Species Status Assessment Report for the Headwater Chub and Lower Colorado River Distinct Population Segment of Roundtail Chub

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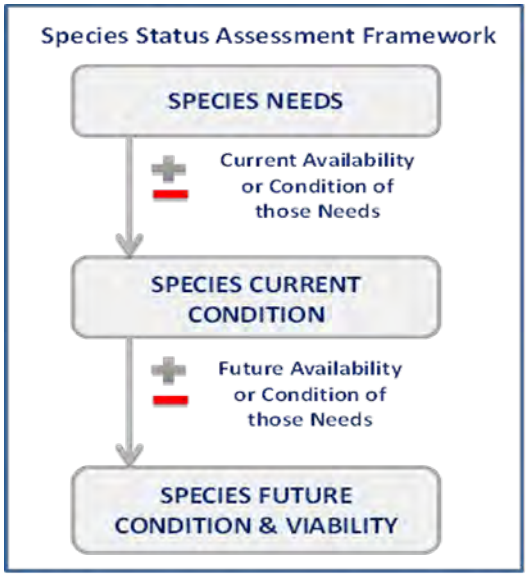
Chapter 1. Introduction

The headwater chub (*Gila nigra*) and the Lower Colorado River distinct population segment (DPS) of the roundtail chub (*Gila robusta*)[1] (roundtail chub DPS)[2] occur in streams in New Mexico and Arizona (Service 2006, 2009). These entities are being reviewed for listing as threatened or endangered species under the Endangered Species Act of 1973, as amended (Act). This Species Status Assessment Report for the Headwater Chub and Lower Colorado River Distinct Population Segment of Roundtail Chub (SSA Report) is a summary of the information assembled and reviewed by the U.S. Fish and Wildlife Service (Service) and incorporates the best scientific and commercial data available. This SSA Report documents the results of the comprehensive status review for the headwater chub and roundtail chub DPS to inform the listing decision under the Act and to inform future conservation efforts.

The Service is engaged in a number of efforts to improve the implementation of the Act (see www.fws.gov/endangered/improving_ESA). As part of this effort, our Endangered Species Program has begun to develop a new framework to guide how we assess the biological status of species. Because biological status assessments are frequently used in all of our Endangered Species Program areas, developing a single, scientifically sound document is more efficient than compiling separate documents for use in our listing, recovery, and consultation programs. Therefore, we have developed the following SSA Report that contains summary information regarding life history, biology, and current and future risk categories facing the headwater chub and roundtail chub DPS.



The objective of the species status assessment (SSA) is to thoroughly describe the viability of the headwater chub and roundtail chub DPS based on the best scientific and commercial data available. Through this description, we will determine what the species need to remain viable, their current condition in terms of those needs, and their forecasted future condition. In conducting this analysis, we take into consideration the changes that are happening in the environment – past, current, and future – to help us understand what conditions drive the viability of the species. We developed a model to analyze the current and future condition using Microsoft Excel. The purpose of the model analysis is to reflect our understanding of the viability of these chub species by applying the best available information to assess the status of these species in a standardized and transparent method.

[1] The Lower Colorado River DPS of roundtail chub is the candidate entity under evaluation in this SSA. The DPS includes three watersheds below Lees Ferry on the Colorado River; the Bill Williams, Gila, and Little Colorado rivers. In this SSA the entity under consideration is the DPS and not the entire species. Where appropriate, information on life history and habitat in this assessment relies on information generated from the entire range of roundtail chub.

[2] Under the Act, a distinct population segment meets the definition of a species and is a listable entity.

For the purpose of this assessment, we define **viability**[3] as a description of the ability of the species to sustain populations in the wild beyond a biologically meaningful timeframe. Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of the species in terms of its **resiliency**, **redundancy**, and **representation**.

- **Resiliency** is having sufficiently large populations for the species to withstand stochastic events. Stochastic events are those arising from random factors such as weather, flooding, or fire. We can measure resiliency based on metrics of population health; in the case of the headwater chub and roundtail chub DPS, abundance and persistence of chubs in currently occupied streams over time, the amount of habitat available in the stream, and presence of nonnative species are primary indicators of resiliency. Resilient populations are better able to withstand disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of climate change and increasing human uses of water.

- **Redundancy** is having a sufficient number of populations for the species to withstand catastrophic events. A catastrophic event is defined here as a rare destructive event or episode involving many populations and occurring suddenly. Redundancy is about spreading risk and can be measured through the duplication and broad distribution of resilient populations across the range of the species. The more resilient populations the species has, distributed over a larger landscape area, the better chances that the species can withstand catastrophic events. For the headwater chub and roundtail chub DPS, we measure redundancy based on the geographic distribution of the occupied streams (evaluated as analysis units [AUs]) across the range of the entities.

- **Representation** is having the breadth of genetic makeup of the species to adapt to changing environmental conditions. Representation can be measured through the genetic diversity within and among populations, and the ecological diversity (variety of ways species interact with each other and the environment) of populations across the species' range. The more representation, or diversity, the species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the case of the headwater chub and roundtail chub DPS, we evaluate representation based on the maintenance of the identified genetic diversity in populations across the geographic range of the two species.

Our objectives for this SSA were: 1) to assess the current condition of each extant headwater chub and roundtail chub DPS analysis unit (AU) relative to a series of condition categories; and 2) to describe the future condition of the headwater chub and roundtail chub DPS AUs by examining a set of future scenarios related to those condition categories; and 3) to use the assessments of current and future conditions to describe of viability in terms of the species' resiliency, redundancy, and representation over our measured time frame to 2046. In this SSA

[3] Viability is not a specific state, but rather a continuous measure of the likelihood that the species will sustain populations over time. From, USFWS. 2015. Draft Species Status Assessment Framework. Version 3.1 for FWS ES HQ and Science Applications Review. January 2015.

we refer to populations of headwater chub and roundtail chub DPS as analysis units (AUs). The AUs are based on the hydrological connectivity of the occupied streams. This is further explained in section 1.1 below.

This SSA Report presents the following information:

(1) Introduction;
(2) Taxonomy and the historical and current distribution of the two species (Chapter 2);
(3) Life history, biology, and resource needs of individuals (Chapter 3);
(4) Taxonomy (Chapter 4);
(5) Population and species needs and current condition of populations (Chapter 5);
(6) Discussion of risk categories and conservation actions (Chapter 6);
(7) Current Condition (Chapter 7).
(8) Future Condition and Viability (Chapter 8)
(9) Appendix A-Glossary of Selected Terms
(10) Appendix B-Evaluating Causes and Effects for Headwater and Roundtail Chub
(11) Appendix C-Status Assessment Model Headwater and Roundtail Chub
(12) Appendix D-Literature Cited
(13) Appendix E – Supplemental Information for Assessment Model
(14) Appendix F- Effects Pathway Conceptual Model

For a glossary of selected terms used in this SSA Report, reference Appendix A. The detailed analysis of potential threats to the chubs as summarized in Chapter 6 is found in the Evaluating Causes and Effects tables in Appendix B. We conducted an analysis to qualitatively characterize the viability of the headwater and roundtail chubs as described in Draft Status Assessment Model Headwater and Roundtail Chub in Appendix C. The literature cited in this SSA Report is in Appendix D[4]. Appendix E contains additional information on our assessment methods, uncertainties, and assumptions. The Effects Pathway Conceptual Model is in Appendix F.

There is a considerable lack of specific information on population size or density for either chub species. Consequently, determining an effective population size is difficult. Further, data is lacking as to the amount and quality of habitats in a stream needed to support a population size or effective population sizes to avoid loss of genetic or ecological diversity. In addition, the relationship between chubs and various nonnative aquatic species that now occupy chub habitat under different physical conditions is unclear. However, we used the best available scientific information to inform our analysis.

For the historical and baseline conditions and distribution of the chubs, we primarily used information from compilations of historical and current survey data of headwater and roundtail chub (Abarca and Weedman 1993, entire; Girmendonk and Young 1997, entire; Voeltz 2002, entire; Carman 2006, entire; Jones *et al*. 2014, entire). Specific survey data from Arizona Game and Fish Department (AGFD) and New Mexico Department of Game and Fish (NMDGF) and other sources were integral sources of biological data and some physical habitat data. We also consulted with knowledgeable individuals within the two state game and fish agencies; other Federal, state, and Tribal entities; consultants; and researchers and academics to obtain

[4] We did not cite every report and information source that was reviewed for this assessment. Only the cited sources are referenced in this SSA Report.

information relevant to the status of headwater chub and roundtail chub DPS. We also used a number of relevant references that were cited in our 12-month findings for the headwater chub and roundtail chub DPS (Service 2006, 2009, respectively) and annual candidate notices of review (Service 2007, 2008, 2009, 2010a and b, 2011a and b, 2012a and b, and 2013a and b). We also reviewed literature regarding related species like the Gila chub (*Gila intermedia*) (Service 2015) and other native fish species, and the broader literature on the risk factors and their effects on southwestern native fish species to provide the basis for this SSA Report.

Importantly, this SSA Report does not result in, or predetermine, any decision by the Service under the Act. In the case of the headwater chub and roundtail chub DPS the SSA Report does not determine whether or not these entities warrant protections of the Act, or whether either species should be proposed for listing as a threatened or endangered species under the Act. That decision will be made by the Service after reviewing this document, along with the supporting analysis, any other relevant scientific information, and all applicable laws, regulations, and policies. The results of the decision will be announced in the **Federal Register**. Instead, this SSA Report provides a strictly scientific review of the available information related to the biological status of the headwater chub and roundtail chub DPS.

1.1 Establishment of Analysis Units for Headwater Chub and Roundtail Chub DPS

1.1.1 Methods

To assess the current and future condition of the chubs we identified "analysis units" (AUs), rather than individual streams or populations, for each species. The AUs were delineated based on the hydrological connection of currently occupied chub streams and the ability of chubs to move within or among streams. A currently occupied stream is defined as a stream or stream reach identified in Voeltz (2002) and most recently Jones et al. (2014) as documented by surveys to contain either roundtail or headwater chub. Table 2.3-1 and 2.3-2 lists the AUs and the streams for each chub species.

There are two types of AUs considered in this SSA Report:

1. those composed of one occupied stream, referred to as Independent AUs and
2. those composed of two or more hydrologically connected occupied streams, referred to as Complex AUs.

Both independent and complex AUs rely on the identified streams to sustain chub populations within their boundaries. The structure of the complexes may vary between AUs. There are AUs with major rivers and associated tributaries, and there are AUs without major rivers, but composed of streams within the same tributary system. Chub movement between hydrologically connected streams is likely variable and dependent on local conditions.

For some occupied streams, there is a manmade or natural barrier that divides the stream into two reaches above and below that barrier. In most of these streams, the lower reach is connected to another occupied stream (generally the mainstem Salt or Verde Rivers) with its own set of biological and physical conditions. For this assessment, these reaches below the barrier are considered a part of the connecting main stream and separate from the reach above the barrier.

We acknowledge that individual chubs from the upper reach do move over the barrier into the lower reach and cannot return upstream. These individuals contribute to the population in the lower reach and the connected stream as would individuals born in those areas and are subject to the same risks. However, our assumption is that the contribution from above the barrier is limited.

For headwater chub there are 22 streams within 3 drainage basins with 8 AUs, 3 individual AUs and 5 complex AUs. The San Carlos Complex is entirely on lands of the San Carlos Apache Indian Tribe; the majority of the lands in the other nine AUs are Forest Service.

Table 1.1-1 Headwater Chub Analysis Units

Drainage Basin	Analysis Unit	Streams Included in the Unit
Gila River	Three Forks Complex	East, Middle, and West Forks Gila River and Diamond Creek (tributary to the East Fork)
	San Carlos Complex	Ash Creek and, San Carlos River
Salt River	Upper Tonto Creek Complex	Gordon, Haigler, Marsh, Buzzard Roost, Rock, Spring, Turkey, and upper Tonto Creeks
	Lower Tonto Creek Complex	Lower Gunn Creek and lower Tonto Creek
	Upper Gunn Creek	Gunn Creek above natural barrier
Verde River	Upper Fossil Creek	Fossil Creek above constructed fish barrier
	Upper Wet Bottom Creek	Wet Bottom Creek above natural barrier
	East Verde River Complex	Gorge, Pine, Rock, and Webber Creeks and East Verde River

For the roundtail chub DPS there are 35 streams within five drainage basins with 15 AUs, 8 individual AUs and 7 complex AUs. The Upper Salt River Complex is dominated by streams on lands of the White Mountain Apache Tribe. The other units are on Federal lands (Bureau of Land Management and Forest Service), and state and private lands.

Figure 1.1-1. Headwater Chub Analysis Units

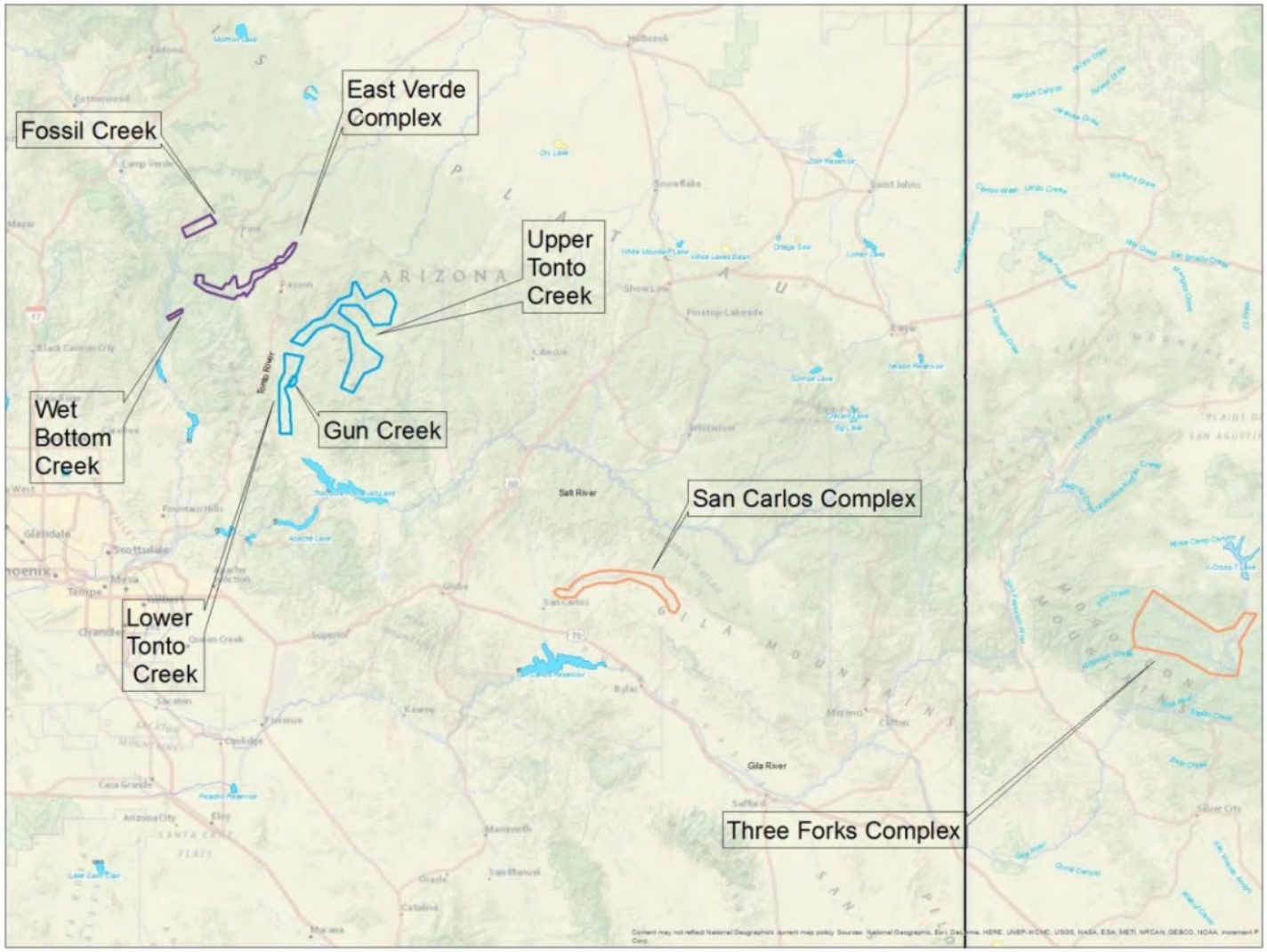


Table 1.1-2 Roundtail Chub DPS Analysis Units

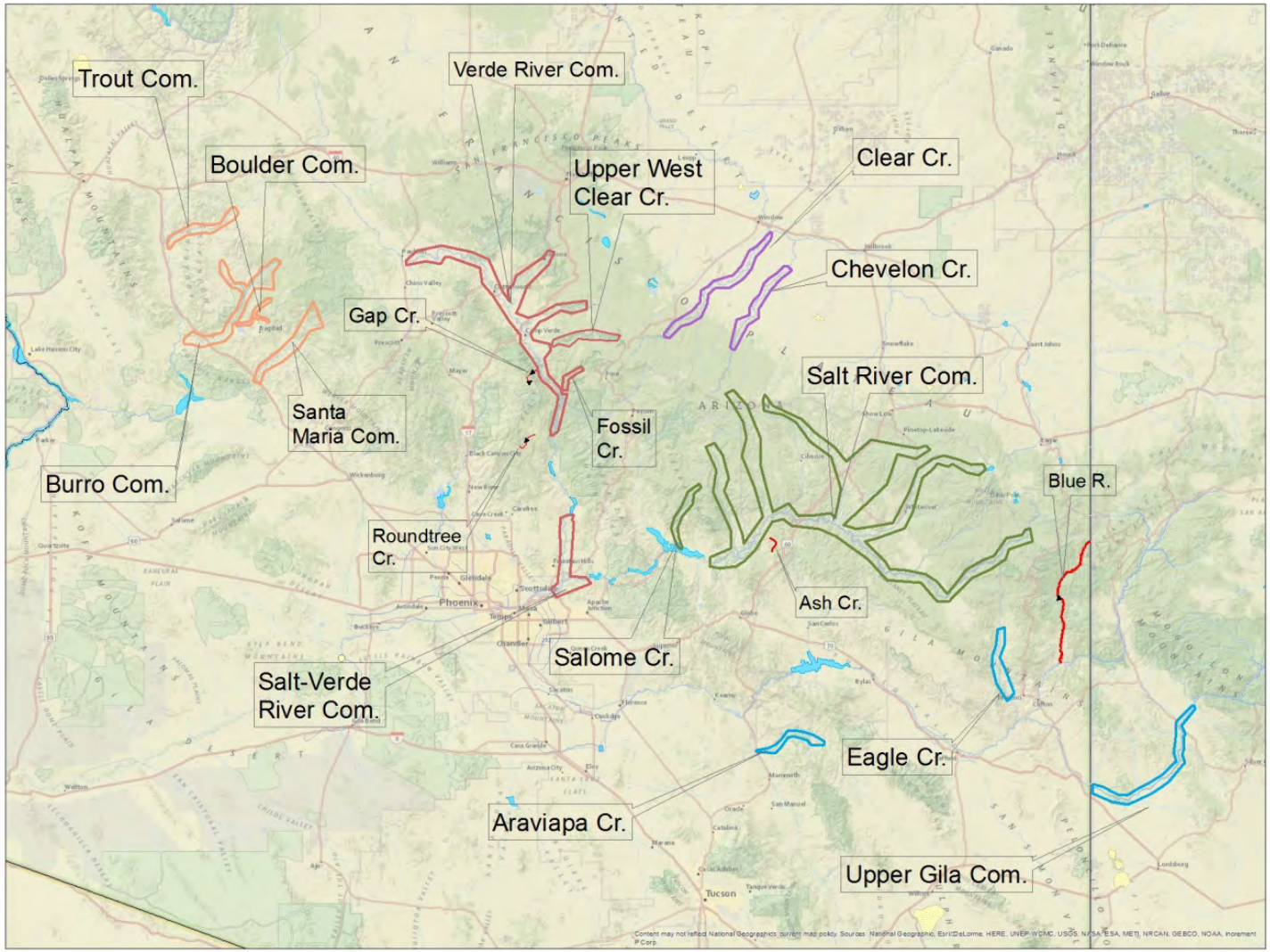
Drainage Basin	Analysis Unit	Streams Included
Bill Williams	Burro Creek Complex	Burro, Conger, and Francis Creeks, lower Boulder Creek
	Boulder Creek Complex	Upper Boulder Creek to Warm Springs, Stone Corral (tributary to Wilder Creek, and Wilder Creeks;
	Trout Creek Complex	Cow, Fort Rock, and Trout Creeks
	Santa Maria Complex	Cottonwood Canyon, Kirkland, and Sycamore Creeks and, Santa Maria River
Gila River	Aravaipa Creek	Aravaipa Creek
	Eagle Creek	Eagle Creek
	Upper Gila River	Gila River from Arizona-New Mexico border to the Gila Forks confluence.
Little Colorado River	Chevelon Creek	Chevelon Creek below Chevelon Canyon Lake to the Little Colorado River
	Clear Creek	East Clear Creek below Yeager Canyon which becomes Clear Creek to the Little Colorado River
Salt River	Salome Creek	Salome Creek
	Upper Salt River Complex	Canyon, Carrizo, Cherry, Lower Cibecue, and Corduroy Creeks, and Black, White, and Salt Rivers above Roosevelt Lake
Verde River	Upper Fossil Creek	Fossil Creek above the constructed fish barrier
	Upper West Clear Creek	West Clear Creek above waterfall
	Confluence Reach Complex	Lowermost Salt and Verde Rivers
	Verde River Complex	Beaver, and Wet Beaver creeks, Oak, lower West Clear, and Fossil Creeks, and mainstem Verde River from headwaters to Horseshoe Reservoir

For the roundtail chub DPS there are 4 streams with newly established populations. All are within the historic range of the five drainage basins and all are independent AUs. We group them separately because they are newly established populations and their long-term success has yet to be demonstrated.

Table 1.1-3. Roundtail Chub DPS Established Analysis Units

Drainage Basin	Analysis Unit
Gila River	Blue River Unit
Salt River	Ash Creek Unit
Verde River	Gap Creek Unit
Verde River	Roundtree Canyon Unit

Figure 1.1-2. Roundtail Chub DPS Analysis Units



Chapter 2. Life History, Biology, and Resource Needs of Individuals

In this chapter we provide basic biological information about the headwater and roundtail chubs, including their morphological descriptions and known life history traits. We then outline the resource needs of individuals of the headwater and roundtail chubs. There are several significant sources of information on headwater and roundtail chubs life history and biology (*e.g.,* Vanicek and Kramer 1969, entire; Neve 1976, entire; Bestgen 1985, entire; Bezzerides and Bestgen 2002, entire) as well as other examinations of life history characteristics of these chubs and research on related species that are supportive to this discussion. This literature does not fully describe the specific needs for all life stages for all environmental factors but does frame the primary considerations for habitat preferences and needs. Here we report those aspects of the chubs' life history that are important to our analysis.

2.1 Headwater Chub Background Information

2.1.1 Species Description

Headwater chub is a moderate-sized cyprinid fish (member of the minnow family Cyprinidae) and is similar in appearance to Gila chub and roundtail chub (two closely related species). When found in the same stream, determination of individuals as headwater or roundtail chub by visual assessment is difficult because there is overlap in the measurements between the species (Minckley and DeMarais 2000; Brandenberg et al. 2015, p. 18). Additionally, conducting the measurements could result in harm to the fish from injury and handling stress and, therefore, is not usually attempted. The body is usually dark olive gray to brown overall, silver laterally, and often with diffuse lateral lines on the sides and is slender and moderately fusiform. When in spawning condition, headwater chub may develop a red-orange coloration on the lower half of the cheek and along the fin bases. A deeply compressed body, flat head, slender caudal peduncle, and an angle along the anal fin base that continues into the caudal fin is characteristic of headwater and roundtail chub. Adults range in size from 200-320 millimeters (mm) (8-12.5 inches (in)). Headwater chub are generally smaller than roundtail chub, likely due to the smaller streams in which they occur (Minckley 1973, pp. 100-102; Sublette et al. 1990, pp. 126-129; Propst 1999, pp. 23-25; Minckley and DeMarais 2000, pp. 254-255; Voeltz 2002, pp. 8-11).

Figure 2.1-1. Headwater Chub. Photo courtesy of John Rinne.

2.1.2 Life History

Headwater chubs live for approximately 8 years and spawn at age 2-3 onward (Bestgen 1985, p. 65) (Neve 1976, pp. 13, 15). Spawning typically occurs between April and May (Bestgen 1985; Brouder et al. 2000) but can occur as early as March (Neve 1976, pp. 13-14). Females spawn by making several passes over the stream substrate to release eggs followed by the males (Bonar et al. 2011, p. 11; Neve 1976, pp. 13-14). Egg production ranges from 1,000 to 33,440 (Neve 1976, p. 13; Bestgen 1985, p. 66). Eggs are adhesive (Neve 1976; p. 14) and hatch within 5 to 6 days (Bonar et al. 2011, p. 22). There is no parental protection of young (Stefferud et al. 2011, p. 5).

Growth and survival of larvae varies with rearing temperature; the best growth was achieved at 27 degrees Celsius (˚C) (81 degrees Fahrenheit (˚F)), but temperatures of 20˚C (68˚F) and higher to 27˚C (81˚F) were documented as providing for good growth of the young fish in their first few months (Bonar et al. 2011, p. 13). Little is known of the normal pattern or growth to adult size. Age 1 and 2 year headwater chubs are considered juveniles and are typically less than 100 mm (4 in) in length. Chubs greater than 100 mm (4 in) are considered adults.

Headwater chub are omnivorous, opportunistic feeders that consume plants, detritus, and arthropods (aquatic and terrestrial). They may also consume small fish as they are the top native fish predator in their habitat (Pilger et al. 2010, p. 306). There are extensive changes in diet by size of the individual and seasonally; likely in part due to changes in abundance of different food items over the year (Neve 1976, pp. 10-12).

2.1.3 Resource Needs (Habitat) of Headwater Chub Individuals

Headwater chubs occur in the middle to upper reaches of moderately-sized streams (Minckley and DeMarais 2000, p. 255) that are considered cool to warm water streams. Habitats in the Gila River containing headwater chubs consisted of tributary and mainstem habitats at elevations of 1,325 meters (m) (4,347 feet (ft)) to 2,000 m (6,562 ft) (Bestgen 1985, entire); Bestgen and Propst 1989, pp. 402-410). Typical adult habitats containing headwater chub consist of nearshore pools adjacent to swifter riffles and runs over sand and gravel substrate, with young of the year and juveniles using smaller pools and areas with undercut banks and low velocity (Bestgen and Propst 1989, pp. 402-410). Maximum water temperatures for habitats of the headwater vary from 20° to 27°C (68° to 81°F), with minimum water temperatures of 7°C (45°F) (Bestgen and Propst 1989, pp. 402-410; Barrett and Maughan 1995, pp. 304-305). Spawning typically occurs in pool-riffle areas with sandy-rocky substrates when water temperatures are between 17˚C (63˚F) (Bonar et al. 2011, p. 10) and 22˚C (72˚F) (Bestgen 1985, p. 64; Bonar et al. 2011, p. 11; Neve 1976, pp. 13-14). Further details of the individual needs of headwater chubs during the various life stages are provided below in Table 2.1-1.

Table 2.1-1. Known Habitat Needs of Headwater Chub by Life Stage

Resource	Resource Needs (Habitat)	References
Spawning to Eggs		
Temperature	In lab spawned at above 17°C (68°F) (range 16.5-18°C (61.7-64.4°F)). Ceased above 19-20°C (66-68°F).	Bonar et al. 2011, pp. 22, 25
	In Fossil Creek varied from 19-23°C (66-73°F)	Neve 1976, p. 4
Habitat	Egg development occurs in substrate	Neve 1976, p. 14
	Pool-riffle areas with sandy/rocky substrates	Neve 1976, p. 14
Larvae/Young of Year		
Temperature	Most growth and least mortality in lab study was at 27°C (81°F)	Bonar et al. 2011, p. 22
	Least growth and average mortality at 19.5°C (67°F)	Bonar et al. 2011, p. 23
	Mortality at 30°C (86°F) was highest	Bonar et al. 2011, p. 24
Habitat	Swifter, shallower water than adults	Ecology Audits 1979, p. 30
	Pools and areas with undercut banks and slow currents	Anderson 1978, p. 19
	Used areas along streambanks and shallow backwaters	Neve 1976, pp. 5, 14
	Ate diatoms and filamentous algae all year	Neve 1976, p. 14
Juveniles		
Temperature	Best growth at 20 and 24°C (68 and 75°F) in lab tests with artificial food	Bonar et al. 2011, p. 26
Depth	High selection for 0.9-1.5 m (3.0-4.9 ft) and low for greater than 2.1 m (6.9 ft)	Barrett and Maughn 1995, p. 302
	Preferred 1-1.5 m (3-5 ft), but not greater than 2.1 m (7 ft)	Barrett 1992, p. 52
	Mean depth 0.55 m (1.8 ft)	Paroz et al. 2006, p. 51
Flow	Velocities near 1.6 meters per second (m/s) (0.5 feet per second (f/s)) preferred; those above 6.6 m/s (2.0 f/s) are not	Barrett 1992, p. 49; Barrett and Maughn 1995, p. 302
	Selected about 0.15 m/s (0.5 f/s) and avoided greater than 0.61 m/s (2 f/s)	Barrett and Maughn 1995
Food	For feeding, young fish move from slow areas into shallower, faster areas at heads of pools	Bestgen 1985, p. 44

	Diet dominated by algae, caddisflies, and other insects, mostly small in size	Bestgen 1985, p. 48
Cover	All types of cover used	Barrett 1992, p. 52; Barrett and Maughn 1995, p. 302
Habitat	Pools and areas with undercut banks and slow current	Anderson 1978, p. 19
	Shallower, low-velocity waters adjacent to overhead bank cover	Bestgen and Propst 1989, p. 407
	Smaller substrate size, sand substrates particularly selected, little for large boulders or bedrock	Paroz et al. 2006, p. 51; Barrett 1992, p. 52; Barrett and Maughn 1995, p. 302
Adults		
Depth	Deep (greater than 1.8 m (6 ft)), but occasionally used shallower (less than 0.9 m (3ft)),	Barrett 1992, p. 48; Barrett and Maughn 1995, p. 302
Flow	Slow-flowing pools (less than 0.009 m/s (0.33 feet per second (f/s))), but did occasionally use swifter (greater than 0.044 m/s (1.5 f/s)) waters including riffles	Barrett 1992, p. 48; Barrett and Maughn 1995, p. 302
Habitat	Found mainly in pool habitat, but also in riffle-run and run habitats	Paroz et al. 2009, p. 23
	Various substrates (fine sand to boulders with sand/gravel preferred)	Bestgen 1985, p. 41
Food	Feed in medium velocity runs (0.3-0.5 m/s (10-18 f/s)) away from streambanks; feed on surface, water column, and bottom	Bestgen 1985, pp. 44, 52
	Opportunistic omnivores, varied seasonally; diet primarily of ostracods, larval insects, and plants, but at over 170 mm (6.7 in) size added fish and crayfish; algae, hellgrammites, crayfish, Dipteran larvae, may eat fish	Neve 1986, p. 10; Bestgen 1985, pp. 48, 52

2.2 Roundtail Chub Background Information

2.2.1 Species Description

The roundtail chub is a large cyprinid fish (member of Cyprinidae, the minnow family). Roundtail chub are similar in appearance to Gila chub and headwater chub (two closely related species). The body is usually olive gray to silvery, with a lighter belly, and occasionally with dark blotches on the sides. When in spawning condition, roundtail chub may develop a red-orange coloration on the lower half of the cheek and along the fin bases. A deeply compressed body, flat head, slender caudal peduncle, and an angle along the anal fin base that continues into the caudal fin is characteristic of headwater and roundtail chub. Depending on the size of the natal stream, adult roundtail chubs are generally larger than adult headwater chub. Adult roundtail chubs are generally 225 to 350 mm (9 to 14 in) in length, but can reach 500 mm (20 in) (Minckley 1973, pp. 101–103; Sublette et al. 1990, pp. 126–129; Propst 1999, pp. 23–25; Minckley and DeMarais 2000, pp. 251– 256; Voeltz 2002, pp. 8–11).

Figure 2.2-1. Roundtail Chub. Photo courtesy of John Rinne.

2.2.2. Life History

Roundtail chub average life span is 8-10 years or more in larger streams and less in smaller tributaries (Bezzerides and Bestgen 2002, p. 21). Maturity occurs between ages 3-5 at 150-300 mm (5.9-11.8 in) (Bezzerides and Bestgen 2002, p. 21; Brouder et al. 2000, p. 12). Growth rates and maximum size vary by streams. Typically, adults are 200-300 mm (7.9-11.8 in) (Bezzerides and Bestgen 2002, p. 18). In the DPS, spawning occurs between April and May (Minckley 1981, p. 189; Brouder et al. 2006, pp. 261-262; Bestgen 1985b, p. 7; Bryan et al. 2000, pp. 27-28; Bryan and Robinson 2000, pp. 20-21). The smallest male in spawning condition was 156 mm (6.1 in) and the smallest female was 189 mm (7.4 in) (Brouder et al. 2000, p. 13). Total fecundity ranged from 7,267 to 26,903 eggs per female with the number of eggs increasing with size of the female. Eggs are adhesive and ranged from 1.8-3.8 mm (0.07-0.15 in) in diameter with a mean of 2.7 mm (0.11 in) (Brouder et al. 2000, p.14). In the lab, eggs hatched after four to seven days at 19˚C (Muth et al. 1985, p. 2).

Roundtail chubs are omnivores, consuming foods proportional to their availability, including aquatic and terrestrial invertebrates, aquatic plants, detritus, and fish and other vertebrates. Like headwater chub, larvae feed on diatoms and filamentous algae (Neve 1976, p. 10) with juveniles eating chironomid larvae and ephemeroptera nymphs (Vanicek and Kramer 1969, p. 202) along with algae, tricopterans, and ostracods (Bestgen 1985, p. 48). Larger juveniles and adults consume aquatic and terrestrial insects, crustaceans, fish, plant matter, and occasional small lizards (Bezzerides and Bestgen 2002, p. 23).

2.2.3 Resource Needs (Habitat) of Roundtail Chub Individuals

Roundtail chubs are found in cool to warm waters of rivers and streams, and often occupy the deepest pools and eddies present in the stream (Minckley 1973, p. 101; Brouder et al. 2000, pp. 6–8; Minckley and DeMarais 2000, p. 255; Bezzerides and Bestgen 2002, pp. 17– 19). Adult roundtail chub favor slow-moving, deep pools with access to feeding areas and containing cover such as large rocks, undercut banks, and woody debris (Bezzerides and Bestgen 2002, p. 18;

Brouder et al. 2000, pp. 6-7; Bryan and Hyatt 2004, p. 9). Spawning occurs in pool, run, and riffle habitats, with slow to moderate water velocities (Propst 1999, p. 24; Brouder et al. 2000, p. 12; Voeltz 2002, p. 16). Roundtail chub larvae use low velocity backwaters (Ruppert et al. 1993, p. 397). Young of the year roundtail chub occupy shallow (less than 50 cm (19.7 in)) and low velocity waters with vegetated shorelines (Brouder et al. 2000, pp. 6-8; Lanigan and Berry 1981, p. 392). Juveniles use habitat similar to young of year but with depths less than 100 cm (39.4 in). Although roundtail chubs are often associated with various cover features, such as boulders, vegetation, and undercut banks, they are less likely to use cover than other related species such as the headwater chub and Gila chub (Minckley and DeMarais 2000, p. 2145).

Water temperatures of habitats occupied by roundtail chub vary seasonally vary between 0-32˚C (32-90˚F) (Bezzerides and Bestgen 2002, p. 19; Bonar et al. 2010, p. 3). Lethal limits are around 34˚C (93˚F) (Carveth et al. 2006, pp. 1435-1436). Spawning is associated with water temperatures of 14 to 24˚C (57 to 75˚F) with most at 18 to -20˚C (64 to -4˚F) (Bezzerides and Bestgen 2002, p. 21; Brouder et al. 2006, pp. 261-262). Further details of the individual needs of headwater chubs during the various life stages are provided below in Table 3.2-1.

Table 2.2-1. Known Habitat Needs of Roundtail Chub by Life Stage

Resource	Resource Needs (Habitat)	References
Spawning to Eggs		
Temperature	Range of 12-22˚C (54-72˚F) in White River, Verde River, and lab	Vanicek and Kramer 1969, p. 207; Brouder et al. 2000, p. 13;Carlson et al. 1979, p. 72-3
	Range of 14-18˚C(57-64˚F) in Yampa at start of spawning period;	Bestgen et al. 2011, p. 13
Spawning Cues	After peak spring flows when flows are declining	Bestgen et al. 2011, p. 13 and many other authors
	Correlated with peak annual discharge, higher discharges provided more recruitment	Muth and Nesler 1993, p. 22
	Spawned 3 weeks after a spring “spate”	Brouder et al 2000, p. 13.
Habitat	Eggs are adhesive and stick to rocks, are broadcast near shore.	Baxter and Simon 1970, p. 69
	Emerge from gravel in about 7 days	Bestgen et al. 2011, p. 13
	Eddies or shallow pools with boulder or cobble substrate	Bonar and Mercado Silva, 2013, p, 24;
	Pools with clean gravels and runs with silt/sand and gravel with no cover, flows are low	Minckley 1981, p 187, 191
Larvae/YOY		
Temperature	Eggs hatched in about 7 days at 18˚C (64˚F)	Bestgen and Zelasko 2004, p. 1
Habitat	Low to no velocity areas associated with backwaters, pools, and runs, ephemeral riverside embayments, use vegetated shorelines. Use a variety of substrates	Bonar and Mercado Silva 2013, p. 24; Muth and Nesler 1993, p. 20; Ruppert et al 1993, p. 397; Brouder et al. 2000, pp 6-7; and other authors
Depth	Shallowest depths (≤20 cm and 21-50 cm (≤7.8, 8.2-19.6 in). Avoided 50-100cm (19.6-39.3 in) and never found over 100 cm (40 in)	Brouder et al 2000, p. 7
	Middle and bottom of water column, mean depth 14.9 cm (7 in)	Bryan et al. 2000, p. 21, 61
Juveniles (<100 mm Total Length (TL))		
Temperature	No data	

Depth	20-200 cm (7.8-78.7 in)	Bonar and Mercado Silva 2013, p. 24
	Shallower portions of pools; 100% probability of use for depths over 18.3 cm (7.2 in) and no use of 2.4 cm (0.96 in)	Turner and Tafanelli 1983a, p. 24-25
Flow	0.0-96 cm/s (0.0-3 f/s)	Bonar and Mercado Silva 2013, p. 24
	Probability of use 100% at 0.09 m/s (0.3 f/s), 25% at 0.2 m/s (0.7 f/s) and 0% at 0.8 m/s (2.5 f/s)	Turner and Tafanelli 1983a, p. 25
	Used low velocities	Brouder et al. 2000, p.7
Food	Aquatic insects on the bottom of pools and eddies	Joseph et al. 2008, p. 84
	Chironomid and ephemeropteran larvae most abundant items	Vanicek and Kramer 1969, pp. 202, 204
Cover	Woody debris or other types	Bonar and Mercado Silva 2013, p. 24
Habitat	Pools and riffles	Bonar and Mercado Silva 2013, p. 24.
	Large, deep pools are used for refuges during low flow conditions	Bower et al. 2008, p. 353
	Pools selected over riffles even when riffles were more abundant	Turner and Tafanelli 1983a, pp. 6, 33-34
	Riffles used in the Bill Williams River	Kepner 1979, p. 15
	Pools and backwaters with some water movements	Lanigan and Berry 1981, p. 392
	Common in riffle areas of lower elevation streams, may be out-competed by red shiner in slower velocity areas	Joseph et al. 1977, pp. 83,84
	Pools and backwaters	Bestgen et al. 2011, p. 13
	Backwaters and nearshore pools	Bestgen and Zelasko 2004, p. 2
	Riffle/pool and submerged vegetation types less than 1m (3 ft) deep.	Ziebell and Roy 1989, p. 22
	Quiet water or shallow pools	Vanicek and Kramer 1969, p.156
	Vegetated shorelines in glides (runs) in West Clear Creek (where there are smallmouth bass in the pools, pools in the upper Verde	Brouder et al. 2000, pp. 6-7
Adults (>100 mm TL)		
Depth	Selected depths 2.1 m (6.9 ft) with few shallower or deeper	Barrett and Maughn 1995, p. 301
	20-200 cm (7.8-78.7 in)	Bonar and Mercado Silva 2013, p. 24
	Large deep pools that may be smaller than shallower pools. Depth is important	Bower et al. 2008, p. 353
	Occupy shallower habitats at night; 3% night observations in > 3 m (9.8 ft) during day 21% in that depth	Beyers et al. 2001, pp, 7, 11
	Used 21-50 cm (8.2-19.6 in) 38.6% of time and 51-100 cm (20-39.3 in) 35.7% of time. Avoided ≤ 20 cm (7.8 in)	Brouder et al. 2000, p. 7
Flow	Did not use velocities above 0.14 m/s (3.28 f/s)	Barrett and Maughn 1995, p. 301
	When instream cover absent, used 0.23-0.76 m/s (0.75-2.5 f/s);	Turner and Tafanelli 1983b, p. 30-31
	15-25 centimeters per second (cm/s (0.5-0.7 f/s))	Rinne 1992, p. 39
	Selected ≤ 20 cm/s (0.65 f/s), used > 20 cm/s (0.65 f/s) in proportion to availability	Brouder et al. 2000, p. 7
Habitat	Concentrate in suitable pools	Kepner 1979, p. 15
	Use largest, deepest, and most permanent pools. Not all pools are selected	Minckley 1973, p. 166
	Deep pools and runs, often with cover	Bestgen and Zelasko 2004, p. 21
	Pools about 2 m deep (6.5 ft) below riffles	Ziebell and Roy 1989, p. 22
	60% pools, 18% glides, and 10% runs	Rinne and Stefferud 1998, p. 19
	Pools, glides, low gradient riffles	Bryan et al. 2000, p. 19-20
Food	Aquatic and terrestrial insects, fish, detritus dominate diet	Quist et al. 2006, p. 25
	Fish and other vertebrates added to diet of aquatic and	Bestgen and Zelasko 2004, p. 21

	terrestrial invertebrates, plankton, detritus and algae	
	Principal food items for fish over 200 mm (7.8 in) were terrestrial insects, plant debris, and fish	Vanicek and Kramer 1969 pp. 202, 204
	Top carnivore of native fish in its streams, preys on larvae and juveniles of other fishes	Rinne 1992, p. 40
	Filamentous algae, detritus, fish, invertebrates (benthic and drifting). Not all available taxa were eaten	Schreiber and Minckley 1981, pp. 411-12, 415

Chapter 3. Historical and Current Range and Distribution

3.1 Calculations of Stream Length

We used stream lengths to evaluate the historical and current range for both species. For the historical stream length, we included the entire stream length from the headwaters to the mouth, which included dry, intermittent, and perennial stream segments. We assume that historically chubs were able to use the entire length of the stream because streams were more connected due to more water being available, nonnatives were not present, and manmade barriers were not present. It is important to understand that the historical stream length we present may not be indicative of the actual habitat available historically (watered stream length) or where the chubs were known to occur historically (surveys were limited in most streams). Consequently, this could overestimate the historical range of the species. However, the best available data does not allow us to be more precise in our evaluation of historical stream length.

For historical stream length data in this SSA Report, we primarily referenced Jones et al. (2014, pp. 113-115). Jones et al.'s (2014) estimation of historical stream length included dry and intermittent segments, and sections located on tribal lands. However, historical stream length data from Jones et al. (2014) was lacking for some streams length because they did not consider the streams to be within the historical or current range of the chubs. Where Jones et al. (2014) did not include data on historical stream length, we used The Nature Conservancy's streams database or Google Earth satellite imagery. We denote which sources we used for the various streams in Table 2.2-3 below. There is a small amount of variation in measurements between sources but these are not significant to the analysis.

We did not use the total stream lengths to assess the currently available habitat for these species, as it does not reflect the conditions on the ground. We estimated current range based on the total estimated perennial and interrupted perennial reaches during the driest time of year within the species' current occupied streams (including reintroduction streams and streams on tribal lands). We used the path measurement feature in Google Earth to identify perennial and interrupted perennial reaches of a stream (see Appendix C-Draft StatusAssessment Model and Appendix E-Supplemental Information on Assessment Model). To clearly articulate how we are using the terms "perennial and interrupted perennial reaches" we have defined our terminology below. These terms refer to the watered segments or reaches within a stream and not the stream as a whole. A stream may have one or more of these "segments" present as defined by the terms below.

1. "Perennial segments" describe areas where the water flow within a specific reach in the stream was continuous or near continuous (less than 0.1 kilometers (km) (0.06 miles (mi)) dry stream bed between watered reaches) during the driest period. Perennial segments have the greatest amount of length with surface water present due to the lower amount of dry streambed.
2. "Interrupted perennial segments" describe areas where the water flow is interrupted by dry sections that were on average between 0.1 and 0.4 km (0.06 and 0,25 mi) in length. We assumed that during most of the year, at least some of these sections would be connected long enough to benefit a larger population over the whole stream. Interrupted

perennial segments had less surface water present within the segment due to the greater amount of dry streambed.

3. "Intermittent segments" describe areas where the water flow is significantly interrupted by dry reaches longer than 0.5 km (0.31 mi). We assumed that the dominance of dry reaches in these segments did not allow for any persistent summer connections between the remaining isolated pools, and that wet season connections might also be significantly limited in extent.

We selected perennial and interrupted perennial reaches during the driest time of year because this is likely the most limiting factor for chubs. A currently occupied stream is defined as a stream or stream reach documented by surveys to contain either roundtail or headwater chub as identified in Voeltz (2002) and most recently Jones et al. (2014). We recognize that the quality of this habitat in terms of the amount of the watered reach that is perennial versus interrupted perennial[5] varies within each stream both temporally and spatially. We further recognize that using a more precise approach for current range than for historical range could overestimate the reduction in range. To address this possible overestimation we identify those stream miles that we know are extirpated and acknowledge the stream miles where there is uncertainty. Table 3.1-1 indicates the estimated historical and current range for this SSA.

Table 3.1-1. Estimated Historical and Current Ranges of the Roundtail and Headwater Chubs in the Lower Colorado River.

		Headwater Chub	Roundtail Chub
Estimated Historical Range[1]	km	892	4,914
	mi	554	3,053
Estimated Current Range[2]	km	432	2,098
	mi	268	1,304
Percent of Estimated Historical Range Currently Occupied		48%	52%
Estimated Reduction in Range	km	460	2,816
	mi	286	1,750
Percent of Estimated Historical Range No Longer Occupied		52	57
Number of Streams Historically Occupied		26	48
Number of Streams Currently Occupied		22	35

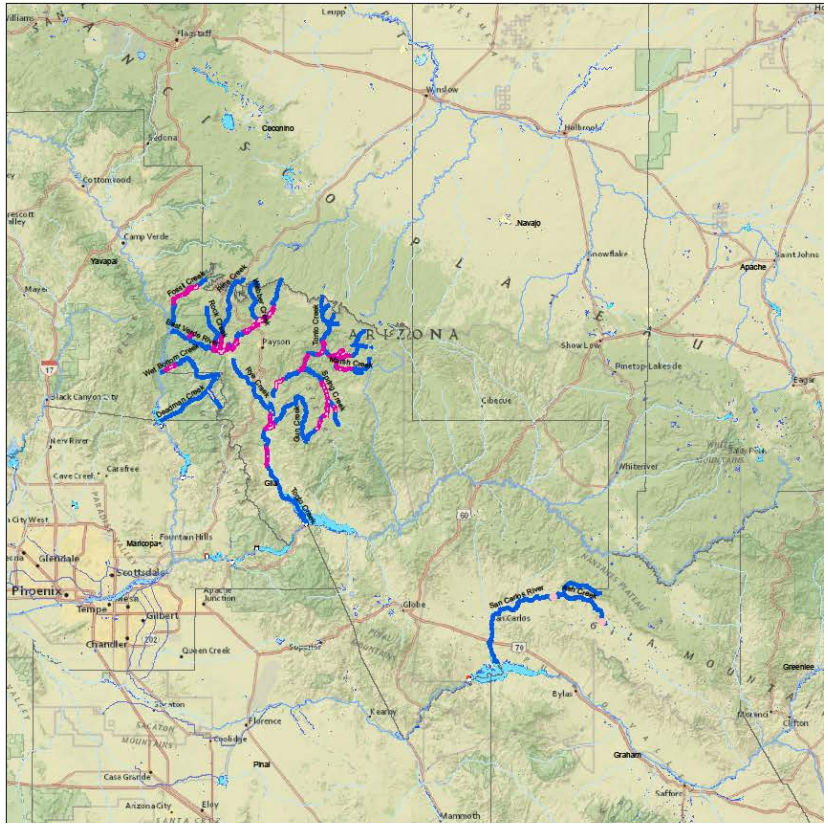
[1] This includes perennial, intermittent, and dry reaches within a stream.
[2] This includes perennial and interrupted perennial reaches within a stream.

3.2 Headwater Chub Historical and Current Stream Length

Headwater chub is only known from three primary river watersheds, the Gila, Salt and Verde Rivers, in Arizona and New Mexico. Populations are still found in the upper Gila River in New Mexico and the Salt, San Carlos, and Verde Rivers in Arizona.

[5] See Appendix F: Water Availability for information on the definitions and concepts used in determining the amount of stream length available for chubs in occupied streams.

Figure 3.2-1. Historical Range and Current Survey Records of Headwater Chub. (Blue represents the historical range and pink represents the current survey records plus 1.5 km (0.9 mi) above and below the survey record site.)



Based on our assessment, headwater chub historically occupied 26 streams with a total stream length of 892 km (554 mi). These streams are listed in Table 3.2-1 below, which identifies the historically occupied streams, the current status, the individual historical and current stream lengths, and citations to materials used to determine stream length.

Table 3.2-1: Historical and Current Range of Headwater Chub by Stream as of 2014 by Stream Length.

Drainage	**Stream Name**	**Known Status as of 2014**	**Historical Estimate of Total Stream Length[1]**		**Current Watered Area Available in 2015[2,3]**	
			km	**mi**	**km**	**mi**
Gila River (New Mexico)	East, Middle, and West Forks	Extant	164	102	135	84
	Diamond Creek	Extant	10	6	3	2
Gila River (Arizona)	Ash Creek	Extant	26	16	4	2
	San Carlos River	Extant	76	47	32	20
Salt River (Arizona)	Buzzard Roost Creek	Extant	7	4	1	1
	Christopher Creek	Extirpated	13	8	N/A	N/A
	Gordon Creek	Extant	23	14	8	5
	Gunn Creek	Extant	42	26	8	5
	Haigler Creek	Extant	37	23	11	7
	Horton Creek	Extirpated	12	7	N/A	N/A
	Marsh Creek	Extant	17	11	8	5
	Rock Creek	Extant	19	12	9	6
	Rye Creek	Extirpated	9	6	N/A	N/A
	Spring Creek	Extant	33	21	28	17
	Tonto Creek	Extant	120	75	66	41
Verde River (Arizona)	Deadman Creek (including South Deadman Creek)	Extirpated	37	23	N/A	N/A
	East Verde River	Extant	86	53	70	43
	Fossil Creek	Extant	28	17	16	10
	Gorge Canyon	Extant	19	12	3	2
	Pine Creek	Extant	33	21	12	7
	Rock Creek	Extant	19	12	7	4
	Webber Creek	Extant	23	14	5	3
	Wet Bottom Creek	Extant	32	20	5	3

Salt River (Arizona)	Turkey Creek	Extant	7	4	1	1
Total Stream Length	**26 streams**	**22 streams**	**892**	**554**	**432**	**268**

[1] This includes perennial, intermittent, and dry reaches within a stream.
[2] This includes perennial and interrupted perennial reaches within a stream.
[3] N/A means this information is not applicable to this AU because the species is extirpated from the area.

Table 3.2-2 provides a summary of the stream miles and percent reduction in range for the headwater chub. In addition, the number of occupied streams historically and currently are provided.

Table 3.2-2. Headwater Chub Historical and Current Stream Length and Number of Streams

Estimated Historical Range	km	892
	mi	554
Estimated Current Range	km	432
	mi	268
Percent of Estimated Historical Range Currently Occupied		48%
Estimated Reduction in Range	km	460
	mi	286
Percent of Estimated Historical Range No Longer Occupied		52
Number of Streams Historically Occupied		26
Number of Streams Currently Occupied		22

[1] This includes perennial, intermittent, and dry reaches within a stream.
[2] This includes perennial and interrupted perennial reaches within a stream.

Table 3.2-3 provides a list of the streams that are no longer occupied by headwater chubs currently. In addition, the length of these streams is provided.

Table 3.2-3. Extirpated Headwater Chub Streams

Drainage	**Stream Name**	**Historical Estimate of Total Stream Length**	
		km	**mi**
Salt River (Arizona)	Christopher Creek	13	8
	Horton Creek	12	7
	Rye Creek	9	6
Verde River (Arizona)	Deadman & South Deadman Creeks	37	23
Total		71	44

Table 3.2-4 provides a list of the streams that currently have a reduced occupied range from their historical range. In addition, the historical occupied length of these streams is provided.

Based on our assessment, headwater chub historically occupied 26 streams with a total stream length of 892 km (554 mi). As of 2015, headwater chub are found in 22 streams with 432 km (268 mi) of available habitat; 406 km (252 mi) from the historical streams and 26 km (16 mi)

from newly discovered streams. This represents at least 48 percent of the estimated historical range and no more than a 52 percent (460 km (286 mi)) reduction in range. Currently, based on the stream lengths from the above tables, we document a loss of 71 km (44 mi) from the four extirpated streams listed in Table 2.2-6 above. We know that chub are not found in portions of Haiger and Tonto Creeks where they were historically documented. In upper Haiger and upper Tonto Creek approximately 25 and 18 km (16 and 11 mi), respectively, are considered unoccupied. This accounts for 114 km (71 mi) (25 percent) of the estimated reduction in range, leaving 346 km (215 mi) not documented.

Table 3.2-4. Headwater Chub Streams with Reduced Area of Occupancy

Drainage	**Stream Name**	**Historical Estimate of Total Stream Length**	
		km	**mi**
Salt River (Arizona)	upper portions of Haigler	25	16
	Tonto Creeks above waterfall barriers	18	11
Total		43	27

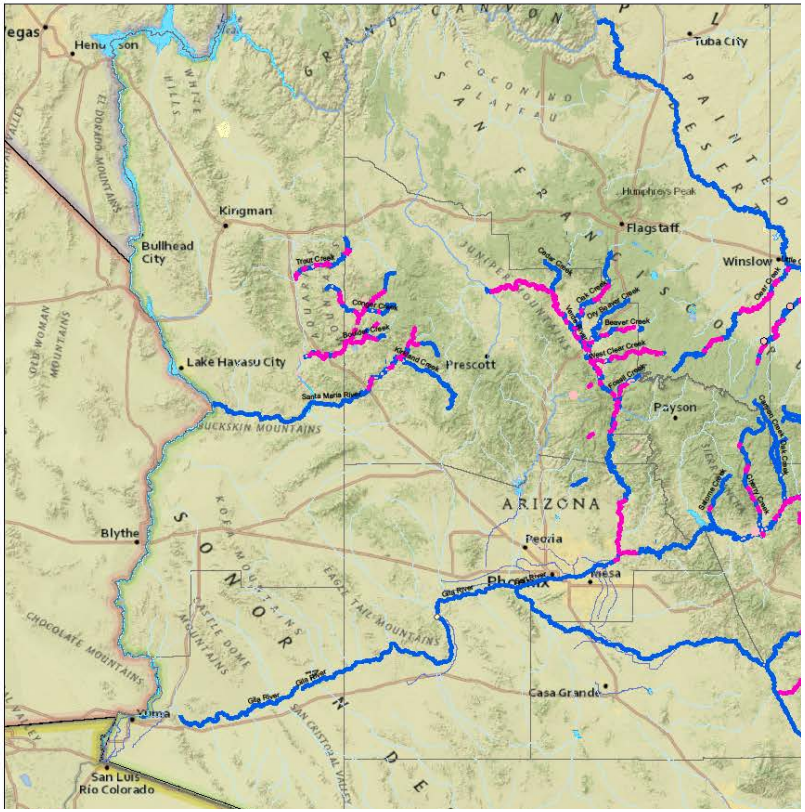
The current distribution of headwater chub in the San Carlos River (76 km (47 mi) historically) and its tributary Ash Creek (26 km (16 mi) historically) (Gila River watershed) is uncertain due to limited recent surveys on the San Carlos Apache Reservation. We have survey records from 1983 and 1985 for a portion of the San Carlos River near Warm Springs documenting chubs there (Marsh 2015, p. 1). Chubs in Ash Creek were documented in 1984-1985 (Jennings 1987, p. 131). For this SSA Report, we consider both Ash Creek and the San Carlos River to be occupied because we do not have newer information to suggest otherwise. The historic and current stream length for San Carlos River and Ash Creek is measured at 76 and 32 km (47 and 20 mi), and 26 and 4 km (16 and 2.5 mi), respectively. This could also be an overestimate of the current occupied stream length by about 32 km (20 mi). If these streams are unoccupied, then the documented reduction in range would be 146 km (91 mi). This would leave 314 km (195 mi) reduction in range not documented.

This leaves 286-318 km (178-198 mi) of the reduction in occupied stream not documented, with the reduction in range from 13 to 52 percent. It is likely that there is more habitat during the wetter times of year that could be available to chubs in the San Carlos River, Tonto Creek, Ash Creek, Gordon Creek, and Gunn Creek. We recognize that chubs confined to the wetted areas during the driest time of year will disperse when there is an increase in the amount of water. However, the available habitat during the driest time of year is the most limiting factor affecting chubs because the carrying capacity of a particular site is limited to the quantity and quality of the habitat.

3.3 Roundtail Chub DPS Historical and Current Stream Length

The roundtail chub DPS was and is only known from five primary river watersheds, the Bill Williams, Gila, Little Colorado, Salt, and Verde Rivers in Arizona and New Mexico.

Figure 3.3-1. Historical Range and Current Survey Records of Roundtail Chub in the LCR DPS. (Blue is the historical range and pink is current survey records plus 1.5 km (0.9 mi) above and below the survey record site)



Based on our assessment, the roundtail chub DPS historically occupied 48 streams with a total stream length of 4,914 km (3,053 mi). These streams are listed in Table 3.3-1, which identifies the historically occupied streams, the current status, the individual historical and current stream lengths, and citations to materials used to determine stream length.

Table 3.3-1. Roundtail Chub DPS Historical and Current Status by Stream Length.

Watershed	**Stream**	**Known Status as of 2009**	**Historical estimate of total stream length[1]**		**Watered area available in 2015[2,3]**	
			km	**mi**	**km**	**mi**
Bill Williams River	Bill Williams River	Extirpated	75	47	N/A	N/A
	Boulder Creek	Extant	60	37	14	9
	Burro Creek	Extant	95	59	76	47
	Conger Creek	Extant	26	16	7	4
	Cottonwood Creek	Extant	15	9		0
	Cow Creek	Extant	5	3	1	1
	Fort Rock Creek	Extant	4	2	7	4
	Francis Creek	Extant	36	22	12	7
	Kirkland Creek	Extant	64	40	37	23
	Santa Maria River	Extant	81	50	28	17
	Stone Corral Canyon	Extant	4	2	3	2
	Sycamore Creek	Extant	38	24	23	14
	Trout Creek	Extant	87	54	53	33
	Wilder Creek	Extant	24	15	12	7
Gila River	Aravaipa Creek	Extant	91	57	44	27
	Blue River	Extirpated	82	51	N/A	N/A
	Eagle Creek	Extant	94	58	32	20
	Lower Gila River	Extirpated	472	293	N/A	N/A
	Upper Gila River	Extant	505	314	403	250
	San Francisco River	Extirpated	256	159	N/A	N/A
	San Pedro River	Extirpated	230	143	N/A	N/A
Little Colorado River	Little Colorado River	Extirpated	580	360	N/A	N/A
	East Clear Creek/Clear Creek	Extant	170	106	36	22
	Chevelon Creek	Extant	135	84	45	28
	Zuni River	Extirpated	140	87	N/A	N/A
Salt River	Black River	Extant	183	114	183	114
	Canyon Creek	Extant	83	52	67	42
	Carrizo Creek	Extant	102	63	61	38
	Cedar Creek	Extant	23	14	Extirpated[4]	N/A
	Cherry Creek	Extant	98	61	25	16
	Cibecue Creek	Extant in lower reach, extirpated below	75	47	2	1

		barrier				
	Corduroy Creek	Extant	58	36	43	27
	Salome Creek	Extant	32	20	22	14
	Salt River	Extant	322	200	322	200
	White River	Extant	28	17	56[5]	35
Verde River	Beaver Creek	Extant	15	9	9	6
	Dry Beaver Creek	Extirpated	29	18	N/A	N/A
	Wet Beaver Creek	Extant	39	24	33	21
	Fossil Creek	Extant	28	17	22	14
	Oak Creek	Extant	81	50	81	50
	West Clear Creek	Extant	59	37	59[6]	37
	Verde River	Extant	270	168	270	168
Total Stream Length	44 streams	35 streams	4,422	3,041	2,098	1,298

[1] This includes perennial, intermittent, and dry reaches within a stream.
[2] This includes perennial and interrupted perennial reaches within a stream.
[3] N/A means this information is not applicable to this AU because the species is extirpated from the area.
[4] Verbal information from the White Mountain Apache Tribe states that they consider Cedar Creek to be extirpated for roundtail chub. Further, for Cibecue Creek, they state there are no records of chub above the waterfall barrier 2 km up from the Salt River confluence, so we have removed the rest of the this creek from consideration.
[5] Now includes occupied portion of North Fork White River.
[6] This is the total watered length of West Clear Creek available, not the determination of which chub is present in which section.

Table 3.3-2. Roundtial Chub DPS Historical and Current Stream Length and Number of Streams.

Species of chub	**Estimated historical range based on stream length(km)** [1]	**Estimated current range (km & % of estimated historical range currently occupied)**[2]	**Estimated reduction in range (km & % of estimated historical range that no longer contains chubs)**	**Number of streams historically occupied** [3]	**Number of streams currently occupied** [4]
Roundtail (AZ)	4,422	2,098 (47%)	2,324 (53%)	48	35

[1] This includes perennial, intermittent, and dry reaches within a stream.
[2] This includes perennial and interrupted perennial reaches within a stream.

Table 3.3-3. Roundtail Chub are Extirpated from the Following Streams.

Watershed	**Stream**	**Historical estimate of total stream length (km)**
Bill Williams River	Bill Williams River	75
Gila River	Blue River	82
	Lower Gila River	472
	San Francisco River	256
	San Pedro River	230
Little Colorado River	Little Colorado River	580
	Zuni River	140
	Dry Beaver Creek	29
Total		1,864

Based on our assessment, the roundtail chub in the LCR DPS historically occupied 48 streams with a total stream length of 4,914 km (3,053 mi). As of 2015, roundtail chub are found in 35 streams with a total of 2,098 km (1,304 mi) of available habitat; 2,077 km (1,291 mi) from the historical streams and 21 km (13 mi) from the newly discovered streams. This represents at least an estimated 43 percent of the historical range and no more than an estimated 57 percent reduction in range. Based on the stream lengths we used in the above tables we document a loss of 1,864 km (1,158 mi) from the six extirpated streams listed in Table 3.2-3 above. This accounts for 88 percent of the stream loss. Approximately 234 km (145 mi) of stream loss is not documented. This is 11 percent of the reduction in range not documented. The current range is estimated at 42 to 47 percent of the historic range, with a reduction in range of 53 to 58 percent reduction in range.

As with headwater chub streams, the quality of this habitat in terms of the amount of the watered reach that is perennial versus interrupted perennial varies within each stream. We also note that documented numbers are low for the large truly perennial streams considered currently occupied (Upper Gila River, Salt River, and Verde River, which total 995 km (618 mi)). The upper Verde River is the only portion of these streams where roundtail chub are reliably found and recruitment is documented. However, this reach of the Verde River receives augmentation of stocked fish by AGFD (Salt River Project 2013, p. c). Because we consider these streams to be occupied throughout, this could overestimate the stream length currently occupied.

Roundtail chub in the upper Gila River in Arizona above San Carlos Reservoir to the Forks Confluence in New Mexico are extremely rare, with no recent records in Arizona. The only two recent records in the upper Gila River are from New Mexico: the Riverside survey site in the Cliff-Gila Valley in 1991 (Paroz et al. 2006, p. 37) and above the Arizona-New Mexico border in 1999 (Blasius 2012, p. 2). For this SSA Report, we consider the upper Gila River in New Mexico to be currently occupied and the reach in Arizona above San Carlos Reservoir to the state line as not currently occupied. Further, we do not consider the reach from San Carlos Reservoir to state line to have been historically occupied. Our reasoning for considering the reach from San Carlos Reservoir to the state line as not occupied is that there are only two

records of chub in this reach. One is a collection record for from the late 1800s at Fort Thomas, which we are not considering a recent record. The second is a museum record from 1984 of a chub in a backwater near the confluence with Bonita Creek, a tributary to the Gila River in Arizona (Voeltz 2002, p. 124). Since Gila chub are present in Bonita Creek, it is likely that this is a Gila chub record. There are few other surveys in the mainstem Gila River between Redrock, New Mexico (a town close to the Arizona-New Mexico border) and the San Francisco River in Arizona (flows into the Gila River just east of the Arizona-New Mexico border). Some of these surveys detected native fish, but not chub (Blasius 2015, p. 1). Therefore, absent any data for this reach, we are not including the reach from San Carlos Reservoir to the state line as historically or currently occupied it as either occupied or extirpated for this SSA Report.

There are also four newly established populations for the roundtail chub DPS: Blue River, Ash Creek, Gap Creek, and Roundtree Creek.

Table 3.3-4. Newly Established Populations for the Roundtail Chub DPS

Drainage Basin	Analysis Unit	Watered area available in 2015 (km, perennial and interrupted perennial reaches of stream)
Gila River	Blue River Unit	81 km (50 mi)
Salt River	Ash Creek Unit	5 km (3 mi)
Verde River	Gap Creek Unit	3 km (2 mi)
Verde River	Roundtree Canyon Unit	3 km (2 mi)
Total		92 km (57 mi)

Chapter 4. Taxonomy and Genetic Management Units

In this chapter, we consider the headwater and roundtail chubs' taxonomy and genetic management units. Currently, the American Fisheries Society (AFS 2013) considers the headwater chub and roundtail chub to be separate species. Consequently, in this SSA Report we evaluated them as separate species. Under the Act, a DPS meets the definition of a species and is a listable entity.

4.1 Taxonomic Considerations for Historical and Current Distribution.

4.1.1 Taxonomic History

Headwater chub was first described as a subspecies, *Gila grahami* or *G. robusta grahami,* from Ash Creek and the San Carlos River in east-central Arizona in 1874 (Cope and Yarrow 1875). In 2000, Minckley and DeMarais proposed full species status. The American Fisheries Society has accepted *Gila nigra* as a full species (Nelson et al. 2004), as have the NMDGF (Carmen 2006) and AGFD (AGFD 2006). DeMarais (1986 and 1992) proposed hybridization between roundtail chub and Gila chub (possibly multiple local events rather than a single event) as the most plausible explanation for the origin of headwater chub.

Roundtail chub (*Gila robusta*) was first described by Baird and Girard (1853) from specimens collected in 1851 from the Zuni River (tributary to Little Colorado River) though that location may not be correct as Smith et al. (1979) reported the type locality was likely the mainstem Little Colorado River and Sublette et al. (1990) suggested the specimens may have been collected from the Rio Pescado (tributary to Zuni River) and incorrectly cited as the Zuni River. Roundtail chub has been recognized as a distinct species since the 1800s.

4.1.2 Assignment to Species

In the lower Colorado River basin, several chub species are closely related. This is likely the result of multiple independent hybridization events over time (Rinne 1976; Rosenfeld and Wilkinson 1989; DeMarais et al. 1992; Dowling and DeMarais 1993; Minckley and DeMarais 2000; Gerber et al. 2001; Schwemm 2006; Schönhuth et al. 2014). When found in the same stream, determination of individuals as headwater or roundtail chub by visual assessment is difficult because there is overlap in the morphological identification measurements between the species (Minckley and DeMarais 2000; Brandenberg et al. 2015, p. 18). Additionally, conducting the measurements could result in harm to the fish from injury and handling stress and, therefore, is not usually attempted. As a result, assignment to species is based largely on geographic location. Dowling et al. (2008, p. 2) assignment testing indicated that individuals from most localities were distinct, populations are evolving independently, and geography plays an important role in patterns of distinctiveness (Dowling et al. 2008, p. 2).

Assignment to one or the other species has been made for all populations or streams of the headwater chub and roundtail chub DPS. However, there is some uncertainty within three streams where the species overlap, and likely hybridize with one another: Fossil Creek and West Clear Creek in the Verde River drainage, and Turkey Creek in the Upper Gila drainage. For the

purposes of this SSA Report and the associated analyses, we will evaluate Fossil Creek as having headwater chub from the constructed barrier upstream to Fossil Springs (above the barrier) and roundtail chub from the mouth of Fossil Creek to Irving (below the barrier), with a mix between Irving and the fish barrier. In West Clear Creek, we consider lower and upper West Clear Creek to be roundtail chub based on our past assignment and we consider Turkey Creek to contain only Gila chub.

4.2. Consideration of Genetic Management Units in Relation to AUs

Dowling et al. (2008, entire) used microsatellites to characterize 33 populations of headwater, roundtail, and Gila chubs to quantify the distribution of genetic variation within and among populations and species, allowing for assessment of patterns of gene exchange and identification of units for management. Assessment of genetic distinctiveness in this manner allows for the identification of management units (Moritz 1994). Individuals from some but not all headwater and roundtail chub occupied streams were included in their analysis and for roundtail chub no streams from the Little Colorado River were included (see Table 4.2-1).

In headwater chub, most of their genetic variation occurs among populations, each of which tends to be distinctive. Each AU is geographically isolated from the other AUs, even in the same drainage basin. Variation within headwater chub populations is consistent with the presumed multiple hybrid origins of this species. The significance of isolation in shaping each population highlights the importance of maintaining each population independently to preserve the unique genetic variation (Dowling et al. 2008, p. 2). In roundtail chub, the genetic variation is within populations. Information about roundtail chub indicated that historically there was greater connectivity and subsequent relatedness over the region, and development of populations in isolation from other roundtail chub populations was not the normal condition across most of the historical range, except in the Bill Williams River and Little Colorado River drainages.

The genetic management units identified by Dowling et al. (2008, pp. 42-43) for both headwater and roundtail chub are listed below in Table 4.2-1. These genetic management units were previously identified by Schwemm et al. (2006, pp. 27-33). These genetic management units reflect differences in genetic make-up that warrant separate consideration for implementation of conservation actions, particularly augmentation and reintroduction projects. We did not intentionally design the AUs around any genetic management units that were present; rather our AUs are based on connectivity of the particular streams. However, given that geography has played a role in the patterns of distinctness, this led to placement of identified genetic management units within AUs. Consequently, consideration of genetic management units as part of the overall analysis is indirectly evaluated for each of the AUs that Dowling et al. (2008) and Schwemm et al. (2006) examined. Table 4.2-1 and 4.2-2 contains the information on which genetic management unit is in which AU for each species.

Table 4.2-1. Management Units Based on Genetic Uniqueness for Headwater Chubs

Genetic Management Unit (GMU)	Drainage Basin	Stream in the GMU	Analysis Unit containing the stream in the GMU	Genetic distinctness
N1A	Gila River	Turkey Creek	Turkey Creek	
N1B	Gila	Gila River Forks	Three Forks	
N2A	Salt River	Tonto Creek	Upper Tonto Creek	
			Lower Tonto Creek	
N2B	Salt River	Marsh Creek	Upper Tonto Creek	
N3A	Salt River	Spring Creek, Rock Creek	Upper Tonto Creek	
N4	Salt River	East Verde River	East Verde River	especially distinct
N5	Verde River	Fossil Creek	Upper Fossil Creek	especially distinct

Table 4.2-2. Management Units Based on Genetic Uniqueness for Roundtail Chubs

Genetic Management Unit (GMU)	Drainage Basin	Stream in the GMU	Analysis Unit containing the stream in the GMU	Genetic distinctness
R1A	Verde River	Upper Verde River, Lower West Clear Creek	Verde River	mostly discrete
R1B	Verde River	Lower Salt River	Confluence	mostly discrete
R2A	Gila River	Aravaipa Creek	Aravaipa Creek	exhibiting more variable levels of assignment probability and cohesiveness
R2B	Gila River	Eagle Creek	Eagle Creek	exhibiting more variable levels of assignment probability and cohesiveness
R3	Salt River	Cherry Creek	Upper Salt River	mostly discrete
R4	Salt River	Black River	Upper Salt River	
R5	Bill Williams River	Boulder Creek	Upper Boulder Creek	especially unique and clearly have been isolated from each other and from Gila River
			Burro Creek	
R6	Bill Williams River	Trout Creek	Trout Creek	especially unique and clearly have been isolated from each other and from Gila River

Chapter 5. Population and Species Needs of Headwater and Roundtail Chub

5.1 Needs of the Headwater and Roundtail Chubs Population and Species

As discussed in Chapter 1, for the purpose of this assessment, we define **viability** as the ability of the species to sustain populations in the wild beyond a biologically meaningful timeframe. Previously in this SSA Report, we described the historical and current distribution, life history, and resource needs of individuals.

5.1.1 Population Resiliency

Resiliency is having sufficiently large populations for the species to withstand stochastic events. For the chubs to maintain viability, their populations, or AUs in this SSA Report, or some portion of their populations, must be sufficiently resilient. The resiliency of headwater or roundtail chub DPS populations is largely governed by the quantity and quality of physical habitat available, the spatial distribution of habitat, and the presence of nonnative species in that habitat.

5.1.1.1 Habitat Availability

Resilient fish populations need a sufficient amount of habitat within the stream to provide the range of habitat conditions needed to complete their life cycle (i.e., spawning habitat, nursery habitat, adult habitat, refugial habitat) (Harig and Fausch 2002, p. 546; Young et al. 2005, p. 2406). Based on the life history information presented in the chapter 2, the chubs have particular preferences for certain physical features (i.e., pools and shorelines with low velocities). The literature on the chubs emphasizes the benefits of habitat complexity through the presence of multiple pools with varying types of instream cover (boulders, pool depth, and woody vegetation) in the pools for adults and other types along the shorelines used by young-of-year and juvenile chubs. The abundance and quality of those resources is a gauge of how well that stream can support a resilient chub population. To fully evaluate the quality of a stream for headwater or roundtail chub, measurements of the preferred habitats relative to the physical conditions present in the stream would be optimal. However, this type of information is only available for very few chub streams, and it may not fully encompass the needs of all life stages.

5.1.1.2 Nonnative Species

In terms of risks associated with nonnative species, the most resilient chub populations are in streams where nonnative fish and crayfish species are entirely absent or there are low numbers of nonnatives. There are streams where chubs and nonnatives co-exists and the reasons for this is not clear. These streams are less resilient than streams with little or no nonnative aquatic species. Streams with no or limited nonnatives are rare throughout the range of the chubs. The degree of population resiliency in streams is a factor of the nonnative community composition as a whole, the abundance of particular nonnative species, and the quality and quantity of available habitat. The literature on the effects of nonnative fish and crayfish on native fish in Arizona and New Mexico documents the adverse effects these nonnatives have on native species through a variety of mechanisms including direct predation on some or all size classes of native fish,

competition for food, and harassment (active or passive) that can result in displacement from preferred habitats and feeding areas. This is discussed more in Chapter 6-Risk Categories, Appendix B-Cause and Effects Analysis Table, and Appendix E-Supplemental Information for Assessment Model.

5.1.1.3 Population Size

Resilient chub populations must be of sufficient size to withstand stochastic events such as demographic effects of low genetic diversity and environmental variability. Larger populations have a higher effective population size, which is a theoretical measure of the number of breeders in the population that contribute to genetic diversity. Populations with a low effective population size are more likely to experience genetic drift and inbreeding and are less likely to adapt to changing environmental conditions. We do not have data to determine the population size or effective population size needed to support either headwater or roundtail chub. However, general guidelines for trout have been developed that suggest effective population sizes of 500 and above have a low risk of genetic consequences and retain long term adaptive potential, and those below 50 are highly vulnerable to inbreeding depression and genetic drift (Allendorf et al. 1997, pp. 142–143; Rieman and Allendorf 2001, p. 756). The literature on fish in general does emphasize that larger total population sizes that support at least the minimum effective population size are needed to provide greater certainty of persistence over time. Therefore, resilient populations have a sufficient effective population size to avoid adverse genetic consequences on the population.

5.1.2 Species Redundancy and Representation

Redundancy is having a sufficient number of populations for the species to withstand catastrophic events. **Representation** is having the breadth of genetic makeup of the species to adapt to changing environmental conditions. The two species need to have multiple populations distributed throughout different drainage basins within their historical range. The wider the distribution of resilient populations and the larger the number of populations, the more redundancy the species will have. This redundancy reduces the risk that a large portion of the species' range will be negatively affected by any single catastrophic event at any one time. Species that are well-distributed across their historical range (i.e., having high redundancy) are less susceptible to extinction and more likely to be viable than species confined to a small portion of their range (Carroll *et al*. 2012, entire; Redford *et al*. 2011, entire). From a rangewide perspective, maintenance of the existing AUs in that watershed is important to provide for redundancy and species viability.

For headwater chub, six of the eight AUs are located in adjoining drainages: three in the Salt River (upper and lower Tonto Creek complex AUs and Gunn Creek individual AU) and three in the Verde River (East Verde River complex AU and Fossil and Wet Bottom creeks individual AUs). The remaining two complex AUs, San Carlos River and Three Forks, are separated from the other six and each other in different drainages not likely to be affected by the same catastrophic natural or anthropogenic event.

For roundtail chub, the 15 AUs are more spread out across the range with occupied streams in five drainages. In the Little Colorado River, loss of one of the two occupied streams would impair redundancy. For the Verde and Salt Rivers complex AU, loss of any stream with documentation of recruitment would impair the entire complex. The survey data suggests that some streams in the Verde and Salt Rivers complex AU have more recruitment events than others but we do not fully understand how the chub populations are maintained across the entire complex. Under these conditions, loss of a stream with sustained recruitment would affect redundancy across the entire unit. For the Gila River drainage basin, loss of Eagle Creek would effectively eliminate the upper portion of that drainage, and loss of Aravaipa Creek in the lower would effectively eliminate the lower portion of that drainage. For the Bill Williams River, the loss of one complex would reduce redundancy but not necessarily impair redundancy.

Maintaining representation in the form of genetic or ecological diversity is important to keep the capacity of the chub to adapt to future environmental changes. As discussed previously in Chapter 2 and Chapter 4, headwater and roundtail chub populations vary in the amount of genetic diversity they contain and how that diversity is distributed across the occupied streams (Schwemm 2006, entire; Dowling et al. 2008, entire). Variation within headwater chub populations is consistent with the multiple hybrid origins of this species. Due to the multiple hybridization events in separate streams that likely gave rise to headwater chub, there are differences between the occupied streams across the occupied range deriving from the specifics of the founding populations and subsequent events that may have reduced population sizes that affected that diversity (Dowling et al. 2008, pp. 10-11). The significance of isolation in shaping each population highlights the importance of maintaining each independently to preserve the unique genetic variation (Dowling et al. 2008, p. 2).

Information about roundtail chub indicates that historically there was greater connectivity and subsequent relatedness over the region and development of populations in isolation from other roundtail chub was not the normal condition across most of the historical range except in the Bill Williams River and Little Colorado River drainages. Unlike the headwater chub, roundtail chub's historical connectivity within the Gila, Salt, and Verde Rivers promoted less diversity over the range; however, the Bill Williams and Little Colorado rivers are isolated and are more unique. Although the AU boundaries were not generated to represent genetic differences, they do capture them in some cases and as they encompass the historical range of the two chubs. Consequently, the AUs provide a picture of representation of the genetic diversity among populations and the ecological diversity across the range of the two species. The drainage basins serve as a proxy for geographic variation that may represent natural variation in the species' genetic diversity as indicated by the genetic management units. Refer back to Figures 1.1-1 and 1.1-2 for maps of the drainage basins and AUs for both species.

Chapter 6. Risk Categories and Conservation Actions

In this chapter we review the past, current, and future risk categories that are affecting what the headwater and roundtail chubs need for long term viability. We analyzed these risk categories in detail using the tables in Appendix B in terms of causes and effects to the species. We also analyzed these impacts by conceptually modeling the effects pathways in Figures 6.3-3 and 6.3-4 below. These tables and diagrams analyze the pathways by which each risk category affects the

species, and each of the causes is examined for its historical, current, and potential future effects on the viability of the headwater and roundtail chubs. Each risk category will be briefly reviewed here; for further information, refer to the tables in Appendix B-Evaluating Causes and Effects for Headwater and Roundtail Chub and Appendix F- Effects Pathway Conceptual Model.

A number of the land management actions had their greatest effects on native fishes in the past when management actions were not focused at providing protection for non-target resources. This is particularly true of livestock grazing, roads management, channelization of streams, and forestry practices. There are legacy effects from these past management actions. However, new and future management directions are considering these risks. These legacy impacts are not likely having population level impacts to chubs. Where this is the case, we note in the summaries below.

6.1 Nonnative Species

Prior to the introduction, spread, and establishment of nonnative predatory and competitive fishes, habitat modification (e.g., destruction and alteration) was the primary driver in the decline of native fishes throughout the lower Colorado River basin (Clarkson et al. 2005, p. 20). It has now been shown that contamination by nonnative fishes, now and in the future, is the most significant risk factor to the lower Colorado River fish fauna due to competition and predation (Minckley and Deacon 1991; Carlson and Muth 1989, p. 220; Mueller 2005, pp. 10–12; Olden and Poff 2005, p. 75) and are the primary impediment to their conservation (Minckley and Marsh 2009, p. 51). Declines in native fish, including roundtail and headwater chubs, is largely attributable to predation, with early life stages (Minckley 1983, p. 182) being the most vulnerable. Clarkson et al. (2005, p. 20) noted that over 50 nonnative species were introduced into the Southwest as either sportfish or baitfish. As an example, the lower West Clear Creek showed a reduction in roundtail chub after smallmouth bass (Micropterus dolomieu) became a significant part of the fish community (Brouder et al. 2000, pp. 9, 13; Jones et al. 2014, pp. 70-71), and in the upper Salt River after flathead catfish (Pylodictis olivaris) were introduced (AGFD 1996)the decline in roundtail chub has been interpreted as resulting from those nonnative expansions. Figure 6.3-3 displays the effects pathways of nonnative fish on chubs.

Table 6.1-1 identifies those nonnative species potentially impacting chubs and describes how chubs are impacted. Of these species, fathead minnow (*Pimephales promelas*), green sunfish (*Lepomis cyanellus*), red shiner (*Cyprinella lutrensis*), western mosquitofish (*Gambusia affinis*), largemouth bass (*Micropterus salmoides*), flathead catfish (*Pylodictis olivaris*, Fuller 1999, p. 208), and channel catfish (*Ictalurus punctatus*) are among the fastest expanding nonnative fishes in the basin and are considered to be the most invasive in terms of their negative impacts on native fish communities (Olden and Poff 2005, pp. 83-84). Table 3.1-2 identifies the level of risk to chubs from the specific nonnative species.

Table 6.1-1. Nonnative Species and Their Potential Effects on Chubs

Nonnative Species	**Age Classes Of Chub Preyed On By Nonnative Species**	**Sizes Of Nonnatives That Prey On Chubs**	**Nonnative Habitat Overlap With Chubs**	**Type of Impact to Chubs**
Black bullhead (*Ameiurus melas*)	Larvae to juvenile	Adults	Yes: also defends nests	Displace from pool habitat. Consumes invertebrates.
Brown trout (wild) (*Salmo trutta*)	Larvae to sub-adult	Sub-adult to adult	Yes: pools	Consumes invertebrates.
Bullfrog (*Rana catesbeiana*)	Larvae to juvenile	Adults	Yes: uses shallow margin areas	Consumes fish, invertebrates, Found mostly in shallow waters where young-of-the-year or small juveniles may be present.
Channel catfish (*Ictalurus punctatus*)	Juveniles to sub-adults	Adults	Yes: deep water areas	Uses deep, quite habitat. Consumes invertebrates.
Common carp (*Cyprinus carpio*)	Eggs primarily	Sub-adult to adult	Yes: uses most habitat types	Consumes invertebrates.
Crayfish	Larvae, small sub-adult	Adults	Yes: uses all habitat types	Will injure/kill fish, alters habitat by burrowing into stream banks and removing aquatic vegetation, may reduce the growth rates of native fish through competition for food, prey on fish eggs and larvae.
Green sunfish (*Lepomis cyanellus*)	Larvae to juveniles	Juveniles to adults	Yes: uses multiple habitat types	Consumes invertebrates.
Fathead minnow (*Pimephales promelas*)	Larvae	Adults	Yes: uses slow water habitats	Consumes invertebrates.
Flathead catfish (*Pylodictis olivaris)*	Sub-adults and adults	Sub-adult, adult	Yes: uses slow and deep areas	Consumes invertebrates.
Largemouth bass (*Micropterus salmoides*)	Larvae to sub-adults	Sub-adult to adult	Yes: low velocity areas	Consumes invertebrates.
Mosquitofish (*Gambusia affinis*)	Larvae	Adults	Yes: shallow vegetated areas	Displaces from pool habitat.
Rainbow trout (wild) (*Oncorhynchus mykiss*)	Larvae to juveniles	Adults	Yes: pools	Uses pool habitat.
River otter (*Lutra canadensis*)	Sub-adult to adult; chub may not be preferred prey due to their speed.	Sub-adult to adult	Uses all habitats	Attacks fish that come too close, will injure/kill fish that cannot escape from them
Red shiner (*Cyprinella lutrensis*)	Larvae	Adult	Yes: shallow habitats	Consumes invertebrates.
Rock bass (*Ambloplites rupestris*)	Larvae to juveniles	Sub-adult to adult	Yes: pools	Uses pool habitat. Consumes invertebrates.

Smallmouth bass (*Micropterus dolomieu*)	Larvae to sub-adults	Sub-adult to adult	Yes	Prefers pools with cover, intolerant of turbidity, may exclude chub from preferred pools. Consumes invertebrates.
Yellow bullhead (*Ameiurus natalis*)	Larvae to juvenile	Sub-adult to adult	Yes	Uses pool habitat. Defends nest and young. Consumes invertebrates.

Table 6.1-2. Category Rankings for Nonnative Species

Level of Impact to Chubs	**Nonnative Species in Category**
Very High	Green sunfish, flathead catfish, smallmouth bass
High	Black bullhead, yellow bullhead, brown trout, largemouth bass, crayfish
Moderate	Channel catfish, rainbow trout, rock bass, red shiner, western mosquitofish, river otter
Low	Bullfrog, common carp, fathead minnow

While there is little direct evidence of extirpation of chubs as a result of nonnative species, extirpation has been documented for other native fish in Arizona and New Mexico. In addition, in Fossil Creek, nonnative predators were removed and chub numbers increased 70 times over the pre-removal numbers due to the success of spawning and survival of young-of-the-year (Marks et al. 2009, pp. 15, 21). However, there are streams where chubs have maintained populations in the presence of one or more of these nonnative species. The mechanisms providing for that co-existence in any particular stream is unknown. The amount of preferred habitat available for both the chub and the nonnative species may play a role, as may the abundance of the nonnative and its means of affecting the chub. In some cases, the nonnative species may have only newly entered the stream and the full effects have not been realized. In other cases, the current habitat and population dynamics may not strongly favor either natives or nonnatives allowing for persistence of both under those conditions. There is a wide range of chub and nonnative species co-occurrence situations. While chubs co-exist with nonnatives in several streams does not mean that nonnatives are not impacting chubs or that chubs are not having population level impacts to chubs, as demonstrated by the removal of nonnatives in Fossil Creek.

In addition, population persistence of native fishes is compromised during prolonged climatically dry periods due to the combined loss of available habitat and heightened risk of competition with and predation by nonnative fishes (Jaeger et al. 2014, p. 2). Further decreases in streamflow continuity associated with more frequent and intensive channel drying during spring (spawning) and summer low-flow months will effectively reduce the amount of available habitat for reproduction and may eliminate critical summertime refuges. Native fishes in the remaining refuges will face extreme physicochemical stress (i.e., high temperature and low dissolved oxygen concentration) and increased species interactions with nonnative species, promoting high local extinction probabilities. The effects from nonnatives can be worse during drought because of the synergistic impacts from the conditions described above.

Nonnative species occupy all but three headwater chub streams and three roundtail chub DPS streams. In Arizona and New Mexico, the States still stock nonnative sport fish for recreational

fishing. However, only triploid rainbow trout (these are sterile and unable to reproduce) are stocked in streams occupied by chubs. In addition, there are six streams (three for headwater chub and three for roundtail chub DPS) that are currently free of nonnatives into which nonnatives could expand or be introduced. We expect that nonnatives will continue to persist in most if not all of the streams they currently occupy and that nonnative impacts will increase in a percentage of streams across the range of both species due to reduction in water leading to increased competition, predation, and harassment.

6.2 Water Availability

Water is the basic habitat component needed for chub survival. As described in Chapter 2 above, water supports the needed physical and biological characteristics in streams needed for the various life stages and life history functions. Chubs are impacted not only by the quantity and quality of water, but also by the timing and spatial distribution of water. There is a strong temporal component to the amount of water available in a stream. Low flow periods occur in May-June and October-November. High flow periods occur in late winter and early spring from snowmelt, and in late summer to early fall from monsoons. Snowmelt during late winter and early spring cue spawning and provide water temperatures suitable for spawning. The driest time of year is between the spring runoff and monsoon season, which is generally May-June. This is when water is most limiting. Following this dry period, monsoon rains are critical to provide needed water for chubs to survive after this dry period. Alterations to this hydrograph affect the timing and distribution of water, which in turn affects life history requirements of chubs such as the timing and periodicity of spawning, elevation distributions within stream systems, and impact the life cycles and availability of food resources (Dallas 2008, pp. 395-397). Figure 6.3-3 displays the effects pathways of water availability on chubs.

Reduction in water can result in a loss of hydrologic connectivity and increased fragmentation within and among streams. Reductions in hydrologic connectivity can prevent spawning related movement and limit access to breeding, rearing, foraging, and hiding areas, and stranding of fish. Streams supporting a diversity of refugia (i.e., pools or other mesohabitats that remain wetted) during drying periods can increase the chances of individuals, populations, and communities surviving until habitats are rewetted and connected (Magoulick and Kobza 2003, pp. 1187-1188; Davey and Kelly 2007, p. 1719). Hydrologic connectivity within streams allows for larger contiguous habitat areas and the recolonization of portions of streams adversely affected by a stochastic event. As natural and human-caused changes reduce the amount of water in a stream, that stream may continue to dry and contract longitudinally and laterally, such that the amount of habitat available to headwater and roundtail chubs will continue to decrease. This reduction can result in separation of two previously connected streams, or maintenance of water in only patches of one stream, both of which contribute to fragmented and isolation of populations.

Loss of natural habitat connectivity and increased fragmentation can also result in genetic isolation among metapopulations of roundtail chubs leading to inbreeding depression and loss of evolutionary potential thereby increasing the extirpation risk in small, isolated populations (Schwemm 2006, p. 28). Isolated and small populations represent a potential genetic bottleneck that could adversely impact populations through inbreeding depression and genetic drift making them more vulnerable to stochastic events that might further reduce their population sizes.

Fagan et al. (2002, p. 3254) found that, as a result of fragmentation and isolation, roundtail chub has a moderately high risk of local extirpation (0.41 percent probability) because recolonization from adjacent populations is less likely. Headwater chub, which has naturally fragmented populations, has a lower risk of local extirpation (0.28 percent probability) as it still occupies many of its historical localities, which are headwater and smaller tributary habitats. However, fragmentation within those headwater chub populations results in the same potential for adverse effects of small, isolated populations. In examining the relationship between species distribution and extinction risk in southwestern fishes, Fagan et al. (2002, p. 3250) found that the number of occurrences or populations of a species is less significant a factor in determining extinction risk than is habitat fragmentation. In addition, during drought, stream intermittency or isolation may cause deterioration of water quality resulting in increases in physicochemical extremes of temperature, dissolved oxygen, pH, and nutrient loading (Lake 2000, p. 578, and Lake 2003, p. 1165).

Historically, the amount of water in any stream at any time was determined by natural water sources such as surface flow, springs, and alluvial groundwater input. Currently, these natural water sources are impacted by climate change and human actions. Climate change results in alteration of the timing and amount of snowmelt and monsoon rains. Further climate change alters the frequency and duration of droughts, and increases evaporation. This is discussed later in the climate change section below.

In addition, some streams have been and continue to be altered by human actions in which flows are reduced due to surface water diversions and alluvial groundwater pumping. The creation of large water storage dams (such as those on the Salt and Verde Rivers) eliminate flowing sections of water and replace them with large reservoirs that support nonnative fish species. Chubs may be found in these large reservoirs initially (Bezzerides and Bestgen 2002, p. 18), but do not persist there. The dams that form the reservoirs are impassible obstacles to chubs and prevent them from moving through the system, resulting in fragments of occupied stream where there was once full connectivity. On the smaller scale, diversion dams that allow for removal of water from the stream for human uses may or may not be barriers to connectivity depending on their size and structure; however, their effect on flows can be substantial depending on the number of diversions in a stream and the season of diversion.

Past and current diversion of water for agricultural practices is a contributing factor to the reduction in water in some areas. For agriculture, the primary diversion season is in the late spring through early fall, generally a low flow time of the year when water supplies are already stressed (Sullivan and Richardson 1993, pp. 37-38). This contributes to local stream drying, where the reach below the diversion can be all or partially dry until flows return due to return flows from agriculture activities, groundwater, or monsoon rains. Return flows from agricultural fields do restore some flow, but they may also contain contaminants. Other inflows from human development include those from wastewater treatment plans and storm drain runoff that may also contain contaminants. In addition to direct removal of surface flow, wells that tap the alluvial groundwater (the shallow aquifer that also supports the surface flow in a stream) can reduce the level of the groundwater such that it is below the streambed elevation and cannot provide surface flows to streams. In areas with few wells, this is generally not a significant concern; however, in

areas with denser human development (as is found along the East Verde River, Oak Creek, and Wet Beaver Creek) stream drying does occur.

Ultimately, the effect of scattered, small, and disjunct populations, without the means to naturally recolonize, weakens the species resiliency as a whole, which ultimately enhances the risk of populations of either or both species becoming extirpated. Maintaining several populations with relatively independent susceptibility to threats is an important consideration in the long-term viability of a species (Shaffer 1987; Goodman 1987). Redundant populations also provide security from catastrophic events or repeated recruitment failure. The change in water availability over time is a critical risk category for headwater and roundtail chubs for future viability.

6.3. Land Uses

6.3.1. Livestock grazing

In the past, poorly managed livestock grazing has damaged approximately 80 percent of stream, cienega (marsh), and riparian ecosystems in the western United States (find cite). Widespread overgrazing denuded rangeland and permanently altered watersheds in Arizona starting in the late-1800s, affecting habitats formerly and currently occupied by chubs in all drainages in the lower Colorado River through a number of mechanism including removal of riparian vegetation, reduced bank stability, increased bank erosion, and sedimentation, all of which can lead to loss of pool and backwater areas (Clary and Medin 1990, pp. 2-3; Fleishner 1994, pp. 630-631; Tellman et al. 1997, p. 167; Propst 1999, p. 25; Voeltz 2002, pp. 23–88). This loss of aquatic habitat complexity may alter the composition and community structure of other aquatic fauna, such as aquatic invertebrates, which can impact chub by reducing the quantity and quality of food (Gorman and Karr 1978, p. 507). Poorly managed livestock grazing results in a shift in the structure and diversity of fish communities due to changes in availability and suitability of habitat types (Li et al. 1987, pp. 627-639; Rahel and Hubert 1991, p. 326). Figure 6.3-4 displays the effects pathways of livestock grazing on chubs.

However, the capability exists to create livestock grazing strategies that are compatible and even complementary to maintaining fisheries habitat, although more research is needed in this regard (Platts 1989, p. 103; Vavra 2005, p. 128; American Fisheries Society 2009). Because the adverse effects of poorly managed livestock are better understood and have been well documented, livestock grazing on Federal and Tribal lands have been modified to reduce or eliminate long term adverse effects. Consequently, even though all streams containing chub populations are surrounded by grazing allotments, impacts from grazing are limited and data does not indicate population level impacts are occurring or will occur in the future.

6.3.2. Recreation

Impacts from recreational activities vary based on the specific activity. Impacts of recreation are highly dependent on a continuum of quantity and quality of activity, with activities such as light hiking having little to no impact and activities such as off-highway vehicle (OHV) use potentially having severe impacts on aquatic habitats (Ouren et al. 2007, pp. 6-22). Excessive

human foot-use and camping can result in trampling of near-shore vegetation and reduced water quality. The use of OHVs in and around streams may reduce vegetation cover and plant diversity, reduce infiltration rates, increase erosion, and reduce habitat connectivity (Ouren et al. 2007, pp. 6–22). Sportfish angling, a popular recreational activity, may affect particular populations of chub. Adverse effects of angling include, but are not limited to, direct catch and bi-catch by anglers with the potential for hooking injuries if fish are not properly handled. Specific problems with recreation have been documented in the Upper Gila River, and Tonto, Webber, Oak, and Fossil Creeks (Voeltz 2002, pp. 39, 59, 77; American Rivers 2007, pp.1-4). Voeltz (2002) noted specific OHV-use related problems in two streams with known populations of roundtail chub, the upper Gila River and Oak Creek. Various types of recreation occurs in all parts of watersheds containing chubs (Voeltz 2002, entire; Paradzick et al. 2006, pp. 107–108; American Rivers 2007, pp. 1–4; Ouren et al. 2007, pp. 6–16; Cantrell 2009, p. 15).

Most current federal and state recreational management addresses the potential impacts from recreation to aquatic and riparian habitat, and reduces or ameliorates the impacts from recreation actions. However, the projected increase in recreational use of the limited areas available may offset gains in habitat quality through improvement of local conditions. Active management and restoration projects may not be sufficient at high-use recreation sites to eliminate existing and prevent new degradation from occurring. The expansion of existing sites or the creation of new ones would be of concern; however, we do not have site specific information to evaluate this. Increased human population growth rate is expected to continue throughout the range of the chubs in the lower Colorado River basin and this growth leads to higher demand for recreational opportunities. In the arid Southwest, the human desire to recreate in or near water, and the relative scarcity of such recreational opportunities, tends to focus impacts on riparian areas.

We assume that in the future, the effects of recreation (both physical and biological) would increase and the potential exists for these activities to impact both chubs species. However, the overall and direct effects of recreation on headwater and roundtail chub and associated habitat are largely unknown. It is likely there will be impacts to individual chub in some sites; however, data does not indicate that recreation is having population level impacts.

6.3.3. Urbanization

Urban, suburban, and rural development a potential stressor in streams or portions of streams with adjacent private lands or facilities that remove water from the stream for human uses (Tellman et al. 1997, pp. 92-93; Cantrell 2009, p. 18). Human development can affect chub and associated habitat in a number of ways, such as direct alteration of stream banks, diversion and depletion of water from streams and connected groundwater, pollution from wastewater, increased land covered by impervious surfaces with greater surface runoff and less infiltration, increased recreation, creation of roads, and increased probability of nonnative species introductions (Reid 1993, pp. 48-50; Waters 1995, pp. 52-53; Glennon 1995, pp. 133-139; Tellman et al. 1997, pp. 92-93; Wheeler et al. 2005, pp. 149-155). Wastewater treatment plants accompany development in urban and suburban areas and can contaminate ground and surface water (Winter et al. 1998, p. 66). Urban runoff contains pollutants including metals, nutrients, and endocrine disrupting compounds which cause water nutrient-enrichment, reducing dissolved oxygen to lethal levels, and affecting fish reproduction and development (Hassler 1947, pp. 383–

384; Kime 1995, p. 52; Wheeler et al. 2005, p. 153; Rosen et al. 2007, pp. 1–4; Cantrell 2009, p. 15).

Increased impervious surfaces creates greater surface runoff and less infiltration. Natural surfaces in a watershed allow infiltration of water slowly into the alluvial groundwater system, which contributes water to streams as subsurface flow. Streams are often dependent on subsurface flow that steadily contributes flow between precipitation events. Impervious surfaces created by development alter this process by preventing precipitation from slowly infiltrating the alluvial groundwater. This results in a reduction in base flow (Simmons and Reynolds 1982, p. 1752; Wang et al. 2000, p. 255; Wheeler et al. 2005, p. 151). This reduction in base flow can change streams from perennial to ephemeral, which has direct consequences to stream fauna (Medina 1990, pp. 358–359). Additionally, increased amounts of surface runoff during storm events results in increased erosion and sedimentation, which can alter stream habitat productivity, adversely affect the food base for fish, eliminate rearing habitats, and fill in pool habitat on which chub rely (Waters 1995, p. 43). Because riparian vegetation contributes leaves, wood, organic debris, and terrestrial invertebrates to streams, vegetation removal can often drastically alter food webs in streams (Vannote et al. 1980, p. 130; Hawkins and Sedell 1981, p. 387; Reid 1993, p. 74).

Urbanization has an uneven effect across the landscape with many streams not affected and others with varying levels of effect. Urbanization effects are most likely to increase along the mainstem Verde River and its tributaries including Oak Creek, Beaver Creek, lower West Clear Creek, and the East Verde River; lower Tonto Creek on the Salt River, and potentially on the White River. Augmentation of natural flows supporting roundtail chub in Eagle Creek provides a more secure water source that is expected to continue with the operation of the Morenci Mine. The transbasin diversion from CC Cragin Reservoir on East Clear Creek will augment summer flows in the East Verde River but at the expense of released flows into East Clear Creek.

Urbanization results in an increased demand for water, which in turn results in a decrease in the water available to chubs. Urbanization likely affects individual chubs but it may also have population level effect in a few as discussed in the preceding paragraph. In addition, urbanization combined with the other actions affecting water availability, such as climate change, are likely to have population level impacts. However, we do not have specific information to connect the risks of urbanization to chub population status in the streams listed above.

6.3.4. Mining

Arizona has the richest copper deposits in the United States and for many years has led the Nation in copper production. The state also ranks in the top five in other non-fuel mineral production for molybdenum, sand and gravel, gemstones, perlite, silver, zeolites, and pumice (ADMMR 2008, 2010). Water is required for most mining and processing, with sources coming from underground aquifers, surface water, precipitation, or a combination of sources (ADMMR 2010). Hard rock mining operations in the vicinity of roundtail chub populations are in the Bill Williams River drainage and Eagle Creek. Other roundtail chub populations that may be indirectly exposed to mining through provision of water supplies for mining actions are Aravaipa

Creek, Cherry Creek, and the mainstem Gila River near Cliff, New Mexico. There are no known mining operations in the vicinity of headwater chubs.

Sand and gravel mining can result in stream disturbance and modifications that are similar to stream channelization (Brown et al. 1998). Specific changes to channel geomorphology include increased bankfull widths, surface area increase of downstream pools (but not depth), increased distance between riffles, and lateral erosion of stream banks that can remove vegetation and undercut riparian trees (Brown et al. 1998). Ongoing sand and gravel mining occurs in lower Tonto Creek (headwater chub) and Trout Creek (roundtail chub).

Hard rock mining expansion continues in Arizona and New Mexico as evidenced by the proposal for the Rosemont Mine on the Coronado National Forest. It is uncertain where future mines would be located; recent mines have not been in areas where effects to these chubs were expected although other native aquatic species were affected. Expansion at existing mines may result in additional need for water from surface flows or connected groundwater that could affect chub streams. Sand and gravel mining has more widespread potential for expansion; however, operators are more likely to consider the advantages of dry or mostly dry areas outside the active channel due to the potential damage from floods. This type of mining is very site-specific based on the quality of the materials available and we are unable to predict future trends for this risk. Data does not indicate that these activities are having population level impacts. However, depending on the type (whether the mining methods require significant water) and location of future mines could result in population level impacts to chubs through the reduction in water.

6.3.5. Roads

Unpaved forest roads collect and channel stormwater runoff into streams, causing physical changes such as channel widening and downcutting. Road networks often cross tributary streams at perpendicular angles or are parallel to mainstream segments, which can alter the geometric interactions involving peak flows (floods) and debris flows (soil, sediment, and wood), and increase the magnitude and frequency of flood flows (Jones et al. 2001). Construction of slab or culvert crossings reduces or precludes movement of fish (Warren and Pardew 1998; Wheeler et al. 2005), potentially resulting in reduced genetic diversity (Wheeler et al. 2005). Culverts can destabilize stream channels and interrupt the transport of woody debris, sediment, substrate, and water (Wheeler et al. 2005). Figure 6.3-4 displays the effects pathways of roads on chubs.

Improved roads construction and management is assumed to decrease adverse effects of roads on chub habitat. Roads primarily have effects to individuals except when connectivity within a stream is precluded and populations can be impacted. Data does not indicate that roads are having population level impacts to chubs.

6.3.6. Forestry Practices

Logging and fuel wood cutting can have adverse impacts to chubs. The alteration of watersheds resulting from logging is deleterious to fish and other aquatic life forms (e.g., Burns 1972, p. 1; Eaglin and Hubert 1993, p. 844), largely due to increases in surface runoff, sedimentation, and

mudslides, and the destruction of riparian vegetation (Lewis 1998, p. 55; Jones et al. 2000, p. 81). All of these effects negatively impact fish (Burns 1972, p. 15; Eaglin and Hubert 1993, p. 844; Barrett et al. 1992, p. 437; Warren and Pardew 1998, p. 637) by lowering water quality and reducing the quality and quantity of pools, either by filling them with sediment, reducing the quantity of large woody debris necessary to form pools, or imposing barriers to movement. Figure 6.3-4 displays the effects pathways of forestry practices on chubs.

Historically these activities resulted in profound changes in many streams of the Southwest including those in which chubs occurs. However, impacts from these actions is largely a stressor of the past (Minckley and Rinne 1985, pp. 150–151; Minckley 1999, p. 216) due to improved management practices for these activities. While there may still be impacts to individuals, data does not indicate that population level impacts are occurring.

6.3.7. Wildfires

In the Southwest, fire is a natural disturbance in montane watersheds that is necessary for ecosystem health and function (Wright 1990; Bowman et al. 2009) and is integral to the forested ecosystems in the Gila and Little Colorado watersheds that contain headwater and roundtail chub. While wildfires have historically always occurred, they typically burned at much lower severity prior to European settlement. Post-European forest and land management activities, such as fire suppression, logging practices, and excessive livestock grazing, have resulted in the accumulation or alteration of forest fuel. This has resulted in an increase in the size, frequency, and severity of wildfires. In addition, the drier, warmer regional climate has resulted in increased spring and summer temperatures and earlier spring snowmelt, which have resulted in more extreme fire behavior (Westerling et al. 2006; Werth et al. 2011). The frequency and duration of drought is predicted to increase in the Southwest based on current climate change models, potentially further influencing the frequency of wildfire and associated impacts (Garfin et al. 2014). Figures 6.3-1 and 6.3-2 show the fire risk level for chub streams. Figure 6.3-4 displays the effects pathways of wildfire on chubs.

Figure 6.3-1. Fire Risk to Headwater Chub Analysis Units (United States Forest Service 2015)

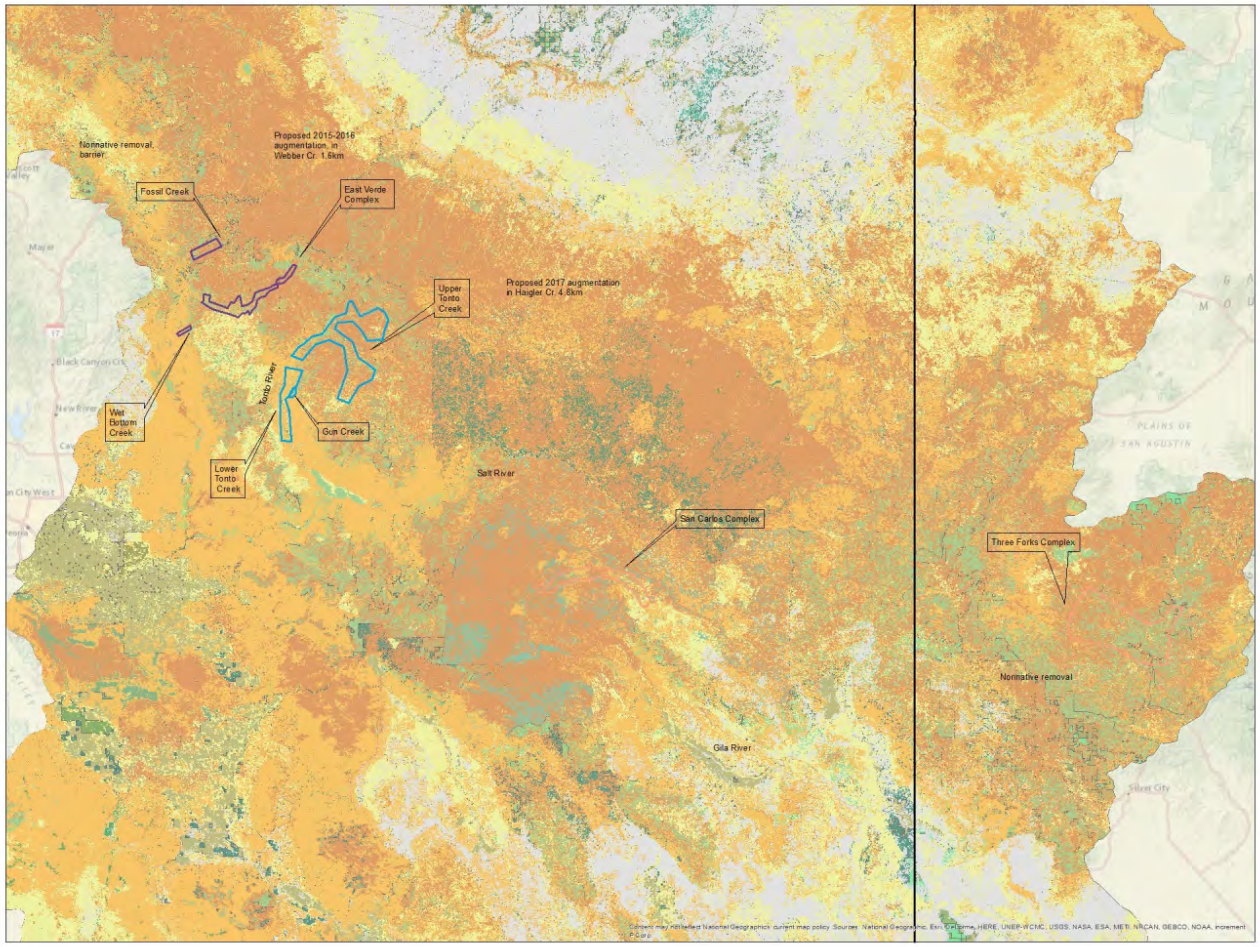
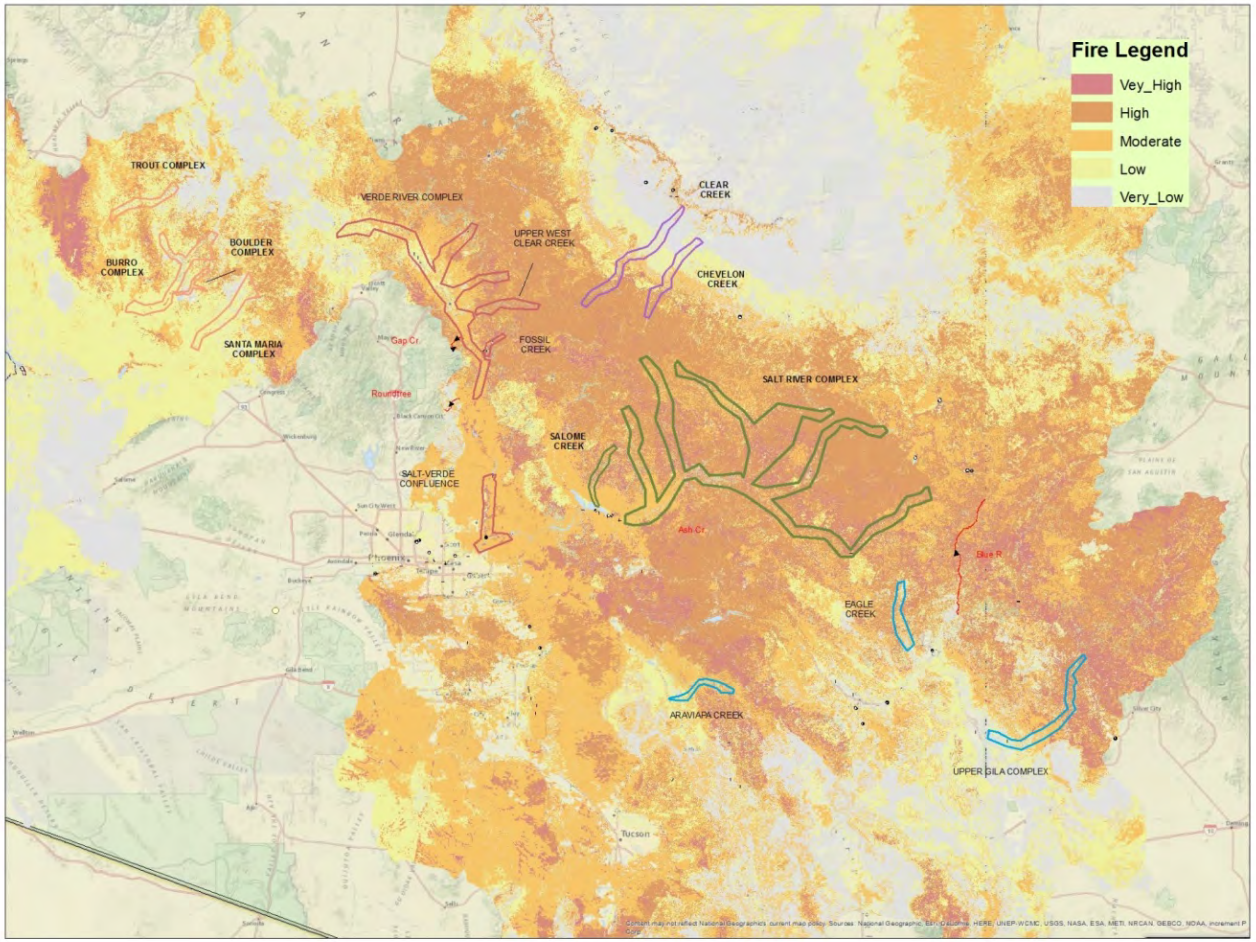


Figure 6.3-2. Fire Risk to Roundtail Chub Analysis Units (United States Forest Service 2015)



The effects of wildfire on aquatic systems and fishes include direct or immediate influence of the fire on water quality and the indirect or subsequent effects on watershed characteristics and processes that influence water quality and quantity, stream channels, and aquatic species. Direct physical effects can result in fatality of fishes, amphibians, invertebrates, and periphyton (Rieman et al. 1997; Gresswell 1999). Fatalities have been associated with the direct effects of severe fires, but these consequences have been most frequently observed in relatively small streams and over limited extent (1-2 km). If a severe fire burns near or across a stream, water temperature can increase substantially (Hitt et al. 2003). However, additional research looking at temperatures in multiple streams impacted by high severity burns found that there were no apparent increases in maximum water temperature during the fires (Mahlum et al. 2011). As smoke, ash, and volatile compounds dissolve, the pH may altered as well as concentrations of trace metals, nutrients, and other chemical constituents in streams (Gresswell 1999). The spatial pattern of direct effects seems to depend on the extent and severity of fire and size of the watershed (Gresswell 1999). In addition, the size of the watershed likely also influences the ability of a fire to influence temperature in the stream. Fire is not likely able to influence temperature in third order or larger streams (Minshall and Brock 1991).

The indirect or subsequent effects of fire on watershed characteristics and processes can influence water quality and quantity, stream channels, and aquatic biota. The extent of the impact of a particular fire depends on the local conditions and nature of the fire and whether post-fire flooding occurs that results in ash from the severely burned uplands entering the stream in a large debris pulse. Further, impacts to chubs from wildfire depend on the size and condition of the stream. If a stream is sufficiently long, fish may survive in an unburned upstream reach or tributary, then recolonize the burned reach when habitat becomes suitable. However, in some cases we have noted that although conditions post-fire likely impacted fish (i.e., individuals in small pools without sufficient flow to buffer them from ash inputs died), fatalities did not occur at the population level and fish rebounded quickly post-ash flow. In a worst case scenario, post-fire effects can result in stream channel changes, riparian habitat effects, and significantly decreased water quality impacts can make streams unsuitable for years following the fire, and subsequent flood event (Rinne and Carter 2008, Reiman et al 2012). The extent of the impact of a particular fire depends on the local conditions and nature of the fire and whether post-fire flooding occurs that results in ash from the severely burned uplands entering the stream in a large debris pulse. If a stream is sufficiently long, fish may survive in an unburned upstream reach or tributary, then recolonize the burned reach when habitat becomes suitable. However, in some cases we have noted that although conditions post-fire likely impacted fish (i.e., individuals in small pools without sufficient flow to buffer them from ash inputs died), fatalities did not occur at the population level and fish rebounded quickly post-ash flow.

Effects to chubs from wildfire vary depending on the fire and streams. The severity and timing of the fire influence the impact of fire to chubs depending on the amount of runoff and degree of sediment and ash in the runoff. In addition, the size and condition of the stream also influences the impact to chubs from fire. In some cases, extremely heavy ash flows have not resulted in the loss off populations, such as high ash flows in West Fork Oak Creek following the Slide Fire (S. Hedwall, pers. comm. 2015). In other cases there have been instances of loss of fish (not chub, but other fish species), such as in upper Whitewater Creek following the Whitewater-Baldy Complex Fire (S. Hedwall, pers. comm. 2015). There are streams where chubs (and other fish

species) survived post-fire ash/sediment flows following wildfire. This happened in the Upper Gila River, Black River, and Spring Creek. It is probable that there were individual fish that died or were harmed, and population numbers or health were reduced. However, populations that were initially depressed in these streams have rebounded, even increasing in abundance or extent relative to prefire conditions. Spring Creek likely recovered because the whole drainage was not affected. Then there are streams like Cave Creek where pools filled with sediment post-fire and have not recovered, and Gila chub population impacts occurred. Fires such as the Rodeo-Chediski (2002), Willow (2004), Picture (2005), and Wallow (2011), Slide 2014 occurred within watersheds occupied by headwater and roundtail chub or considered historic habitat, yet have not resulted in the elimination of chub populations to our knowledge, and in some circumstances benefited native fishes by eradicating nonnative fish (e.g., Black River [Wallow Fire], Spring Creek complex [Picture Fire]).

The Forest Service has implemented a suite of practices to reduce the risk of high-severity fires in the range of the chubs, such as prescribed burning, mechanical thinning, and retention of large trees. These actions can help reduce the risk of extreme fire behavior (Finney et al. 2005). Although considerable work has been accomplished to reduce fuel loads and plans to continue these efforts are documented, wildfire still poses a risk to the chubs.

Wildfire has been perceived as a destructive force in streams (Rieman and Clayton 1997), but not all fires result in detrimental impacts to streams, and subsequently to the fish occupying the stream. The fire effects, both direct and indirect, depend on the extent and severity of fire, and size of the watershed (Gresswell 1999, Rieman et al. 2012). Impacts from wildfires could result in individual as well as population level impacts to both species. The effects from climate change, such as increased temperatures, increased evaporation, and change in timing and amount of precipitation is likely to create conditions more favorable to wildfire. Conversely, forestry management actions reduecing fuel loads could mitigate impacts from fire. It is highly likely that wildfires will continue throughout the range of these species. However, the timing, location, and severity of such wildfires is uncertain.

Figure 6.3-3. Conceptual Diagram of Effects Pathways of Land Management, Water, and Nonnative Species Risk.

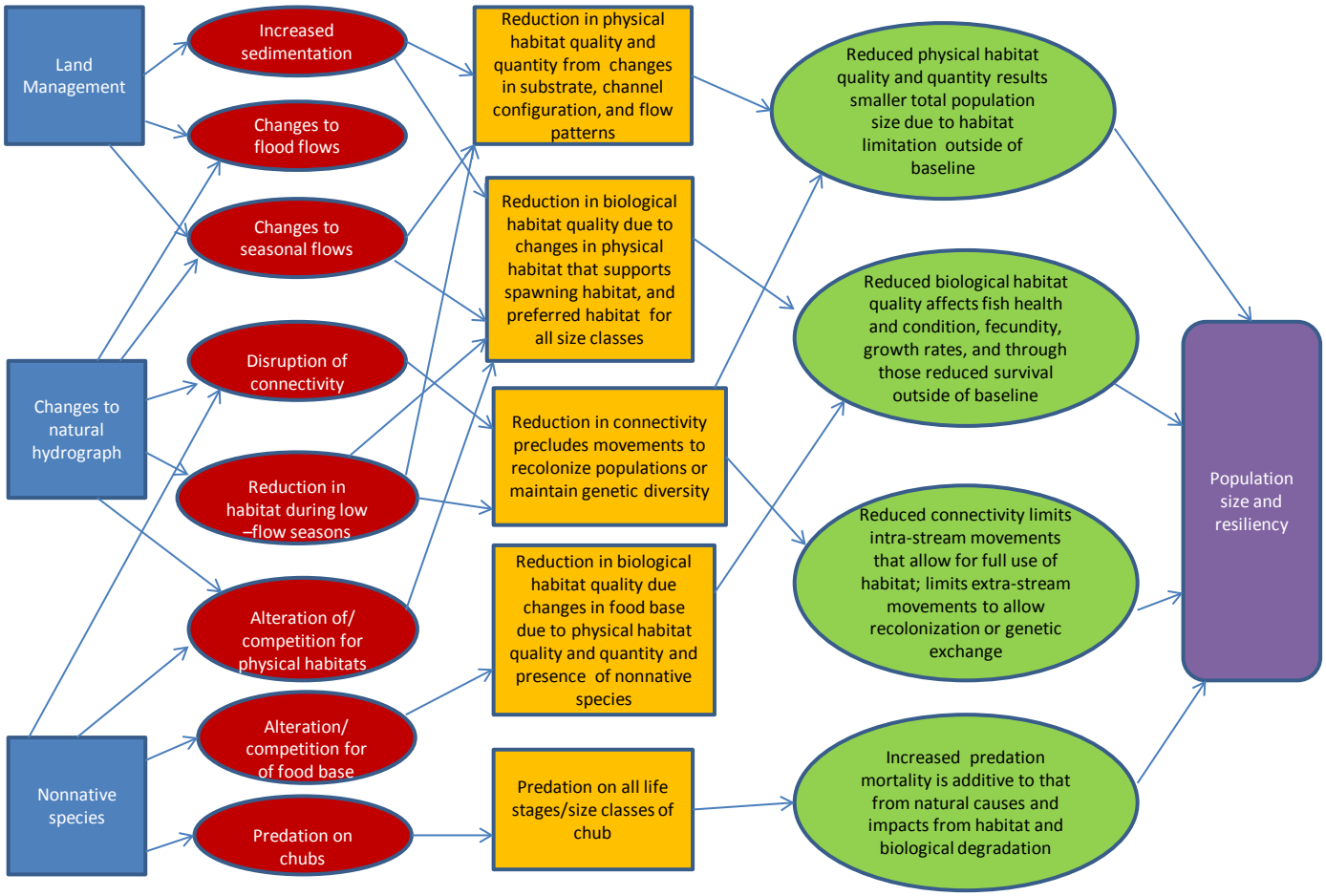
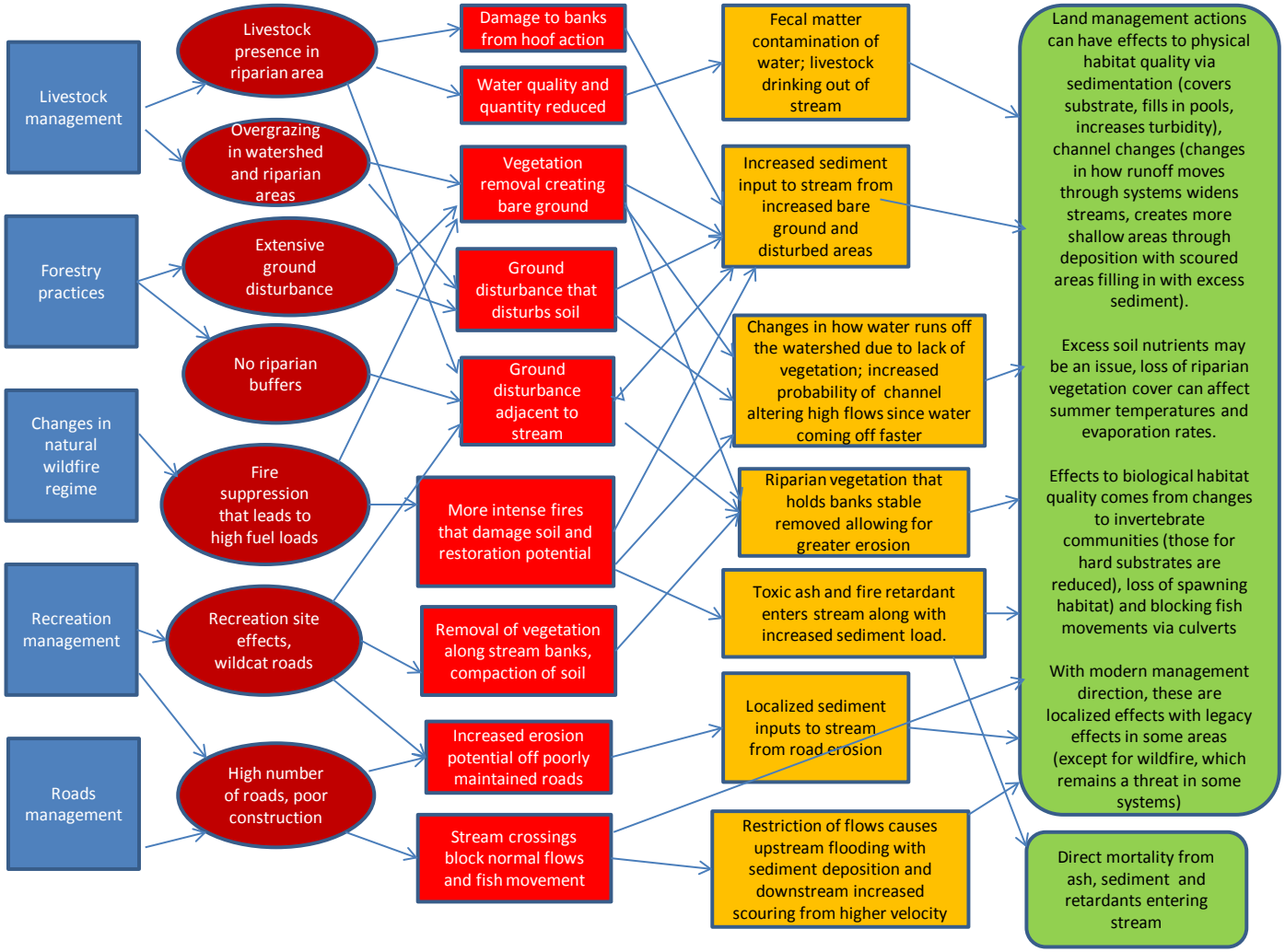


Figure 6.3-4. Conceptual Diagram of Effects Pathways of Risk.



6.4 Demographic Risk

Current or historical population size or density is not known for all occupied chub streams. Further, we are not able to determine if AUs are of an effective population size. Consequently, we are unable to compare historical versus current populations or AUs in this manner. However, small and isolated populations are vulnerable to loss of genetic diversity, which decreases a population's ability to adapt to environmental changes and increases vulnerability to extirpation.

Estimating effective population size (a theoretical measure of the number of individuals in a population that actually contribute genetic information to the next generation [i.e., genetic diversity]) of a population is one way to measure the risk of a population experiencing those negative genetic effects. Effective population size is generally much lower than census population size due to unequal sex ratios, variable probability of reproductive success, and nonrandom mating (Baalsrud 2011, p. 1). General guidelines developed for conservation management of imperiled species suggest effective population sizes of 500 and above have a low risk of inbreeding and retain long term adaptive potential, and those below 50 are highly vulnerable to inbreeding depression and genetic drift (Allendorf et al. 1997, pp. 142–143; Rieman and Allendorf 2001, p. 756). Loss of genetic diversity through long-term effects of small population size does not automatically result in the loss of that population. A population is more subject to inbreeding effects where deleterious genes gain expression, and the young may have reduced fitness to cope with existing or changing conditions.

The headwater and roundtail chub developed as a result of multiple independent hybridization events over time (Rinne 1976; Rosenfeld and Wilkinson 1989; DeMarais et al. 1992; Dowling and DeMarais 1993; Minckley and DeMarais 2000; Gerber et al. 2001; Schwemm 2006; Schönhuth et al. 2014). Schwemm (2006) discussed the challenges of identifying each population in the complex to individual species because of various factors, including speciation that is shaped by multiple evolutionary forces, known intermittent exchange of genetic variation, and relatively recent divergence within the three species. Variation within headwater chub populations is consistent with the multiple hybrid origins of this species. The significance of isolation in shaping each population highlights the importance of maintaining each independently to preserve the unique genetic variation (Dowling et al. 2008, p. 2). Information from roundtail chub indicated that historically there was greater connectivity and subsequent relatedness over the region and development of populations in isolation from other roundtail chub was not the normal condition across most of the historical range except in the Bill Williams River and Little Colorado River drainages.

For headwater chub, demographic effects could result if AUs become fragmented due the unique genetic variation within each AU. For roundtail chub, demographic effects could result if AUs are fragmented but if connectivity between AUs is fragmented. As the demand for water due to humans and the effects of climate change increase, water is likely to become more limited. This loss of water affects the water flow in a stream, and the number and length of watered and dry stream segments (i.e., increased fragmentation of a stream). As fragmentation increase so does the risk of demographic impacts. Demographic impacts as a result of water reduction and

nonnative species are ongoing and are likely to continue in the future given climate change model projections and human population increases.

6.5 Diseases and Pathogens

Nonnative parasites such as Asian tapeworm (*Bothriocephalus acheilognathi*), anchor worm (*Lernaea spp*.), and Ich (*Ichthyophthirius multifiliis*) are found within the lower Colorado River basin and infect individual roundtail and headwater chubs. These parasites and others, such as black and yellow grub (*Uvulifer ambloplitis* and *Clinostomum complanatum*), likely occur throughout the range of these two species. While the current level of exposure to these parasites does not appear to have population level effects on headwater or roundtail chub, there are effects to individuals particularly where there is isolation of fish in pools during the hotter parts of the summer when fish are stressed by crowding, temperature, and water quality (Rottmann et al. 1992, p. 1). Parasite infestations are expected to increase and become more virulent with climate induced stream warming, resulting in accelerated development and maturation rates, earlier and prolonged transmission, and shifts in their spatial and temporal distributions (Marcogliese 2001; Rahel et al. 2008, p. 555; Mohant et al. 2010, p. 124). Climate induced environmental stressors, such as temperature variations, water availability, and food reductions, can further exacerbate the effects of nonnative parasite infestations of fish, which can lead to increased mortality rates (USGS 2004, p. 1; USGS 2005, p. 2; Linder et al. 2012, p. 123).

The potential for the effects of disease and parasites to become greater in the future is primarily tied to changes in habitat conditions that could favor these organisms and the degree of exposure that may occur with changes in water availability. These risk could be exacerbated by climate change as water flow decreases and isolated pools increase. However, data does not indicate that these factors are having population level impacts to either species.

6.6 Climate Change

Many of the current climate change models focus on larger landscape or global scale climate predictions that are generally not useful in determining climate changes in the current or historical range of roundtail and headwater chub. We identified two current, regional downscaled models that make projections about the hydrologic connectivity where roundtail and headwater chub occur. One study by Jaeger et al. (2014) focuses on the Verde River Basin in Arizona over current (1988-2006) and midcentury (2046-2064) time periods. The other study by Garfin et al. (2014) focuses on the Gila River in Arizona and New Mexico within similar time periods (1971-2000 and 2041-2070)

Jaeger et al (2014) provides a demonstration of projected changes in regional climate regimes, more frequent and severe droughts, that will likely have significant consequences to patterns of intermittence and hydrologic connectivity in dryland streams in the southwest (Jaeger et al. 2014, p. 3). Model predictions show that climate change will likely shrink the length of the remaining flowing reaches (Jaeger et al. 2014, p. 3). During the spring and early monsoon seasons, the flowing regions are projected to diminish between 8% and 20%. These regions that support flow are increasingly isolated as adjacent dry fragments expand in length and occur more frequently across these seasons. Model predictions suggest that midcentury and late century climate will

likely reduce network-wide hydrologic connectivity for native fishes by 6–9% over the course of a year and up to 12–18% during spring spawning months (Jaeger et al. 2014, p. 3).

The availability of water in much of the western United States is highly dependent on snowmelt, in part because much of the western United States receives the majority of precipitation during the cold season (Mock, 1996) and in part because runoff from snowmelt is far more gradual than from rainfall. In the Gila River basin Garfin et al. (2014) found that the average monthly streamflow showed a shift in the hydrograph toward earlier peak streamflow (to February) and lower overall annual streamflow due to slight decreases in average precipitation and increases in evapotranspiration, all of which are associated with a projected increase in temperatures. Warm winters produced earlier runoff and discharge but less snow water equivalent and shortened snowmelt seasons in many snow dominated areas of North America (Barnett et al. 2005; Rood et al. 2008; Reba et al. 2011).

The Verde River Basin follows a seasonal connectivity regime that exerts strong influences on the physical, chemical, and biological processes throughout the riverine network. Connectivity naturally declines during spring as the snowmelt season progresses and intermittent stream channels go dry. In the summer monsoon season, river networks experience short episodes of contraction and expansion of wetted areas. During these times, fish become concentrated in available refuges but have opportunities to recolonize habitat upon rewetting of dry channels during the monsoon rains and are able to take advantage of decreased predation and competition and increased food availability. Winter reflects a resetting of the river system at the network scale, when connectivity is characteristically highest, allowing for organic matter and nutrients to be transported and processed downstream and fish to redistribute across the river network. Despite native fishes having evolved life history strategies to cope with the harsh environmental conditions that occur as a result of stream drying events, the predicted spatiotemporal changes in streamflow likely will have adverse consequences for the distribution, abundance, and persistence into the future.

Water quantity and median streamflow (shown in parenthesis) predicted changes in the Gila River, on average, decrease 6% (15%) near Gila; decrease 8% (15%) near Virden; and decrease 11% (19%) in the San Francisco at Clifton for the 2041 to 2070 time period. In presently dry regions, the frequency of droughts will likely increase by the end of the 21st century under the scenario where emissions continue to rise throughout the 21st century (medium confidence) (IPCC p. 67). During the 2046–2065 period under the scenario where emissions continue to rise throughout the 21st century, more than 50% of summers exceed the respective late-20th-century maximum seasonal temperature value over most of the continent (IPCC p. 1454). In smaller dryland streams, surface flows are predominantly susceptible to slight changes in climate (Jaeger et al. 2014); such as increased temperatures and evaporation, less snow, less persistent snow pack (Garfin et al. 2014), amount of precipitation, and seasonality of precipitation changes (Gori et al. 2014; Christensen and Lettenmaier 2006). Even modest warming and reduced precipitation impacts the frequency and extent of dry streambeds and reduced hydrologic connectivity (Jaeger et al. 2014). Also the changes in the temperature and precipitation patterns result in smaller peak flows in the spring, earlier snowmelt, base flow and runoff, and lower summer flows (Ashfaq et al. 2013; Gori et al. 2014). The overall reduction of the snowmelt recession period and lower flows extends and intensifies the summer low flow period which inevitably leads to higher water

temperatures, and reduced depth and velocity of available water likely leading to pools interspersed and connected by shallow water habitats (Gori et al. 2014). Given the severity, likelihood, and scope of the projected impacts from climate changes it is likely that population level impacts will occur in the future.

6.7. Synthesis: Headwater and Roundtail Chubs Risk Factors

The stressors with the most significant potential for population level effects to the chubs are water availability (which includes fragmentation, human uses, and climate change components), nonnative species, climate change, fire, and the demographic impacts from these stressors. The synergistic effects from these risk categories decrease the chubs ability to maintain large populations to provide resiliency, redundancy, and representation.

6.8 Conservation Actions

This section focuses on those ongoing conservation actions where on-the-ground benefits to headwater and roundtail chub have been documented as of 2015. .

6.8.1 Mandatory Conservation Programs

There are three mandatory conservation programs benefitting the chubs: the Conservation and Monitoring Program for Sportfish Stocking (CAMP) (implemented by AGFD, the Horseshoe-Bartlett Habitat Conservation Plan (HCP, implemented by Salt River Project[6]) and the Gila River Basin Native Fish Conservation Program (implemented by the U.S. Bureau of Reclamation). The AGFD also has implemented some voluntary projects and those are also considered below.

The primary benefit to chub populations from CAMP is the securing or establishment of six chub populations (three for each species). Securing a population means reducing the stressors affecting an existing population, while establishing a population means introducing chub to a new stream or expanding its range within an existing occupied stream. Establishment of a hatchery broodstock for the streams at risk of loss of wild populations provides for reintroduction to those areas. Removal of nonnatives has been used as a securing action for Fossil Creek for both headwater and roundtail chub. The population establishment actions under consideration are all in very small streams or segments of streams. The long-term success of these populations are uncertain.

[6] In its Roosevelt Lake Habitat Conservation Plan, Salt River Project has one conservation area on lower Aravaipa Creek that is intended to protect stream flow through the native fish reach. As roundtail chub are present in that reach, they also benefit from this action.

Table 6.8-1: Conservation and Monitoring Program for Sport Fish Stocking Projects.[7]

Project Name	Status	Benefit
Headwater Chub Projects		
Fossil Creek nonnative species removal	Complete	Securing: Elimination of nonnative fish species from above constructed fish barrier. If re-invaded, would require re-treatment.
Webber Creek reintroduction	First stocking proposed 2015-2016	Establishment/restoration: Chub in Webber Creek are very rare; augmentation of this population is to increase numbers and restore to recruiting status at least 1.6 km (1 mi) of stream.
Upper Haigler Creek reintroduction	First stocking proposed 2017	Establishment: Chub in Upper Haigler Creek are extirpated, reintroduction is to restore this population to 4.8 km (3 mi) of stream
Stream assessments	Ongoing	Assessment of several fishless streams for suitability to stock chub to establish populations.
Pond assessments	Ongoing	Assessment of existing ponds to hold refuge populations.
Roundtail Chub Projects		
Fossil Creek nonnative species removal	Complete	Securing: Elimination of nonnative fish species from above constructed fish barrier. If re-invaded, would require re-treatment.
Gap Creek introduction	Ongoing	Establishment: Third stocking completed, status monitoring initiation. Has 3.27 km (2 mi) of intermittent perennial stream
Upper Boulder Creek reintroduction	On hold	Establishment: Expand occupied range in Boulder Creek by 3.32 km (2 mi) of intermittent perennial stream. Future stockings on hold waiting for permission of landowner.
Stream assessments	Ongoing	Assessment of several stream reaches for suitability to stock chub
East Clear Creek broodstock development and maintenance	Ongoing	Securing: provide hatchery population to protect against adverse events in the stream and eventually provide progeny for reintroduction into the drainage.
Chevelon Creek broodstock development and maintenance	On hold	Securing: disease losses of captured fish moved to hatchery resulted in cessation of collection efforts; future collections are possible once concerns are addressed to create broodstock.
Cane Springs Ranch Pond	Ongoing	Securing: first stocking of Trout Creek lineage complete. In lieu of establishing a hatchery broodstock, this pond will hold a population for future augmentations into the drainage. Genetic and other management protocols not yet developed.
Meath Wash Pond	Ongoing	Securing/Refuge: Verde River lineage from hatchery stocked. Genetic and other management protocols not

[7] The Service and AGFD are currently discussing how projects such as establishing broodstocks and creation of refuge ponds relate to the goal of meeting the three populations' requirement for each chub. For this table, we include these projects as AGFD has proposed their status.

		yet developed
Stream assessments	Ongoing	Assessment of several fishless streams for suitability to stock chub to establish populations.
Pond assessments	Ongoing	Assessment of existing ponds to hold refuge populations.

The Horseshoe-Bartlett HCP provides funding for support of Bubbling Ponds State Fish Hatchery to raise roundtail chub (and other native fish) for stocking into the Verde River drainage. To date, those stockings have been into reaches of the Verde River and tributaries that have low numbers of roundtail chub (Middle and Lower Verde River, Oak Creek). In addition, stocking into areas where recruitment is limited, to support the larger extant population in the Upper Verde River and Stillman Lake, and the introduction site at Roundtree Canyon. The success of the mainstem and tributary stockings to augment populations is unknown; large populations of nonnative fish are present in these streams which has already significantly inhibited chub recruitment in these streams. The value and purpose of the ponds acting as refuges has not been established beyond being holding sites for excess hatchery production of the Verde River lineage in the hatchery and to foster public support for the species. The Roundtree Canyon reintroduction site is 3 km (1.9 mi) of isolated stream. It was established in 2008 and has been augmented with additional chub three times. No spawning of roundtail chub has been documented to date.

Table 6.8-2: Horseshoe-Bartlett HCP Roundtail Chub Stocking Projects

Project Type	**Species**	**Project Name**	**Status**	**Benefit**
Stocking	Roundtail chub	Stocking into Verde River	Ongoing	Stocking of Verde River lineage progeny from hatchery
			2009	200 into Roundtree Creek[8]
				1,927 into Middle Verde River at Childs
			2010	504 into Middle Verde River at Childs
				1,448 into Stillman Lake in Upper Verde River
			2011	100 into a private pond in the Town of Strawberry
			2012	450 into Roundtree Creek
				851 into Lower Verde River at Childs
				3,808 into Upper Verde River at Perkinsville
				3,808 into Middle Verde River at Beasley Flat
				995 into two ponds at Wickenburg

				Ranch
				1,398 into Oak Creek at Grasshopper Point
			2013	48 into Meath Wash Pond
				169 into Oak Creek at Crescent Moon (larger fish)
				6,441 into Oak Creek at Crescent Moon
				500 into Raymond Ranch Boy Scout Ranch Pond (existing refuge site)
				13,029 into Upper Verde River at Perkinsville

The Gila River Basin Native Fish Conservation Program conservation efforts have provided ancillary and significant direct benefits to existing headwater and roundtail chub streams in Arizona and New Mexico, including reintroduction of roundtail chub into the Blue River, an 82 km (51 mi) long stream historically occupied by that species. Roundtail chub were stocked into the river in 2012 and spawned in 2014. Additional chub were stocked in May 2015 to augment the population. This project has a high potential for success. Future projects may involve chubs more directly but those commitments have not been finalized.

Table 6.8-3. Gila River Basin Native Fish Conservation Program Conservation Actions

Project Type	**Species**	**Stream**	**Status**	**Benefit**
Fish barrier construction	Headwater and roundtail chub	Fossil Creek	Complete	Barrier prevents the upstream movement of nonnative fish into the creek. Renovation to remove nonnative species funded by AGFD.
	Roundtail chub	Aravaipa Creek	Complete	Roundtail chub are part of the native fish assemblage in the creek.
	Roundtail chub	Blue River	Complete	Reintroduction of roundtail chub to an extirpated historical site and replicate Eagle Creek lineage
Broodstock development	Roundtail chub	Eagle Creek	Ongoing	Eagle Creek chubs declining, broodstock to provide refuge and progeny to stock Blue River and possibly augment Eagle Creek
Nonnative fish removal	Roundtail chub	Blue River	Ongoing	Nonnative species removal from reintroduction area to hopefully eliminate them
	Headwater chub	West Fork Gila River	Ongoing	Experimental removal project to assess results of nonnative predator removal to improve chub populations

There is also a 6 Species Conservation Plan, which AGFD is a participant. Under this plan, the AGFD has implemented conservation actions not associated with the above programs that support roundtail chub, particularly the Verde River lineage. The purpose and role of the refuge ponds and their future use is uncertain without a genetic management program to ensure the progeny maintain the current levels of diversity.

Table 6.8-4. Independent AGFD Actions for Roundtail Chub

Project Type	**Project Name**	**Status**	**Benefit**
Broodstock development	Verde River broodstock	Complete	Provides progeny for stocking into occupied reaches of the Verde River to support those populations and to introduce into refuge or introduction areas
Refuge/off site holding	Southwestern Academy Blanchard Ponds	Ongoing	Verde River lineage, first stocked from hatchery in 2008. No genetic or other management plan in place; long term purpose to be holding site for fish and potential use for augmentations.
	Camp Raymond Boy Scout Camp Pond	Ongoing	Verde River lineage, first stocked from hatchery in 2009. No genetic or other management plan in place; long term purpose unclear

6.8.2 Trans-basin diversions to East Verde River

In addition to the conservation programs discussed above, the Arizona Water Settlements Act of 2004 (ASWA 2004) is providing for the return of the trans-basin diversion from East Clear Creek (Little Colorado River drainage) to the East Verde River (Verde River drainage) via a pipeline from CC Cragin Reservoir to the headwaters of the East Verde River above the reach occupied by headwater chubs. In 1965, as part of a water use agreement between Salt River Project and Phelps-Dodge Morenci Inc., water stored in Blue Ridge Reservoir (now CC Cragin Reservoir) was transferred via a pipeline to the East Verde River and released into the stream to flow down to the Verde River. These releases occurred annually from 1965-1990, generally from March to November with the amount of water varying significantly (2,652 to 11,096 acre feet (af) (3,271,193 to 13,686,714 cubic meters[9]) Releases after 1990 were not made annually but resumed in 2011 after repairs to the diversion infrastructure (SRP 2011).

Without the trans-basin diversion, the East Verde River in the reach above Highway 87 experiences very low flows during the late spring to early summer months, the result of naturally occurring low flows and removal of water from the stream by diversions and groundwater pumping that results in the river becoming intermittent through the headwater chub reach (Girmandonk and Young, 1997, p. 42; USFS 2011, pp. 106-108). These trans-basin flows were

[9] The management of the reservoir is to draw it down to minimum pool every year. The amount of water diverted depends upon the amount of water that enters the reservoir during spring runoff that can be diverted before the reservoir spills, and the 15,000 af storage capacity above the minimum pool.

not intended to support the headwater chub population, but did provide a significant benefit during those periods when the water was available.

Under the terms of the Arizona Water Settlements Act, the trans-basin diversions will become active again. Up to 3,500 af (4,317,186 cubic meters) of the annual diversion is earmarked for domestic use by the Town of Payson and other northern Gila County communities. That portion of the diverted flow (which has a maximum rate of 35 cfs) would be shunted into a pipeline for delivery to the new water treatment plant (USFS 2011). The remainder would be released into the East Verde River to flow downstream to the Verde River, passing through the headwater chub reach below Ellison Creek. The amount of this flow will vary over each year based on the amount of water available for release from CC Cragin; in 2014 a total of 3,200 af was released (Salt River Project 2014, p. 1).

Over the period of United States Geological Society gage records, the average total diversion from CC Cragin is approximately 9,500 af per year (11,718,077 cubic meters). With the diversion for Payson and the other communities taking up to 3,500 af (4,317,186 cubic meters)of that, the remaining 6,000 af (7,400,891 cubic meters)would be able to support the flows through the 17 km (10.5 miles) headwater chub reach between Ellison Creek and Highway 87. We recognize that the annual amount of such flows will vary over time and the effects to the native and nonnative fish community in the Ellison to Highway 87 of these supplemental flows is also uncertain. Any additional groundwater pumping for domestic uses for the communities bordering the East Verde River may also affect the net amount of water available in the river due to the diversion, potentially reducing the benefit to chubs.

6.8.3 Instream Flow Rights

The Arizona Department of Water Resources can issue certificates to land owners or managers for instream flow water rights. Since 1981, Arizona Department of Water Resources has issued 13 certificates for instream flows as shown in Table 6-8.1.

Table 6.8-1. Instream Flow Certificate Holders within the Range of Both Chub Species

Certificate Holder	**Stream**	**Acre feet per year**
Bureau of Land Management (Safford District)	Aravaipa Creek	10,860
U.S. Forest Service (Apache-Sitgreaves National Forest)	Chevelon Creek	8250.3
U.S. Forest Service (Coconino National Forest)	West Clear Creek	8,688
	Wet Beaver Creek	3,909.8
U.S. Forest Service (Tonto National Forest)	Fossil Creek	57,074.71
	East Verde River	2,894.3
	East Verde River	2,889.6
U.S. Forest Service (Coconino, Prescott, and Tonto National Forest	Verde River	18,045

s)		
	Verde River	72,167.5
The Nature Conservancy	Aravaipa Creek	14,901.28
	Aravaipa Creek	13,566.47
	Aravaipa Creek	11,212.17
	Aravaipa Creek	10,432.68

Like other surface water rights, instream flow rights have a priority dates that establishes their status where rights with an older priority date are senior rights and newer rights with a more recent priority date are junior rights. The amount of water included in the certificate is protected against being appropriated by any junior water right holder; in practice, this means that new surface water rights cannot impinge on any senior certificated right, which protects the flow in the stream from future uses that would reduce the amount of water available for that senior right.

6.9 Regulatory Measures

Headwater chub are not designated by AGFD as a sportfish in any waterbody with the exception of Fossil Creek. Roundtail chub are a designated sportfish species in Arizona. In New Mexico, catch of headwater and roundtail chub is prohibited, due to their endangered status under the New Mexico Wildlife Conservation Act (Carman, 2006, p. 1).

6.10 Summary

Past conservation efforts include the establishment of new populations and the renovation or securing of currently occupied areas. Newly established populations are sites where chubs have been released within the species historic range. This is involves locating a site with suitable habitat free of nonnatives or removing nonnatives, either naturally or due to the chemical treatment of rotenone. Establishment of a hatchery broodstock for the streams at risk of loss of wild populations provides for newly established populations to those areas. Renovation or securing of a population involves salvaging the chub species from the stream, then the removal of nonnative species, potentially the installation of a barrier to keep nonnatives out of the site, and then the release of salvages chubs back into the stream. Stream renovation is labor and time intensive. The salvage of chubs takes significant resources in terms of time, personnel, and funding. Temporary housing for the salvaged chub is needed while the nonnatives are removed. The eradication of nonnatives from streams is essential for establishing new populations or securing populations. However, removing nonnatives from a stream is difficult and typically requires multiple efforts. Rotenone is the most effective means of eradicating nonnatives from a stream. If there is not a barrier to prevent nonnatives from moving into the renovated area then a barrier will need to be constructed prior to removing the nonnatives. Once the nonnatives are removed and a barrier in place, chubs are released back into the stream. It is likely that not all nonnatives were removed and a roetenone treatment will be necessary at some point in the future. This will require salvaging the chubs again and applying the rotenone, and then releasing the salvage chubs.

The removal of nonnatives has been used as a securing action for Fossil Creek for both headwater and roundtail chub. This effort has been successful, but significant time and resources were expended to secure the site and continue to be needed to maintain this site. Consequently,

there is uncertainty regarding the securing of sites in the future. There are currently four newly established sites for the roundtail chub in the lower Colorado River basin. The four new established populations are: Blue River, Ash Creek, Gap Creek, and Roundtree Creek. Blue River is the only established site with documented reproduction. This site has a high potential for success; however, it is a relatively new site established in 2012. The other three sites have not shown reproduction. Their long-term viability is uncertain. Additional uncertainty is present because in Arizona the future use of Rotenone is uncertain due to the state legislature considering prohibiting its use. Without this tool, management of nonnative species will become more difficult and the success of future conservation efforts more uncertain.

Chapter 7. Current Condition of Headwater and Roundtail Chub

7.1 Methodology

The current conditions of the two chubs can be summarized based on the status, number, and distribution of the current populations. For this assessment, we analyzed chubs by AUs. As described above, AUs can consist of single streams or multiple, interconnected streams (i.e. complex).

7.1.1 Model Assessment

We developed a qualitative model to assess and synthesize our understanding of the current and future condition of chubs (see Appendix C-Status Assessment Model). The model assessed the status of the chubs based on three categories, which we refer to as condition categories: water availability, nonnative species, and chub population structure. Conservation measures were not a condition category in current condition because such actions were incorporated as part of the current condition baseline. We focused our analysis on those factors that were likely to have population impacts. For each of these condition categories we developed metrics to assess the current condition of each AU. We developed qualitative and numerical value ranking criteria for each metric. The assignment of numerical and qualitative ranking values of the different metrics to a stream reflects our best professional judgment of the current condition of the species to provide an explicit way to communicate our understanding. These judgments were based on our understanding of these risk factors as explained in Appendix B and F, and Chapter 6. The qualitative measures are represented by a numerical value to allow a final score to be calculated. We applied the model metrics for each stream within an AU. The numerical ranking values for the various metrics of the three condition categories were combined for each stream. The final numerical ranking for each stream was summed to determine the final numerical ranking score for the AU (see Chapter 7 for the AUs and streams contained in each). We have constructed one model to assess both headwater and roundtail chub. We think the similarities of habitat selection, life history, and current condition categories for the two species are similar enough to allow both species to be assessed using the same metrics.

Although, not incorporated into our model, we also considered risk from wildfire, additional risk from climate change, water loss due to anthropogenic factors (e.g., surface water diversion and groundwater pumping), and demographic impacts from these risks and reduction in range. These are discussed below. We assessed if an AU in were to experience a wildfire, loss of connectivity, decreased water flow due to anthropogenic actions and climate change, and demographic impacts, how would that further affect the condition of the AU. We evaluated impacts from these additional risk to each AU and the species as a whole.

Table 7.1-1. Current Condition Metrics And Ranking Criteria

Condition Category	Metrics
Chub population structure	• Percent presence of chub in survey datasets over time • Abundance of chub in the stream • Presence of multiple size classes (as a surrogate for age classes)
Nonnative species	• Nonnative community level effects to chub
Water availability	• Total wetted length of the stream • Percentage of total wetted length with perennial flows • Number of stream segments (fragments) in the total wetted length

To provide context for the final AU ranking scores we developed ranking categories. Four ranking categories were identified based on the risk of extirpation : 1) minor risk, 0–5 percent; 2) low risk, 6–30 percent; 3) moderate risk, 31–60 percent; and 4) high risk >60 percent. The extirpation risk is the likelihood that an AU will be extirpated based on the level of risk to the AU now or in the near future (next 5 years). For example, an AU with minor risks will have a 0-5% likelihood of being extirpated. For each risk threshold, we qualitatively defined the risk in terms of the condition categories used in the model- nonnatives, water availability, and chub population structure. The percentages associated with the four risk categories is to clearly characterize and communicate our understanding of risk of extirpation, and describe how we are using the terms–minor, low, moderate, and high risk–in this SSA Report to describe the condition of AUs. Tables 7.1.2 and 7.1-3 provide the scoring ranges for each risk category and Table 7.1.3 provides a description of each risk category. Please refer to Appendix C- Status Assessment Model and the Appendix F-Supplemental Information for Assessment Model for specific information describing how the AU ranking categories and their metrics were developed. This analysis reflects our understanding of the best available scientific and commercial data using our professional judgment. We apply the results of our model and the four above components to the concepts of resiliency, redundancy, and representation to describe the viability of the headwater and roundtail chubs.

Table 7.1-2. Ranking Categories to Assess AU Risk of Extirpation.

	AU Scoring Range	
Extirpation Risk	Minimum	Maximum
High	>36	
Moderate	24	36
Low	14	23
Minor	0	13

Table 7.1-3. Extirpation Risk Ranking Categories for AUs.

Category	Nonnative	Water Availability	Chub Abundance
Minor Risk Extirpation 0-5%	The nonnative species community is at level 0 or 1 (model definition of level 1: Not likely to impact at a population level but does have negative effects to chub individuals). Potential expansion of new nonnatives into AU is unlikely.	>10km (6.2 mi) perennial habitat, that is mostly contiguous, and habitat is such that chubs are reproducing/recruiting frequently and maintaining population size	Reproducing/recruiting frequently and maintaining population size
Low Risk Extirpation 6-30%	The nonnative species community is at level 1 or 2 (model definition for level 2: density and demographics are negatively impacted to point that normal stochastic events could have significant influence on the population). Not applicable for every stream within the AU because some streams may contain nonnatives and chubs co-existence for a length of time. Population levels are not necessarily being impacted to the point that persistence and recruitment are not occurring in every stream. Potential expansion of new nonnatives into AU is unlikely.	>10 km perennial habitats with some interrupted perennial sections more vulnerable to stochastic events, localized impacts from stream drying during dry time of year, but overall wetted area sufficient to maintain a population and reproducing/recruiting but less than in the minor risk situation	Population levels are not necessarily being impacted to the point that persistence and recruitment are not occurring in every stream. Overall wetted area sufficient to maintain a population and reproducing/recruiting but less than in the minor risk situation
Moderate Risk Extirpation 31-60%	Nonnative species community is at a level 2 (but some streams could have a level 1). However, may contain streams where nonnatives and chubs co-existed for a length of time, recent survey information is showing an increase in nonnative abundance and/or distribution, and a decline in chub distribution and/or abundance, to the point that a further increase in nonnatives, or stochastic events, put these AU much more at risk for extirpation. Chub recruitment and persistence are negatively affected but chub persist. Potential expansion of new nonnatives possible.	<10km (6.2 mi) perennial habitat, higher interrupted perennial reaches, higher # disconnected pools, much of the watered area consists of disconnected, perennial pools, greater risk of stochastic events	Chub recruitment and persistence are negatively affected but chub persist.
High Risk Extirpation >61%	Nonnative species community is at a level 3 (model defines level 3: a population level effect is present that exerts significant pressure on chub numbers and reproductive success.), though there may be some individual streams within the AU where it is a 2 (or lower). As the % of streams scoring a level 3 within the AU increases, so does the overall risk to the entire AU. Tend to have long perennial streams with high nonnatives which can provide habitat for chub recruitment to prevent extirpation.	<3km (1.9 mi) perennial habitat, stochastic risk is high, or the streams are largely unmanageable from a fisheries community standpoint due to water uses and/or nonnative species composition (example: Salt/Verde confluence AU) that the other factors (generally nonnative community) greatly outweigh the potential benefits of larger/longer habitat reaches.	Chub recruitment to prevent extirpation.

7.1.2 Other Factors

Although, not incorporated into our model, we also considered risk from wildfire, additional risk from climate change, water loss due to anthropogenic factors (e.g., surface water diversion and groundwater pumping), and demographic impacts from these risks and reduction in range. These are discussed below. We assessed if an AU were to experience a wildfire, loss of connectivity, decreased water flow due to anthropogenic actions and climate change, and demographic impacts, how would that further affect the condition of the AU. We evaluated impacts from these additional risk to each AU and the species as a whole.

Wildfire could impact one or more AUs now or in the future. Impacts could range from loss of individuals to loss or significant impacts to entire AUs or multiple AUs. The likelihood of wildfire now or in the future is high; however, the severity, timing, and location of the wildfire is uncertain.

Climate change is projected to reduce the flowing stream length. The model captures this by reducing the stream length by certain percentages. However, there are other impacts from climate change that we considered but were not able to incorporate into the model. This includes the increased lengths of dry reaches within a stream, loss of connectivity within and among streams, changes in the timing and amount of snowmelt and monsoon rains, changes in the frequency and duration of droughts, and the increase in temperatures resulting in increased evaporation. Increased dry reaches can impact chub movement and dispersal. Connectivity within streams is important for chubs to maintain genetic diversity. Alterations in the timing and amount of water in the spring could result in delayed or reduced reproduction and recruitment. Alterations in the timing and amount of monsoon rains could result in a decrease in refugia areas for chubs after the driest time of the year. Impacts from climate change occur throughout the range of the chub and are likely to affect all streams to some degree. In addition, to the reduction in water from climate change we also considered loss from surface water diversions and groundwater pumping. These impacts are likely to impact all AUs to some degree.

7.2 Headwater Chub Current Status

Based on our assessment, headwater chub historically occupied 26 streams with a total stream length of 892 km (554 mi), in eight AUs across three drainage basins. Our estimate of the current range of headwater chub is that they are found in 22 streams with a total watered length of 432 km (268 mi), in eight AUs across the three drainage basins. At least 48 percent of the estimated historical range is occupied and there has been no more than a 52 percent reduction in range. Currently, one AU is in minor risk, three AUs are in the low risk, and four are in the moderate risk categories. Meaning that the one in minor risk has a risk of 0–5 percent risk of extirpation, the three AUs in low risk have a 6–30 percent risk of extirpation, and the four AUs in the moderate risk have a 31–60 percent risk of extirpation.

Four AUs are projected as currently having a minor or low risk of extirpation. We consider the one AU in the minor risk category, Fossil Creek, to be resilient because it contains very few nonnative aquatic species, it has a stream length of over 15 km (9 mi), and chub population

structure is high (meaning chubs are abundant and recruitment is high). All these components increase the AU's ability to withstand a stochastic event such as wildfire and weather, which are the other risks we considered in our assessment. Based on this, resiliency is likely sufficient for this AU and the risk of extirpation is considered to be 0 to 5 percent.

Although less resilient than an AU in the minor risk category, the AUs in the low risk category are also considered sufficiently resilient, because they have low nonnative aquatic species, sufficient stream length, and/or chub population structure is good (chubs are common to abundant and recruitment is moderate to high). These components increase the AU's ability to withstand a stochastic event such as wildfire or weather, which are the other risks we considered in our assessment. However, their ability to withstand a stochastic event is less than an AU in the minor risk and the range of extirpation risk is greater (6-30 percent). The range in risk of extirpation is a factor of the variability in the level of impacts from nonnative aquatic species, water availability, and chub population structure, and the uncertainty in the species response from these risks factors because each AU is different.

Impacts from nonnative aquatic species and water availability, as well as wildfire, climate change, and demographics are affecting AUs in the minor and low risk categories but these AUs are currently maintaining chubs and are therefore likely to withstand a stochastic event. In addition, there are two AUs in the moderate risk category that are close to the low risk category score, indicating that while they are in the moderate category they are at the low end of this category (i.e., closer to low risk). While impacts from climate change are likely currently impacting chub populations at some scale these impacts are not having population level impacts to all AUs at this time. Nonnative aquatic species occur in all but three streams that headwater chub occupy. While chubs co-exists with nonnative aquatic species occurs in several streams this does not mean that nonnative aquatic species are not impacting chubs.

There are eight streams of approximately 5 km (3 mi) or less in length. These streams are theoretically at a higher risk of extirpation from catastrophic events than are longer streams. The extirpation of chubs from these streams could reduce the resiliency of the AU; however, these streams are spread throughout seven AUs. Further, there are two AUs, Wet Bottom Creek and Upper Gunn Creek, of approximately 5 km (3 mi) or less.

Currently, there are eight AUs: three individual AUs containing one stream and five complex AUs containing more than one stream. Six of the eight AUs are located in adjoining drainages: three in the Salt River (upper and lower Tonto Creek complex AUs and Gunn Creek individual AUs) and three in the Verde River (East Verde River complex and Fossil Creek and Wet Bottom Creek individual AUs). The result is a distribution with nine (41%) of the remaining occupied streams in one drainage, Tonto Creek, adjacent to, Verde River, that contain five (23%) of the remaining 11 populations. The result is a distribution with 64 percent of the occupied area within immediate proximity to each other in two adjacent drainage basins, which is a concern for catastrophic events (such as fire). The remaining two complexes, San Carlos River and Three Forks, are in drainage basins separate from the other six and each other, and are not likely to be affected by the same catastrophic natural or anthropogenic event.

Headwater chub populations are naturally fragmented due to the individual hybridization events that created the species. Currently, each AU is geographically isolated from the other AUs even in the same drainage basin. The current range of the species includes AUs that represent the known diversity of ecological settings and genetic materials for the headwater chub. Multiple populations continue to occur across the range of the species to maintain ecological and genetic diversity (i.e., representation) at the present time.

While the majority of streams occupied by chubs have nonnatives, there is little direct evidence of extirpation or significant population reductions of chubs from nonnative species currently; however, there is evidence of extirpation or significant population reductions of other native fish by nonnatives in Arizona and New Mexico. Further, while the mechanism is unknown, currently there are several streams within multiple AUs containing chubs that have maintained populations in the presence of one or more of these nonnative species.

Table 7.2-1. Current Status of Headwater Chub by Analysis Unit (C=complex; I=individual unit)

Watershed	Sub-Watershed	Analysis Unit	Type/Number of streams	Ranking
Gila River	Lower Gila River	San Carlos	C/2	**Moderate Risk**
	Upper Gila River	Three Forks	C/4	**Low Risk**
Salt River	Tonto Creek	Lower Tonto Creek	C/2	**Moderate Risk**
	Tonto Creek	Upper Gunn Creek	I	**Moderate Risk**
	Tonto Creek	Upper Tonto Creek	C/8	**Low Risk**
Verde River	East Fork Verde River	East Fork Verde River	C/5	**Moderate Risk**
	Verde River	Upper Fossil Creek	I	**Minor Risk**
	Verde River	Upper Wet Bottom Creek	I	**Low Risk**

Figure 7.2-1. Current Conditions of Headwater Chub Analysis Units from SSA Model

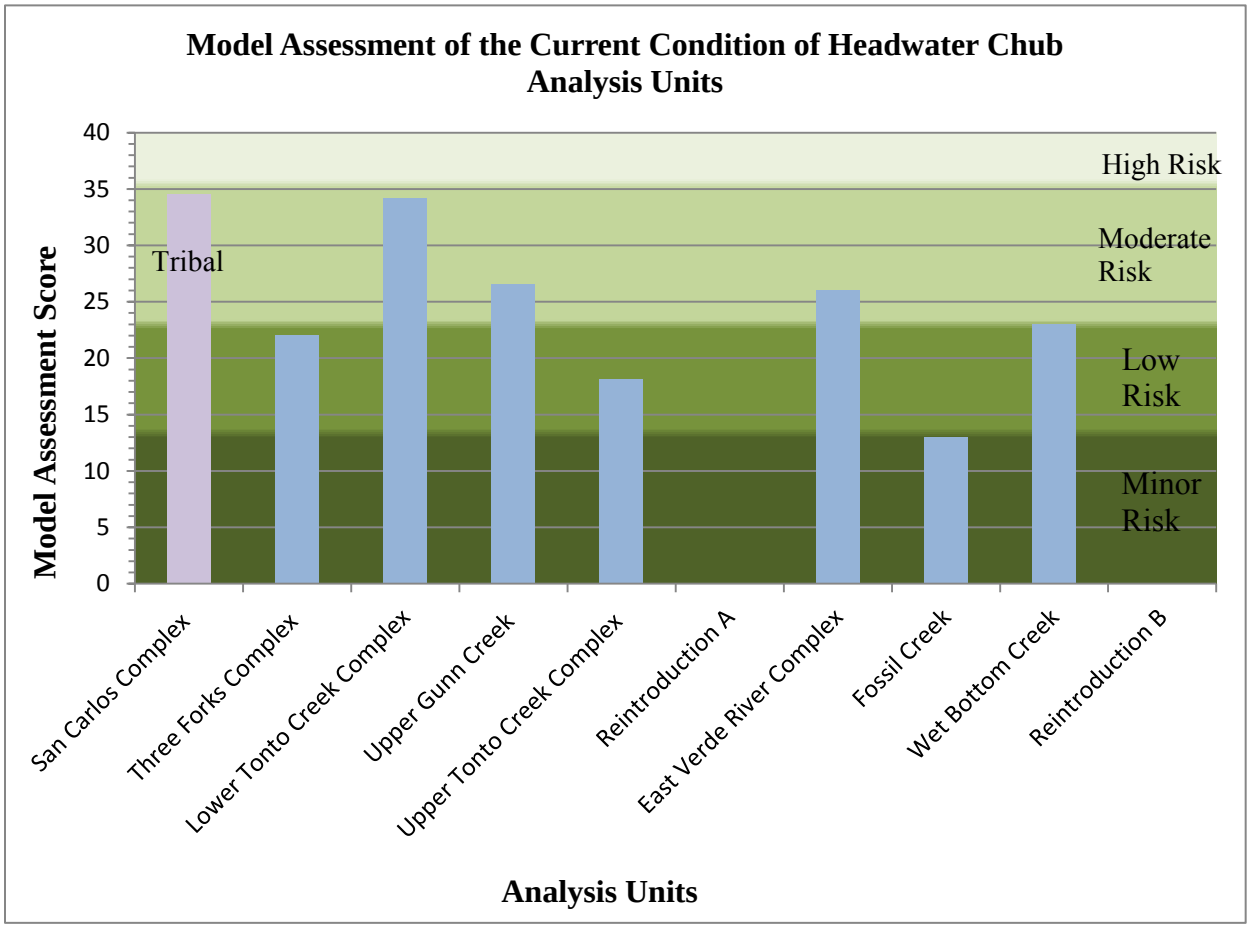


Figure 7.2-2. Distribution of Headwater Chub Analysis (Purple=Verde River Drainage Basin, Blue=Salt River Drainage Basin, and Peach=Gila River Drainage Basin)

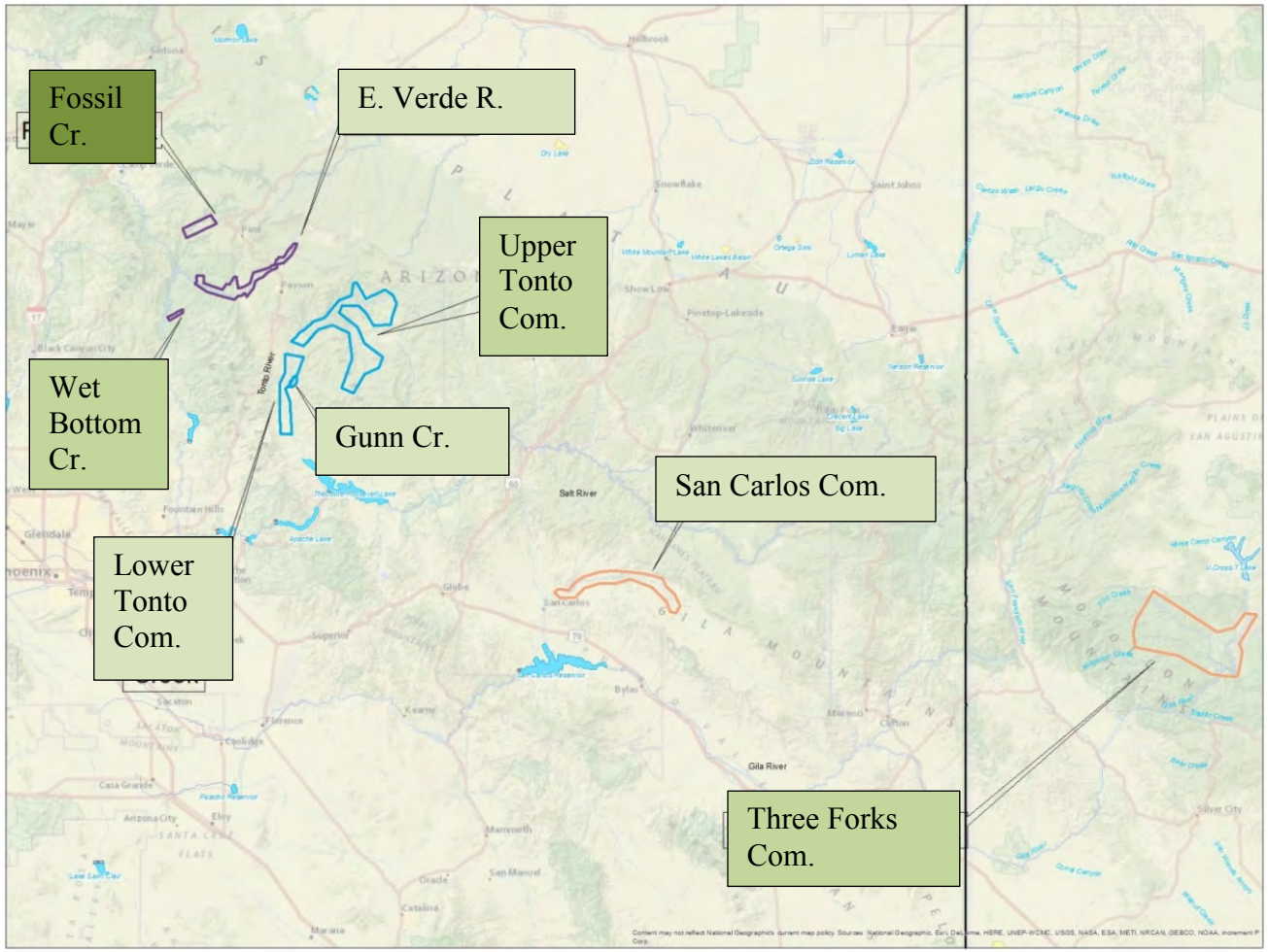


Table 7.2-3. Headwater Chub Analysis Unit Risk Category Ranking- Current Condition

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Gila River	0	1	1	0
Salt River	0	1	2	0
Verde River	1	1	1	0
Total	1	3	4	0

One of the AUs was in Minor Risk: Fossil Creek.

Fossil Creek is a moderate size stream with a steady 43 cfs (1.2 cms)flow that has a constructed fish barrier at the lower end (to prevent predatory nonnatives from moving upstream), limited nonnative species present (crayfish and river otter), and abundant chubs throughout the available reach.

Three AUs ranked as Low Risk: Three Forks, Upper Tonto Creek, and Wet Bottom Creek.

1. The Three Forks is the only AU for headwater chub in New Mexico. The water availability is excellent with perennial flows connecting all four streams in the AU. The nonnatives are abundant throughout (except in newly documented Diamond Creek, which is a very small stream with one survey). Wildfires in 2001-2003 and 2011-2012 (Paroz et al. 2010, p. 7; NMDGF 2013, pp. 15, 17) have adversely affected all fish populations in this AU through the effects of ash flows that cause fatalities and increases in silts that fill in pools and armor the substrates until removed by subsequent high flows (NMDGF 2010, p. 12). Overall, chub numbers are low and nonnatives are abundance contributing to the Low Risk ranking.

2. Upper Tonto Creek has eight connected streams totaling over 89 km (55 mi) with abundant chub populations and a moderate level of nonnatives.

3. Wet Bottom Creek is a small stream with barriers of small height that are blocking upstream movement of additional nonnative species. It has limited nonnatives and chubs are common. Due to the small size of the stream there is less opportunity for internal refuge areas, and the occupied area may be subject to additional seasonal drying during droughts.

Four AUs ranked as Moderate Risk and all were complex AUs: San Carlos River, Lower Tonto Creek, East Fork Verde River, and Upper Gun Creek.

1. San Carlos River is entirely on lands of the San Carlos Apache Tribe and there is very limited information on the status of chub in these two streams. There are only four surveys available to us outside of the initial work in 1874: one for Ash Creek in 1985 wherein chub were documented as present; and three for the San Carlos River (1968,

1983, and 1985) and chub were documented in 1968 and 1983. Because we have no information to indicate otherwise, we assume these streams continue to be occupied. The status of High Risk is due to high numbers of nonnative species, limited water availability, and low chub numbers.

2. The Lower Tonto Creek Complex has two streams; lower Tonto Creek and lower Gunn Creek. Both reaches are below barriers containing higher category chub populations. Lower Tonto Creek has very limited areas of suitable habitat (pools), abundant nonnative species, and recent chub records are only associated with high flow events. Lower Gunn Creek has a limited amount of wetted area and nonnative species are common.
3. East Fork Verde River AU has five streams; four are small tributaries to the main East Fork Verde. Nonnative species are abundant in most of the AU. Chub are common in the upper part of the East Fork Verde River and rare below. Chubs were last documented in Webber Creek (a tributary) in 2000 and may still be present in low numbers. The other three tributary streams (Gorge Canyon, Pine, and Rock creeks) were not documented until after 2002 and contain chub. These tributaries are all located in the middle to lower reaches of East Verde River. Chub records from the East Verde River in these reaches are sparse. These small streams contain robust nonnative species populations along with the chubs. The reasons for the continued co-existence of chubs and the nonnatives in these small streams are not understood.
4. Upper Gunn Creek has low nonnatives and chub are common; however, it has only 4 km of intermittent perennial watered area. Due to the small size of the stream there is less opportunity for internal refuge areas, and the occupied area may be subject to additional seasonal drying during droughts.

7.3 Roundtail Chub DPS Current Status

Based on our assessment, roundtail chub DPS historically occupied 48 streams with a total stream length of 4,914 km (3,053 mi). Currently, there are 15 AUs across 5 drainage basins: Bill Williams River, Gila River, Little Colorado River, Salt River, and Verde River. roundtail chub are found in 35 streams with a collective minimum of 2,098 km (1,303 mi) of available habitat. This represents at least 43 percent of the historical range and no more than a 57 percent reduction in range. The stream lengths range from 7–320 km (4–199 mi) with an average stream length of 50 km (10 mi). Only three streams lack nonnative aquatic species impacting chubs. One stream, Fossil Creek, has undergone renovation (meaning nonnatives have been removed). There are also four newly established sites (see Table 7.3-3 below). The model output of the 15 AUs resulted in 1 AU as minor risk, 7 as low risk, 6 as moderate risk and 1 as high risk. Eight AUs are projected as currently having minor or low risk of extirpation (see Table 7.3-1 below).

We consider AUs within the minor to low risk categories to have sufficient resiliency in the present time because they have low nonnative aquatic species, sufficient stream length, and/or chub population structure is good (chubs are common to abundant and recruitment is moderate to high). These components increase the AUs ability to withstand a stochastic event such as wildfire and weather, which are the other risk factors we considered in our assessment. However, their ability to withstand a stochastic event is less than an AU in the minor risk and the range of extirpation risk is greater (6-30 percent). The range in risk of extirpation is a factor of the variability in the level of impacts from nonnative aquatic species, water availability, and chub

population structure, and the uncertainty in the species response from these risks factors because each AU is different.

Impacts from nonnative aquatic species and water availability, as well as wildfire, climate change, and demographics are affecting AUs in the minor and low risk categories but these AUs are currently maintaining chubs and are therefore likely to withstand a stochastic event. In addition, there are two AUs in the moderate risk category that are close to the low risk category score, indicating that while they are in the moderate category they are at the low end of this category.

While impacts from climate change are likely currently impacting chub populations at some scale these impacts do not appear to be having population level effects at this time. Nonnative aquatic species occur in all but three streams that headwater chub occupy. While chubs co-exists with nonnative aquatic species in several streams this does not mean that nonnative aquatic species are not impacting chubs.

The AUs in the minor and low risk category occur within multiple drainage basins. Further, the current range of the species includes AUs that represent the known diversity of ecological settings and genetic materials for the headwater chub. The current and ongoing threats are not likely to impact all remaining populations significantly now. Impacts from climate change moves slowly and take time to impact a population. The increase or spread of nonnative aquatic species moves faster than climate change or demographics effects but it will likely take a few years for a nonnative aquatic species to expand in a currently occupied stream or become established in a new stream. Wildfire is likely to have immediate impacts but it is unlikely that wildfire will impact all AUs at the current time. As a result, it is unlikely that a single stochastic event (e.g., drought, wildfire) or catastrophic event will affect all known extant populations equally or simultaneously now.

Table 7.3-1. Current Status of Roundtail Chub by Analysis Unit (C=complex; I=individual unit)

Watershed	Sub-Watershed	Analysis Unit	Type/Number of streams	Ranking
Bill Williams River	Boulder Creek	Upper Boulder Creek	C/3	**Low**
	Burro Creek	Burro Creek	C/4	**Low**
	Santa Maria River	Santa Maria River	C/4	**Moderate**
	Trout Creek	Trout Creek	C/3	**Low**
Gila River	Lower Gila River	Aravaipa Creek	I	**Low**
		Eagle Creek	I	**Low**
	Upper Gila River	Upper Gila River	I	**Moderate**
Little Colorado River	Chevelon Creek	Chevelon Creek	I	**Low**
	Clear Creek	Clear Creek	C/2	**Moderate**
Salt River	Upper Salt River	Salome Creek	I	**High**
		Upper Salt River	C/9	**Moderate**
Verde River	Lower Verde	Confluence Salt-Verde	C/2	**Moderate**
	Fossil Creek	Upper Fossil Creek	I	**Low**
	Verde River	Upper West Clear Creek	I	**Minor**
	Verde River	Verde River	C/6	**Moderate**

Figure 7.3-1. Current Conditions of Headwater Chub Analysis Units

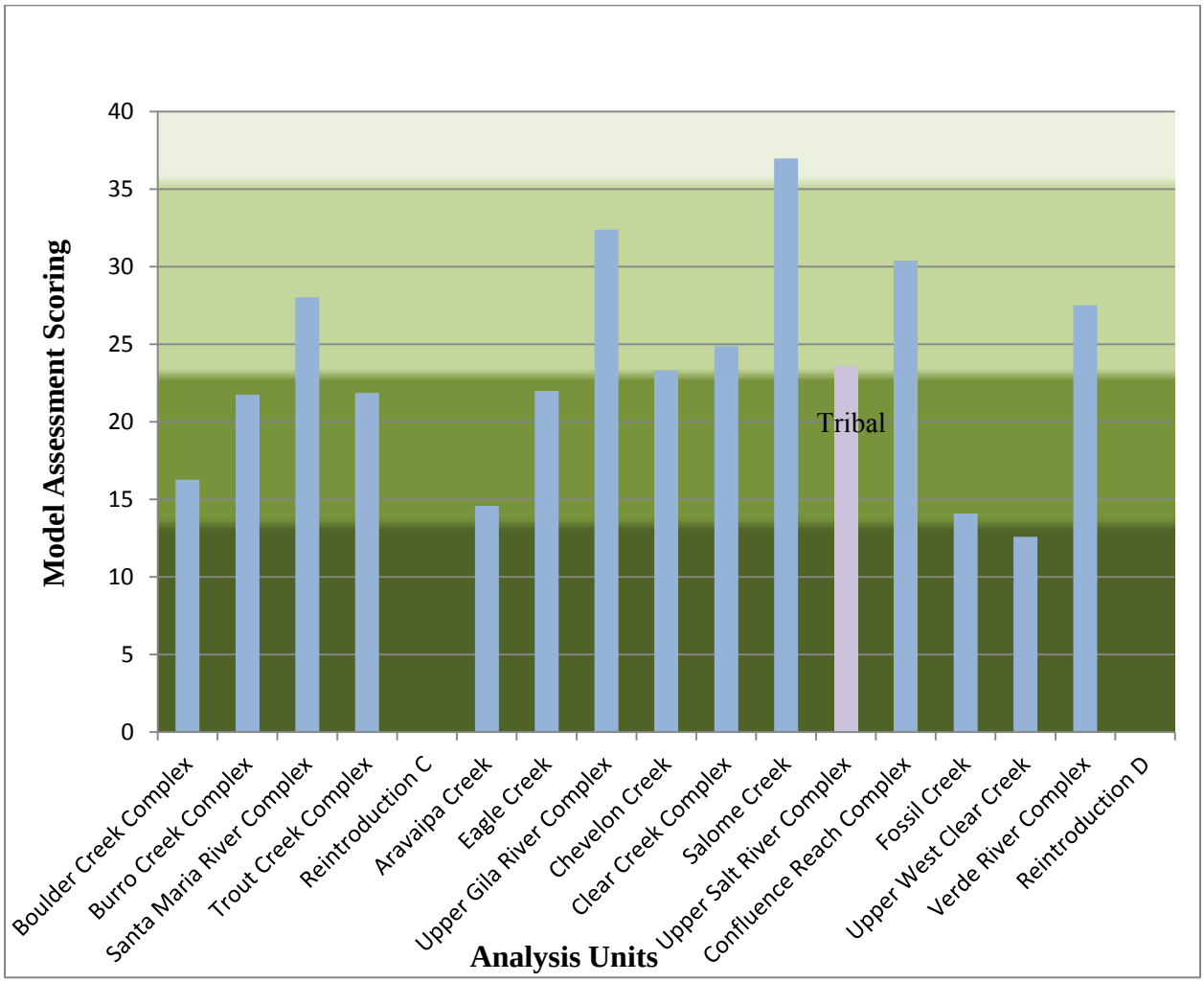
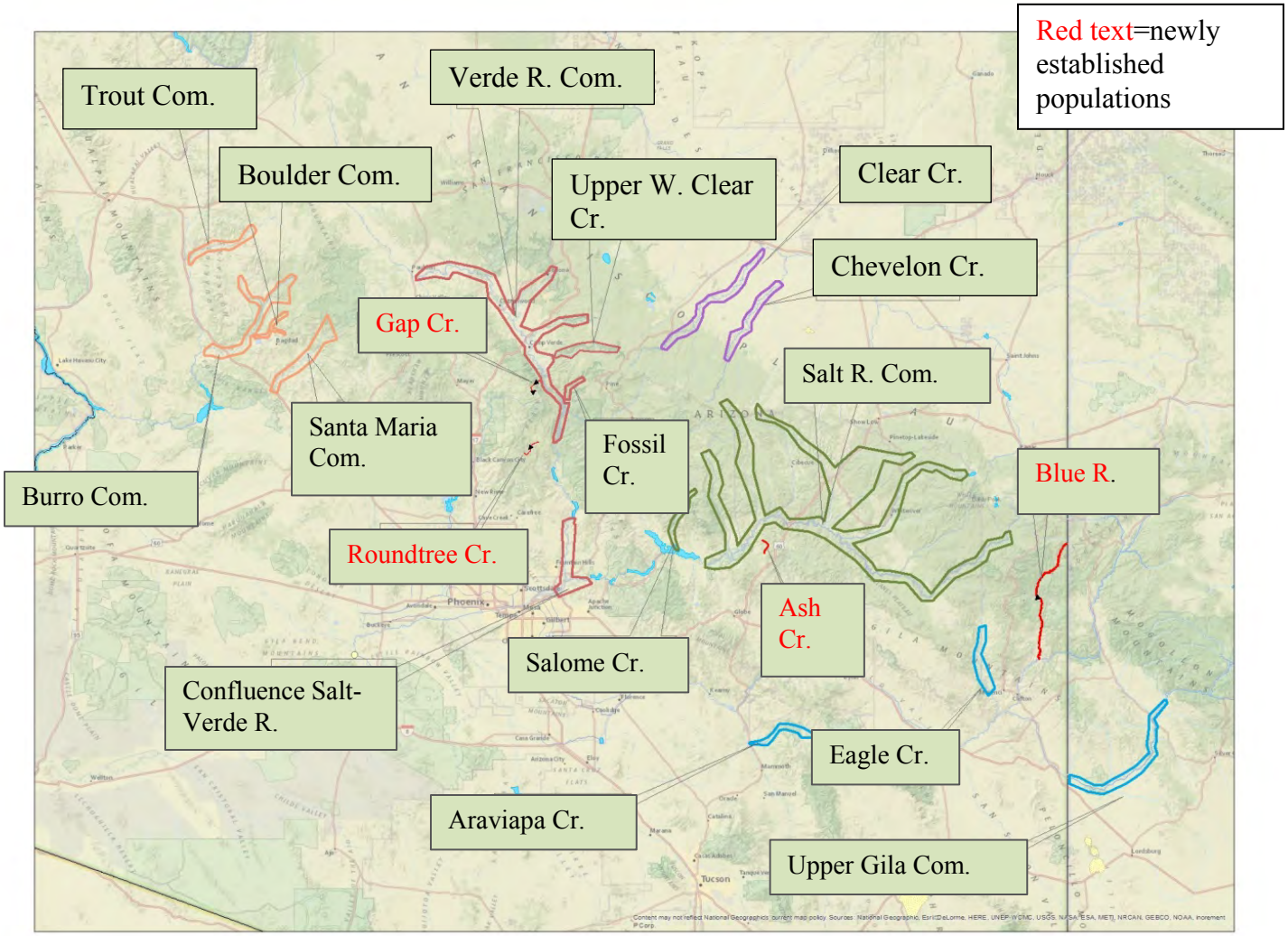


Table 7.3-2. Roundtail Chub Distribution of Analysis Units Throughout All Watershed Units by Ranking Under Current Condition

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Bill Williams	0	3	1	0
Gila River	0	2	1	0
Little Colorado River	0	1	1	0
Salt River	0	0	1	1
Verde River	1	1	2	0
Total	1	7	6	1

Figure 7.3-2. Distribution of Headwater Chub Analysis (Purple=Little Colorado River Drainage Basin, Blue=Gila River Drainage Basin, Peach=Bill Williams River Drainage Basin, Red=Verde River Drainage Basin, and Green=Salt River Drainage Basin)



One AUs ranked as Minor Risk: Upper West Clear Creek.

1. Upper West Clear Creek AU provides some immigration of roundtail chub from upstream of the barrier. Differential survival by size of the immigrants due to nonnative predation is a factor in the ultimate contribution to the mainstem Verde River population. Upper West Clear Creek benefits from low nonnative rankings, abundant chubs, and long stream length.

Seven AUs ranked as Low Risk: Upper Boulder Creek, Burro Creek, Trout Creek, Aravaipa Creek, Eagle Creek, Chevelon Creek, and Fossil Creek.

1. The Boulder Creek AU benefits from low nonnatives, common to abundant chubs, and long stream length.
2. In the Burro Creek AU, chub are abundant in one stream, common in two, and low in one. Conger Creek in the Burro Creek AU has no nonnatives in the occupied reach (they are present below a dry reach were chub are not documented to occur and Francis Creek has an upper reach with no nonnatives and a lower reach with nonnatives).
3. Trout Creek AU has had recent chub declines within Trout Creek itself and an expansion of nonnative species in the drainage. Benefitting the unit's status is the recent documentation of two small tributaries of Trout Creek AU that support larger chub populations than in Trout Creek.
4. Aravaipa Creek AU is a long stream but chub populations are naturally low due to limitations on pool habitat availability.
5. Eagle Creek AU has a moderate amount of nonnatives, low documented abundance of chub, and is a moderate length stream. Eagle Creek AU has had recent declines in population (from unknown causes) that warranted collection of individuals for a captive broodstock and stocking of this lineage into the Blue River for replication.
6. The Chevelon Creek AU has few nonnatives and an abundance of chub; however, that abundance is within a limited (11 km, 6.8 mi) reach of the total watered area available (45 km, 28 mi). In addition, flows through the occupied reach are controlled by three upstream man-made lakes.
7. Fossil Creek AU provides some immigration of roundtail chub from upstream of their barrier; differential survival by size of the immigrants due to nonnative predation is a factor in the ultimate contribution to the mainstem Verde River population. Fossil Creek AU benefits from low nonnatives, common to abundant chubs, and long stream length.

Five AUs ranked Moderate Risk: Santa Maria Complex, Upper Gila River Complex, Clear Creek Complex, Upper Salt River Complex, Confluence Salt-Verde Unit, and Verde River Complex.

1. In the Santa Maria AU, chubs are common in two streams and low in two streams. Streams with low chub numbers are generally those where the nonnative numbers are highest. Cottonwood Canyon and Sycamore Creek have reaches above barriers where there are no nonnatives, and other areas with nonnatives present. This complex demonstrates how the variety of conditions in complex streams work together to affect the chub status. This is in Moderate Risk condition largely due to nonnatives found

throughout the occupied areas and low to common numbers of chubs in most of the occupied area.

2. The Clear Creek AU, ranking reflects the few nonnatives and abundance of chubs in a moderate length stream. The primary occupied length where recruitment is documented is from 10 km (6.2 mi). East Clear Creek flows are also controlled by two upstream manmade lakes.
3. Without the two records in 1991 and 1999, the Upper Gila would likely have been declared extirpated. This AU demonstrates how the variety of conditions in complex streams work together to affect the chub status. This is in Moderate Risk condition largely due to nonnatives found throughout the occupied areas and low-common numbers in most of the occupied area.
4. The Upper Salt River AU includes the mainstem Salt River to Roosevelt Lake, the two streams (Black and White rivers) that combine to form the Salt River, and 6 tributary streams, five of which are on the Fort Apache Indian Reservation of the White Mountain Apache Tribe. All of the White River and portions of the Black and Salt rivers are also on White Mountain Apache Tribe and San Carlos Apache Tribe lands. The availability of information on Tribal streams or segments of streams is limited to that the White Mountain Apache Tribe and San Carlos Apache Tribe will share with us that can be included in the administrative record. The important consideration for the Upper Salt River Complex is that the entire length of the Black and Salt rivers dominates the water availability component of the AU, contains the greatest number and abundance of high-risk nonnative species, and has very low chub populations with limited recruitment likely occurring. The White Mountain Apache Tribe considers roundtail chub in Cedar Creek to be extirpated, and Canyon Creek has no recent surveys and its value is unknown. Off the Tribal lands, Cherry Creek is stressed by a nonnative population and there are low numbers of chub present.
5. In the Salt-Verde Confluence AU, when spring high flows enable recruitment, the Verde River arm can successfully restore moderate to large numbers of roundtail chub to the unit; however, without such flows, the population in the unit declines as fish die of old age. The small amount of recruitment in non-flood years keeps this unit from being extirpated.
6. Within the mainstem of the Verde River (headwaters to Horseshoe Reservoir), the Upper Verde (headwaters to Tapco Diversion Dam) has the most consistent ability to spawn and recruit roundtail chub; however, success is still driven by spring high flows that also displace nonnative species. Over the last several years, there were no high spring flows and hatchery born roundtail chub were being stocked in the Upper Verde under a conservation program. In the middle and lower reaches of the Verde River near and below Beasley Flats to Childs is the other documented spawning site. This area is also being augmented with hatchery born roundtail chub under a conservation program. Overall, the nonnative conditions in the streams in the Verde River Complex are the drivers of roundtail chub status in the unit. Perennially watered reaches are not lacking in this unit, as at most there is limited seasonal drying due to diversion of surface and groundwater for summer irrigation and other human uses. These reduced flow reaches are not significant impediments to overall movement within the AU even in the summer. Based on survey data on their populations and size classes present, the other two primary tributaries, Beaver (including Wet Beaver) and Oak Creeks do not provide any measure

of recruitment to the overall Verde River population. This complex demonstrate how the variety of conditions in complex of streams work together to affect the chub status. This are in Moderate Risk condition largely due to nonnatives found throughout the occupied areas and low-common numbers in most of the occupied area

One AU ranked High Risk: Salome Creek

1. Salome Creek AU is a small stream with few nonnative species documented, but green sunfish are very abundant throughout the system and the documented location of the chub population is very small. Intensive surveys within the documented occupied area would assist in understanding the status of this unit.

We also analyzed the four established AUs using the same model (see Table 7.3-3. Blue River is the only established site with documented reproduction. The other three sites have not showed reproduction. These sites are free of nonnatives. These are relatively new sites and their success is unclear.

Table 7.3-3 Current Condition Ranking of New Populations of Roundtail Chub

Drainage Basin	**Analysis Unit**	**Qualitative Ranking**
Gila River	Blue River Unit	Low Risk
Salt River	Ash Creek Unit	Low Risk
Verde River	Gap Creek Unit	Low Risk
Verde River	Roundtree Canyon Unit	Low Risk

Chapter 8. Future Condition and Viability

We have considered what the headwater and roundtail chubs needs for viability and the current condition of those needs (Chapters 5 and 7), and we reviewed the risk categories that are driving the historical, current, and future conditions of the species (Chapter 6, Appendices B and F). We now consider what the species' future conditions are likely to be. We analyzed the future conditions based on a model that allowed us to qualitatively forecast the future status of the species under four different possible future scenarios based on our understanding of the risks faced by the headwater and roundtail chubs. In addition, we considered risk from wildfire, additional risk from climate change, the reduction in range, and demographic impacts from these factors. We focused our analysis on those factors that were likely to have population impacts. This analysis reflects our understanding of the best available scientific and commercial data using our professional judgment. We apply the results or our analysis to the concepts of resiliency, redundancy, and representation to describe the viability of the headwater and roundtail chubs.

> **Note:** This chapter contains **summaries** of the analysis of viability. For further information, see **Appendix C,** which contains detailed information about how we modeled the future conditions of the species.

8.1 Forecasting Future Conditions

8.1.1 Status Assessment Model

8.1.1.1 Introduction

We analyzed the future risk of extirpation in 2046 using the same model we used to assess current condition. However, for the future condition we added a metric to assess conservation measures. We used the current condition of nonnative aquatic species, water availability, and chub population structure as the baseline to analyze projected future impacts. As stated in the current condition, we modeled water availability using stream length as a surrogate for available habitat. To model projected future impacts from climate change we applied a reduction in length to the baseline stream length (i.e., water availability) to all streams. Under the analysis of the current condition, the nonnative aquatic species were evaluated in terms of the impacts from the community of nonnatives aquatic species present in a stream. To project future impacts from nonnative aquatic species we applied an increase in the magnitude of impacts from the community of nonnative aquatic species present to a percentage of streams. We did not project future impacts to chub population structure because the model output of the current condition is the baseline for the condition of chubs. To measure conservation efforts we projected the future establishment of new populations and the renovation of streams. We continue to use the same model for both species, as we did in our analysis of current condition.

The model analyzed the future condition of each AU under four different scenarios based on three condition categories using the model output of the current condition as the baseline. Below we describe our analysis using the model and incorporate the consideration of risk from wildfire, additional risk from climate change, the reduction in range, and demographic impacts from these factors, which were not captured in the model. This assessment provides our understanding of

the future condition of the species. The details of the model are described in Appendix C-Status Assessment Model.

8.1.1.2 Condition Categories and Scenario Development

Nonnative species occur in all but six streams (three for each species) currently occupied by chubs. We expect that nonnatives will continue to persist in most if not all of the streams they currently occupy. However, the level of impact from nonnatives and the number streams likely to be impacted is uncertain. There is little direct evidence of extirpation of chubs due to nonnative species; however, in Fossil Creek, nonnative predators were removed and chub numbers increased 70 times over the pre-removal numbers due to the success of spawning and survival of young-of-the-year chubs (Marks et al. 2009, pp. 15, 21). Further, there are streams where chubs have maintained populations in the presence of one or more of these nonnative species; however, the mechanisms providing for that co-existence in any particular stream is unknown. The management of nonnatives is an important tool in the conservation of these species. The most effective method to control nonnatives is Rotenone. However, in Arizona the future use of Rotenone is uncertain due to the state legislature possibly prohibiting its use. Without this tool, management of nonnative species will become more difficult.

Currently, reduction in water is impacting all occupied chub streams at different levels. Model predictions show that climate change will shrink the length of the remaining flowing reaches (Jaeger et al. 2014, p. 3). During the spring and early monsoon seasons, the flowing regions are projected to diminish between 8% and 20%. The regions that support flow are increasingly isolated as adjacent dry fragments expand in length and occur more frequently across these seasons. Impacts from climate change throughout the range of these species is highly likely; however, we are less certain about the specific, localized impacts from climate change and the species response.

Currently, for roundtail chub, there are four newly established populations and one stream renovation. Of the four new populations only one has documented reproduction. Blue River is the only site that has documented reproduction. The reason for this is unclear but could be that Blue River is a much larger site, with a watered length of about 81 km (50 mi), where the other three sites are very small, with a watered length of about 5 km (3 mi). The renovation site, Fossil Creek, has demonstrated success. However, the time and resources expended for such an effort is demanding. Further, this site has required continuing maintenance. Within the next 30 years it is feasible that an additional currently occupied stream will be successfully renovated.

Given our uncertainty regarding if or when streams or AUs occupied by chubs will experience an increase in nonnatives, a reduction in water in the future, or conservation actions, we have qualitatively forecasted the future condition under four different possible future scenarios based on our understanding of the risks to these species. The four future scenarios incorporate increased risk to AUs from nonnative species and water availability in the year 2046, about 30 years from the present. The future scenarios incorporate an increase in impacts from nonnatives, a reduction in stream length, and new populations and renovation sites.

To measure impacts from nonnatives in the future scenarios we evaluated an increase in the level of impact from the nonnative community across a porion of streams because it is unlikely that all streams will suffer from increased impacts from nonnative species we applied the increase to only a portion. It is more realistic that a portion of streams will suffer from impacts. There are two factors to consider in projecting future impacts from nonnatives, the number (or percentage) of streams where nonnatives could expand or that could be invaded by nonnative species not currently present, and how much of a change in the nonnative community risk factor could result from the expansion or invasion. Using the best professional judgment of species experts, a percentage of streams potentially impacted from nonnatives were estimated. This estimation was based on our understanding of minor, moderate, and high impact levels from nonnatives across the range of each species. A minor scale of impact from nonnatives was estimated to consist of 13% of the streams occupied by a chub species, moderate impacts was estimated at about 45%, and high impacts was estimated at 70%. For headwater chub, 13% and 45% of the streams is 3 and 9 streams respectively, and for roundtail chb it is 4 and 14 streams, respectively. We did not analyze the high impact from nonnatives (the 70% of streams) because we did not think this was a realistic scenario.

After removing those streams that already had a high level of impact from aquatic nonnatives, we randomly selected the streams where the increase in aquatic nonnative impact would be applied. Tables 8.1.1.2-1 and 8.1.1.2-2 list the 13% and 45% of streams, respectively, occupied by headwater chub that were randomly selected to demonstrate projected nonnative impacts under future scenarios. Tables 8.1.1.2-3 and 8.1.1.2-4 list those 13% and 45% of streams, respectively, occupied by roundtail chub that were randomly selected to demonstrate projected nonnative impacts under future scenarios. It is important to recognize that these streams are only selected for demonstration purposes only and that in reality; it is not known whether these specific streams will realize such impacts from nonnative species. The objective of randomly selecting streams is to demonstrate how streams with similar characteristics (i.e. stream length, nonnative impacts, and chub abundance) are projected to respond to increased impacts from nonnative species.

Table 8.1.1.2-1. List of Headwater Chub Streams Randomly Selected to Represent the 13% of Streams to Project Future Nonnative Species Impacts.

Major Drainage	**Drainage Basin**	**Analysis Unit**	**Streams Included**
Salt River	Salt River	Upper Tonto Creek Complex	Spring Creek
Salt River	Salt River	Lower Tonto Creek Network	Gunn Creek-below barrier
Verde River	Verde River	Fossil Creek	Fossil Creek-above barrier

Table 8.1.1.2-2. List of Headwater Chub Streams Randomly Selected to Represent the 45% of Streams to Project Future Nonnative Species Impacts.

Major Drainage	Drainage Basin	Analysis Unit	Streams Included
Salt River	Salt River	Upper Tonto Creek Complex	Spring Creek
Salt River	Salt River	Lower Tonto Creek Network	Gunn Creek-below barrier
Verde River	Verde River	Fossil Creek	Fossil Creek-above barrier
Salt River	Salt River	Upper Gunn Creek	Gun Creek (above barrier)
Verde River	Verde River	East Verde River Complex	Gorge Canyon
Verde River	Verde River	East Verde River Complex	East Verde - lower
Verde River	Verde River	East Verde River Complex	Webber Creek
Salt River	Salt River	Upper Tonto Creek Complex	Buzzard Roost
Gila River	Upper Gila River	Three Forks Complex	West Fork Gila River

Table 8.1.1.2-3. List of Roundtail Chub Streams Randomly Selected to Represent the 13% of Streams to Project Future Nonnative Species Impacts.

Drainage Basin	Analysis Unit	Streams Included
Salt River	Upper Salt River Complex	Corduroy Creek
Salt River	Upper Salt River Complex	Black River
Verde River	Verde River Complex	Fossil Creek -below barrier
Little Colorado River	Chevelon Creek	Chevelon Creek

Table 8.1.1.2-4. List of Roundtail Chub Streams Randomly Selected to Represent the 45% of Streams to Project Future Nonnative Species Impacts.

Drainage Basin	Analysis Unit	Streams Included
Salt River	Upper Salt River Complex	Corduroy Creek
Salt River	Upper Salt River Complex	Black River
Verde River	Verde River Complex	Fossil Creek -below barrier
Little Colorado River	Chevelon Creek	Chevelon Creek
Bill Williams	Santa Maria River Complex	Cottonwood Canyon
Bill Williams	Burro Creek Complex	Boulder Creek-below barrier
Verde River	Verde River Complex	Upper Verde
Bill Williams	Santa Maria River Complex	Kirkland Creek
Salt River	Upper Salt River Complex	Carrizo Creek
Bill Williams	Burro Creek Complex	Conger Creek
Bill Williams	Trout Creek Complex	Cow Creek
Bill Williams	Boulder Creek Complex	Boulder Creek-above barrier
Verde River	Upper West Clear Creek	West Clear Creek-above barrier

Bill Williams	Trout Creek Complex	Trout Creek

To measure impacts from the reduction in water availability in the future scenarios we evaluated an increase in the level of impact across all streams because impacts from climate change occur at a landscape scale. However, the future scenarios incorporate various levels of climate change severity to account for the uncertainty in future climate change projections. Impacts from water availability in the future are based on progressively deceasing linear length of watered habitat. The quantitative decrease is based on Jaeger et al. (2014). During the spring and early monsoon seasons, flowing regions are projected to diminish between 8%, and 20% during the 1988–2006 and 2046-2064 time periods, respectively. The average annual projected decrease in flowing regions is 4%. Consequently, the future scenarios incorporate climate change reductions of 4, 8, and 20%.

We identified two levels of conservation: a high management option and a low management option. The high management option projects that there will be two streams that are renovated or secured (eliminating nonnatives), and two new projected populations will be established per species. The low management option only projects the establishment of one new population per species and no renovations. We assumed each newly established population would have high chub abundance and high recruitment. The two renovation streams were randomly selected for each chub species. However, we first eliminated occupied streams where barriers or other securing actions were not feasible or were already secure from the list of potential sites. Tables 8.1.1.2-5 and 8.1.1.2-6 below list the randomly selected streams for renovation.

Table 8.1.1.2-5. List of Headwater Chub Streams Randomly Selected to Represent Conservation Streams to Project Future Conservation Actions.

Major Drainage	**Drainage Basin**	**Analysis Unit**	**Streams Included**
Gila River	Upper Gila River (NM)	Three Forks Complex	West Fork
Verde River	Verde River	East Verde River Complex	East Verde River lower-

Table 8.1.1-6. List of Roundtail Chub DPS Streams Randomly Selected to Represent Conservation Streams to Project Future Conservation Actions.

Drainage Basin	**Analysis Unit**	**Streams Included**
Salt River	Upper Salt River Network	Cherry Creek
Verde River	Verde River Network	Wet Beaver Creek

For the two new populations for each chub, we did not select real streams but identified a set of conditions to represent a proxy stream similar to what would be considered in selecting a real site for a new population. We randomly selected the drainage basins of the new population sites. For the purposes of the model, we assumed all of these efforts would be successful.

- For headwater chub, the proxy would be 5 km (3 mi) long, entirely perennial with only one segment, no nonnatives, 100% positive survey, abundant population of chubs, and three size classes present.

- For roundtail chub, the proxy would be 10 km (6.2 mi) long, entirely perennial with only one segment, no nonnatives, 100% positive survey, abundant population of chubs, and three size classes present.

Using the information described above we identified four future scenarios to forecast the future condition of each species in the year 2046, about 30 years from the present. This timeframe was used by Jaeger et al. (2014) in their analysis of climate change impacts on the flows in the Verde River. We selected Jaeger et al. (2014) because it analyzed the potential effects of climate change on a watershed important to both species. The four future scenarios attempt to capture scenarios that project a relatively positive outlook and a relatively negative outlook for chubs, and two intermittent scenarios. These scenarios are summarized in Table 8.1.1.2-7.

Table 8.1.1-7. Future Scenario Descriptions

Scenario	**Nonnative**		**Water Availability**	**Conservation**
	% of streams impacted by nonnatives	**Nonnative Community level increase**	**Decrease in stream length**	**Reintroduction, renovation, securing**
Scenario 1-Low NN impact to a few streams, low water loss, high mngt.	13%	1	-4%	High Management
Scenario 2-Moderate NN impact to a few streams, moderate water lass, high mngt	13%	2	-8%	High Management
Scenario 3-Moderate NN impact to a few streams, moderate water lass, low mngt.	13%	2	-8%	Low Management
Scenario 4-High NN to a high # of streams, high water loss, low mngt	45%	1	-20%	Low Management

To provide context for the final AU ranking scores we developed ranking categories. Section 7.1 in the Current Condition section and Tables 7.1-1 and 7.1-3 describe the categories.

For a detailed description of the methodology used in this analysis, as well as a discussion of the strengths and limitations of this analysis, please refer to Appendix B, Status Assessment Model and in Appendix E Supplemental Information for Assessment Model.

8.1.2 Other Factors

As with our analysis of current condition, we also assessed risk from wildfire, additional risk from climate change, water loss due to anthropogenic factors (e.g., surface water diversion and groundwater pumping), and demographic impacts from these risks factors and the reduction in range, in addition to the factors analyzed in the model. We evaluated impacts from these additional risks to each AU and the species as a whole.

It is highly likely that wildfire will occur within the range of either of these species. However, the severity of the fire and the impacts to chubs is uncertain. Effects to chubs from wildfire vary depending on the fire and streams. The severity and timing of the fire influence the impact on fire to chubs depending on the amount of runoff, and degree of sediment and ash in the runoff. In addition, the size and condition of the stream also influences the impact to chubs from fire. There are streams where chubs (and other fish species) survived the post-fire ash/sediment flows following wildfire. Then there are streams where pools filled with sediment post-fire and have not recovered. Currently, there is landscape scale forest management being implemented across the range of the chubs to reduce forest fuels; therefore, reducing wildfire risk and severity. It is likely that these efforts will continue into the future; however, the scale and location of such efforts are uncertain. The effects from climate change, such as increased temperatures, increased evaporation, and change in timing and amount of precipitation is likely to create conditions more favorable to wildfire. Wildfire could impact any stream within the range of both species. Severe or extensive wildfires that occur in smaller AUs and independent AUs are more likely to have an impact on these species as a whole. However, we are unable to predict when or where such fires could occur, nor the impacts to chubs from these fires, but we recognize that fires are highly likely.

The model analyzes the reduction in stream length on both species but it does not capture other impacts from climate change or human water use. Climate models project an increase in the severity and duration of droughts, an increase in temperature resulting in increased evaporation, changes in the timing and duration of snowmelt, and changes in the timing and amount of monsoon rains, as well as the reduction in flowing regions of streams. Model predictions suggest that midcentury and late century climate will reduce network-wide hydrological connectivity. As the human population increases the demand for water increases. This reduction in water affects the timing, amount, and distribution of water within streams. Climate change is a landscape level impact and is highly likely to impacts all streams within the chubs range. However, the severity of the impact is likely to vary across the chubs range. Impacts to streams from human actions will likely be more localized and will vary throughout the range of the chubs depending on the level of urbanization and type of land use. Currently, reduction in water is impacted by both climate change and human actions. It is highly likely that climate change and increased human population levels occur. However, we are less certain about the specific localized impacts from climate change and human water consumption, and the species response.

Climate change is likely to exacerbate impacts from nonnatives, water quality, and connectivity. It is likely that the increase in the frequency and severity of droughts, the reduction in flowing regions within a network of streams, and an increase in the length of dry patches within a stream, as a result of climate change, will exacerbate the impacts from nonnatives. As the available watered segments decrease the interactions between nonnatives and chubs increase, with more larvae and young-of-the-year removed from the chub populations due to predation by

nonnatives. In addition, resources become more limited and the competition for these resources increases. The reduction in water will likely decrease the water quality (e.g., decreased dissolved oxygen, temperature increases, pH, and nutrient loading) which nonnatives are likely more capable of adapting to than chubs. In addition, there is the potential that the six streams (three for headwater chub and three for the roundtail chub DPS) that currently do not have nonnatives could become occupied by nonnatives.

Also not captured in the model is the loss of connectivity within and among streams due to reduced water. Historically roundtail chub had greater connectivity and subsequent relatedness over the region and development of populations in isolation from other roundtail chub was not the normal condition across most of the historical range except in the Bill Williams River and Little Colorado River drainages. In the roundtail chub DPS, genetic variation occurs mainly within populations. For roundtail chub, demographic effects could result not only if AUs are fragmented but if connectivity among AUs is fragmented. In headwater chub, most of their genetic variation occurs among populations, each of which tends to be distinctive. Each AU is geographically isolated from the other AUs even in the same drainage basin. For headwater chub, demographic effects could result if AUs become fragmented due the unique genetic variation within each AU. As the demand for water due to humans and the effects of climate change increase, water is likely to become more limited. This loss of water affects the water flow in a stream and the number and length of watered and dry stream segments (i.e., increased fragmentation of a stream). As fragmentation increases so does the risk of demographic impacts.

8.2 Results: Projected Future Condition

This section provides an overview of the modeled risk of extirpation for each AU of each species. Refer to Appendix C for additional details.

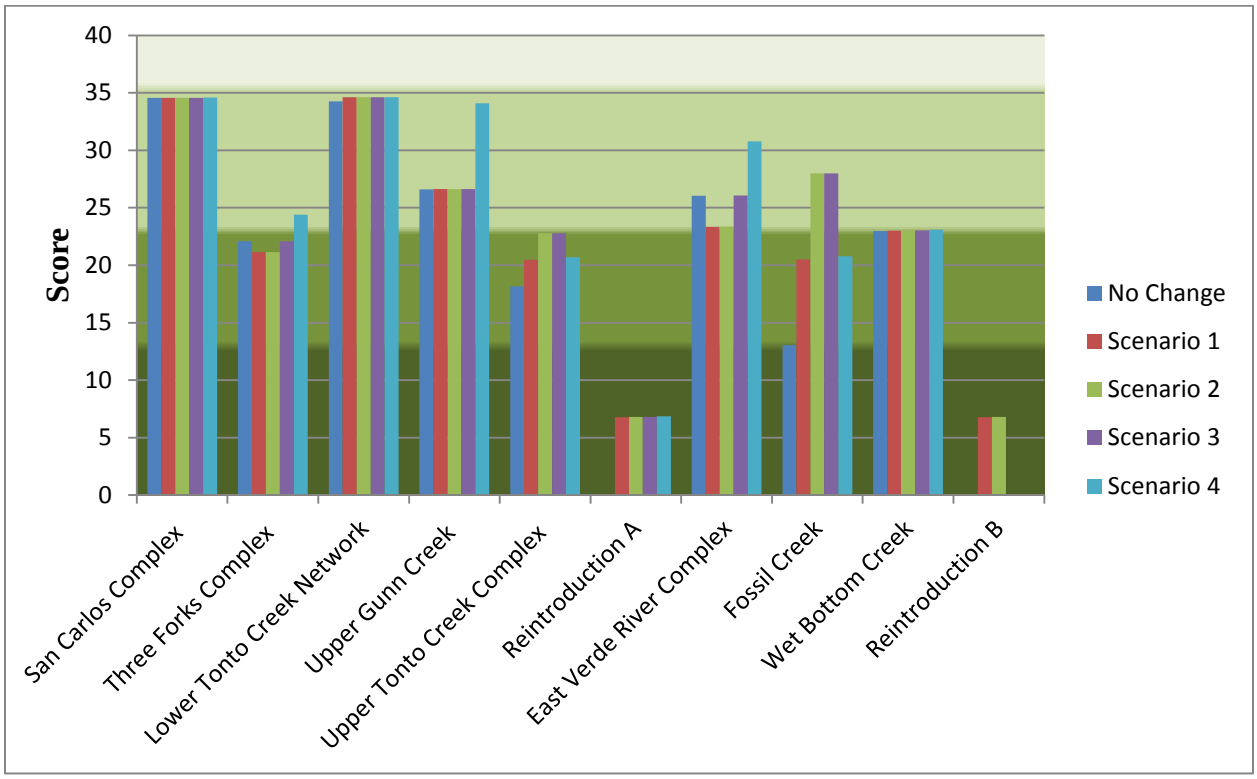
8.2.1. Headwater Chub Projected Future Condition

Table 8.2.1-1 below shows the projected future condition of headwater chub AUs under the four scenarios described above based on the results from the model assessment.

Table 8.2.1-1. Projected Future Condition of Headwater Chub

Analysis Unit Name	Current Condition	Scenario 1	Scenario 2	Scenario 3	Scenario 4
San Carlos Complex	Moderate	Moderate	Moderate	Moderate	Moderate
Three Forks Complex	Low	Low	Low	Low	Moderate
Lower Tonto Creek Network	Moderate	Moderate	Moderate	Moderate	Moderate
Upper Gunn Creek	Moderate	Moderate	Moderate	Moderate	Moderate
Upper Tonto Creek Complex	Low	Low	Low	Low	Low
Reintroduction A	N/A	Minor	Minor	Minor	Minor
East Verde River Complex	Moderate	Low	Low	Moderate	Moderate
Fossil Creek	Minor	Low	Moderate	Moderate	Low
Wet Bottom Creek	Low	Low	Low	Low	Low
Reintroduction B	N/A	Minor	Minor	NA	NA

Figure 8.2.1-1. Headwater Chub Analysis Unit Scoring Under the Four Scenarios



The Three Forks Complex did not contain any streams that were randomly selected to incur increases in nonnative impacts and contained a stream that was selected as a conservation stream for the high management option, so in Scenario 1 and 2 (which both have high management) there is a decrease in the risk of extirpation of that AU. However, in Scenario 4 a stream was selected to incur an increase in nonnative impacts but no streams were selected to incur conservation actions, Therefore, the risk of extirpation increases in Scenario 4. In the Upper Tonto Creek Complex a stream was also selected as a conservation stream, in addition, there were streams where an increase in nonnative species impacts were projected. The risk of extirpation decreases in Scenario 4 because while there are more streams (45%) that incur impacts from nonnatives, these impacts are less (1 level community increase) than in Scenarios 2 and 3 (2 level community increase). This same situation is reflected in Fossil Creek.

Scenario 1 forecasted a low increase (an increase of 1 ranking level) in the impacts from the community level of nonnative in 13 percent of the streams, a decrease in the stream length of 4 percent to all streams, and high conservation management. High conservation management consists of two newly established populations and two renovated streams.

Table 8.2.1-2. Distribution of Headwater Chub Analysis Units within Drainage Basins under Scenario 1.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Gila River	0	1	1	0
Salt River	1	1	2	0
Verde River	1	3	0	0
Total	2	5	3	0

Figure 8.2.1-2. Headwater Chub Analysis Unit Scoring Under Scenario 1.

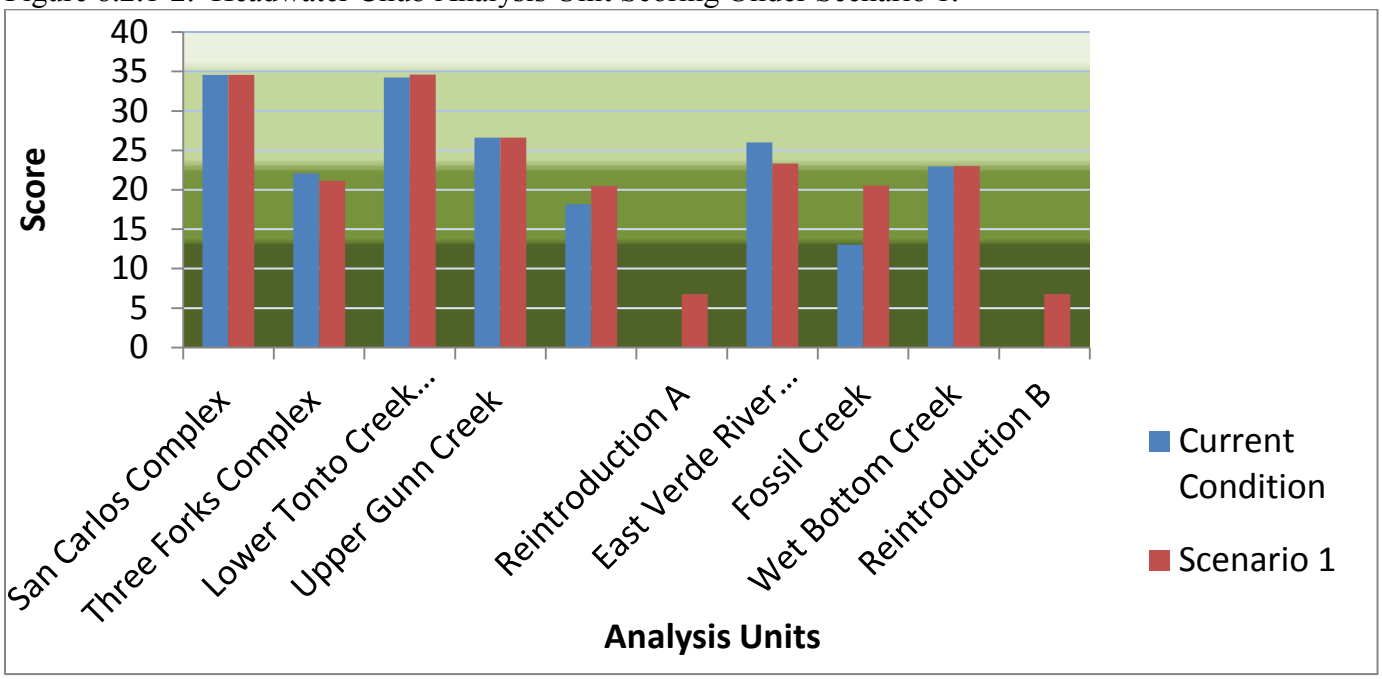
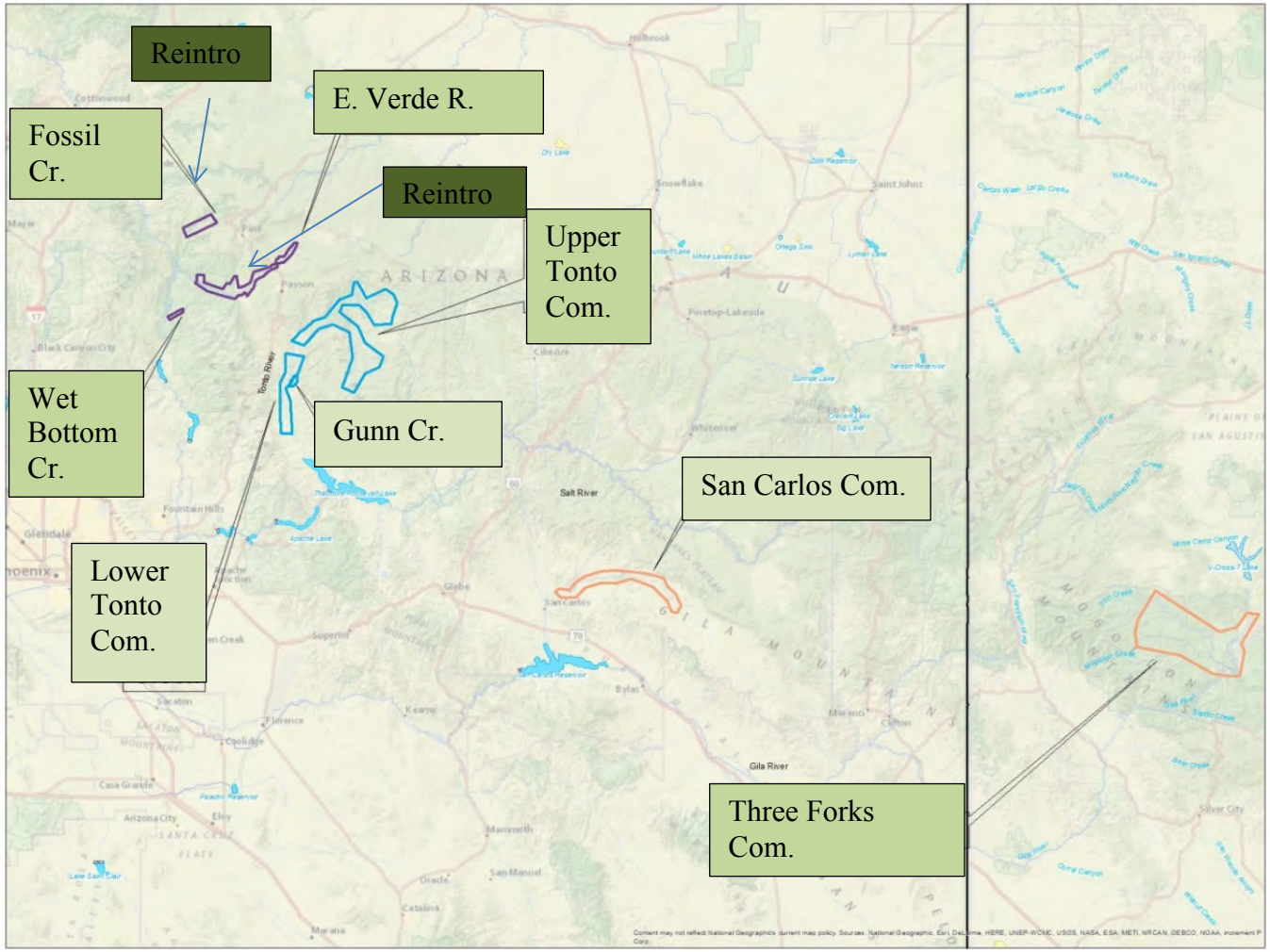


Figure 8.2.1-3. Distribution of Headwater Chub Analysis Units Under Scenario 1 (Each color represents a drainage basin: Purple=Verde River Drainage Basin, Blue=Salt River Drainage Basin, and Peach=Gila River Drainage Basin)



Scenario 2 forecasted a moderate increase (an increase of 2 ranking level) in the impacts from the community level of nonnative in 13 percent of the streams, a decrease in the stream length of 8 percent to all streams, and high conservation management. High conservation management consists of two newly established populations and two renovated streams.

Table 8.2.1-3. Distribution of Headwater Chub Analysis Units within Drainage Basins Under Scenario 2.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Gila River	0	1	1	0
Salt River	1	1	2	0
Verde River	1	2	1	0
Total	2	4	4	0

Figure 8.2.1-4. Headwater Chub Analysis Unit Scoring Under Scenario 2.

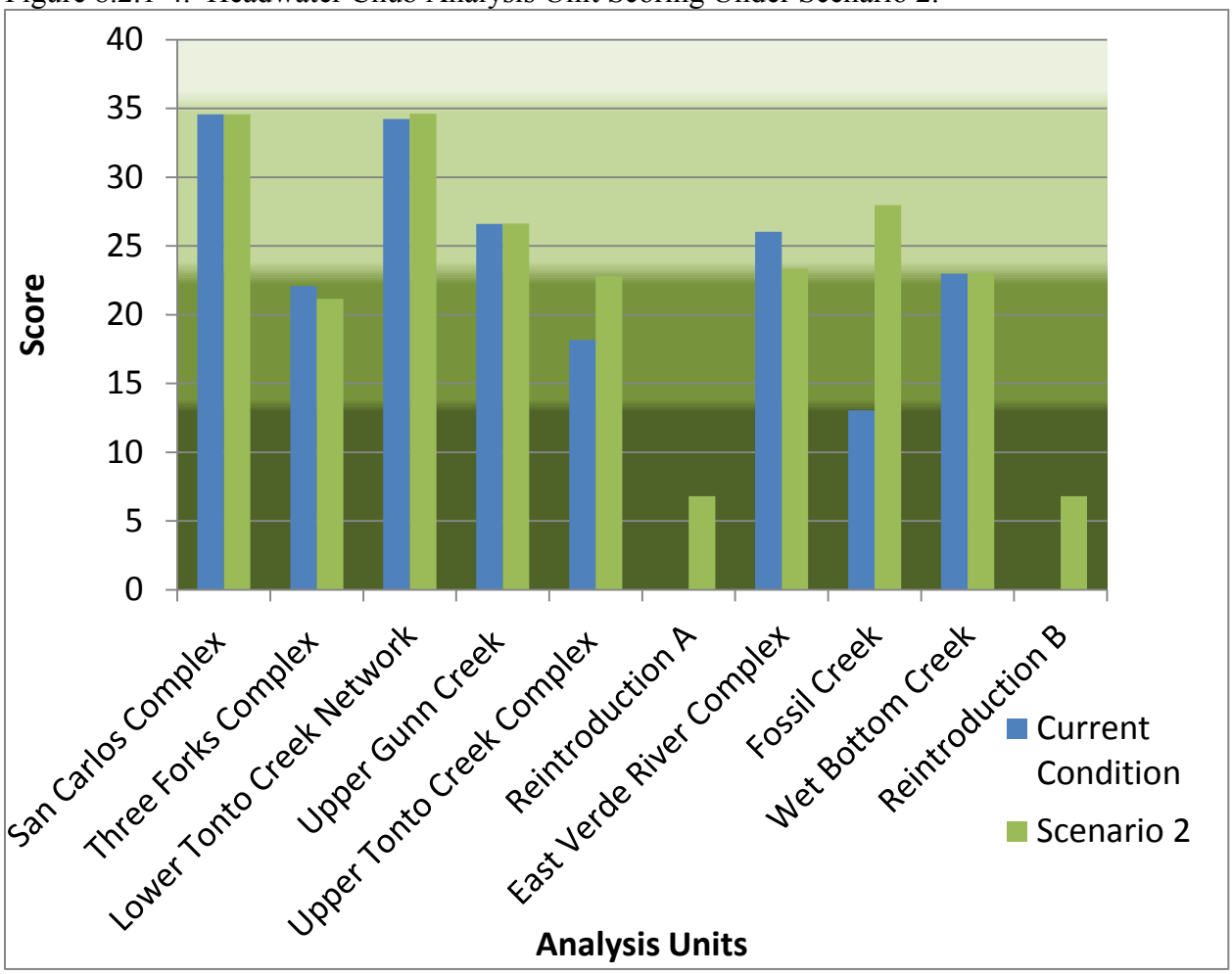
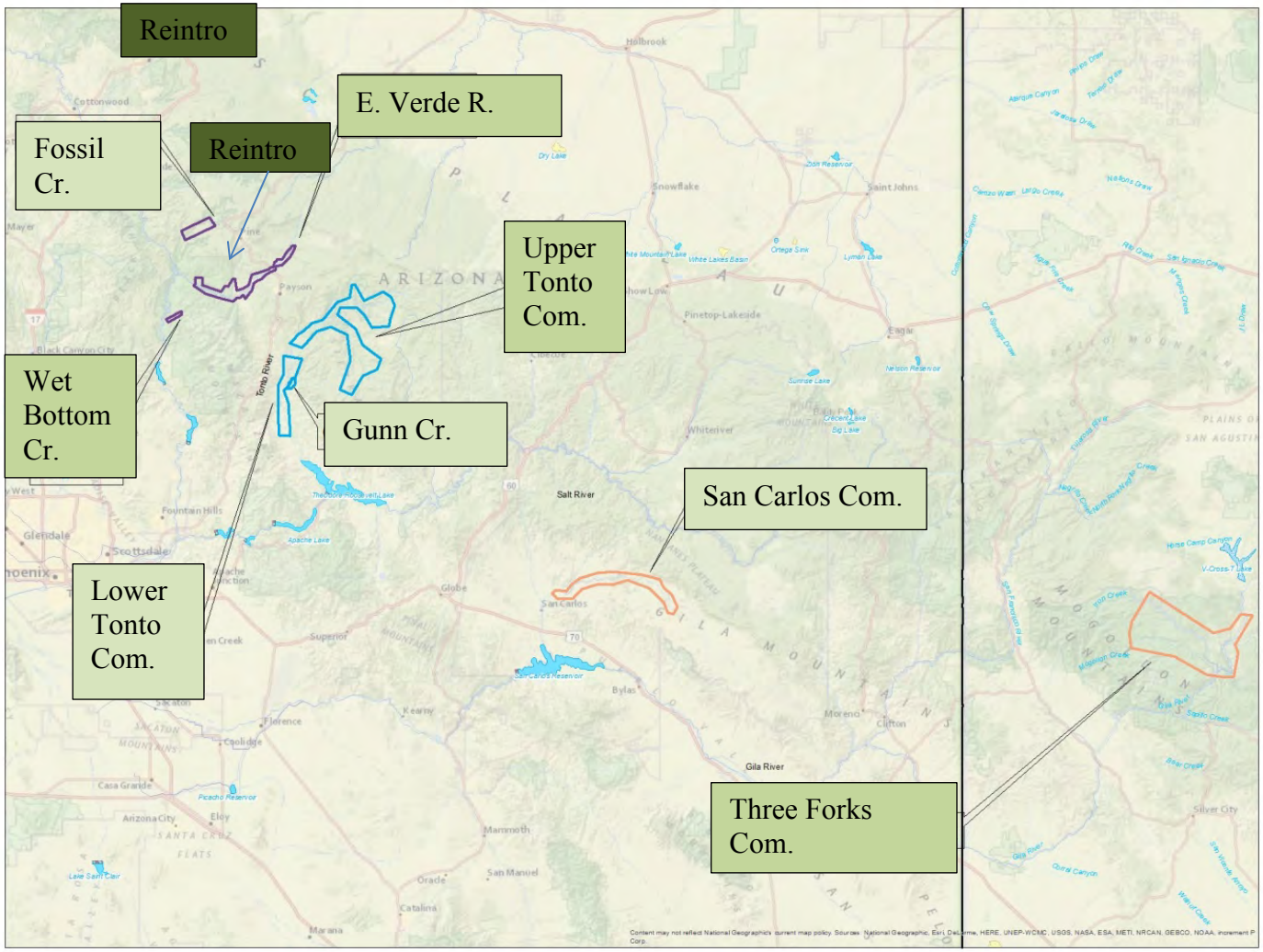


Figure 8.2.1-5. Distribution of Headwater Chub Analysis Units Under Scenario 2 (Each color represents a drainage basin, Purple=Verde River Drainage Basin, Blue=Salt River Drainage Basin, and Peach=Gila River Drainage Basin)



Scenario 3 forecasted a moderate increase (an increase of 2 ranking level) in the impacts from the community level of nonnative in 13 percent of the streams, a decrease in the stream length of 8 percent to all streams, and low conservation management. Low conservation management consists of two newly established populations and no renovated streams.

Table 8.2.1-4. Distribution of Headwater Chub Analysis Units within Drainage Basins under Scenario 3.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Gila River	0	1	1	0
Salt River	1	1	2	0
Verde River	0	1	2	0
Total	1	3	5	0

Figure 8.2.1-6. Ranking of Headwater Chub Analysis Units Within Drainage Basins Under Scenario 3.

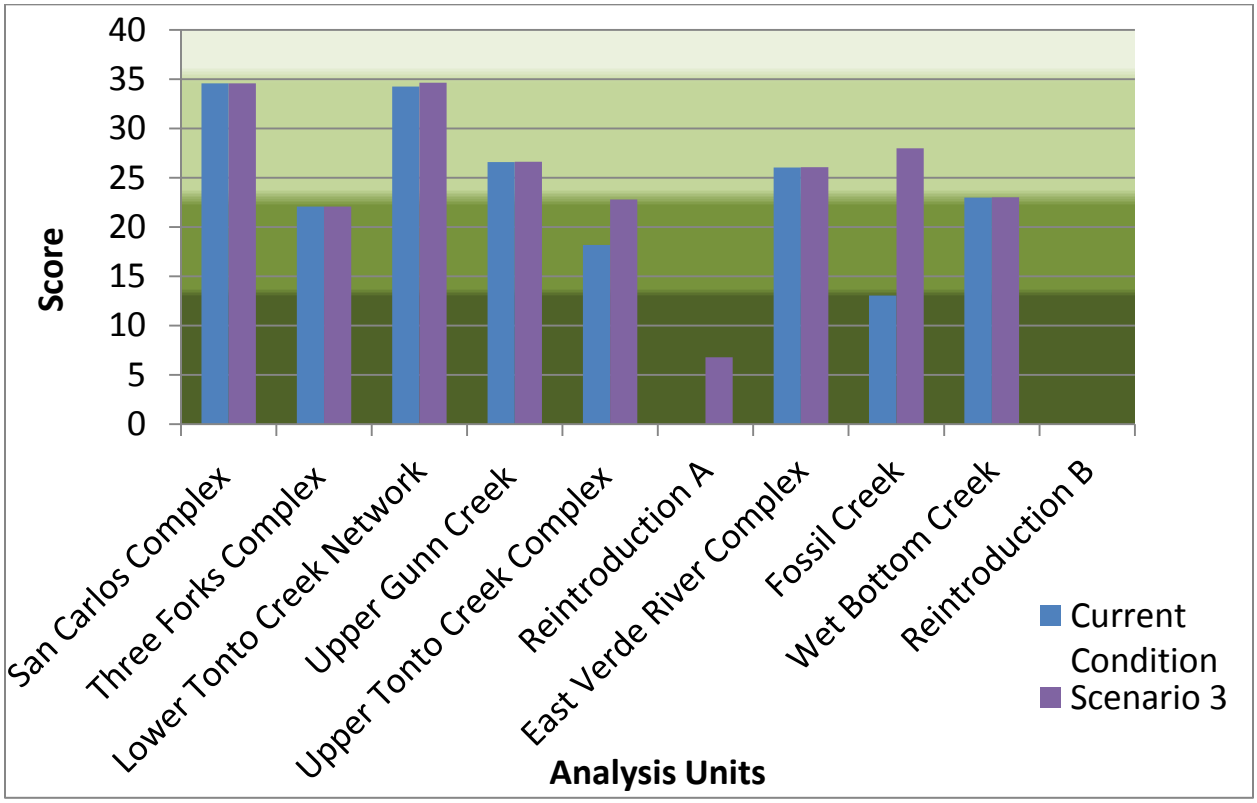
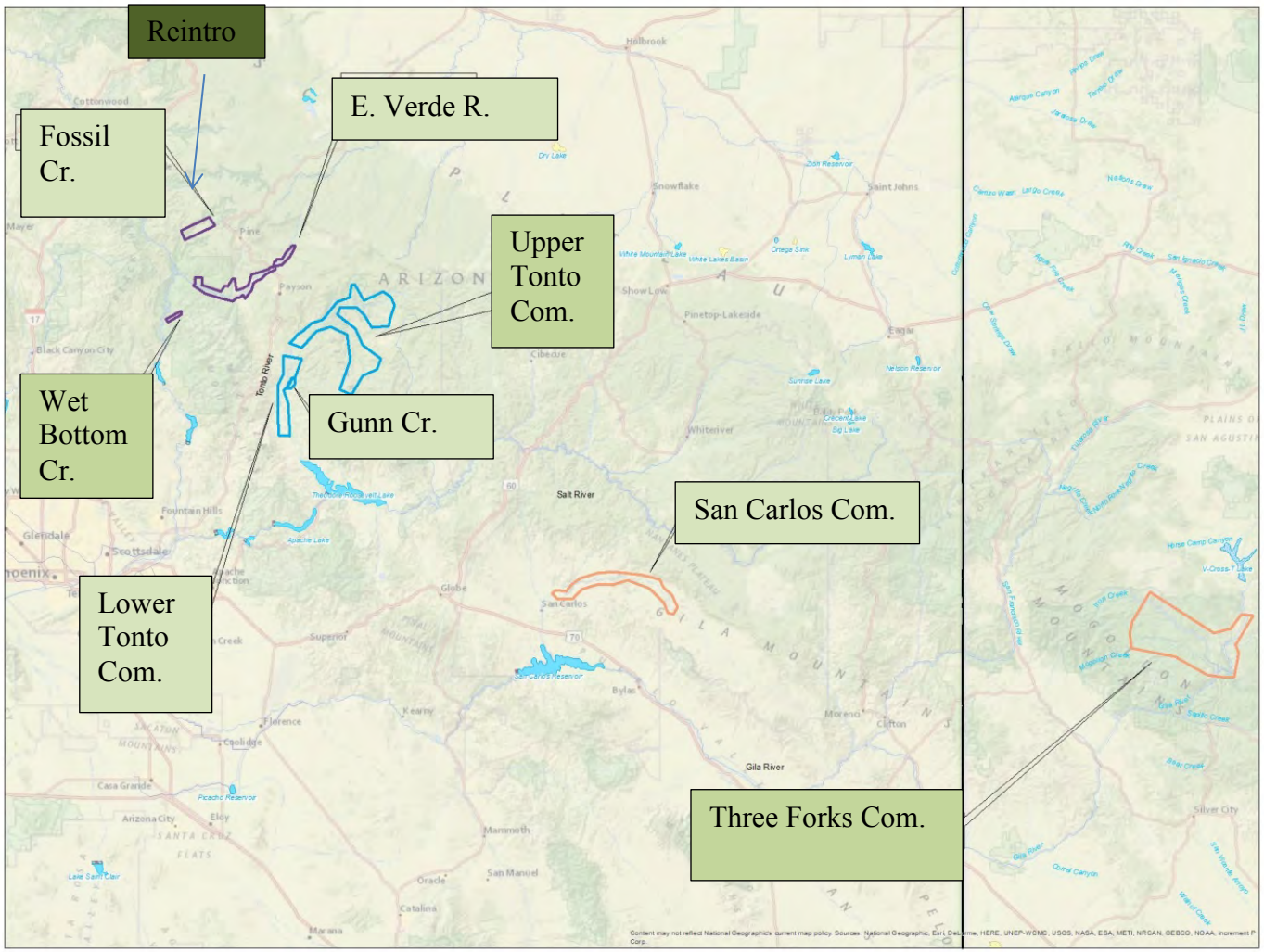


Figure 8.2.1-7. Distribution of Headwater Chub Analysis Units Under Scenario 3 (Each color represents a drainage basin: Purple=Verde River Drainage Basin, Blue=Salt River Drainage Basin, and Peach=Gila River Drainage Basin)



Scenario 4 forecasted a low increase (an increase of 1 ranking level) in the impacts from the community level of nonnative in 45 percent of the streams, a decrease in the stream length of 20 percent to all streams, and low conservation management. Low conservation management consists of two newly established populations and no renovated streams.

Table 8.2.1-5. Distribution of Headwater Chub Analysis Units within Drainage Basins Under Scenario 4.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Gila River	0	0	2	0
Salt River	1	1	2	0
Verde River	0	2	1	0
Total	1	3	5	0

Figure 8.2.1-8. Ranking of Headwater Chub Analysis Units within Drainage Basins Under Scenario 4.

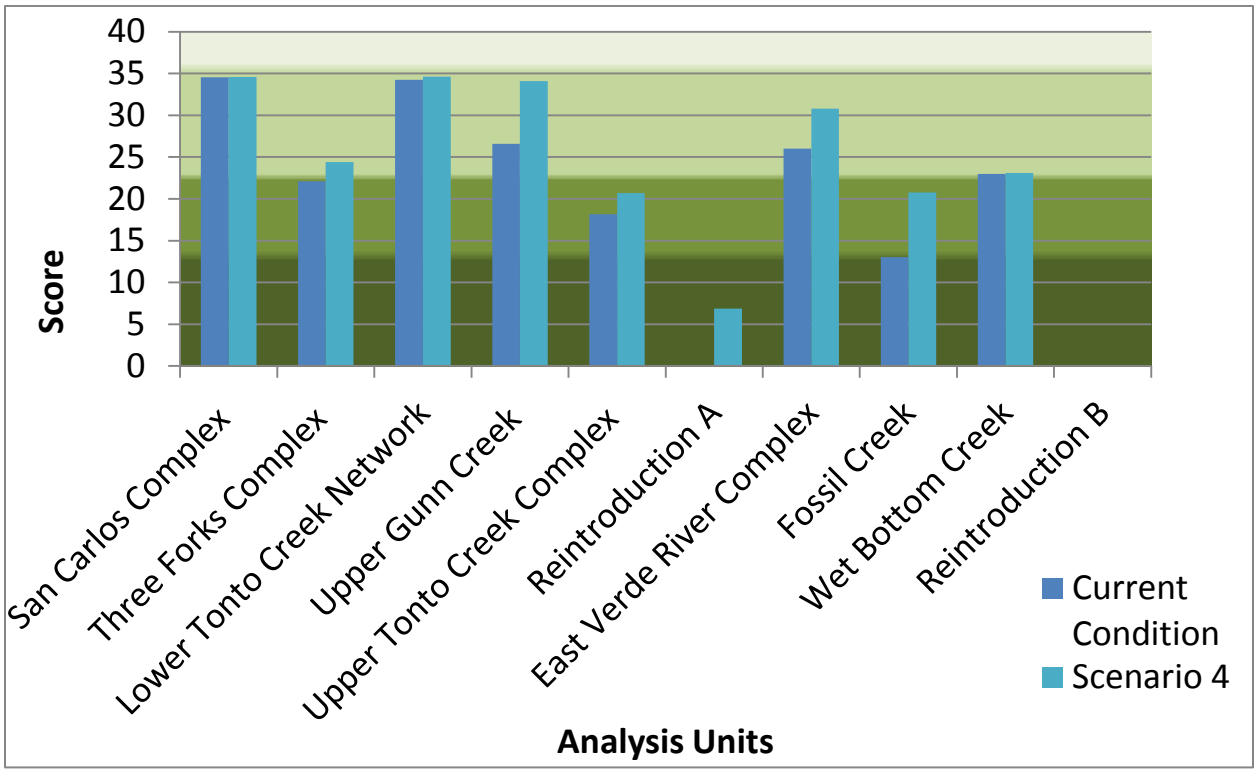
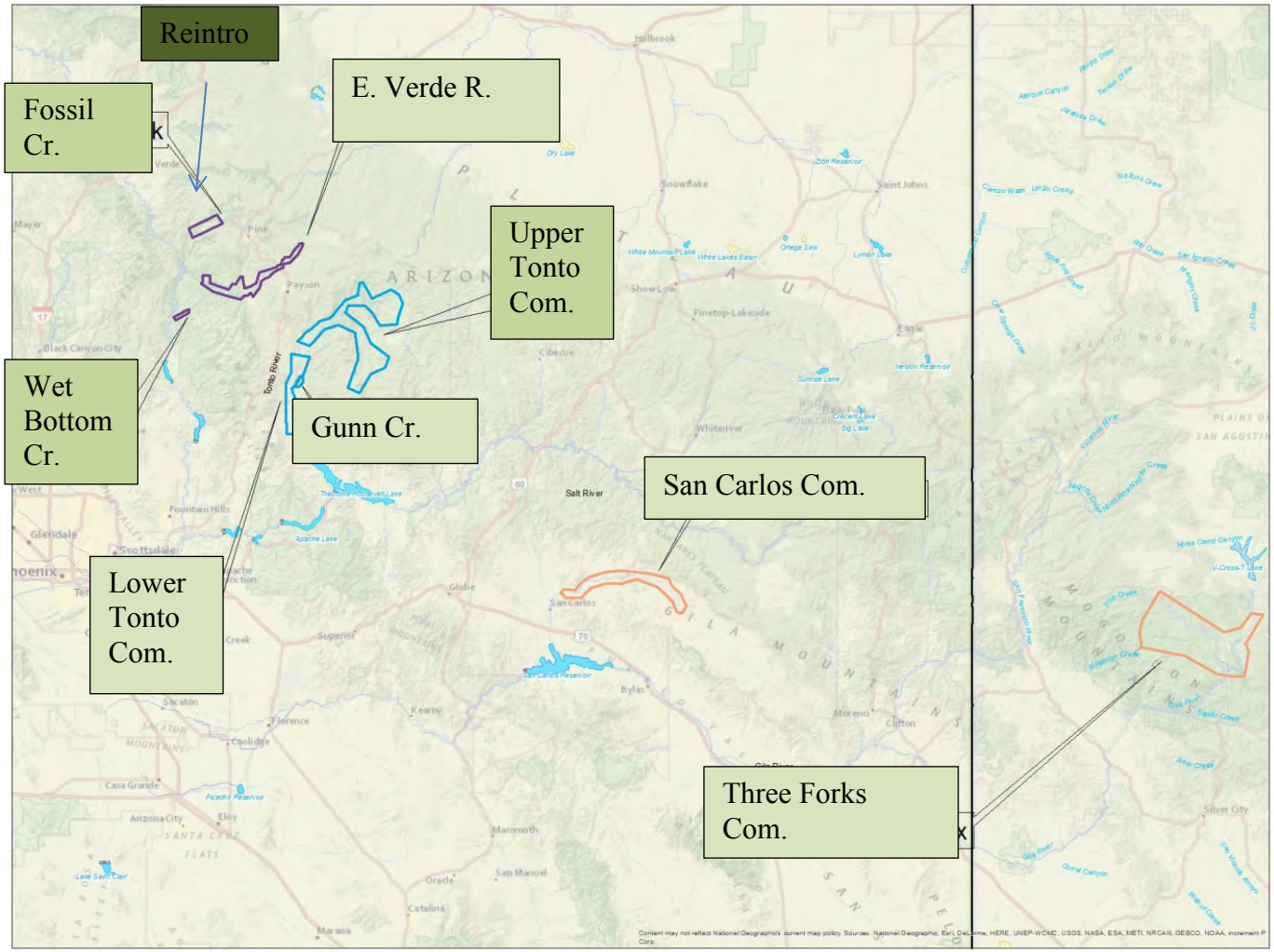


Figure 8.2.1-9. Distribution of Headwater Chub Analysis Units under Scenario 4 (Each color represents a drainage basin: Purple=Verde River Drainage Basin, Blue=Salt River Drainage Basin, and Peach=Gila River Drainage Basin)



As the risk in nonnatives and water availability, increase the number of AUs shift from low to moderate risk. However, impacts do not shift the condition of any of the AUs into high risk.

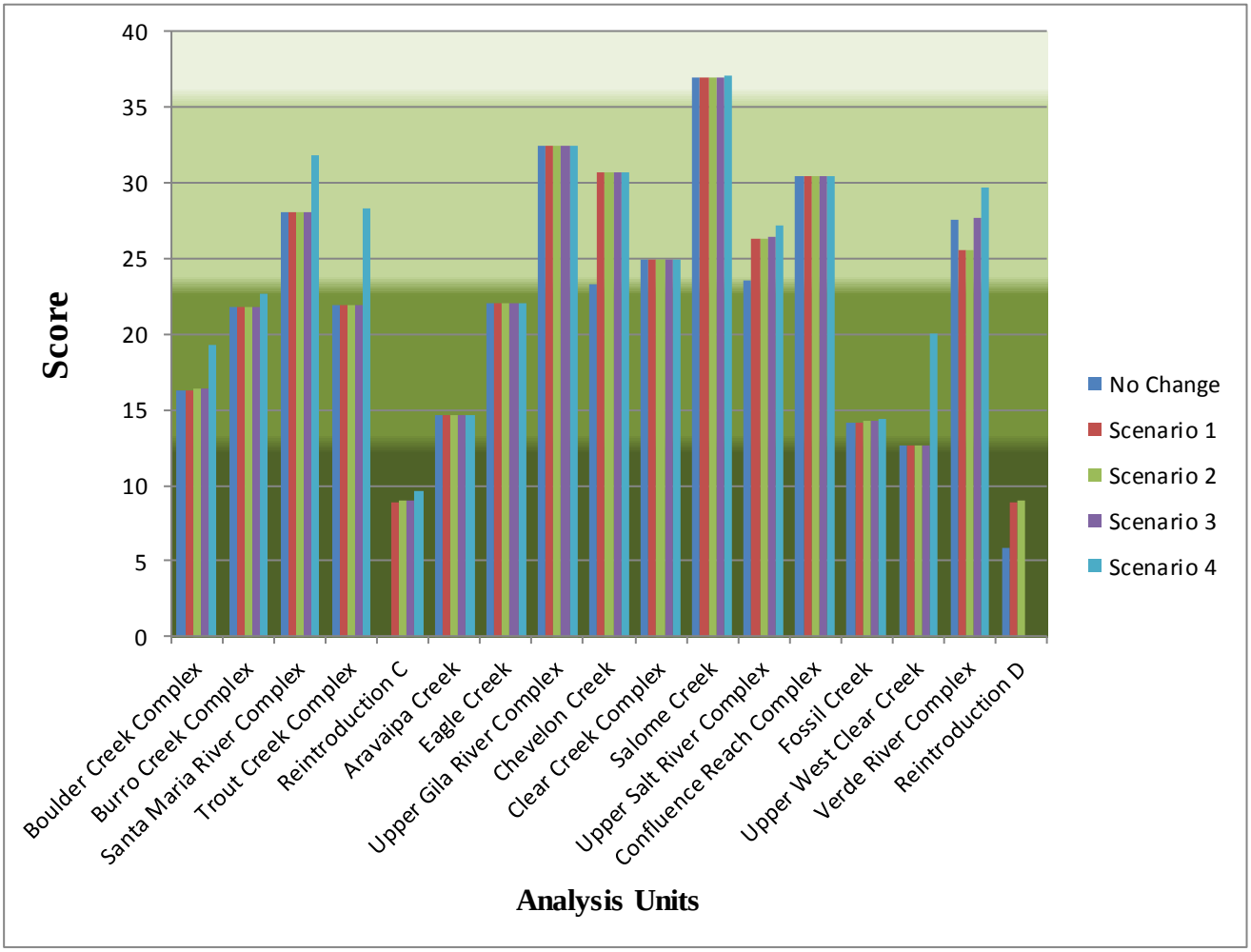
8.2.2 Roundtail Chub Projected Future Condition

Roundtail Chub Wild Populations

Table 8.2.2-1. Projected Future Condition of Roundtail Chub DPS Analysis Units.

Analysis Unit	Current Condition	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Boulder Creek Complex	Low	Low	Low	Low	Low
Burro Creek Complex	Low	Low	Low	Low	Low
Santa Maria River Complex	Moderate	Moderate	Moderate	Moderate	Moderate
Trout Creek Complex	Low	Low	Low	Low	Moderate
Reintroduction C		Minor	Minor	Minor	Minor
Aravaipa Creek	Low	Low	Low	Low	Low
Eagle Creek	Low	Low	Low	Low	Low
Upper Gila River Complex	Moderate	Moderate	Moderate	Moderate	Moderate
Chevelon Creek	Low	Moderate	Moderate	Moderate	Moderate
Clear Creek Complex	Moderate	Moderate	Moderate	Moderate	Moderate
Salome Creek	High	High	High	High	High
Upper Salt River Complex	Moderate	Moderate	Moderate	Moderate	Moderate
Confluence Reach Complex	Moderate	Moderate	Moderate	Moderate	Moderate
Fossil Creek	Low	Low	Low	Low	Low
Upper West Clear Creek	Minor	Minor	Minor	Minor	Low
Verde River Complex	Moderate	Moderate	Moderate	Moderate	Moderate
Reintroduction D		Minor	Minor	NA	NA

Figure 8.2.2-1. Graph of Roundtail Chub DPS Analysis Unit Scoring Under Four Scenarios



Scenario 1 forecasted a low increase (an increase of 1 ranking level) in the impacts from the community level of nonnative in 13 percent of the streams, a decrease in the stream length of 4 percent to all streams, and high conservation management. High conservation management consists of two newly established populations and two renovated streams.

Table 8.2.2-2. Distribution of Roundtail Chub DPS Analysis Units within Drainage Basins Under Scenario 1.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Bill Williams	1	3	1	0
Gila River	0	2	1	0
Little Colorado River	0	1	1	0
Salt River	0	0	1	1
Verde River	2	1	2	0
	3	7	6	1

Figure 8.2.2-2. Ranking of Roundtail Chub DPS Analysis Units within Drainage Basins Under Scenario 1.

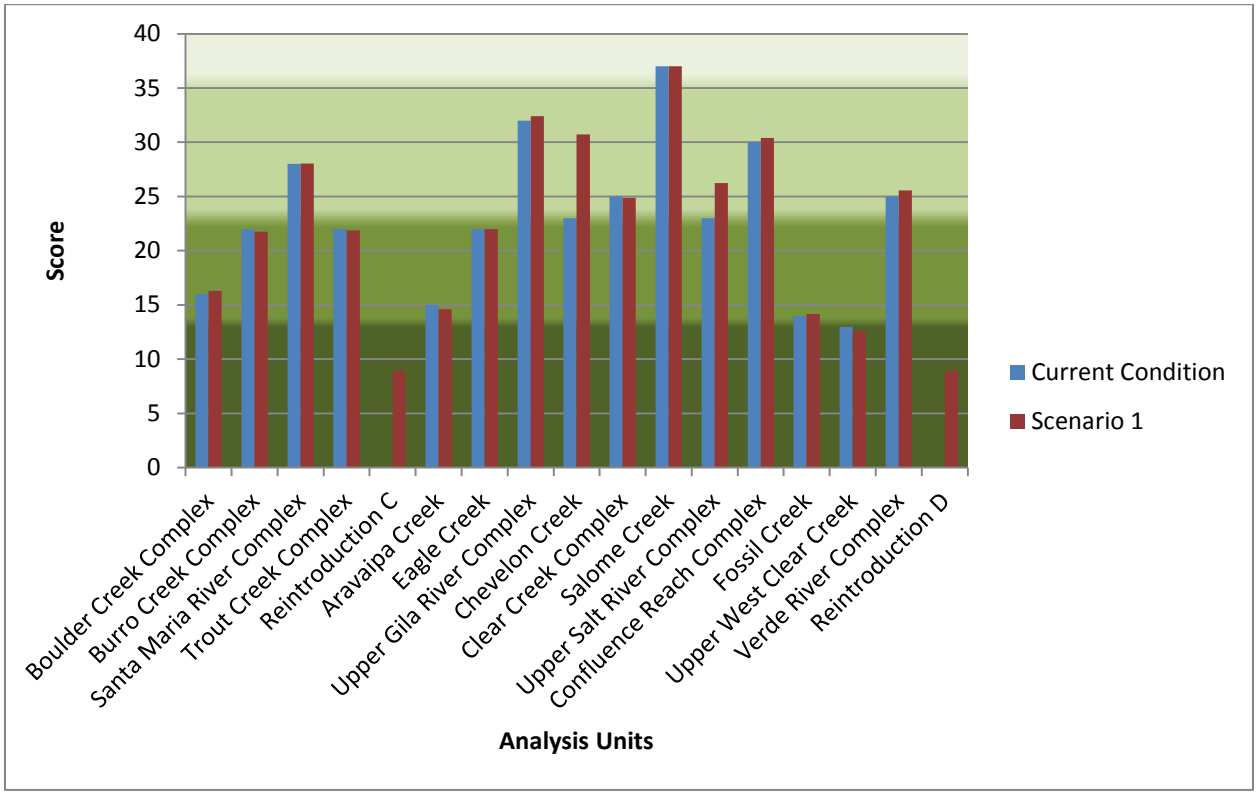
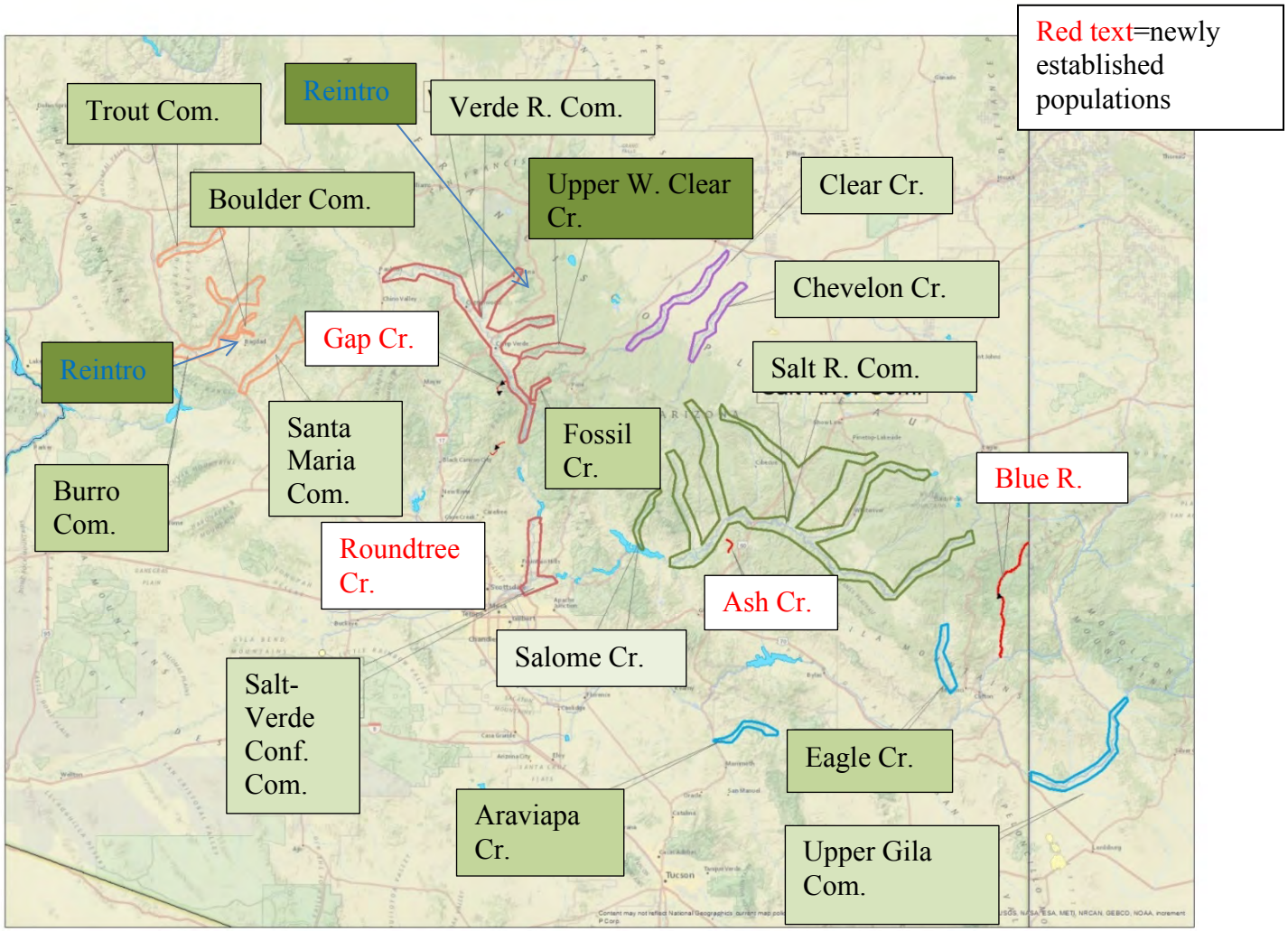


Figure 8.2.2-3. Distribution of Roundtail Chub DPS Analysis Units under Scenario 1 (Each color represents a drainage basin: Purple=Little Colorado River Drainage Basin, Blue=Gila River Drainage Basin, Peach=Bill Williams River Drainage Basin, Red=Verde River Drainage Basin, and Green=Salt River Drainage Basin)



Scenario 2 forecasted a moderate increase (an increase of 2 ranking level) in the impacts from the community level of nonnative in 13 percent of the streams, a decrease in the stream length of 8 percent to all streams, and high conservation management. High conservation management consists of two newly established populations and two renovated streams.

Table 8.2.2-3. Distribution of Roundtail Chub DPS Analysis Units Within Drainage Basins Under Scenario 2.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Bill Williams	1	3	1	0
Gila River	0	2	1	0
Little Colorado River	0	1	1	0
Salt River	0	0	1	1
Verde River	2	1	2	0
	3	7	6	1

Figure 8.2.2-4. Distribution of Roundtail Chub DPS Analysis Units Within Drainage Basins Under Scenario 2.

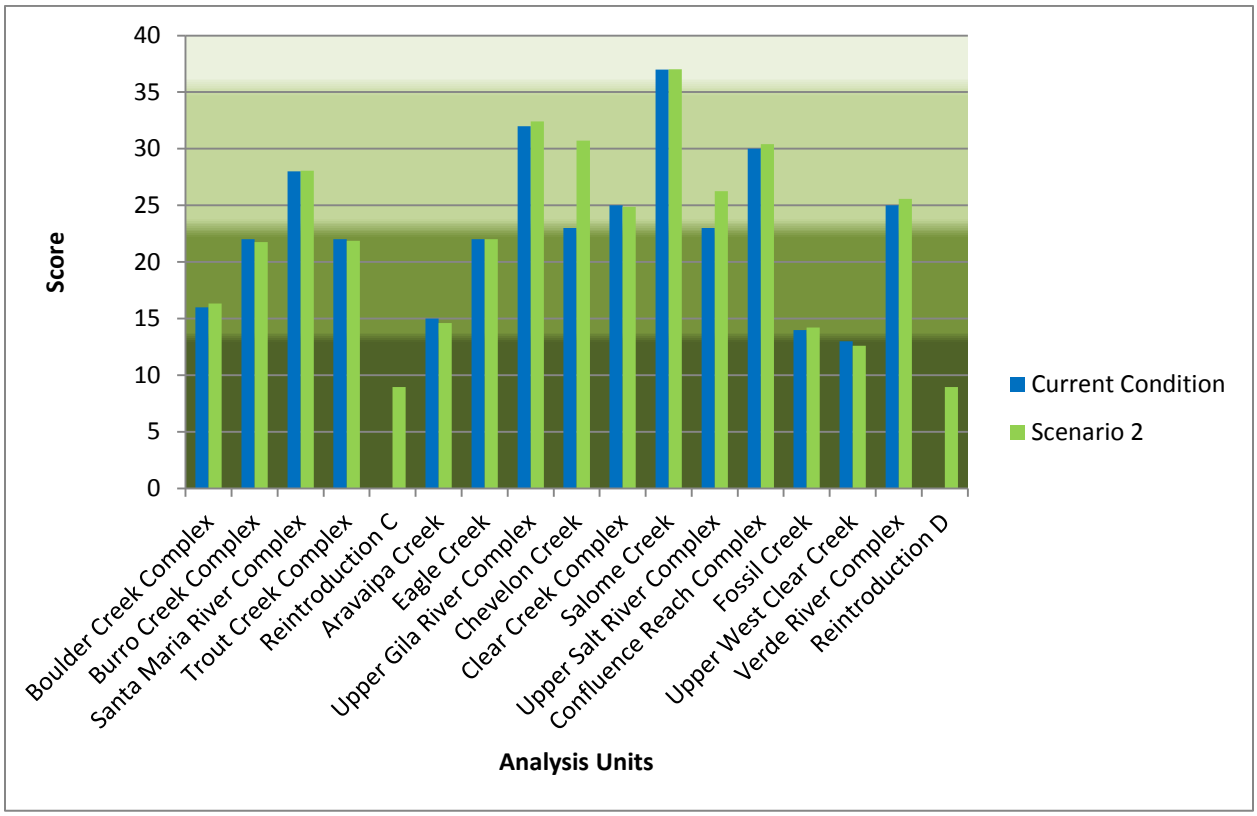
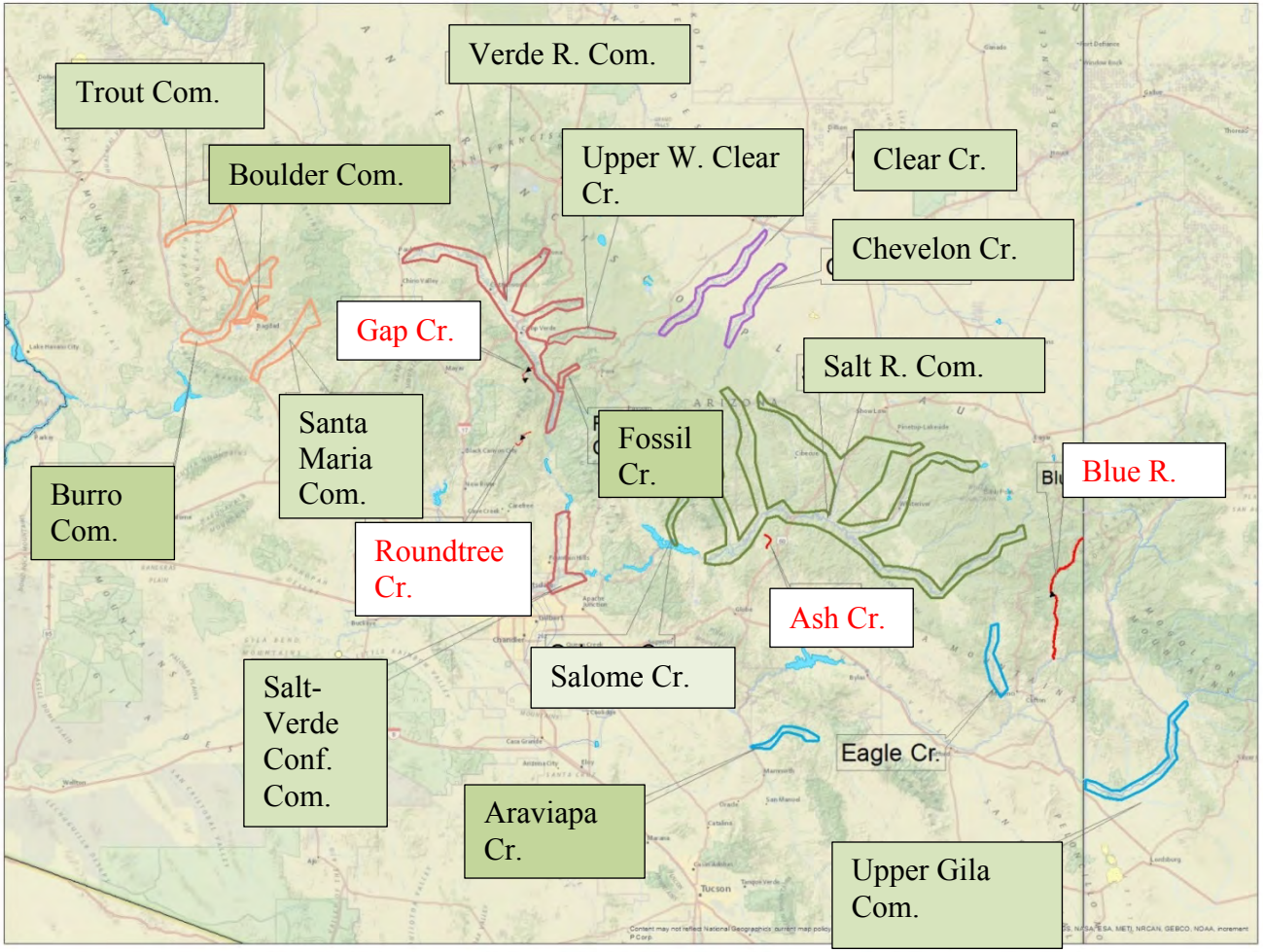


Figure 8.2.2-5. Distribution of Roundtail Chub DPS Analysis Units under Scenario 2 (each color represents a drainage basin: Purple=Little Colorado River Drainage Basin, Blue=Gila River Drainage Basin, Peach=Bill Williams River Drainage Basin, Red=Verde River Drainage Basin, and Green=Salt River Drainage Basin)



Scenario 3 forecasted a moderate increase (an increase of 2 ranking level) in the impacts from the community level of nonnative in 13 percent of the streams, a decrease in the stream length of 8 percent to all streams, and low conservation management. Low conservation management consists of two newly established populations and no renovated streams.

Table 8.2.2-4. Distribution of Roundtail Chub DPS Analysis Units Within Drainage Basins Under Scenario 3.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Bill Williams	1	0	1	3
Gila River	0	2	1	0
Little Colorado River	0	1	1	0
Salt River	0	0	1	1
Verde River	1	1	2	0
	2	7	6	1

Figure 8.2.2-6. Ranking of Roundtail Chub DPS Analysis Units Within Drainage Basins Under Scenario 3.

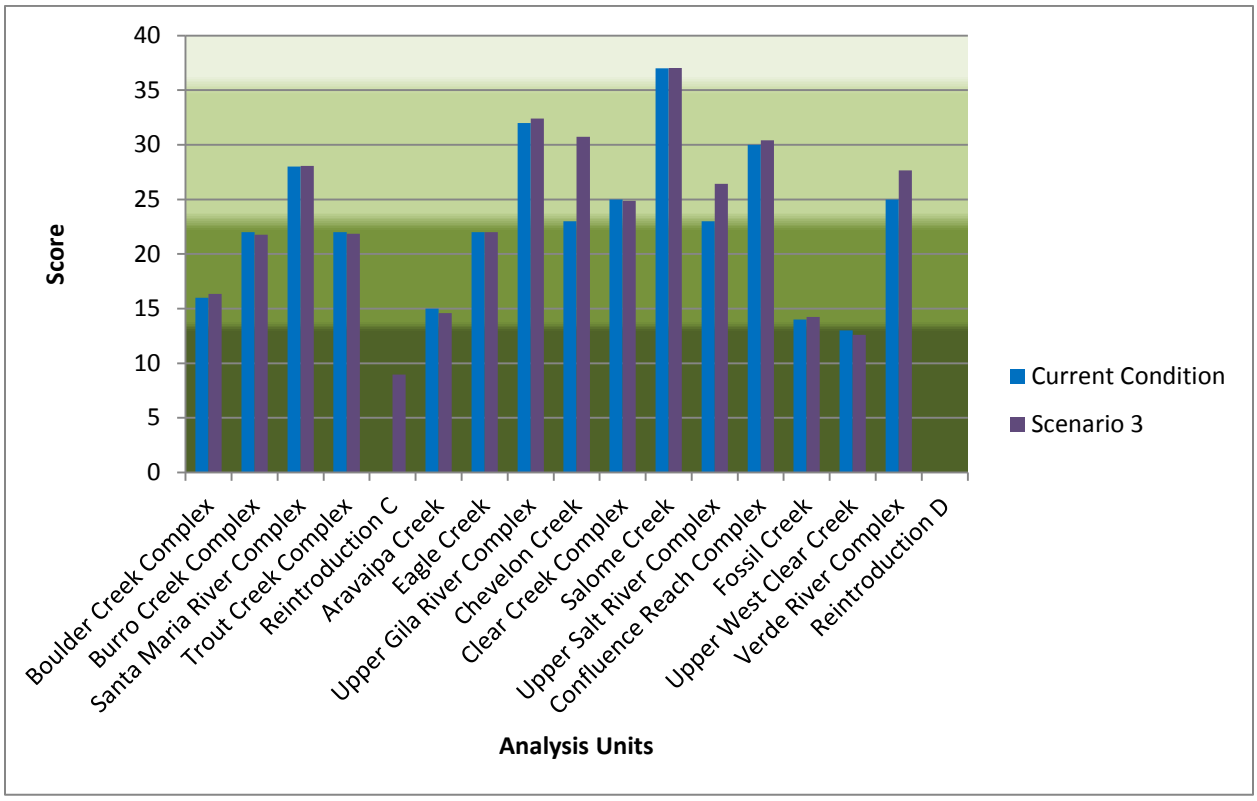
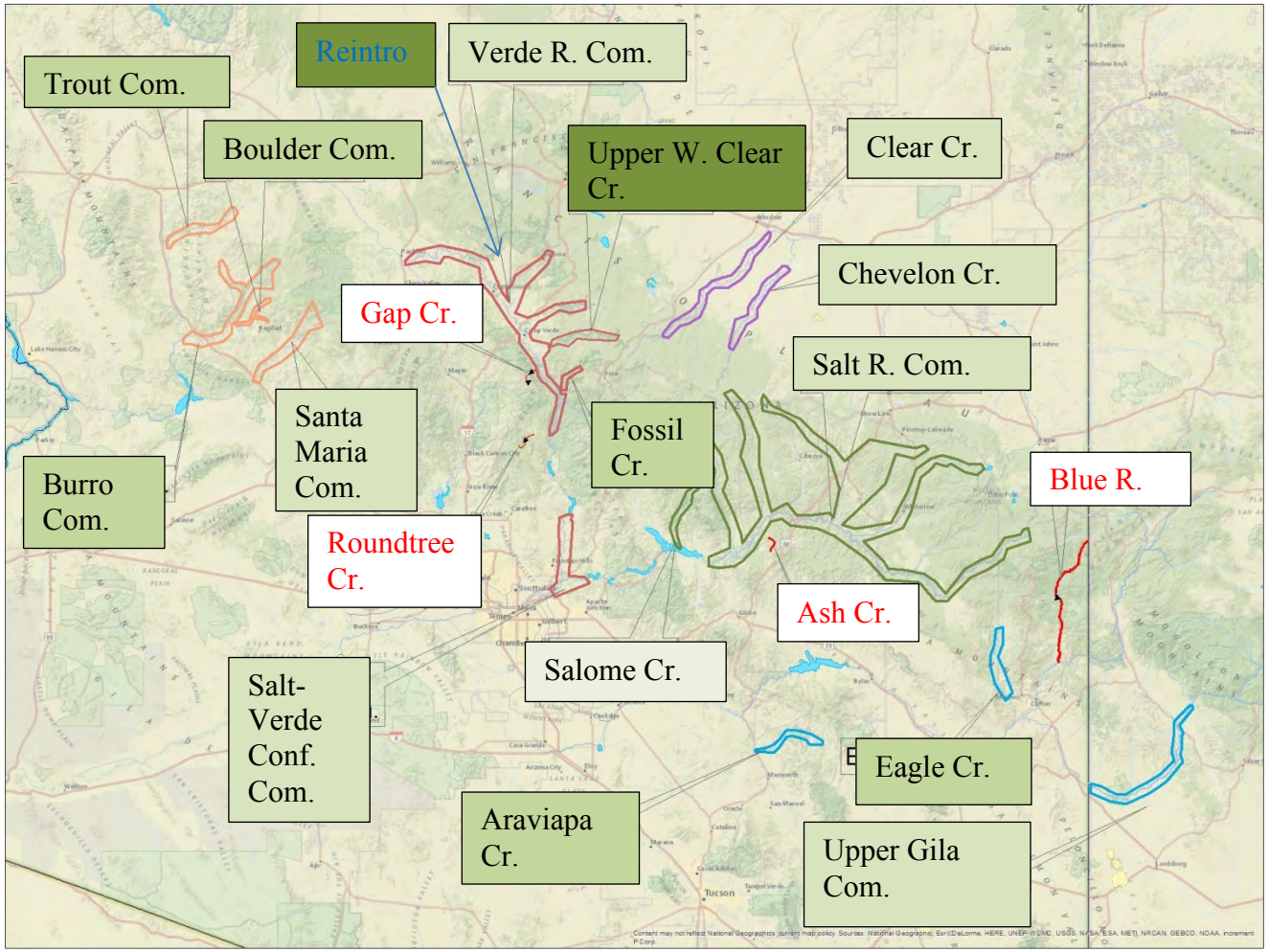


Figure 8.2.2-7. Distribution of Roundtail Chub DPS Analysis Units under Scenario 3 (each color represents a drainage basin, Purple=Little Colorado River Drainage Basin, Blue=Gila River Drainage Basin, Peach=Bill Williams River Drainage Basin, Red=Verde River Drainage Basin, and Green=Salt River Drainage Basin)



Scenario 4 forecasted a low increase (an increase of 1 ranking level) in the impacts from the community level of nonnative in 45 percent of the streams, a decrease in the stream length of 20 percent to all streams, and low conservation management. Low conservation management consists of two newly established populations and no renovated streams.

Table 8.2.2-5. Distribution of Roundtail Chub DPS Analysis Units Within Drainage Basins Wnder Scenario 4.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Bill Williams	1	2	2	0
Gila River	0	2	1	0
Little Colorado River	0	0	2	0
Salt River	0	0	1	1
Verde River	0	2	2	0
	1	6	8	1

Figure 8.2.2-8. Ranking of Roundtail Chub DPS Analysis Units Within Drainage Basins Under Scenario 4.

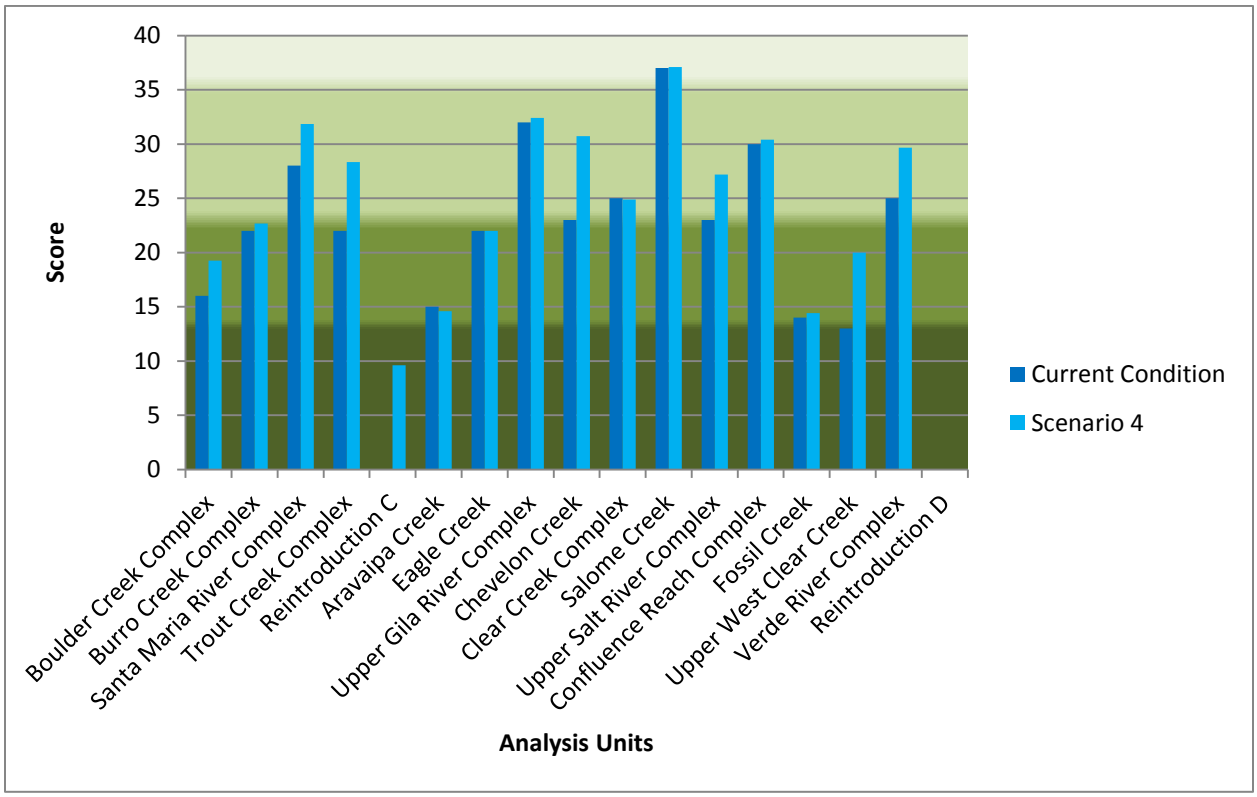
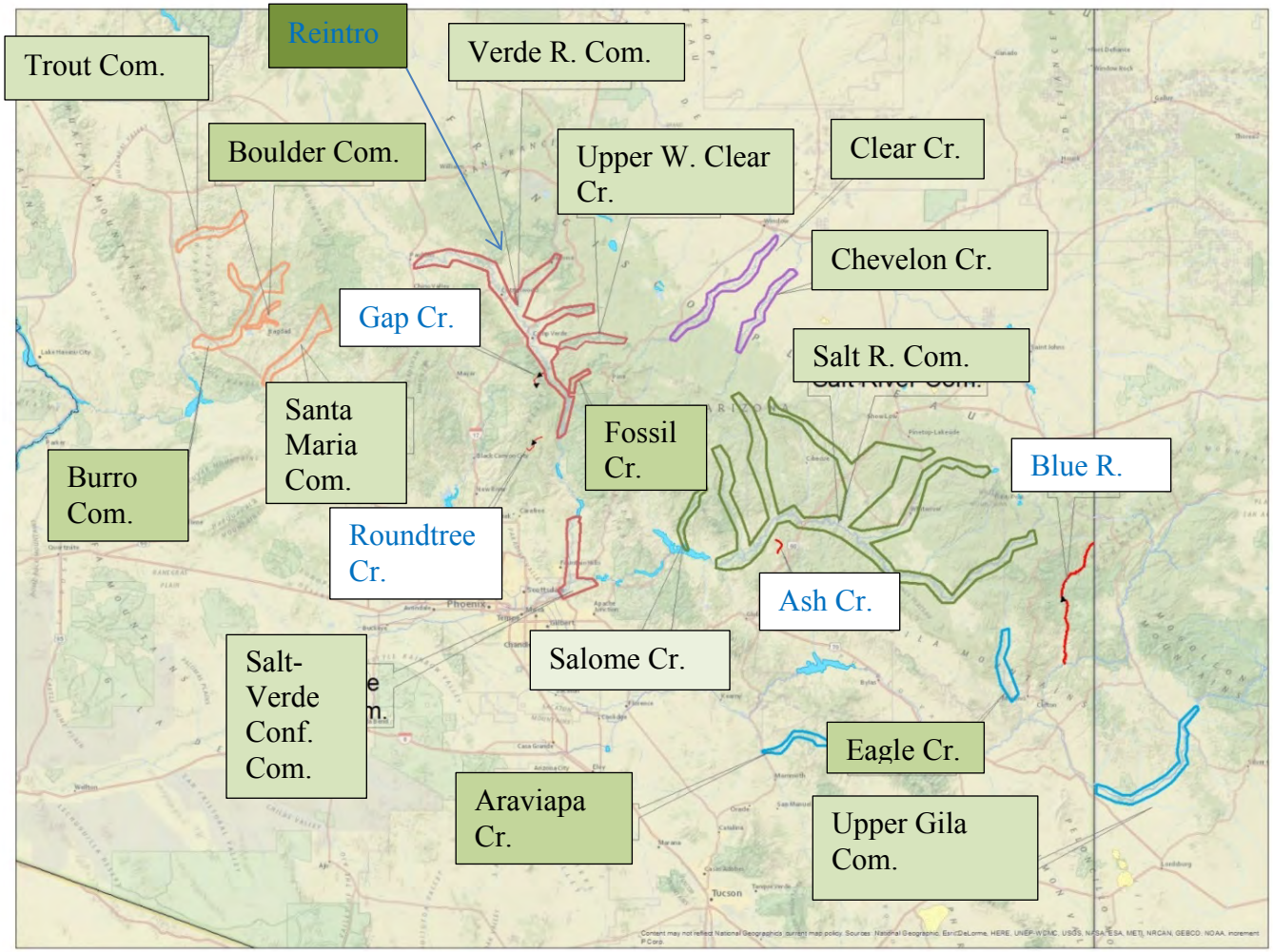


Figure 8.2.2-9. Distribution of Roundtail Chub DPS Analysis Units under Scenario 4 (Each color represents a drainage basin: Purple=Little Colorado River Drainage Basin, Blue=Gila River Drainage Basin, Peach=Bill Williams River Drainage Basin, Red=Verde River Drainage Basin, and Green=Salt River Drainage Basin)



As the risk in nonnatives and water availability, increase the number of AUs shift from low to moderate risk. Impacts to one AU shifts the condition into high risk.

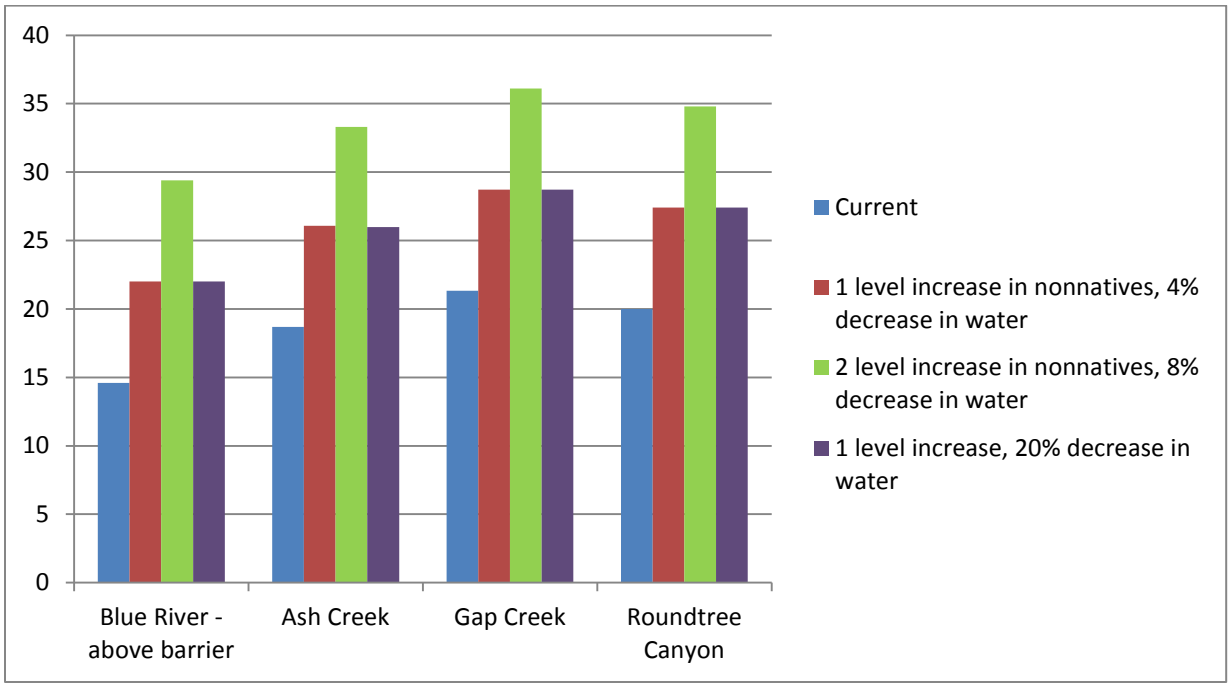
Roundtail Chub Newly Established Populations

In the model, we projected that all four of the newly established AUs experienced an increase in community level impacts from nonnative as described for each scenario. We applied a reduction in stream length to all four AUs. We did not apply any conservation measures since these AUs are conservation actions that have already been implemented.

Table 8.2.2-6. Projected Future Condition of Newly Established Roundtail Chub DPS.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Bill Williams	0	3	1	0
Gila River	0	3	1	0
Little Colorado River	0	1	1	0
Salt River	0	1	1	1
Verde River	1	3	2	0
	1	11	6	1

Figure 8.2.2-13. Projected Future Condition of Newly Established Roundtail Chub DPS Analysis Unit



Blue River is the only newly established stream where recruitment has been documented. The remaining three streams have received chubs at least three different times in three different years. They are persisting but not necessarily due to reproduction. In the model, we projected that no recruitment is occurring into the future. Table 8.2.2-7 through Table 8.2.2-10 show the projected future condition of wild and newly established AUs across drainage basins.

Scenario 1 forecasted a moderate increase (an increase of 1 ranking level) in the impacts from the community level of nonnative in all streams and a decrease in the stream length of 4 percent to all streams.

Table 8.2.2-7. Distribution of Roundtail Chub DPS Analysis Units Including Newly Established Populations Within Drainage Basins Under Scenario 1.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Bill Williams	1	3	1	0
Gila River	0	3	1	0
Little Colorado River	0	1	1	0
Salt River	0	1	1	1
Verde River	2	1	4	0
	3	9	8	1

Scenario 2 forecasted a moderate increase (an increase of 2 ranking level) in the impacts from the community level of nonnative in all streams and a decrease in the stream length of 8 percent to all streams.

Table 8.2.2-8. Distribution of Roundtail Chub DPS Analysis Units Including Newly Established Populations Within Drainage Basins Under Scenario 2.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Bill Williams	1	3	1	0
Gila River	0	2	2	0
Little Colorado River	0	1	1	0
Salt River	0	0	2	1
Verde River	2	1	4	0
	3	7	10	1

Scenario 3 forecasted a moderate increase (an increase of 2 ranking level) in the impacts from the community level of nonnative in all streams and a decrease in the stream length of 8 percent to all streams.

Table 8.2.2-9. Distribution of Roundtail Chub DPS Analysis Units Including Newly Established Populations Within Drainage Basins Under Scenario 3.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Bill Williams	1	3	1	0
Gila River	0	2	2	0
Little Colorado River	0	1	1	0
Salt River	0	0	2	1
Verde River	1	1	4	0
	2	7	10	1

Scenario 4 forecasted a low increase (an increase of 1 ranking level) in the impacts from the community level of nonnative in all streams and a decrease in the stream length of 20 percent to all streams.

Table 8.2.2-10. Distribution of Roundtail Chub DPS Analysis Units Including Newly Established Populations Within Drainage Basins Under Scenario 4.

Drainage Basin	Minor Risk	Low Risk	Moderate Risk	High Risk
Bill Williams	1	2	2	0
Gila River	0	3	1	0
Little Colorado River	0	0	2	0
Salt River	0	1	1	1
Verde River	0	2	4	0
	1	8	10	1

8.3 Viability Discussion

We defined viability as the ability of the species to sustain populations in the wild beyond a biologically meaningful timeframe. We are defining the headwater and roundtail chub DPS viability by characterizing the status of each species in terms of its resiliency, redundancy, and representation. Assessing these conditions does not result in a threshold determination (i.e., the subspecies is or is not resilient), but instead we present the results as a risk analysis that reflects our understanding of the relationship between the species' condition, the risks they face, and a range of forecasted possible outcomes in the future at the AU and species levels.

To evaluate the viability of headwater and roundtail chub we first determined conceptually what the species needs for viability. We have summarized these needs in Table 8.3.1-1 and 8.3.2-1 (Column 2) beginning with what populations need for resiliency. We then assessed the current condition of the species based on how those needs currently are or are not being met at the population and rangewide scales (Table 8.3.1-1 and 8.3.2-1, Column 3). We used our status assessment model (Appendix C) to forecast the possible future conditions of the species given our understanding of the risks faced by each of the current AUs and the expectations for future restoration of populations (Table 8.3.1-1 and 8.3.2-1, Column 4). Finally, we considered the risk of wildfire, risk from climate change, the reduction in range, and the demographic impacts from these factors. The following discusses our results in terms of resiliency, redundancy, and representation.

8.3.1 Headwater Chub

In considering the future viability of the headwater chub, it is important to consider the current condition of the species in relation to its historical condition. Across the analysis area, the quality and quantity of habitat, abundance of headwater chub, and condition of the AUs has been reduced. The primary reason for the reduction from historical conditions is the introduction of nonnative species and changes in flows that led to a reduction in water availability in many locations. Specifically, we consider the reduction in range and the condition of the AUs. In addition, we considered the risk of extirpation based on our model assessment of four future

scenarios, as well as wildfire, climate change, and demographic impacts from these risks, which are not captured in the model.

Looking to the future, our model suggests the AUs are likely to exist across the historical range; however, 64 percent of the AUs would occupy an area within immediate proximity to each other in two adjacent drainage basins, increasing their risk from catastrophic events (such as wildfire). The distribution of the AUs in the future could possibly be adequate to support representation and redundancy for the species, if a sufficient number of AUs were projected to be resilient. However, AUs that are not resilient cannot reliably contribute to redundancy or representation, and only two to three of the eight AUs are considered resilient. Further, the redundancy and representation of the species is diminished based on the projected future condition of the AUs, and the potential impacts from wildfire, additional impacts from climate change, water loss due to anthropogenic factors (e.g., surface water diversion and groundwater pumping), and the demographic impacts from these risk factors, as well as the inability to rely on conservation measures. Redundancy and representation is reduced because stressors could potentially affect multiple AUs across the range of the headwater chub over the next 30 years and several of these AUs are projected to have diminished resiliency.

Table 8.3.1-1. Summary of Species Status Assessment for Headwater Chub.

	Needs	Current Conditions	Future Condition (Viability)
Resiliency: Population (large populations to withstand stochastic events)	• Multiple, large interconnected populations • AUs with >20 km (12.4 mi) of suitable stream habitat (including protection of flows to maintain habitat and connectivity) • Free of nonnative species that are significant predators and/or competitors on the chub that have population level effects • Pools, with nearby riffle-run habitat for adults • Shallow waters along streambanks for juveniles • Pool -riffle areas with sandy/rocky substrates for egg development • Spring flows for spawning	• 22 streams • 8 extant AUs across range (1 minor risk, 3 low risk, 4 moderate risk, 0 high risk) • Stream lengths range from 3 to 70 km (2 to 44 mi) Average stream length is 17 km (10 mi) • Only 3 streams lack nonnative species impacting chubs	• Status Assessment Model estimates risk of extirpation of each AU based on: *Nonnative Species *Water Availability *Conservation <u>Scenario 1:</u> • 10 AUs (2 new populations established sites and 2 renovation sites) • 2 Minor risk • 5 Low risk • 3 Moderate risk • 0 High risk • 18 km (11 mi) decrease in stream length (4%) • 10km (6.2 mi) of streams newly established populations • 7 streams lack nonnative species impacting chubs <u>Scenario 2:</u> • 10 AUs (2 new populations and 2 renovation sites) • 2 Minor risk • 4 Low risk • 4 Moderate risk • 0 High risk • 35 km (21.7 mi) decrease in stream length (8%) • 10km (6.2) of stream with new established populations

			• 7 streams lack nonnative species impacting chubs
			
			<u>Scenario 3:</u>
			• 9 AUs (1 new populations)
			  • 1 Minor risk
			  • 3 Low risk
			  • 5 Moderate risk
			  • 0 High risk
			• 35 km (21.7 mi) decrease in stream length (8%)
			• 5km (3 mi) of streams with newly established populations
			• 4 streams lack nonnative species impacting chubs
			
			<u>Scenario 4:</u>
			• 9 AUs (1 new population)
			  • 1 Minor risk
			  • 3 Low risk
			  • 5 Moderate risk
			  • 0 High risk
			• 86 km (53.4 mi) decrease in stream length (20%)
			• 5 km (3 mi) of streams with newly established populations
			• 4 streams lack nonnative species impacting chubs

Redundancy (number and distribution of	-Multiple highly resilient populations within each of the three Drainage Basin	Drainage Basin Distribution: • 8 extant AUs	*2046 Model Future Conditions*: Drainage Basin Distribution: • 2 Gila River AUs

populations to withstand catastrophic events)	within their historical range	across range • 2 Gila River AUs • 3 Salt River AUs • 3 Verde River AUs AU Connectivity • 3 (38%) AUs are isolated • 5 (62%) AUs have some connection Range • Estimated 48-87% historical range currently occupied (or 13-52% reduction in range)	• 3 Salt River AUs • 3 Verde River AUs <u>Scenario 1:</u> • ~ 46-84% historical range currently occupied <u>Scenario 2:</u> • ~ 45-80% historical range currently occupied <u>Scenario 3:</u> • ~ 45-80% historical range currently occupied <u>Scenario 4:</u> • ~ 39-70% historical range currently occupied *Non-Model Conditions* -Wildfire could impact streams or parts or all of an AU • 8 streams ~ 5km (3 mi) or less, size makes them more at risk from catastrophic events • 2 AUs ~ 5km (3 mi) or less, catastrophic event could reduce redundancy -Urbanization: 1 AU-likely impacted -Climate Change: • Reduce network-wide hydrologic connectivity • Alterations in the timing and amount of snowmelt affecting spawning • Alterations in the timing and amount of monsoon precipitation after driest period affecting refugia habitat
Representation (genetic and ecological diversity	-Genetic diversity-resilient populations representing extant	• 8 extant AUs across range	*AU Characteristics* • 3 independent AUs

to maintain adaptive potential)	diversity within each of the three drainage basin	• Most of their genetic variation occurs among populations, each of which tends to be distinctive	• 1 AU with high uncertainty in chub presence • 2 AUs with 5+ streams • 6 AUs in drainage basins immediately adjacent to each other. *Non-Model Conditions* Wildfire could impact streams or parts or all of an AU • 8 streams ~ 5km (3 mi) or less, size makes them more at risk from stochastic events • 2 AUs ~ 5km (3 mi) or less, stochastic event could reduce representation

8.3.2 Roundtail Chub

In considering the future viability of the roundtail chub in the LCR DPS, it is important to consider the current condition of the species in relation to its historical condition. Across the analysis area, the quality and quantity of habitat, abundance of roundtail chub, and condition of the AUs has been reduced. The primary reason for the reduction from historical conditions is the introduction of nonnative species and changes in flows that led to a reduction in water availability in many locations. Specifically, we consider the reduction in range and the condition of the AUs. In addition, we considered the risk of extirpation based on our model assessment of four future scenarios, as well as wildfire, climate change, and demographic impacts from these risks, which are not captured in the model.

Looking to the future, our model suggests the AUs are likely to occur across the historical range; however, 64 percent of the AUs would occupy an area within immediate proximity to each other in two adjacent drainage basins, increasing their risk from catastrophic events (such as wildfire). The distribution of the AUs in the future could possibly be adequate to support representation and redundancy for the species, if a sufficient number of AUs were projected to be resilient. However, AUs that are not resilient cannot reliably contribute to redundancy or representation, and only two to three of the 15 AUs are considered resilient. Further, the redundancy and representation of the species is diminished based on the projected future condition of the AUs, and the potential impacts from wildfire, additional impacts from climate change, water loss due to anthropogenic factors (e.g., surface water diversion and groundwater pumping), and the demographic impacts from these risk factors, as well as the inability to rely on conservation measures. Redundancy is reduced because threats could potentially affect multiple AUs across the range of the headwater chub over the next 30 years and several of these AUs are projected to have diminished resiliency.

Table 8.3.2-1. Summary of Species Status Assessment for Roundtail Chub.

3 R's	Needs	Current Conditions	Future Condition (Viability)
Resiliency: Population (populations to withstand stochastic events)	-Multiple, large interconnected populations -AUs with >20 km (12.4 mi) of suitable stream habitat (including protection of flow to maintain habitat and connectivity) -Free on nonnative species that are significant predators and/or competitors on the chub that have population level effects • Pools, with nearby riffle-run habitat for adults • Shallow waters along streambanks for juveniles • Pool -riffle areas with sandy/rocky substrates for egg development • Spring flows for spawning	• 35 streams • 15 extant AUs across range (1 minor risk, 7 low risk, 6 moderate risk, 1 high risk) • Stream lengths range from 7 to 320 km (4-199 mi) • Average stream length is 50 km (10 mi) • Only 3 streams lack nonnative species impacting chubs • 4 newly established populations • 1 renovated/secured site	• Status Assessment Model estimates risk of extirpation of each AU based on: *Nonnative Species *Water Availability *Conservation Scenario 1: • 17 AUs (2 new populations established and 2 renovation sites) • 3 Minor risk • 7 Low risk • 6 Moderate risk • 1 High risk • 80 km (50 mi) decrease in stream length (4%) • 20km (12.4 mi) of reintroduced streams • 7 streams lack nonnative species impacting chubs <u>Scenario 2:</u> • 17 AUs (2 new populations and 2 renovation sites) • 3 Minor risk • 7 Low risk • 6 Moderate risk • 1 High risk • 160 km (99 mi) decrease in stream length (8%)

			• 10km (6.2 mi) of reintroduced streams
			• 7 streams lack nonnative species impacting chubs
			•
			<u>Scenario 3:</u>
			• 16 AUs (2 new populations and 2 renovation sites)
			  • 2 Minor risk
			  • 7 Low risk
			  • 6 Moderate risk
			  • 1 High risk
			• 160 km (65.8 mi) decrease in stream length (8%)
			• 10km (6.2 mi) of reintroduced streams
			• 4 streams lack nonnative species impacting chubs
			
			<u>Scenario 4:</u>
			• 16 AUs (1 new population)
			  • 1 Minor risk
			  • 6 Low risk
			  • 8 Moderate risk
			  • 1 High risk
			
			• 401 km (248 mi) decrease in stream length (20%)
			• 10 km (6.2 mi) of reintroduced streams
			• 4 streams lack nonnative species impacting chubs

Redundancy (number	-Multiple highly resilient	Drainage Basin Distribution:	*2046 Model Future Conditions:*

and distribution of populations to withstand catastrophic events)	populations within each of the Watershed Units within their historical range	-15 extant AUs across range • 4 Bill Williams AUs • 3 Gila River AUs • 2 Little Colorado River AUs • 2 Salt River AUs • 4 Verde River AUs AU Connectivity • 9 (60%) AUs are isolated • 6 (40%) AUs have some connection Range • Estimated 47-52% of historical range occupied	-Drainage Basin Distribution: • Same as current condition <u>Scenario 1:</u> • About 46-50% of historical range occupied <u>Scenario 2:</u> • About 44-48% of historical range occupied <u>Scenario 3:</u> • About 44-48% of historical range occupied <u>Scenario 4:</u> • About 38-42% of historical range occupied *Non-Model Conditions* -Wildfire could impact streams or parts or all of an AU • 8 streams ~ 5km (3 mi) or less, size makes them more at risk from catastrophic events • 2 AUs ~ 5km (3 mi) or less, catastrophic event could reduce redundancy -Urbanization: 1 AU-likely impacted -Climate Change: • Reduce network-wide hydrologic connectivity • Alterations in the timing and amount of snowmelt affecting spawning

			• Alterations in the timing and amount of monsoon precipitation after driest period affecting refugia habitat
Representation (genetic and ecological diversity to maintain adaptive potential)	-Genetic diversity-resilient populations representing with connectivity and subsequent relatedness over the range	• More genetic variation within populations and connectivity may be more of an issue (than with headwater chub) •	*AU Characteristics* • 9 independent AUs • 1 AU with high uncertainty in chub presence • 3 AUs with 5+ streams • 6 AUs in drainage basins immediately adjacent to each other. *Non-Model Conditions* Wildfire could impact streams or parts or all of an AU • 4 streams ~ 5 km (3 mi) or less, size makes them more at risk from stochastic events • 1 AUs ~ 5 km (3 mi) or less, stochastic event could reduce representation

Appendix A

Glossary of Selected Terms

In separate file.

Appendix B

Evaluating Causes and Effects for Headwater and Roundtail Chub Species Status Assessment

In separate file.

Appendix C

Draft Status Assessment Model Headwater and Roundtail Chub

In separate file.

Appendix D

Literature Cited in the SSA Report

In separate file.

Appendix E

Supplemental Information for Assessment Model

In separate file.

Appendix F

Effects Pathway Conceptual Model