Three Forks Springsnail
(Pyrgulopsis trivialis)
5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Arizona Ecological Services Field Office
Phoenix, Arizona
August, 2022

5-YEAR REVIEW

Species reviewed: Three Forks Springsnail (*Pyrgulopsis trivialis*)

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5-YEAR REVIEW
Three Forks Springsnail (*Pyrgulopsis trivialis)*

1.0 GENERAL INFORMATION

1.1 Reviewers:

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Cooperating Field Office(s):
Not applicable

Cooperating Regional Office(s):
Not applicable

1.2 Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (Service or USFWS) is required by section 4(c)(2) of the Endangered Species Act (ESA) to conduct a status review of each listed species once every 5 years. The purpose of a 5-year review is to evaluate whether the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing as endangered or threatened is based on the species' status considering the five threat factors described in section 4(a)(1) of the ESA. These same five factors are considered in any subsequent reclassification or delisting decisions. In this 5-year review (Review), we consider the best available scientific and commercial data on the species and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the Review, we must propose to do so through a separate rule-making process including public review and comment.

1.3 Methodology used to complete the review:

This review was conducted through a public review notification in the Federal Register, 87 FR 5834, and written in conjunction with the drafting of the Three Forks springsnail (*Pyrgulopsis trivialis*) Species Status Assessment. Because of the drafting of these documents in tandem, this review relies heavily on the information incorporated in the draft Species Status Assessment draft. The draft Species Status Assessment utilized input from key partners, such as the Arizona Game and Fish Department (AGFD). Because of the collaboration on the draft Species Status Assessment to date, this review can be considered a collaborative review as well.

Overall, this Review incorporates the best available information through reports, peer-reviewed literature, and communication with species experts. The use of the name "Three Forks springsnail" refers to *Pyrgulopsis trivialis*. When information is not available at the species level, we sometimes used closely related congeners (organisms belonging to the same taxonomic genus) as surrogate species but are always careful to make this clear throughout the report. For instance, some assumptions are made using the life history of Page springsnails (*P. morrisoni*), which is a different species of springsnail that is also endemic to Arizona. Although deemed reasonable, we recognize use of a congener contains inherent uncertainties[1].

1.4 Background:

1.4.1 FR Notice citation announcing initiation of this review:

U.S. Fish and Wildlife Service (USFWS). 2022. Endangered and threatened species: initiation of 5-year status reviews of 35 species in the southwest. 87 FR 5834-5838.

1.4.2 Listing history:

<u>Original Listing</u>
FR notice: 77 FR 23060-23092
Date listed: April 17, 2012
Entity listed: Species, Three Forks springsnail
Classification: Endangered

1.4.3 Associated Rulemakings:

The Three Forks springsnail was proposed as endangered on April 12, 2011 (USFWS 2011; 76 FR 20464) and listed as a species in danger of extinction in the United States on November 17, 2012, under the Endangered Species Act (ESA) of 1973 as amended (USFWS 2012; 77 FR 23060). We designated critical habitat for Three Forks springsnails in 2012 because the physical and biological features essential to species conservation require protections and special management conditions (USFWS 2012; 77 FR 23060).

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[1] We made assumptions from the Page springsnail due to the species having the most recent species-specific information for a springsnail in the Southwest. These assumptions have inherent uncertainties because the Three Forks springsnail is a different species of the same genus and family as Three Forks springsnail. We need additional species-specific information for the Three Forks springsnail before we are able to minimize these assumptions and uncertainties.

1.4.4 Review History:

This is the first 5-Year Review for the species.

1.4.5 Species' Recovery Priority Number at start of 5-year review:

2, reflecting taxonomic classification as a full species, and that threats to the species are both imminent and high in magnitude.

1.4.6 Recovery Plan or Outline

Name of plan or outline: Not applicable
Date issued:
Dates of previous plans or outline, if applicable: Not applicable

2.0 REVIEW ANALYSIS

Section 4 of the Act (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species meets the definition of "endangered species" or "threatened species." The Act defines an "endangered species" as a species that is "in danger of extinction throughout all or a significant portion of its range," and a "threatened species" as a species that is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The Act requires that we determine whether a species meets the definition of "endangered species" or "threatened species" due to any of the five factors described above.

The identification of any threat(s) does not necessarily mean that the species meets the statutory definition of an "endangered species" or a "threatened species." In assessing whether a species meets either definition, we must evaluate all identified threats by considering the expected response of the species, and the effects of the threats—in light of those actions and conditions that will ameliorate the threats—on an individual, population, and species level. We evaluate each threat and its expected effects on the species, then analyze the cumulative effect of all of the threats on the species as a whole. We also consider the cumulative effect of the threats in light of those actions and conditions that will have positive effects on the species—such as any existing regulatory mechanisms or conservation efforts. The Service recommends whether the species meets the definition of an "endangered species" or a "threatened species" only after conducting this cumulative analysis and describing the expected effect on the species now and in the foreseeable future.

2.1 Updated Information and Current Species Status

2.1.1 Biology and Habitat

2.1.1.1 New Information on the species' biology and life history:

The Three Forks springsnail is a narrow spring-ecosystem endemic species. With a shell height (length) ranging from 0.06 to 0.19 inches (in) (1.5 to 4.8

millimeters [mm]), the Three Forks springsnail is variable in size. More specifically, the springsnail has an ovate- to narrowly conic shape and 3.5 to 5.0 whorls. The early protoconch (top of the shell) is very weakly punctate (only a few dots/tiny holes), with the latter portion of the shell smooth or with faint spiral lines. The whorls following the protoconch are rarely shouldered and slight to moderately convex. The aperture (central opening of the shell) connects to the body whorl. The inner lip of the aperture is complete and thin. The outer lip is slightly forward. The umbilicus is nearly absent. The shell of the springsnail ranges from tan to green to black, and the operculum (plate that closes the opening of the shell when the snail retracts) is ovate and amber in color (Hershler 1994 p. 68-69). Examination of reproductive organs or molecular analysis are required to verify the species' identity (Hershler et al. 2014 p. 694). For a more detailed description and thorough review of Arizona hydrobiid snails' morphological characteristics, see Hershler (1994) and Hershler and Ponder (1998).

In Hydrobiids like Three Forks springsnail, the sexes are morphologically separate, with females typically larger than males. Empirical and definitive observations of Three Forks springsnail reproduction are limited. Therefore, while there is a general insight into ecological conditions suitable for reproduction, species-specific information is limited, and any significant inter-specific variations of ecological requirements are unknown. In general, *Pyrgulopsis* species are dioecious (individuals with different sexes), where females are oviparous (egg-laying) (Hershler et al. 2014 p. 694), and reproduction appears to occur throughout the year in warm water and seasonally in colder environments (Mladenka and Minshall 2001 p. 209). Inference of the high altitude and cooler spring temperatures (59° Fahrenheit [°F] or 15° Celsius [°C]) would suggest the Three Forks springsnail is a seasonal breeder. However, we do not know if other environmental cues such as photoperiod, water temperature, water quality, or food availability, could affect breeding. Given their similar environments, we infer from the Page springsnail that the Three Forks springsnail may have a peak reproductive period from mid-August through September. This inference is additionally supported by observations of possible juvenile Three Forks springsnails (Pearson et al. 2014 p. 65) and a potential "die-off" of Three Fork springsnail adults that starts in September.

While juvenile Three Forks springsnails have been observed in captivity at the Phoenix Zoo, egg laying, and development have not yet been observed. Based on observations of single egg laying by the Page springsnail, we assume that the Three Forks springsnail also lays single eggs. Laboratory observations of the Page springsnail also showed females laying one egg approximately every eight to 10 days (Pearson et al. 2014 p. 66). We are, however, uncertain whether the Three Forks springsnail follows a similar trend.

For many Hydrobiids, the larval stage of the organism occurs in an egg capsule, and upon hatching, tiny snails crawl out into their adult habitat (Brusca et al.

1990 p. 759, Hershler and Sada 2002 p. 256). Based on this information, we assume that completion of the entire larval stage for the Three Forks springsnail would also occur within the egg.

Pearson *et al.* (2014 pp. 66–67) observed the development rate of Page springsnails in a laboratory setting, noting that growth was rapid during the first two weeks, but reduced as snails approached adult size. Wells *et al.* (2012 p. 73) also observed in a laboratory setting that it took six to seven weeks for Page springsnails to reach full maturity. Given the similarities of the environment between the Page and Three Forks springsnail (dry arid climate, variable precipitation), we assume that the Three Forks springsnail develops at a similar rate. The lifecycle of the Three Forks springsnail is represented below in Figure 1.

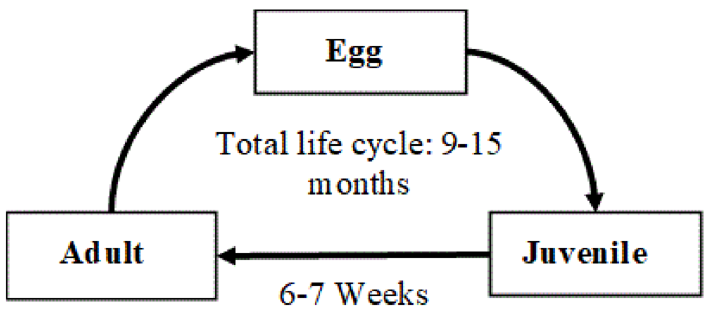

Figure 1. Life cycle of the Three Forks springsnail from egg to juvenile to adult, which all occurs within 9-15 months. Diagram from the draft SSA.

Studies on the survival, growth, and longevity of the Three Forks springsnail have not yet occurred. General insights related to Hydrobiids indicated that lifespan is about one year, and adults can overwinter by burrowing in sediments (Lysne and Koetsier 2006 p. 235, Lysne et al. 2007 pp. 649–650, Pearson et al. 2014 p. 64). For most aquatic gastropods, lifespan is usually nine to 15 months (Pennak 1989 p. 552). Survival of one species from the genus *Pyrgulopsis* in the laboratory was nearly 13 months (Lysne et al. 2007 p. 650). Therefore, we conclude that an average lifespan of one year is a reasonable estimate for the Three Forks springsnail (Figure 1).

We do not know if the Three Forks springsnail exhibits burrowing behavior, but if they do, it may allow them to survive at ephemeral sites like other mollusks (Lysne and Koetsier 2006 p. 235, Pearson et al. 2014 p. 64). However, the duration of a dry period that a springnail may survive is unknown. Understanding any potential burrowing behavior during a dry period would be helpful to determining conservation implications of habitat changes for the species because, given the springsnails's size and restriction to spring systems, significant dispersal events likely do not occur if habitat becomes temporarily unsuitable. Limited dispersal of aquatic snails has occurred via attachment to the feathers of migratory birds (Roscoe 1955 p. 66, Dundee et al. 1967 pp. 89–

90, Wesselingh et al. 1999, van Leeuwen and van der Velde 2012 pp. 967–970) and stochastic events such as floods may assist with reintroductions and dispersal (Piorkowski and Diamond 2015 p. 27). Given the information available however we conclude that such dispersal events are infrequent and cannot be relied upon for any site colonization or significant genetic flow.

2.1.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, birth rate, seed set, germination rate, age at mortality, mortality rate, etc.), or demographic trends:

Because of the short life span of the Three Forks springsnail, abundance at a population-site can fluctuate from year to year. By plotting the last five surveyed years however, we have determined general fluctuations in abundance. We have evaluated 26 sites for Three Forks springsnail occupancy. Of these sites, none showed high condition (positive trend line with no more than one decline in abundance); seven showed moderate condition (positive trendline with two or more declines in abundance); and five showed low condition (negative trendline regardless of number of declines in abundance). The remaining sites are either considered extirpated (11) or are of unknown historical occupancy (3).

Demographic features, such as sex ratio, birth rate, and demographic trends are currently unknown for this species.

2.1.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

As a relic of the Pleistocene Epoch, the *Pyrgulopsis* genus is assumed to be resilient to disturbance and localized reductions in abundance given its persistence over geologic time. High reproductive and recruitment rates within populations and resilience to the adverse effects of genetic bottlenecking following population dips likely attribute to this resilience (Martinez and Sorensen 2007 p. 31, U.S. Fish and Wildlife Service 2015 p. 16). Although their natural history suggests species in *Pyrulopsis* are fairly resilient, they are still susceptible to effects of genetic drift and bottlenecking (Johnson 2005 pp. 2307–2308). We assume these attributes are the same for the Three Forks springsnail; however, few species-specific genetic studies have been done. Studies completed in 2003 and 2007 compared genetics in the Three Forks Springs complex to Boneyard Bog (Hurt and Hedrick 2003 p. 16, 2007 p. 27) while those completed in 2012 identified a unique haplotype in springsnails at Lopez Spring (Myers and Varela-Romero 2012 p. 32). The 2012 study suggested that springsnails from Lopez Springs are the closest genetic neighbor to those formerly at the Three Forks Spring complex and would be the preferred source population for reintroductions into extirpated sites (Myers and Varela-Romero 2012 p. 32). Overall, haplotypes and the genetic distances between these populations are unknown. Likewise, the genetic relatedness of other populations along Boneyard Creek is unknown because those springsnails populations are too small in number to provide a sufficient sample size for genetical testing.

2.1.1.4 Taxonomic classification or changes in nomenclature:

As noted above, the Three Forks springsnail is a member of the genus *Pyrgulopsis* in the family Hydrobiidae. Springsnails are relicts of the Pleistocene Epoch (2.5 million to 10,000 years ago), an era when the Southwest was much wetter. It is one of approximately 170 known species of Hydrobiid snails in the United States, and one of 13 described species in the genus *Pyrgulopsis* that occur in Arizona (Hurt 2004 p. 1176). The Three Forks springsnail, initially described as *Fontelicella trivialis* by Taylor (1987 pp. 30–32), was later described as *Pyrgulopsis confluentis* by Hershler and Landye (1988 pp. 32–35) from a spring-fed pond at Three Forks, Apache County, Arizona. The species was renamed again to *Pyrgulopsis trivialis* by Hershler (1994 pp. 68–69). We have carefully reviewed the available taxonomic information and conclude that *P. trivialis* is a valid taxon. The currently accepted classification is shown in Table 1.

Table 1. Three Forks springsnail taxonomy.

Class	Subclass	Family	Genus	Species
Gastropoda	Rissooidea	Hydrobiidae	*Pyrgulopsis*	*Pyrgulopsis trivialis*

Taxonomic research has not been conducted on all sites we consider occupied for the species. However, until this research occurs, we assume that all currently identified sites are the Three Forks springsnail, given the sites' proximity within a single watershed and drainage.

2.1.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, pollinator availability, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

The known historical range of the Three Forks springsnail was limited to the Three Forks complex, a series of five different springheads and spring runs along the East Fork of the Black River in the White Mountains on the Apache-Sitgreaves National Forests. Surveys in this area leading up to 2003 showed signs of decline. The last documented springsnails in the complex occurred in 2003, and the complex is now considered extirpated. Based on the species' life history, the historical range also included the then unknown Boneyard Creek and Boneyard Bog Complexes. Furthermore, it is not unreasonable to consider that the historical range also included sites within this drainage that were extirpated before the springsnails surveys were completed.

The current range of the Three Forks springsnail includes 26 springs and seeps along Boneyard Creek and its confluence with the North Fork and East Fork of the Black River in the White Mountains on the Apache-Sitgreaves National Forests (Figure 2). The current range can be broken up into three geographically distinct complexes: the Three Forks complex; the Boneyard Creek complex; and the Boneyard Bog complex. Each of these spring complexes occurs in shallow canyon drainages or open mountain meadows at 8,200 feet (ft) (2,500 meters [m]) in elevation. The entire range of the springsnail, encompassed within 3.7 miles (mi) (6 kilometers [km]), is along perennial waterways. This current range includes the Boneyard Bog Complex, the Boneyard Creek Complex, and the Three Forks Complex. The Three Forks complex is included despite being considered as locally extirpated since 2003 when springsnails were last documented (U.S. Fish and Wildlife Service 2012, Martinez and Sorensen 2016). The Boneyard Creek Complex includes the Lopez Spring population, with the closest haplotype to the Three Forks Complex haplotype. However, the Lopez Spring population has shown consistent signs of decline, with only one springsnail found in 2019 (Unpublished AGFD Surveys, 2019).

- **Three Forks Complex**

The Three Forks Springs Complex includes five different springs and spring runs, spring seeps, and a spring-fed pond, all of which flows a short distance to the Black River (Figure 2). The complex also includes a small amount of upland area, approximately 3.3 ft (1.0m) in width, which encircles the springhead, runs, seeps, and the creek, creating a contiguous area of approximately 6.1 ac (2.5 ha) in Apache County, Arizona. The entire complex is in Federal ownership and managed by the Apache-Sitgreaves National Forests. The various spring runs, Boneyard Creek inflow, and meeting of the North and East Forks of the Black River provide habitat connectivity to other features within the complex.

The Three Forks Springs Complex is currently unoccupied. Three Forks springsnails were first documented there in 1973 (Landye 1973 p. 49) and were last documented in 2003 (Martinez and Sorensen 2016). Leading up to 2003, crayfish were first found at Three Forks Springs Complex in 1993, and by 2000 had become established in that complex and nearby waterways (Fernandez and Rosen 1996 pp. 10–12, Myers 2000). Additionally, in 2004, it is suspected that the waters became contaminated by wildfire suppressant chemical deposition that drifted into the complex during the management of the Three Forks Fire. Fire retardant chemicals can be toxic to aquatic organisms; however, they become nontoxic within a few days of contact with water. These reactions are discussed in greater detail below.

Currently, the Three Forks Springs Complex contains all of the habitat features and functions to allow the springsnail to persist except for the high density of invasive crayfish. In 2014, AGFD with the U.S. Forest Service (USFS), USFWS, The Nature Conservancy, Phoenix Zoo, and the National Wild Turkey Foundation conducted alterations to Three Forks Spring Box 2. Subsequent surveys suggest successful elimination of crayfish from this spring box. Similar alterations for the other spring boxes and spring run sites could be beneficial to this complex. We consider the Three Forks Spring Complex necessary for the conservation of the species because: (1) It can support all of the Three Forks springsnail's life processes, (2) the geographic area occupied at the time of the final listing rule is not sufficient for recovery, and (3) it increases the species' population redundancy. The primary threats in this complex are crayfish and overgrowth of vegetation in modified spring boxes. The range-wide threats, like contamination from fire retardant, drought, also occur.

- **Boneyard Creek Complex**

The Boneyard Creek Springs Complex consists of 11 springs, spring runs, and spring seeps, which are all connected by Boneyard Creek. The complex also includes a small amount of upland area, approximately 3.3 ft (1.0 m) in width, on each side of the springhead, runs, seeps, and the creek which creates a single, contiguous area of approximately 5.8 ac (2.3 ha), in Apache County, Arizona. The entire complex is in Federal ownership and managed by the Apache-Sitgreaves National Forests. Of the 11 springheads in the complex, seven are along Boneyard Creek and four are located at Lopez Spring. Boneyard Creek ensures habitat connectivity and provides the only means of springsnail movement downstream.

The Boneyard Creek Springs Complex, currently occupied, contains all the habitat functions and resources essential for the persistence of the species apart from an encroaching crayfish population.

<u>Lopez Spring</u>

Lopez Spring is a part of the Boneyard Creek Complex because it shares the same drainage and Boneyard Creek provides connectivity among populations. However, we describe it separately here because a 2012 genetics study found that the springsnail haplotypes at this site are likely the closest genetic neighbor to the extirpated Three Forks Springs Complex snails (Myers and Varela-Romero 2012 p. 32). Lopez Spring contains four of the 11 springheads in the Boneyard Creek Complex. All four features (springheads and spring runs) are comprised predominantly of pebble or cobble substrates and watercress as the dominant vegetation. Flow and depth at the majority of springheads is low, with an average depth of 0.8 inches (2 cm).

- **Boneyard Bog Complex**

Connected by Boneyard Creek, the Boneyard Bog Complex comprises nine springs, spring runs, and spring seeps that are monitored regularly. The complex also includes a small amount of upland area, approximately 3.3 ft (1.0 m) in width, on each side of the springhead, runs, seeps, and the creek which creates a contiguous area of approximately 5.8 ac (2.3 ha), in Apache County, Arizona. The entire complex is in Federal ownership and managed by the Apache-Sitgreaves National Forests. The Boneyard Bog Complex provides for springsnail movement downstream and is necessary for habitat connectivity.

Currently occupied, the Boneyard Bog Complex contains all the habitat functions and resources essential for the persistence of the species; however, there is an encroaching crayfish population.

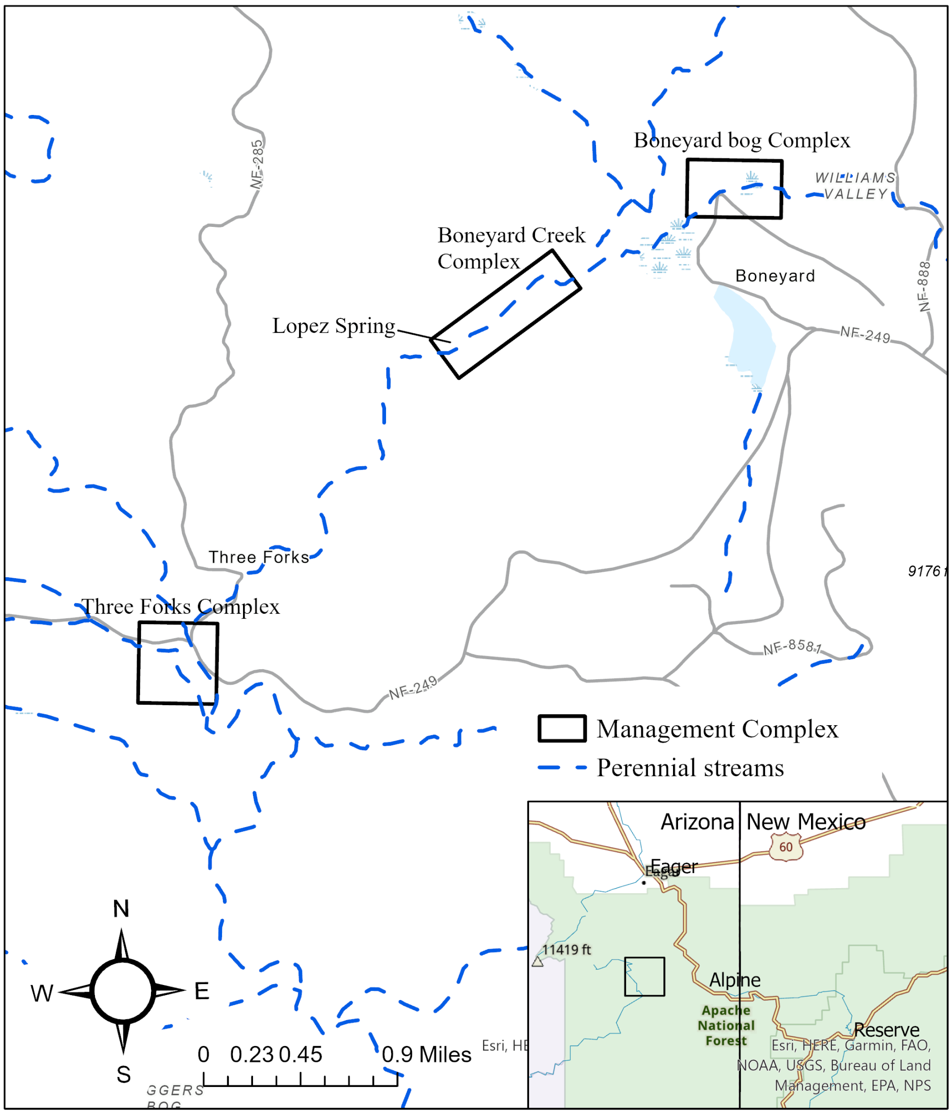

Figure 2 Range of the Three Forks springsnail with population complexes.

2.1.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

The Three Fork springsnail is typically found in areas with free-flowing springheads, concrete boxed springheads, spring runs, spring seeps, and shallow ponded water (Figure 3; (Martinez and Myers 2008 p. 189). The springsnail is associated with gravel and pebble substrates, shallow water up to 2.4 in (6 cm) deep, high conductivity, alkaline waters with a pH of 8, and low numbers of pond snails (*Physa gyrina*) (Martinez and Myers 2008 pp. 189–194). Furthermore, springsnail density is greater in water depths less than 2.2 in (5.6 cm), where the density of pond snails is less than 5.5 per square yard (yd^2) (4.6 per square meter[m^2]), and where the distance from the springhead is less than 2.6 ft (0.8 m). Although research indicates the species exhibits higher density in shallower water, the species does not appear to be intolerant of deeper ponded water. The habitat features most important to the Three Forks springsnail, based on our understanding of their life history and ecology, include:

1. Adequately clean spring water (free from contamination) emerging from the ground and flowing on the surface;
2. Periphyton (attached algae), bacteria, and decaying organic material for food;
3. Substrates that include cobble, gravel, pebble, sand, silt, and aquatic vegetation, for egg-laying, maturing, feeding, and escape from predators; and
4. Either an absence of nonnative predators (crayfish) and competitors (pond snails) or their presence at low population levels.

Results obtained by Martinez and Rogowski (2011) support the hypothesis that in the wild, distance from spring vents correlates with the number of springsnails. They found that depth of water, distance from the springhead, and pH explained 36.1% of the variance in density of springsnails. Springsnail density began declining after 0.8 meters from the springhead, and when water depth was greater than 5.6 cm (Martinez and Rogowski 2011 p. 218). In 2015, research by Piorkowski and Diamond on the Huachuca springsnail, found in the Huachuca Mountains of southern Arizona, further supported this finding. In this instance, Huachuca snails were not present more than 39.4 ft (12 m) from a spring vent (Piorkowski and Diamond 2015 p. 16). This study, as well as research conducted by Hershler (2014 p. 698), emphasized that habitat characterized by minimal competition and predation by invasive species has a positive effect on springsnail populations. This was also supported by Piorkowski and Diamond's findings in 2015 (2015 p. 17).

Figure 3. Habitat photos of both a modified springbox and artisanal spring.

2.1.1.7 Conservation Measures:

Current conservation measures include annual surveys, which involve opportunistic crayfish removal, and the modification of the Three Forks springs complex springboxes to prevent crayfish access and establishment.

2.1.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms):

2.1.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

Human caused impacts to Three Forks Springsnail habitat and range include wildland fire chemical products, and trampling and grazing (both from wildlife, feral horses, and livestock).

Wildland Fire Chemical Products

Land management agencies use wildland fire chemical products to assist in fire suppression efforts. These products, which include suppressants and retardants, reduce fire intensity and rate of spread, decreasing risks to firefighters and property. Application of the products can be manual or through aerial drops. The application method greatly influences the area of exposure. Increased use of wildland fire chemical products is expected as wildlife frequency and intensity increase.

The USFS has approved three types of wildland fire chemical products for use: long-term fire retardants, Class A foam suppressants, and water enhancers (USFS 2007). Long-term fire retardants, comprised of retardant salts (ammonium salts-typically industrial strength fertilizers), alter the way a fire burns and decrease fire intensity even after the water contained in the retardant has evaporated. Class A foam suppressants contain foaming and wetting agents which are similar to dish soap. This combination slows a fire's growth by enhancing water penetration into fuels. Water enhancers contain ingredients that alter the water allowing it to cling better to vertical and smooth surfaces, increasing its effectiveness and adhesion to fuels (USFS 2007). Some ingredients found in fire suppressing chemicals include ammonium phosphate, ammonium polyphosphate (sources of nitrogen and phosphorus), guar beans, xanthan gum, calcium phosphate, color pigments (red iron oxide or other die), and other corrosion inhibiting additives (USFS 2007). Long-term retardants and Class A foam suppressants have both been associated with negative environmental impacts. These impacts have included harming and killing vegetation, nitrate poisoning in animals, and killing fish or other aquatic organisms (Gaikowski et al. 1996 pp. 1368–1373, Little and Calfee 2002 pp. 15–22, USFS 2007). Given the potential impacts, guidelines are in place that outline avoidance areas for aerial applications and reporting and monitoring requirements (USFS 2019 pp. 11-19, 35-43). Although avoidance is preferred, direct application to waterways may be authorized in certain circumstances (USFS Forest Service 2019 p. 24), which could result in direct waterway effects. There is also the potential that circumstances of a fire, such as the proximity to a waterway and terrain, may result in retardants entering the waterway indirectly through environmental drift or runoff. It is believed that indirect environmental drift of wildland fire chemical products used for the 2004 Three Forks Fire contributed to the extirpation of the Three Forks springsnail in the Three Forks Springs Complex (Calfee and Little 2003 p. 1525).

The forested areas in which Three Forks Springsnail occurs, coupled with the increasing frequency of moderate to high intensity fires and the restricted range of the springsnail suggest that wildland fire chemical products, including both suppressants and retardants, pose a significant threat to the Three Forks springsnail.

Trampling and Grazing

Trampling and grazing from feral horses, burros, wildlife, and livestock have been described as stressors to springsnails and other spring-invertebrates in various parts of Arizona and the southwest. Trampling and grazing generates sediment, can erode springhead banks and channels, and potentially causes direct mortality from crushing (Folsom and Sorensen 2018 p. 8, Pagowski and Sorensen 2018 p. 15). However, there is also concern that a lack of grazing and foraging due to fencing of springheads and runs can also lead to habitat degradation as vegetation becomes overgrown, which can reduce spring flow (Folsom and Sorensen 2018 p. 10). In marshy spring systems a marked decrease in plant diversity was observed when grazing was removed indicating that light grazing helps maintain plant diversity (Allen-Diaz et al. 2004 p. 146, Jackson and Allen-Diaz 2006 p. 496). Ungrazed systems also show an impaired ability to retain nitrate due to accumulation of dead plant matter, which inhibits new plant growth (Allen-Diaz et al. 2004 pp. 146–147).

We do not consider stress from grazing a factor for the Three Forks springsnail at this time. Historically occupied sites at the Three Forks Complex are either cement springboxes or rocky substrate that is not likely to erode from occasional feral horse, burro, wildlife, or livestock use. The majority of springs and spring runs along Boneyard Creek are enclosed by elk-fencing which prevents access, and while evidence of grazing (hoof prints) have been observed in the Boneyard Bog area, impacts to the spring heads and spring runs has been limited. There is concern that the vegetation within the enclosures could become overgrown and inhibit available spring flow and thus suitability to the springsnail. Research is needed to determine the impacts from grazing and trampling, and grazing exclusions to inform management of these systems.

2.1.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

This is not considered a stressor for the species.

2.1.2.3 Disease or predation:

Nonnative species pose one of the most significant threats to flora and fauna globally, as they often outcompete or prey upon native species, and have higher tolerances to disturbance and higher reproductive capacities than native species. Crayfish and New Zealand mud snails (*Potamopyrgus antipodarum)* are of particular concern to Three Forks springsnail.

<u>*Crayfish*</u>

Crayfish reduce species diversity and destabilize food chains in riparian and aquatic ecosystems through their effect on vegetative structure, stream substrate (*i.e.*, silt, sand, cobble, boulder) composition, and predation on eggs, larval, and adult forms of native invertebrate and vertebrate species Fernandez and Rosen (1996 p. 3). Crayfish threaten theThree Fork springsnail by preying on all springsnail life stages and decreasing habitat quality (Lodge and Lorman 1987 p. 594, Hanson et al. 1990 pp. 73–77, Lodge et al. 1994 p. 1276). In addition, by grazing on aquatic and semiaquatic vegetation, crayfish alter the abundance and structure of aquatic vegetation, which reduces cover and affects forage quality for aquatic herbivores (Lodge and Lorman 1987 p. 594, Fernandez and Rosen 1996 pp. 10–12). Filamentous algae (*Cladophora glomerata*), an important component of aquatic vegetation that provides cover and microhabitat for aquatic species, is at least 10-fold greater in aquatic habitats that lack crayfish (Creed 1994 p. 2098). Crayfish also burrow into stream banks which increases bank erosion, stream turbidity, and siltation of stream bottoms (Fernandez and Rosen 1996 pp. 10–12). The resulting substrate conditions can result in springsnail, or other small aquatic snails, becoming buried in the altered substrates.

Where crayfish overlap with the Three Forks springsnail, crayfish populations have a noticeable influence on springsnail populations. In 1996, a controlled environment study reported crayfish consumption of all pond snails and eggs within a week, and a significant reduction of vegetation and other invertebrates within thirteen days, resulting in elimination of snails in four out of five tanks (Fernandez and Rosen 1996 p. 25). As crayfish invade the Three Forks springsnail's range they outcompete the springsnail for food resources and prey on springsnails themselves, and substantial reductions in springsnail populations have been documented. For example, abundant populations of the Three Forks springsnail at Lopez Spring experienced sudden declines following initial documentation of crayfish presence (J. Sorensen AGFD, pers. comm 2020). Unfortunately, crayfish have since moved further up Boneyard Creek and are now present in Boneyard Bog. The exact year crayfish became established in Boneyard Bog is uncertain, but it is generally accepted to have been in the early 2000s. Modifications to springboxes in the Three Forks Spring Complex have shown success in preventing crayfish establishment (Sorensen and Lerich 2015). Expansion of such conservation measures may prove essential to Three Forks springsnail recovery. Erman (2002 p. 9) suggests that mechanical obstruction or removal of non-native species is needed to conserve rare and/or endemic spring species, however, cautions that total eradication is usually an unobtainable objective and may cause more harm than good. Although more research is needed to fully understand the ecological relationship between crayfish and the Three Forks springsnail, the best available scientific and commercial information strongly suggests that crayfish are a significant threat for the springsnail and its habitat.

New Zealand mudsnail

The New Zealand mudsnail can reach high densities very quickly, has high tolerance to physical disturbance, and has a high invasion potential because of its viviparous reproductive strategy (Lysne and Koetsier 2008 p. 108, Oliver et al. 2021 p. 1). New Zealand mudsnails likely outcompete native springsnails for periphyton and exhibit faster growth rates in areas with native springsnails presence, while native springsnails exhibit slower growth rates when New Zealand mudsnails are present (Riley et al. 2008 p. 517). Currently, New Zealand mudsnails are not present within or near the range of the Three Forks springsnails, however, the potential for this non-native species to become introduced into creeks and spring runs is possible as they have been detected upstream of the community of Whiteriver, approximately 36 mi (60 km) from the Three Forks springsnail (Findley et al. 2021 p. 3). If New Zealand mudsnails are introduced into Three Forks springsnail habitat, recent research suggests that establishment of New Zealand mudsnails within Three Forks springsnail habitat complexes is unlikely. Water in Three Forks springsnail habitat has low specific conductivity near the thresholds (~100 uS) known to reduce growth and fecundity of the New Zealand mudsnail (Herbst et al. 2008, Larson et al. 2020). Additionally, application of a copper-based molluscicide is an effective eradication technique for mudsnails. One hundred percent (%) mortality, however, occurs for all mollusks (native and non-native) and chronic low doses are needed to avoid impacts to fish (Oliver et al. 2021 p. 7).

2.1.2.4 Inadequacy of existing regulatory mechanisms:

The existing regulatory mechanisms, such as the species being classified as endangered, as well as being on the State of Arizona's list as a species of greatest conversation concern are, thus far, sufficient for the protection of the Three Forks springsnail, and its critical habitat.

2.1.2.5 Other natural or manmade factors affecting its continued existence:

Climate change drives numerous stressors that negatively impact Three Forks springsnail habitat, thus impacting species demography and population viability. Below we discuss the stressors resulting from the overarching source of climate change. These stressors include drought, wildfire, contaminants, and flooding and erosion/deposition. All of which can be linked to climate change.

Drought

The National Climate Assessment indicates that the southwestern United States will continue to get hotter and drier into the future (Garfin et al. 2014 pp. 464–466). From 2000 to 2020, average temperatures for northeastern Arizona have differed from the long-term average by an increase of 1.4 to 1.6° F (approximately 17° C) and the region has been abnormally dry, experiencing increased moderate to severe drought conditions (U.S. EPA 2016).

The Three Forks springsnail requires spring environments that have sufficient flow volume to complete their life history. Sufficient flow removes fine grain sediments, allowing for the growth of periphyton on hard substrates and providing suitable egg-laying sites. Springs are 'recharged' from two possible sources to support discharge, the first being groundwater and the second being precipitation and snowpack melt. Because springflow can be dictated by the depth to groundwater, and groundwater fluctuations, understanding the yield of groundwater-outflows can be informative. However, quantification of groundwater data for the Black River sub-basin of the Salt River-Highland

Basin Hydrological Unit (Stitzer et al. 2009 p. 137) has not occurred. Wells in this sub-basin though are typically low yielding with an average depth of 500 ft (152 m). For example, a nearby well was estimated to have yields less than 100 gallons per minute (379 liters per minute) (Stitzer et al. 2009 p. 8). The Black River Sub-basin is comprised of volcanic rocks (basalt flows, rhyoltic ash flows, tuffs and tuffaceous agglomerates) with depths up to or exceeding 3,000 ft (914 m) in some areas (Stitzer et al. 2009 p. 8). Therefore, because of the porous nature of the volcanic rocks, recharge of the aquifer under this sub-basin happens through infiltration of precipitation through the ground, with the highest amount of precipitation occurring in the winter and summer. Between 1961 and 1990, the average annual precipitation was 24 to 26 inches (61-66 cm) (Stitzer et al. 2009 p. 126). Avery and Soles (Avery and Soles 2003 p. 65) found that the springs within Three Forks springsnail historical range are reliant more on precipitation and snowmelt than groundwater upwelling.

Because flow in these springs is dependent on precipitation and groundwater recharge, drought could influence the species persistence. Levels of precipitation and snowmelt are subject to variation under climate change projections (Wieder et al. 2022 p. 6). Recent studies have noted that there is in an increase in the fraction of winter precipitation falling as rain, rather than snow in the lower elevations (maximum of 8,000 ft [2,438 m] elevation). Decreases in the amount and distribution of spring runoff is likely if this trend continues at elevations of 8,000 ft (2,438 m) or higher (Stitzer et al. 2009 p. 21). These changes would shift the streamflow to earlier in the year, resulting in a decrease in summer flows, which are already typically low. A change from snow to rain would spread the water availability more evenly throughout the year but could result in an increase in evapotranspiration and less time and water to recharge the aquifer (Longley 2017 p. 3).

While it sounds counterintuitive, drought could also increase the potential for flooding (Seneviratne et al. 2012 p. 113). As evapotranspiration increases and infiltration decreases, soils become more prone to runoff, resulting in flooding events following higher precipitation events (Seneviratne et al. 2012 p. 118). Climate change models also suggest that useable water (runoff plus recharge) will decrease (Longley 2017 p. 8), over-land precipitation may decrease by 2%, and evapotranspiration may increase by 2% (Arora and Boer 2001 p. 338). If precipitation and snowmelt drop to levels that cause springs to become ephemeral, then Three Forks springsnail populations could lose resiliency or be extirpated due to desiccation. Because the entire range of the species is within 3.7 miles and within a single drainage, multiple springs may be affected in one season.

Wildfire

In the western United States, drought driven by climate change is altering natural fire regimes, with wildfires becoming more frequent, larger, and more severe (Westerling et al. 2006 pp. 940–943, Singleton et al. 2019 p. 712). In 2011, the Wallow Fire burned 217,741 ac (88,116 ha) in Arizona and New Mexico, encompassing the entire known range of the Three Forks springsnail. High severity fire burned 48% of the dry mixed-conifer forest within the Wallow Fire perimeter. This percentage is higher than the historical norm for this forest type and increases the potential for erosion and flooding (Roccaforte 2013 p. 13).

Moderate- to high-intensity wildfires have the potential to encompass the entire range of the Three Forks springsnail (Martinez and Sorensen 2016 p. 3) and scorch the soils, which leads to erosion, flooding, changes in water chemistry, and higher silt concentrations (Ice et al. 2004 p. 20, Parise and Cannon 2012 pp. 219, 221). Indirect effects of fire, such as erosion, flooding and reduced water quality, are stressors on the Three Forks springsnail. Generally, undisturbed or lightly-burned forest soils have relatively high infiltration rates (Moody and Ebel 2012 p. 62). Moderate- to high-intensity wildfires, however, can reduce infiltration by exposing mineral soils to raindrop impact that can seal soil pores at the surface. This soil sealing occurs when soils are heated during exposure to high intensity fire. The heat pulse into the soil from a wildfire will first drive off water occupying larger pores, which control the gravity-dominated stage of infiltration, within hours. Continued heating drives off water from smaller pores associated with the early capillary-dominated state of infiltration within minutes. Sufficient heat can drive off all the bound water contained in inter-aggregate and intra-aggregate pores, creating hyper-dry conditions equivalent to oven-dry soils (Moody and Ebel 2012 p. 59). These hyper-dry, water-repellent soils must first rewet before water repellency is decreased sufficiently to permit capillarity and gravity-dominated infiltration. Rewetting requires either that water pressure exceeds the water-entry pressure or there is an extremely long contact time (Moody and Ebel 2012 p. 59). Overall, soil sealing compounds water repellency and reduces evapotranspiration because of the loss of vegetation, resulting in dramatic changes in both annual and peak streamflow and likelihood of flooding (Ice et al. 2004 p. 18). In a 2012 study, burned soils became virtually impenetrable because of the “perched water table” at the ash-soil interface (Ebel et al. 2012 p. 10). Ash thickness controls infiltration, acting as a barrier that controls the initial rewetting of the soil by the diffusion-absorption process. This layer of ash, incorporated into the soil by bioturbation or removed by wind or runoff, is temporary. Post-wildfire, water quality is reduced, and elevated nutrients such as nitrogen, phosphorus, and calcium, magnesium, and potassium concentrations are often observed. Over time, as soils stabilize and vegetation recovers, nutrient concentrations typically return to pre-fire levels (Ice et al. 2004 p. 18). There is also evidence that ash, when mixed with water, creates a high pH solution (Parise and Cannon 2012 p. 219), which could result in the water becoming too alkaline for springsnails to survive.

Flooding

Climate change may have effects on precipitation, discussed in "*Drought*" above, that are expected to alter the timing and type of precipitation received at elevations at or below 8,000 ft. This is expected to result in a more even distribution of water throughout the year. However, this could also result in increased evapotranspiration, less time and water to recharge aquifers (Longley 2017 p. 3), and potentially increased flooding because soils would be unable to sufficiently absorb precipitation before runoff occurs (Seneviratne et al. 2012 pp. 113, 118). In addition to this increased risk of flooding, there is an increased risk of erosion due to post-fire flooding caused by soils that become hydrophobic.

Erosion, both from heavy rain events that result in flooding, or from rains following a higher-severity wildfire, contribute deposition of silt and sand to waterways. For aquatic species, the availability of substrate can dictate the availability of food, breeding habitat, and shelter from predators. Springsnails require hard substrates like pebbles and cobble, as well as vegetation, to adhere to for feeding, breeding, and egg laying. Too high a content of silt or sand limits the ability of springsnails to meet their dietary and reproductive needs. It is thought that high silt-sand concentrations may also impede springsnail movement, however, applicable research has not occurred. A number of factors determine silt-sand content in a spring system, but a primary factor is rate of spring flow. However, even when spring flows are adequate, an increase in silt and sand due to post-fire flooding may limit habitat suitability for the Three Forks springsnail. With increased erosion from flood waters normal flows may be inadequate to remove silt and sand, which then settle and accumulate, minimizing available hard surfaces. Because of this, a potential flood event could reduce a populations resiliency if spring flow is not sufficient to remove these fine-particulate deposits.

Population Size

Finally, small population size is considered a stressor to the species. Population size typically influences the ability of a species to recuperate after a stochastic event and be resilient to genetic bottlenecking that occurs from inbreeding. In this way, a sustainable population is best described as a population with the numbers that enable it to recover after an event where individuals are lost and have a greater genetic structure to prevent inbreeding. However, we do not currently have enough genetic information to know if we should focus on maintaining the resiliency of existing populations or focus on homogenizing populations to reestablish gene flow and extirpated populations. We recognize that maintaining genetic and ecological diversity (representation) and multiple populations distributed across the range (redundancy) is necessary for the species to adapt to changing physical and biological conditions (resiliency); however, we are concerned that the limited number of currently occupied sites will influence the species' overall viability. Research to understand the population size needed for sustainability over time has not yet occurred;

however, field studies and the establishment of a captive population of Huachuca springsnails at the Phoenix Zoo indicate that a minimum of 200 springsnails is needed to either maintain or establish a self-sustaining population. This minimum estimate, coupled with the endemic nature of the springsnails genus, indicates that springsnails are likely inherently resistant to genetic bottlenecking and able to recover following the loss of some individuals. In a 2001 study, a USFWS biologist removed 1,776 Page springsnails from a small (<2.5 m^2 area) endemic spring over the course of four months. The population had recovered by the following year, indicating that springsnails may exhibit high fecundity and recruitment rates (Martinez and Sorensen 2007 p. 31), though the study recommended not removing this many individuals from a population without replacement.

Historically, multiple Three Forks springsnail populations were consistently above the minimum 200 with some populations reaching survey counts of over 1,000 in the early 2000s (Martinez and Sorensen 2016 pp. 13–22). However, after crayfish became present at a population, subsequent survey counts significantly dropped. Many populations are now considered small, or consistently below 200 individuals, making them more susceptible to adverse effects from crayfish or other stochastic events. However, it should be noted that because of the small and cryptic nature of the species, we recognize that surveys are not likely detecting a substantial number of snails, meaning that a population that is consistently considered small may, in fact, be more robust.

2.2 Synthesis

The Three Forks springsnail continues to be at high risk of extinction due to the endemic nature of the species and its limited representation and redundancy across its range. The entire range of the species is considered protected because it is entirely on USFS owned land and is therefore not subject to groundwater pumping or habitat loss through development. However, the continued spread and presence of predatory crayfish, and increased climate change effects, including the threats of catastrophic wildfire and drought possibly leading to dewatering of the springs, contribute to this species being at high risk. Ongoing conservation actions include continued monitoring of the effects of these stressors and mitigation of them where possible, such as removal of crayfish from springs and installation of fences and flashing. Overall, however, given the continued presence and degree of threats to the species, we recommend the Three Forks springsnail remain listed as endangered.

3.0 RESULTS

3.1 Recommended Classification:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (*Indicate reasons for delisting per 50 CFR 424.11):*

____ *Extinction*
___ *Recovery*
____*Original data for classification in error*
_X_ No change is needed

3.2 New Recovery Priority Number (indicate if no change; see 48 FR 43098):

No change recommended.

Brief Rationale:

The species remains restricted to a select number of springs, and threats remain prevalent across the range.

3.3 Listing and Reclassification Priority Number, if reclassification is recommended (see 48 FR 43098):

Reclassification (from Threatened to Endangered) Priority Number: N/A
Reclassification (from Endangered to Threatened) Priority Number: N/A
Delisting (Removal from list regardless of current classification) Priority Number: N/A

Brief Rationale: N/A

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The establishment of a refugia population at the Phoenix Zoo is of high importance. This has proven to be an effective measure for the Huachuca springsnail and would allow for captive propagation of individual Three Forks springsnails for use in reintroduction to previously extirpated population-sites and augmentation of populations with lower abundance. Next, the continued protection of springs in the Boneyard Creek and Boneyard Bog complexes is needed. These protections could include the installation of flashing around the perimeter of the enclosure fences already present, or the installation of both fencing and flashing for those springs that are currently without protection. Finally, we recommend the movement of boulders to be by springs that are considered to be at higher risk of flooding and silt-inundation it is the hope that these boulders could offer a buffer to any oncoming flood waters and help divert those waters and runoff materials.

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U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW of Three Forks Springsnail (*Pyrgulopsis trivialis*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Nichole Engelmann, Fish and Wildlife Biologist

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service, Arizona Ecological Services Office

Approve HEATHER WHITLAW Digitally signed by HEATHER WHITLAW Date: 2022.08.31 07:42:27 -07'00'