,000 fish per surface acre when stocking larval fish or approximately 1,500 fish per surface acre when stocking 100-150 mm TL fish (i.e., 4-6 inch fish; USFWS database, M. Baker pers. comm.).

The annual stocking of early life stage razorback sucker into grow-out ponds will allow for the establishment of multi-year class populations of fish, from which appropriately-sized ($\geq$ 300 mm TL) fish can be harvested each year for stocking efforts.

A study being initiated in 2003 will explore the possibility of increasing razorback sucker growth in grow-out ponds via fertilization or other pond management techniques. If this study is successful, it may be possible to increase the survival of early life stage razorback sucker stocked into grow-out ponds by facilitating rapid growth to sizes beyond predation thresholds. Since stocking related to meeting the target number of razorback sucker for this plan (> 5,800 adults) will not begin until fall 2004, the questions of increased grow-out pond productivity should become a priority for the SJRIP in the near future.

Stocking Site

All razorback sucker to be stocked as part of this eight-year augmentation effort will be stocked immediately downstream of Hogback Diversion (RM 158.6) as specified in the 1997 razorback sucker augmentation plan (Ryden 1997). The reason for this is that Hogback Diversion is the upstream limit of the federally-designated Critical Habitat range for this species (USFWS 1994).

, Guideline: All razorback sucker will be stocked immediately downstream of the Hogback Diversion at RM 158.6.

Monitoring

Numbers of razorback sucker in the San Juan River are currently well below the target number specified in this augmentation plan addendum. Until numbers of razorback sucker increase markedly over current numbers, monitoring efforts that are already in place for assessing stocked razorback sucker (Ryden and Pfeifer 2001) combined with the long-term fish community monitoring program that takes place each fall (Propst et al. 2000) should be sufficient to track general population trends among endangered fish populations. Simple, within-year population estimators (e.g., Schnabel and Petersen population estimates) can be used to determine the population of razorback sucker between RM 158.6 and 2.9.

It is recommended that as early as calendar year 2006, the SJRIP initiate an intensive, riverwide, mark-recapture study (like the one being done in the UCRB for Colorado pikeminnow beginning in 2003) to obtain high-precision point estimates to determine the number of adult razorback sucker present in the San Juan River. This sampling should encompass the San Juan River from the Hogback Diversion downstream to Lake Powell.

Finally, in support of the razorback sucker augmentation effort, it is recommended that intensive, mechanical removal of nonnative fishes should be continued, on all research and monitoring trips. Mechanical removal of nonnative fishes can be done opportunistically during these trips at no additional cost to the SJRIP and requires no additional manpower.

Adaptive Management

The evolution of the razorback sucker augmentation program - from an experimental stocking study in 1994, to an augmentation effort in 1997, to the building of grow-out ponds (1997-2001), to the development of this augmentation plan addendum - is a good example of the adaptive management process in action. As with all other management- and recovery-oriented actions being performed under the SJRIP, this augmentation plan addendum is itself subject to adaptive management. It is the intention of the SJRIP Biology Committee to always use the best science available at the time when making management- and recovery-related decisions. If at any point in the future, new data becomes available that indicates a change in approach or techniques is necessary to achieve the goal and objective of this augmentation plan addendum (or if the goal or objective themselves should change), this augmentation plan addendum can be revised to reflect the new information.

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LITERATURE CITED

Bestgen, K. R. 1990. Status review of the razorback sucker, Xyrauchen texanus. Contribution Number 44, Colorado State University Larval Fish Laboratory. Submitted to the U. S. Bureau of Reclamation, Salt Lake City, UT. 92 pp.

Betsgen, K. R., G. B. Haines, R. Brunson, T. Chart, M. Trammel, R. T. Muth, G. Birchell, K. Chistopherson, and J. M. Bundy. 2002. Status of wild razorback sucker in the Green River basin, Utah and Colorado, determined from basinwide monitoring and other sampling programs. Contribution Number 126, Colorado State University Larval Fish Laboratory. Colorado State University, Fort Collins. 73 pp.

Burdick, B. D. 1992. A plan to evaluate stocking to augment or restore razorback sucker in the upper Colorado River. U. S. Fish and Wildlife Service, Grand Junction, CO. 56 pp.

Burdick, B. D., and R. B. Bonar. 1997. Experimental stocking of adult razorback sucker in the upper Colorado and Gunnison rivers. U. S. Fish and Wildlife Service, Grand Junction, CO. 28 pp. + appendices.

Burdick, B. D., and R. L. Hamman. 1993. A study to evaluate several tagging and marking systems for Colorado squawfish, razorback sucker, and bonytail. U. S. Fish and Wildlife Service, Grand Junction, CO. 56 pp.

Crist, L. W., and D. W. Ryden. 2003 (in Prep). Genetics Management Plan For The Endangered Fishes Of The San Juan River. San Juan River Recovery Implementation Program, U. S. Fish and Wildlife Service, Albuquerque, NM.

Gilpin, M. 1993. A population viability analysis of the Colorado squawfish in the upper Colorado River basin. U.S. Fish and Wildlife Service, Denver, CO. 53 pp.

Hamman, R. L. 1985. Induced spawning of hatchery-reared razorback sucker. Progressive Fish-Culturist 47:187-189.

Hudson, J. M. 2001. State of Utah stocking plan for endangered fish species of the upper Colorado River basin: Revised plan. Publication Number 01-22. Utah Division of Wildlife Resources, Salt Lake City, UT. 14 pp.

Jordan, D. S. 1891. Report of the explorations in Colorado and Utah during the summer of 1889, with an account of the fish found in each of the river basins examined. Bulletin of U. S. Fish Commission. Volume IX:1-40.

Koster, W. J. 1960. *Ptychocheilus lucius* (Cyprinidae) in the San Juan River, New Mexico. Southwestern Naturalist 5:174-175.

Lanigan, S. H., and H. M. Tyus. 1989. Population size and status of the razorback sucker in the Green River basin, Utah and Colorado. North American Journal of Fisheries Management 9:68-73.

McAda, C. W., and R. S. Wydoski. 1980. The razorback sucker, Xyrauchen texanus, in the upper Colorado River basin, 1974-76. U. S. Fish and Wildlife service Technical Paper 15 pp.

Minckley, W. L. 1983. Status of the razorback sucker, *Xyrauchen texanus* (Abbott), in the lower Colorado River basin. Southwestern Naturalist 28:165-187.

Modde, T., K. P. Burnham, and E. J. Wick. 1996. Population status of razorback sucker in the middle Green River. Conservation Biology. 10:110-119.

Nesler, T. P. 2001. Stocking plan for endangered Colorado River fish species in Colorado. Colorado Division of Wildlife, Denver, CO. 24 pp.

Osmundson, D. O., and L. R. Kaeding. 1989. Colorado squawfish and razorback sucker grow-out pond studies as part of conservation measures for the Green Mountain and Rudei reservoir water sales. U. S. fish and Wildlife Service, Grand Junction, CO. 57 pp.

Osmundson, D. O., and L. R. Kaeding. 1991. Recommendations for flows in the 15-mile reach during October-June for maintenance and enhancement of endangered fish populations in the upper Colorado River. Final Report. U. S. fish and Wildlife Service, Grand Junction, CO. 82 pp.

Platania, S. P. 1990. Biological summary of the 1987 to 1989 New Mexico-Utah ichthyofaunal study of the San Juan River. Report to the New Mexico Department of Game and Fish, Santa Fe, and the U. S. Bureau of Reclamation, Salt Lake City, UT. 143 pp.

Propst, D. L., S. P. Platania, D. W. Ryden, and R. L. Bliesner. 2000. San Juan River monitoring plan and protocols. San Juan River Recovery Implementation Program, U. S. Fish and Wildlife Service, Albuquerque, NM. 20 pp. + appendices

Ryden, D. W. 1997. Five-year augmentation plan for razorback sucker in the San Juan River. U. S. Fish and Wildlife Service, Grand Junction, CO. 27 pp.

Ryden, D. W. 2000a. Monitoring of experimentally stocked razorback sucker in the San Juan River: March 1994-October 1997. U. S. Fish and Wildlife Service, Grand Junction, CO. 132 pp.

Ryden, D. W. 2000b. Monitoring of razorback sucker stocked into the San Juan River as part of a five-year augmentation effort: 1997-1999. Interim Progress Report (Draft Final). U. S. Fish and Wildlife Service, Grand Junction, CO. 49 pp.

Ryden, D. W. 2001a. Monitoring of razorback sucker stocked into the San Juan River as part of a five-year augmentation effort: 2000 Interim Progress Report. U. S. Fish and Wildlife Service, Grand Junction, CO. 83 pp.

Ryden, D. W. 2001b. Long-term monitoring of sub-adult and adult large-bodied fishes in the San Juan River, 2000: Interim Progress Report. U. S. Fish and Wildlife Service, Grand Junction, CO. 61 pp.

Ryden, D. W., and F. K. Pfeifer. 1994. An experimental stocking plan for razorback sucker in the San Juan River. U. S. Fish and Wildlife Service, Grand Junction, CO. 26 pp.

Ryden, D. W., and F. K. Pfeifer. 2001. Razorback sucker augmentation: Fiscal year 2002 project proposal. Pages D-11 to D-16 *in* San Juan River Recovery Implementation Program Fiscal Year 2002 Annual Budget and Work Plan. San Juan River Recovery Implementation Program, U. S. Fish and Wildlife Service, Albuquerque, NM.

San Juan River Basin Recovery Implementation Program Biology Committee and Hydrology Committee. 2002. Long Range Implementation Plan: San Juan River Basin Recovery Implementation Program. Draft (dated 21 August 2002). U. S. Fish and Wildlife Service, Albuquerque, NM.

San Juan River Recovery Implementation Program Biology Committee. 1995a. Program Document. U. S. Fish and Wildlife Service, Albuquerque, NM. 56 pp.

San Juan River Recovery Implementation Program Biology Committee. 1995b. Long range implementation plan: San Juan River recovery implementation plan. U. S. Fish and Wildlife Service, Albuquerque, NM. 19 pp. + appendices.

U. S. Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants: the razorback sucker (Xyrauchen texanus) determined to be an endangered species. Department of the Interior, U. S. Fish and Wildlife Service, Federal Register, 23 October 1991, 56:54957-54967.

U. S. Fish and Wildlife Service. 1994. Determination of critical habitat for the Colorado River endangered fishes: razorback sucker, Colorado squawfish, humpback chub, and bonytail chub. Dept. of the Interior, U. S. Fish and Wildlife Service, Federal Register, 21 March 1994, 59:13374-13400.

U. S. Fish and Wildlife Service. 1998. Razorback Sucker (*Xyrauchen texanus*) Recovery Plan. U. S. Fish and Wildlife Service, Denver, CO. 76 pp.

U. S. Fish and Wildlife Service. 2002. Razorback Sucker (*Xyrauchen texanus*) Recovery Goals: amendment and supplement to the Razorback Sucker Recovery Plan. U. S. Fish and Wildlife Service, Denver, CO. 78 pp. + appendix.

Valdez, R., P. Mangan, R. Smith, and B. Nilson. 1982. Upper Colorado River investigation (Rifle, Colorado to Lake Powell, Utah). Pages 101-279 *in* W. H. Miller et al., editors. Colorado River Fishery Project Fianl Report; Part Two, Field Studies. U. S. Fish and Wildlife Service and Bureau of Reclamation. Salt Lake city, UT.

Van den Avyle, M. J. 1993. Dynamics of exploited fish populations. Pages 105-135 *in* C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, MD.

Williamson, J. H. 1991. A protocol for the handling and transport of wild Colorado squawfish and razorback sucker in the Upper Colorado River Basin. U.S. Fish and Wildlife Service, Denver, CO. 5 pp.