United States Department of the Interior

U. S. GEOLOGICAL SURVEY

NEVADA WATER SCIENCE CENTER
160 North Stephanie Street
Henderson, Nevada 89074

April 18, 2017

U.S. Fish and Wildlife Service
Attention: Daniel Russell
2800 Cottage Way, Room W-2606
Sacramento, CA 95825

Dear Dr. Russell:

I have reviewed the 2017 Draft Species Status Assessment for 14 Nevada Springsnails. Overall, I found this SSA to be informative and well-written. Some information was repeated, which could be condensed into an appendix (i.e. Tetratech 2012) unless it is desired that each section is to be stand-alone. Of particular note, Manse Spring is flowing and has been flowing for at least several years, although it did go dry at one point in the 1970s. I do not know exactly when it began flowing again, but USGS measurements at the site as recently as 2011 can be obtained at this URL: https://waterdata.usgs.gov/nwis/measurements/?site_no=360919115541501

My other comments are contained within the Track Changes version of the text. Thank you for the opportunity to review this SSA.

Sincerely,

/s/
Megan E. Poff
Supervisory Hydrologist, USGS Nevada Water Science Center

COVER PAGE

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

ABBREVIATIONS AND ACRONYMS

Acronym or Abbreviation	Full Name
°C	Degrees Celsius
°F	Degrees Fahrenheit
µS/cm	microSiemens per centimeter
3Rs	Resiliency, Redundancy, and Representation
BLM	Bureau of Land Management
CA	California
cfs	Cubic feet per second
cm/sec	Centimeters per second
CPOM	Coarse particulate organic matter
CPUE	Catch Per Unit Effort
CSI	Coyote Springs Investment, LLC
DCNR	Nevada Department of Conservation and Natural Resources
DO	Dissolved oxygen
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FLPMA	Federal Land Policy and Management Act
ft	Foot or feet
GCM	General circulation model
GIS	Geographic Information Systems
GWD Project	Clark, Lincoln, and White Pine Counties Groundwater Development Project
HA	Hydrographic Area
in	Inch(es)
In/sec	Inches per second
IPCC	Intergovernmental Panel on Climate Change
km	kilometers
L/min	Liters per minute
m	Meter(s)
mi	miles
mm	Millimeter(s)
mg/L	Milligrams per liter
MGD	Million gallons per day
MVNWR	Moapa Valley National Wildlife Refuge
MVWD	Moapa Valley Water District
NDOW	Nevada Department of Wildlife
NDWP	Nevada Division of Water Planning
NEPA	National Environmental Policy Act of 1970
NSE	Nevada State Engineer
NV	Nevada

Acronym or Abbreviation	Full Name
NVE	Nevada Energy
ppm	Parts per million
RMP	Resource Management Plan
Service	U.S. Fish and Wildlife Service
SMNRA	Spring Mountains National Recreation Area
SNWA	Southern Nevada Water Authority
sp. ***or*** **spp.**	Species
SSA	Species Status Assessment
TDS	Total Dissolved Solids
UDWR	Utah Division of Wildlife Resources
UDWRi	Utah Division of Water Rights
USGS	United States Geological Survey
USFS	United States Forest Service
UT	Utah
WAP	Wildlife Action Plan
WCP	Wetland Conservation Plan
WMA	Wildlife Management Area
WSA	Wilderness Study Area

GLOSSARY OF TERMS

Term	Definition	Reference
Abundant	Catch per unit effort greater than 20 individuals	
Aquifer	Rock or sediment layer that contains and transmits groundwater	
Alluvial slope spring	Spring occurring on the lower slope of an alluvial cone at the point where the water table slope and surface gradient are equal; also known as a border spring	
Catch per unit effort (CPUE)	The average (mean) number of springsnails captured (catch) calculated by the total number of springsnails captured divided by the number of grabs performed to capture those springsnails (unit of effort)	
Channel roughness	Measure of how rough the bed of a river or stream is; a measure of the amount of frictional resistance water experiences when passing over channel features	
Clastic sandstones and siltstones spring	Spring originating in one of these rock types. Sandstone is a rock composed of sand-sized grains of various minerals, mostly of uniform size. Siltstone is a fine-grained sedimentary rock which mainly consists of consolidated silt	
Climate change	Change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both	
Common	Catch per unit effort between 6 and 20 individuals	
Confined aquifer	Aquifer that contains water that would rise above the top of the aquifer in a penetrating well; also known as an artesian aquifer	
Detritus	Dead particulate organic material of plants and animals	
Exposure	Extent to which a target resource and	

	stressor actually overlap in space and/or time.
Fluvial deposit spring	Spring originating from fluvial deposits, which are areas of water deposited on the landscape from a flowing river/stream in the past
Helocrene	Natural spring where water egresses into a marsh
Immediacy	Action time frame of the stressor; is the stressor present and acting on the target now, anticipated in the future, or has the impact already occurred, in which case restoration is more appropriate than threat reduction
Intensity	Strength of the stressor itself
Invasive species	Species that is not native to an ecosystem and causes, or is likely to cause, economic or environmental harm or harm to human health
Limnocrene	Natural spring where water is initially contained in a basin, or large, deep pool of water
Local aquifer	Aquifer fed by precipitation from a large area and supported springs are located between valley floors and mountain bases
Macroinvertebrate	Organism without backbones, which are visible to the eye without the aid of a microscope. Aquatic macroinvertebrates live on, under, and around rocks and sediment on the bottoms of lakes, rivers, and streams
Macrophyte	Aquatic plant that is large enough to be visible to the naked eye. A macrophyte may be an emergent, submergent, or floating type of aquatic plant
Mountain block aquifer	Aquifer that is usually perched, relatively small and fed by precipitation from a small area
Nonnative	Originating in a different region and acclimated to a new environment
Parthenogenesis	Type of asexual reproduction in which the offspring develops from unfertilized eggs
Perched aquifer	Aquifer that occurs above the regional

	water table and is generally a relatively small body of water	
Population	Group of individuals of the same species that have the potential to interbreed	
Redundancy	Ability of a species to withstand catastrophic events	
Regional aquifers	Very large aquifer characterized by water that is warmer and moves slower through the aquifer, in comparison to perched and local aquifers; supported springs are supplied from recharge extending over vast areas	
Relative abundance	A quantitative index of population size based on the number of individuals observed in a sample relative to other samples, which is also used to examine changes in the number of individuals in a sample to position in the springbrook from source to terminus, and to quantify habitat use	Sada and Mihevc 2011, p. 12
Representation	Ability of a species to adapt to changing environmental conditions	
Springbrook	to be provided	

1 INTRODUCTION

The Species Status Assessment (SSA) framework (U.S Fish and Wildlife Service (Service) 2016, entire) is an in-depth review of a species' biology and risks, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the resulting SSA Report to be easily updated as new information becomes available and to support all functions of the Service's Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery. As such, the SSA Report will be a living document on which other documents, such as listing rules, recovery plans, and 5-year reviews, would be based if any of the species warrants listing under the Endangered Species Act (ESA).

On February 17, 2009, we were petitioned by the Center for Biological Diversity to list 42 Great Basin and Mojave Desert springsnails as threatened or endangered species under the ESA. Fourteen of those springsnail species are presented in this SSA Report. We published a 90-day finding in the Federal Register on September 13, 2011 (76 FR 56608), in which we determined that the petition presented substantial scientific or commercial information for 32 of the springsnail species, including the 14 springsnail species addressed in this report, indicating that listing may be warranted. Thus, we initiated status reviews for those species.

This SSA Report is intended to provide biological support for the decision on whether any of 14 springsnail species may be warranted for listing as an endangered or threatened species under the ESA and, if so, whether to and where to propose the designation of critical habitat. The 14 springsnail species presented in this SSA Report are as follows:

- Spring Mountains pyrg (*Pyrgulopsis deaconi*)
- Corn Creek pyrg (*Pyrgulopsis fausta*)
- Moapa pebblesnail (*Pyrgulopsis avernalis*)
- Moapa Valley pyrg (*Pyrgulopsis carinifera*)
- Grated tryonia (*Tryonia clathrata*)
- Blue Point pyrg (*Pyrgulopsis coloradensis*)
- Hubbs pyrg (*Pyrgulopsis hubbsi*)
- Pahranagat pebblesnail (*Pyrgulopsis merriami*)
- White River Valley pyrg (*Pyrgulopsis sathos*)
- Flag pyrg (*Pyrgulopsis breviloba*)
- Lake Valley pyrg (*Pyrgulopsis sublata*)
- Butterfield pyrg (*Pyrgulopsis lata*)
- Hardy pyrg (*Pyrgulopsis marcida*)
- Bifid duct pyrg (*Pyrgulopsis peculiaris*)

The format for this SSA Report includes:

- Description framework for what the species needs in terms of the distribution of resilient populations across their range for species viability (Chapter 2).
- Background information on the range and distribution of the 14 springsnail species; general biological information for springsnails; and general information on spring

characteristics, function, and hydrology important for understanding the physical and biological needs of individuals and populations (Chapter 3).
- Descriptions of potential factors that may impact springsnail species' needs and current conditions (Chapter 4).
- Evaluation of the current condition of each springsnail species, including quantity and quality of springsnail habitat that is present at a spring or spring province, information on needs that may be unique to a particular species, the historical and current distribution of the species, the relative abundance of each springsnail population, and the current conditions of each species' population(s) (Chapter 5).
- An evaluation of the potential future condition of each springsnail species, including a description of the species' viability in terms of resiliency, redundancy, and representation as presented under three potential future condition scenarios (Chapter 6).

This SSA Report does not result in a decision by the Service on whether these taxa are warranted for listing under the ESA. Instead, this SSA Report provides a review of the best available scientific and commercial information strictly related to the biological condition of the 14 springsnail species. Any listing determination may be made by the Service after reviewing this document and all relevant laws, regulations, and policies. Results of any potential warranted 12-month finding and proposed listing determination, if applicable, would be announced in the Federal Register, with appropriate opportunities for public input.

2 ANALYSIS FRAMEWORK

2.1 Analysis Area

The 14 springsnail species evaluated in this SSA Report are distributed throughout springs and spring provinces in White Pine, Nye, Lincoln, and Clark counties, Nevada and in Millard County, Utah (Figure 2.1). Within these 5 counties, the species are known to occur in 52 different springs and spring provinces throughout 15 hydrographic basins (Figure 2.1). Each of these species has a narrow range and is endemic to a limited number of springs and spring provinces. Species-specific information and maps of the spring locations are in Chapter 5.

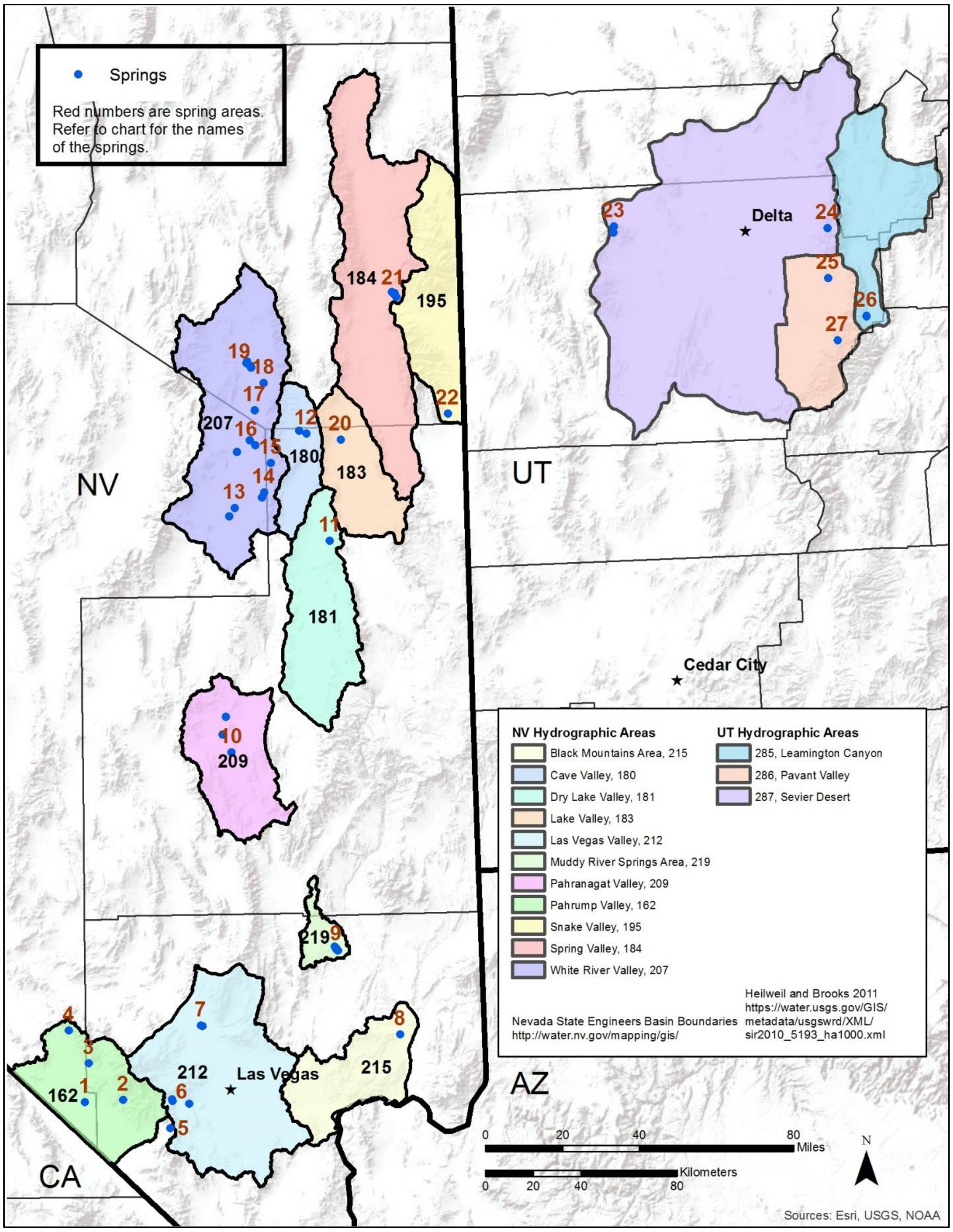


Figure 2.1. Fourteen springsnail species, the springs (see Table 2.1 to cross reference springs and spring province names) and hydrographic areas in which they occur, Nevada and Utah.

Table 2.1. Cross reference list for Figure 2.1 of springs and spring provinces where the 14 springsnail species occur in Nevadda and Utah.

MAP ID	SPRINGS
1	Manse Spring
1	Unnamed Spring Near Sacramento Pass 1
2	Kiup Spring
3	Horse Springs Province
4	Crystal Spring
5	South Rainbow Spring
6	Lost Creek Springs Province
6	Red Spring
6	Willow Spring
7	Corn Creek Springs Province
7	Southeast of Corn Creek Spring
8	Pederson Springs Province
8	Blue Point Spring
9	Apcar Springs Province
9	Plummer Springs Province
9	Muddy Spring
9	Baldwin Spring
9	Cardy Lamb Spring
10	Ash Springs Province
10	Crystal Springs Province
10	Hiko Spring
11	Meloy Spring
12	Homestead Springs Province
12	Parker Station Spring
12	Parker Station Province
13	Hot Creek Springs Province
13	Moon River Spring
13	Hot Creek Springs Province
14	Butterfield Springs Province
14	Flag Springs Province
15	Silver Springs Province
16	Emigrant Springs Province
16	Hardy Springs Province
16	Moorman Spring
17	Ruppes Boghole Province
18	Lund Spring
19	Arnoldson Spring
19	Indian Springs Province
19	Nicholas Spring
19	Preston Big Spring
19	Cold Spring
20	Wambolt Springs Province
20	Unnamed Spring near Sacramento Pass 1
21	Cache Springs Province
21	Rock Spring
21	Turnley Spring
22	Unnamed Springs North of Big Springs Province
23	Red Cedar Spring
23	Antelope Spring
24	Big Spring
25	Church Spring
26	Mapel Grove Springs Province
26	Mapel Grove Springs Province
26	Mapel Grove Springs Province
26	Mapel Grove Springs Province
26	Mapel Grove Springs Province

Comment [PME1]: Not sure why Mapel Grove Springs Province is listed five times here?

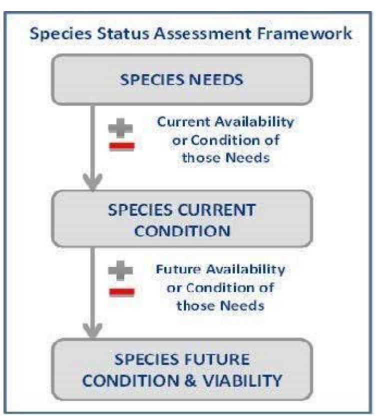


Figure 2.2. Species status assessment framework.

2.2 Overview of Springsnail Resiliency, Redundancy, and Representation

To evaluate the biological status of the springsnails both currently and into the future, we assessed a range of conditions to allow us to consider the species' needs and ultimately their resiliency, redundancy, and representation (3Rs). This SSA Report provides a thorough assessment of springsnail biology and natural history, and assesses demographic risks, stressors, and limiting factors in the context of determining the viability and risks of extinction for each species.

Definitions of the 3Rs

The following are working definitions of the 3Rs that will be used throughout this document. They are derived from the SSA framework (Figure 2.2; Service 2016, entire):

- **Resiliency** is having sufficiently large populations for the species to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health; for example, birth versus death rates and population size. 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 anthropogenic activities.

- **Redundancy** is having a sufficient number of populations for the species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations). Redundancy is about spreading the risk and can be measured through the duplication and distribution of populations across the range of the species. The greater the number of populations a species has distributed over a larger landscape, the better it can withstand catastrophic events.

- **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 (also called environmental variation or environmental diversity) of populations across the species' range. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics within the geographical range.

2.3 Methodology

In preparing this SSA Report, we reviewed available reports and peer-reviewed literature, incorporated survey information, contacted species experts to collect additional unpublished information, participated in site visits to the springs and surrounding areas, and reviewed and incorporated aerial imagery and Geographic Information Systems (GIS) data. We identified uncertainties and data gaps in our assessment of the current and future conditions of the species. We also reviewed available relevant literature for similar species, and we state assumptions and uncertainties made during our assessment of the ecological needs of the 14 springsnail species.

Because springsnails require springs for their survival, we described the general spring characteristics and function. We determined that spring sources and a range of environmental metrics and spring characteristics provide the basic needs of springsnails. These data are typically collected during spring surveys, which we used to determine if the reported values are within the expected range for a given species. We used these data to compare historical and current conditions and determine a baseline for the future conditions analysis.

We created a conceptual model identifying key stressors, sources of those stressors, and effects to the species ecological needs. These needs include sufficient water quality, water quantity in the form of adequate spring discharge and free-flowing water, and suitable substrate and vegetation. We identified potential stressors and their sources from survey information, literature, reports, discussion with scientific experts, and personal knowledge. After also taking into consideration beneficial effects associated with any past or ongoing conservation measures, we evaluated the potential impacts on springsnail needs to determine springsnail resiliency. In many cases, historical negative effects occurred, for example diversions or dredging, that are no longer acting as a stressor at a site because the site has naturalized or the habitat has recovered. We relied on information from 2016 surveys (Sada 2017, entire) to assess the effects of current stressors on springsnail habitat and populations, and their immediacy, intensity, exposure, and response (see Glossary).

Groundwater development or use is potentially an important stressor for springsnails. Therefore, in the water management section, we used the perennial or safe yield data for each hydrographic area to determine how much groundwater is currently used or available for use based upon appropriated water rights. We also considered the source of the aquifer to determine how or if groundwater withdrawal would affect springsnails in springs supported by the aquifer and its source.

We evaluated the current conditions of springs occupied by the springsnails based on survey reports and data from multiple years of surveys and multiple surveyors.Water quality assessments included water temperature, pH, dissolved oxygen (DO), and electrical conductance. Since it is difficult to measure the total dissolved solid levels (TDS) in the field, the electrical conductivity of the water was used as a surrogate to estimate TDS. Water quality data at springs provided the range of values recorded at the spring source. We recognize that some additional seasonal variation in water quality may occur at springs where only a few measurements are made or some variation may exist from the use of different equipment or methodologies. We also converted measurements to a standard metric. Finally, there were some instances that we excluded extreme outlier values as anomalies or errors, recognizing that further evaluations could provide insight or explanation that may or may not be biologically relevant to the species under review at this time. Sada (2017, pp. 23–25) describes the 2016 field survey methods in detail.

Survey data also provided details on the distribution of a species and the habitat conditions at each spring. We determined springsnail distribution by assessing the amount of spring area and length of springbrook (see Glossary of Terms) occupied by springsnails. We assessed general habitat conditions by: (1) Considering the measurements of spring discharge, springbrook flow, springbrook length and wetted width, maximum water depth, and mean current velocity; and (2) estimating the percent of emergent and bank vegetation and substrate composition.

We used aerial imagery and GIS data to complete our analysis of the current conditions, particularly for those locations that were not surveyed in 2016. The location and extent of diversions, impoundments, springbrook flow, grazing, and fences were determined from aerial imagery. We then determined the importance of each stressor on each population of springsnail including the action timeframe for the stressors (immediacy) and strength or intensity of the stressors. Next, we determined how much of the area occupied by a population was exposed to the stressors, and the behavioral and physiological responses of the population to the stressors.

To determine the historical and current abundance and distribution of each of the 14 springsnail species, we considered available survey reports and data. Survey data was compiled from multiple years of surveys and multiple surveyors. Methodologies to assess and describe abundance varied slightly between datasets. To address these variations, we used standardized relative abundance categories for each springsnail population based on catch per unit effort (CPUE). The number of springsnails in each category is consistent with those from historical surveys. CPUE is the average (mean) number of springsnails captured (catch) calculated by the total number of springsnails captured divided by the number of grabs performed to capture those springsnails (unit of effort). For example, if 150 springsnails were captured in 10 grabs, the catch per unit effort would be 15. This qualitative assessment of relative abundance is used to determine the amount of occupied habitat in each spring and variability in abundance along springbrook gradients. The relative abundance categories are as follows:

- None = catch per unit effort of 0 individuals
- Scarce = average catch per unit effort less than 6 individuals
- Common = average catch per unit effort between 6 and 20 individuals
- Abundant = average catch per unit effort greater than 20 individuals

For most species, the most recent survey data were collected in 2016; however, some springs where species had previously been documented were not accessible in 2016, and others could not be located (e.g., Butterfield Springs A and B). Where more than one species of springsnail occurs at a site during surveys, the surveyor identifies individual springsnails, if possible to determine the percentage of each species in the samples. If species identity could not be differentiated by the surveyor or other qualified experts, the counts or abundance estimates were indicative for all species present. It is important to recognize that springsnail population size varies temporally and spatially (see Chapter 3.1.2 for more details).

We considered the best available information on potential stressors to determine the expected future trend of a spring or springsnail population. In the absence of information to suggest an action or event (stressor) will occur in the future to the extent that habitat conditions or populations may increase or decrease, our expectation of future trends is no change. We indicate our confidence of this assessment of future trend based on the degree of uncertainty an action or event will occur and if it occurs, the level of habitat or population change that is likely to result.

For the purpose of this assessment, we generally defined viability as the ability of the species to sustain populations in natural spring ecosystems over time, in this case, 50 years. We chose 50 years for the timeframe of our future condition analysis because it is within the range of the available hydrological and climate change model forecast (see Intergovernmental Panel on

Climate Change (IPCC) 2014, pp. 10-15). Additionally, because of the short generation time of these springsnails (approximately 1 year), 50 years encompassed approximately 30 to 40 generations, which is a relatively high number of generations over which to observe effects to the species.

Using the SSA framework (Figure 2.2), we considered the needs of each species in order to evaluate current conditions and to characterize the status of the species in terms of the 3Rs. We selected three potential future condition scenarios for the springsnails to evaluate the future condition and viability of each species. These scenarios represented no measureable reduction in spring flow from current conditions (Scenario 1), a reduction of spring flow beyond natural fluctuations but not to an extreme extent (Scenario 2), and an extreme reduction or elimination of spring flow (Scenario 3). Because Scenario 1 is equivalent to current conditions, we presented the majority of this analysis under "Current Conditions—Springsnail Habitat and Populations" (Chapter 5). Additional species-specific information for this scenario is under "Potential Future Conditions – Species Viability" (Chapter 6). For Scenario 3, we determined spring conditions would likely result in springsnail extirpation or extinction, and this outcome is described in Chapters 6.1.3, 6.2.3, and 6.3.3. For most springsnail populations, we determined Scenario 2 would be most likely to occur, and our analyses in Chapter 6 focus primarily on this scenario.

3 SPECIES NEEDS

This chapter presents general information on the historical range and distribution of the 14 springsnail species, followed by basic biological information including taxonomy and genetics, morphological features, life history traits, and feeding habits. Spring characteristics and function are also described because springs and spring provinces constitute springsnail habitat. Additional species-specific descriptions and information are in Chapter 5.

3.1 Springsnail Biogeography, Biology, and Habitat

3.1.1 Range and Distribution

The Great Basin is home to 61 percent of all *Pyrgulopsis* species (Hershler and Sada 2002, p. 255), and *Pyrgulopsis* is the largest genus of aquatic mollusks in North America (over 120 species) (Hershler and Sada 2002, p. 255; Liu and Hershler 2005, p. 284). The genus *Tryonia* contains over 20 species that range throughout the southern U.S. (Hershler 2001, p. 1; Hershler et al. 2006, p. 378), with most concentrated in the Southwest (Hershler 2001, p. 1). Most springsnail species are endemic to a limited number of springs within a valley or hydrographic basin (Hershler and Sada 2002, p. 255). The current range and distribution of springsnails likely are reflective of late Cenozoic regional hydrographic history and other means, such as birds (Hershler and Sada 2002, p. 255; Hershler and Liu 2008, p. 99). Elevations of the springs and spring provinces where these species occur in Nevada and Utah are typically below 2,200 meters (m) (7,218 feet (ft)) (Sada 2009, p. 3). Spring ownership includes private, state, and Federal lands.

3.1.2 Biology and Life History

3.1.2.1 *Taxonomy and Genetics*

Each of the 14 springsnail species we review in this SSA (Table 3.1) are recognized and accepted as unique species (Johnson *et al.* 2013, pp. 247–282). Of the 14 springsnail species, 13 are in the Hydrobiidae family of the genus *Pyrgulopsis* (Call and Pilsbry 1886, entire), and 1 is in the Cochliopidae family of the genus *Tryonia* (Stimpson 1865, entire). The scientific names for these species represent the most current taxonomic classifications; however, the classification of gastropods has significantly changed during the past 2 decades (Brown and Lydeard 2010, p. 294) and is still evolving (Johnson *et al.* 2013, p. 251). For example in 1994, the Moapa pebblesnail, Moapa Valley pyrg, and Pahranagat pebblesnail were previously assigned to the genus *Fluminicola* and were reassigned to *Pyrgulopsis* (Hershler 1994, pp. 19, 26, 49); the Moapa Valley pyrg was elevated from a subspecies to species (Hershler 1994, p. 26); and the Cochliopidae family was previously considered a subfamily of Hydrobiidae but has since been elevated to family rank (Wilke *et al.* 2001, p. 1; Johnson *et al.* 2013, p. 251). Both families and respective subordinate taxa are phylogenetically classified as Caenogastropoda clade (a group of organisms with a common ancestor), which has been a part of several reorganizations since the taxonomic group was first introduced in 1960 by Cox (Bouchet and Rocroi 2005:247–252, Colgan *et al.* 2007:718) and includes as many as 136 extant families.

Table 3.1. Hierarchy of main taxonomic ranks, scientific name and author, and common names of the ranks reviewed in this SSA Report.

Taxonomic Rank	Scientific Name and Author	Common Name(s)
Kingdom	Animalia	animal
Phylum	Mollusca (Linnaeus 1758)	mollusk
Class	Gastropoda (Cuvier 1795)	gastropod, snail
Order	Neotaenioglossa (Haller 1892)	
Family	Hydrobiidae (Troschel 1857)	Hydrobiid, mud snail, pebblesnail, pyrg, pyrg pebblesnail, springsnail
Genus	*Pyrgulopsis* (Call and Pilsbry 1886)	pebblesnail, pyrg, springsnail
Species	*Pyrgulopsis avernalis* (Pilsbry 1935)	Moapa pebblesnail
	Pyrgulopsis breviloba (Hershler 1998)	Flag pyrg
	Pyrgulopsis carinifera (Pilsbry 1935)	Moapa Valley pyrg
	Pyrgulopsis coloradensis (Hershler 1998)	Blue Point pyrg
	Pyrgulopsis deaconi (Hershler 1998)	Spring Mountains pyrg
	Pyrgulopsis fausta (Hershler 1998)	Corn Creek pyrg
	Pyrgulopsis hubbsi (Hershler 1998)	Hubbs pyrg
	Pyrgulopsis lata (Hershler 1998)	Butterfield pyrg
	Pyrgulopsis marcida (Hershler 1998)	Hardy pyrg
	Pyrgulopsis merriami (Pilsbry and Beecher, 1892)[a]	Pahranagat pebblesnail
	Pyrgulopsis peculiaris (Hershler 1998)	Bifid duct pyrg
	Pyrgulopsis sathos (Hershler 1998)	White River Valley pyrg
	Pyrgulopsis sublata (Hershler 1998)	Lake Valley pyrg

Taxonomic Rank	Scientific Name and Author	Common Name(s)
Family	Cochliopidae (Tryon 1866)	Tryonia pebblesnail
Genus	*Tryonia* (Stimpson 1865)	pebblesnail, springsnail, tryonia
Species	*Tryonia clathrata* (Stimpson 1865)	Grated tryonia

[a] See (Pilsbry 1892:143)

The genetic diversity of springsnails is not well understood, particularly as it relates to their ability to adapt to short- and long-term environmental changes. Given the long period of time springsnail populations have persisted in their respective spring systems, we assume they may be able to withstand and adapt to some disturbances in environmental conditions. However, based on their restricted distributions within a springbrook, they also seem to be limited to a range of physical and biological parameters that exist within that occupied area (Sada 2017, p. 13), one known parameter being their dependency on perennial water (Hershler and Liu 2008, p. 92). In addition, the long-term isolation and small area within some spring systems may make springsnails weakly adapted to survive introduced predation and competition subsequently causing extirpations in some populations of springsnail species (Sada 2017, p. 11).

3.1.2.2 *Morphological Description*

Species within each genus *Pyrgulopsis* and *Tryonia* appear relatively similar to inexperienced and unaided eyes but have been collected, described, and differentiated based on subtle morphological characteristics using methods described by Hershler and Sada (1987, pp. 780–785) and Hershler (1989, pp. 176–179; 1994, pp. 2–4; 1998, pp. 3–11; 2001, p. 2). Species descriptions occur by examining adults, some live but primarily dry and alcohol-preserved specimens, with the aid of photographs from a scanning electron microscope (Hershler and Sada 1987, pp. 780–785; Hershler 1989, pp. 176–179; 1994, pp. 2–4; 1998, pp. 3–11; 2001, p. 2). Closely related springsnail species can be distinguished by the characteristics of their soft anatomy (Burch 1982, p. 7; 1989, p. 37). Species within both genera are differentiated by thorough detailed examination and comparison of differences between morphological characteristics of adult shell, operculum, digestive system, body pigmentation, pallial cavity, and reproductive system (Hershler and Sada 1987, pp. 780–785; Hershler 1989, p. 176–179; 1994, pp. 2–4; 1998, pp. 3–11; 2001, p. 2).

In general, species of *Pyrgulopsis* and *Tryonia* are similarly sized. Freshly hatched *Pyrgulopsis* less than a week old may be less than 0.3 millimeter (mm) up to 0.8 mm (0.01 inch (in) up to 0.03 in) in total length (Mladenka and Minshall 2001, p. 208; Wells *et al.* 2012, pp. 74–75; Pearson *et al.* 2014, p. 66). The shell heights of adult *Pyrgulopsis* may range between approximately 1 and 5 mm (0.04 and 0.2 in) in length and have 3 to 5 whorls (Hershler 1998, pp. 4–9), whereas adult grated tryonia shell height may be approximately 3 to 7 mm (0.1 to 0.3 in) in length and have between 5 to 9 whorls (Hershler 2001, p.7).

In general, species of *Pyrgulopsis* and *Tryonia* are morphologically similar with hardened shells and soft anatomy. Both have spiraling conic shells (one spiral is a whorl) with a shell opening (aperture) that can be sealed with an operculum (a secreted plate that closes the aperture) when the soft anatomy is drawn into the shell (Burch 1982, pp. 64–65; 1989, p. 35). The soft anatomy includes a foot, head, mantle, and visceral mass (Brown and Lydeard 2010, p. 279). Under the shell, the mantle covers the visceral mass, which contains most of the organs (Brown and

Lydeard 2010, p. 279; Pyron and Brown 2015, p. 386). The mantle extends over the head and has a mantle cavity where gills used for breathing occur and are protected by the shell (Burch 1989, p. 53; Brown and Lydeard 2010, p. 279; Pyron and Brown 2015, p. 386). When relaxed, the head and flat-bottomed foot can extend from the shell opening (Pyron and Brown 2015, p. 386). The foot is used for locomotion as mucous is secreted over a substrate (Pennak 1953, pp. 667–671; Brown and Lydeard 2010, p. 279).

Shell appearance changes as springsnails mature. Young springsnails have almost translucent shells that progressively develop shell coloration and whorls as they near adult size (Mladenka and Minshall 2001, p. 208; Wells *et al.* 2012, pp. 73–74; Pearson *et al.* 2014, p. 66). The adult shells often appear (with the periostracum or skin like layer covering the shell) tan or brown for *Pyrgulopsis* (Hershler 1998, pp. 15–108) and gray or clear for Tryonia (Hershler 2001, p. 3).

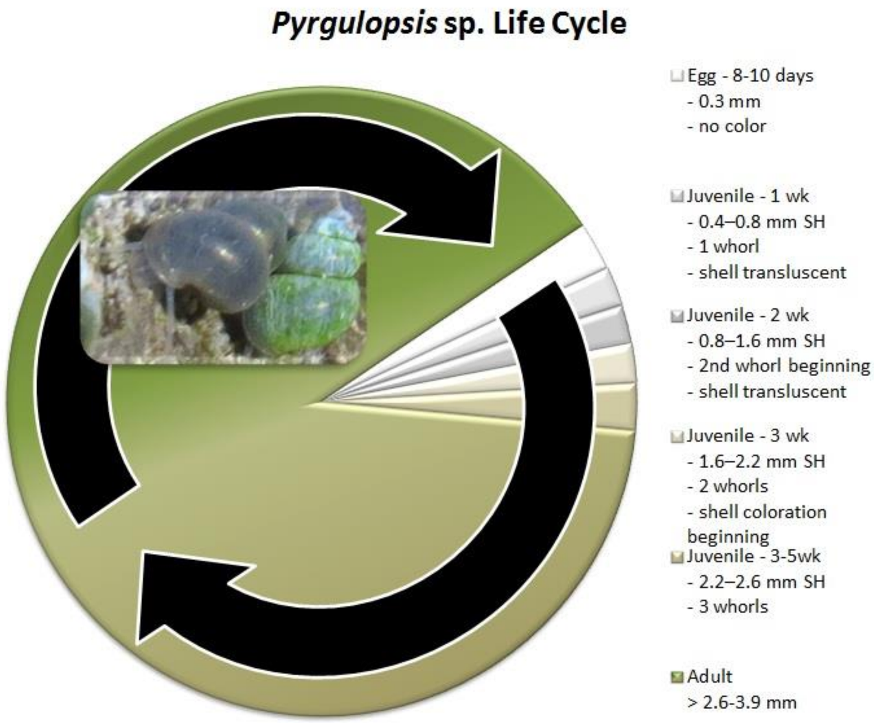
3.1.2.3 ***Reproduction, Survival, Growth, and Longevity***

Some but limited information is available specific to the life history of the 14 springsnail species reviewed in this SSA Report; most of the information used is inferred or generalized from closely related taxa. Less information is available on the life history of *Tryonia* than *Pyrgulopsis*. However, in general, data is known about springsnail species' size, and the timing and duration of life stages vary depending on environmental conditions.

Springsnails are dioecious (Hershler 1998, p. 10; 2001, pp. 3–5), where male and female organs occur in separate individuals, and they are sexually dimorphic (animals with different male and female forms) in size. Females tend to be larger than males in *Pyrgulopsis* (Hershler and Landye 1988, pp. 8–41, 60; Mladenka and Minshall 2001, p. 209) and *Tryonia* (Hershler and Thompson 1987, p. 27; Hershler 2001, pp. 6–14). In grated tryonia, males are often half the height of females (Hershler and Thompson 1987, p. 27; Hershler 2001, pp. 6–14) as compared to 80–90 percent or more for *Pyrgulopsis* species (Hershler and Landye 1988, p. 60).

After internal fertilization (Kabat and Hershler 1993, p. 6), a springsnail's life cycle (Figure 3.1) begins as an egg. In *Pyrgulopsis* species, a female lays an egg capsule on hard substrate containing multiple embryos[1] (oviparous) (Hershler 1998, p. 14). There is little specific information about species' substrate needs and the substrate available will vary among spring systems (see Chapter 4) for any known species-specific information). The egg capsule matures on the substrate and hatches after a brief time, such as 8 days (Brown *et al.* 2008, p. 487). The number of eggs produced by an individual female *Pyrgulopsis* is unknown. In contrast, *Tryonia* are ovoviviparous (Hershler 2001, p. 3) with eggs being held in a brood pouch (Brown and Lydeard 2010, p. 282) where they develop until they hatch internally (Dillon, Jr. 2006, p. 251). Grated tryonia develop about 15 embryos per brood (Hershler 2001, p. 8).

[1] Pearson *et al.* (2014, p. 66) report that "an egg containing a single snail rather than an egg capsule containing multiple embryos" was deposited by Page springsnails.



Adapted from Pearson et al. 2014, Table 1 for *Pyrgulopsis morrisoni.*
SH = shell height. Photo of *P. turbatrix* by C. Kallstrom/USFWS.

Figure 3.1. Basic life cycle of a springsnail.

Springsnails mature from eggs to adulthood relatively quickly. In captivity under constant conditions in the closely related Page springsnail (*Pyrgulopsis morrisoni*), eggs hatch approximately 1 week after being deposited (Pearson *et al.* 2014, p. 66). *Pyrgulopsis* species develop from freshly hatched eggs to adult size in 6 or 7 weeks (Wells *et al.* 2012, p. 73; Pearson *et al.* 2014, pp. 66–67); however, it is unknown at what age they become sexually mature. *Pyrgulopsis* species are described to have limited ability or tendency to move (vagility) (Liu *et al.* 2003, p. 2,771; Hershler and Liu 2008, p. 100). Therefore, once eggs have been deposited, they hatch into young springsnails and likely remain near the stream area of hatching through adulthood unless they are passively dispersed by stream current.

The annual temperature regime of springs influences the occurrence and abundance of springsnails and subsequent population dynamics. Hatching of young *Pyrgulopsis* and recruitment may occur continuously throughout the year (Mladenka and Minshall 2001, p. 209) and are dependent on water temperatures. In thermal springs, hatching typically increases between winter and spring when water temperatures are near their thermal minimum (Mladenka and Minshall 2001, p. 209). In cold springs, hatching typically increases between summer and fall when spring water temperatures are near their thermal maximums (Lysne *et al.* 2007, pp.

Comment [PME2]: What range of temperature would you classify a spring as thermal?

Comment [PME3]: Same comment for cold springs as for thermal springs.

649–650). Thus, the relative density of a springsnail species within a spring can fluctuate dramatically during the year (Mladenka and Minshall 2001, fig. 2; Martinez 2009; p. 31). Population relative abundance or densities are predominately reflective of adult and larger juveniles because they are more readily observed or captured during monitoring. Within a single year, the density of springsnails per square meter fluctuates between 10s or 100s of springsnails to 1,000s or 10,000s of springsnails (Mladenka and Minshall 2001, p. 208). Springsnails' high rates of fecundity and recruitment may contribute to a population's resiliency (Martinez and Sorensen 2007, p. 31).

The annual fluctuation in densities observed in some studies (e.g. Mladenka and Minshall 2001, p. 207; Martinez 2009, p. 31) also is likely reflective of the average lifespan of springsnails. The lifespan for most species of springsnails is thought to be 9 to 15 months (Pennak 1953, p. 680). Laboratory studies of two different *Pyrgulopsis* sp. have documented similar lifespans. One study of the Page springsnail documented a high rate of survival to 10 months (Wells *et al.* 2012, pp. 74–75). Another study of the Jackson Lake springsnail (*P. robusta*) documented lifespans of individuals between 11 and 14 months with an average survival of approximately 13 months (382 days) (Lysne 2003, as cited in Lysne *et al.* 2007, p. 649). Given the similarity in genus and life history needs, etc., it is probable that the lifespan of *Tryonia* may be similar to *Pyrgulopsis*; however, this is currently unknown.

3.1.2.4 ***Feeding Habits***

Pyrgulopsis and *Tryonia* species are herbivores or detritivores that primarily graze on the periphyton of exposed surfaces of macrophytes (an aquatic plant that grows in or near water and is either emergent, submergent, or floating) and substrate (Mladenka 1992, pp. 46, 81; Hershler and Sada 2002, p. 256; Martinez and Thome 2006, p. 8; Pyron and Brown 2015, p. 401). Macrophytes may be native species such as rushes (*Juncus* spp.), sedges (*Carex* spp.), or spikerushes (*Eleocharis* spp.); or nonnative species including watercress (*Nasturtium* spp.). Periphyton consists of algae, bacteria, detritus, fungi, diatoms, and protozoa contained within a matrix of polysaccharides (also known as biofilm) (Lysne *et al.* 2007, p. 649; Vu *et al.* 2009, p. 2,536). While periphyton is easier to acquire and is more nutrient-rich than macrophytes, macrophytes will be consumed if periphyton is depleted (Pyron and Brown 2015, p. 399). If this occurs at high snail densities, macrophyte richness may decrease (Sheldon 1987, p. 1,928).

Freshwater snails in the Hydrobiidae family have a radula, which is a ribbon-shaped structure in the anterior end of the digestive tract used to scrape off food during feeding (Burch 1982, p. 290). The radula contains rows of minute sharp teeth, each with one to ten basal cusps (or blades) used for cutting (Burch 1982, pp. 219, 290; Hershler 1994, p. 5). The radula can extend out of the mouth, scrape particles from a substrate, and retract the material into the mouth (Pyron and Brown 2015, pp. 384, 386). This material is broken down further by grinding the food against the roof of the mouth with the radula (Pyron and Brown 2015, p. 386). Digestive enzymes, containing cellulases, are able to break down the cell walls of consumed algae (Kesler 1983, p. 178).

3.2 Spring Characteristics and Function

Springs are relatively small aquatic and riparian systems that flow onto the land surface through natural processes and are maintained by groundwater. They range widely in size, water chemistry, morphology, landscape setting, and persistence. They occur from mountain tops to valley floors, some of which occur in clusters (defined in this SSA Report as spring provinces; (see Glossary)), and are predominantly isolated from other aquatic and riparian systems. Springs occur where subterranean water under pressure reaches the earth's surface through fault zones, rock cracks, or orifices that occur when water creates a passage by dissolving rock. Sada and Pohlmann (2002, pp. 3–5) consider most springs as unique based on the province influences of aquifer geology, morphology, discharge rates, and regional precipitation.

Spring hydrology depends on subterranean water flow through aquifers and precipitation that enters the soil and accumulates in aquifers where it is stored; this is influenced by characteristics of regional and local geology, and how water moves through an aquifer. Geologically, Nevada and Utah are broken into valleys by intervening mountain ranges. Most of the valleys contain alluvial sediments that are often permeable aquifers. These valley aquifers are recharged by springtime runoff of snowmelt from adjacent mountain ranges. There are also regional aquifers that facilitate groundwater transport between valleys. Regional aquifer waters are often ancient and are not as affected by annual precipitation as compared to valley aquifers.

Comment [PME4]: What age is considered "ancient?"

Three aquifer types occur in arid parts of the U.S: mountain block, local, and regional aquifers (Sada and Mihvec 2011, pp. 1–2). These aquifers differ primarily in their water transit time or residence time (see Glossary) and water depth, which in turn affects water temperature, water chemistry, and spring discharge. Sada and Mihvec (2001, pp. 2) describe these aquifers as follows:

- Mountain block aquifer springs have short residence times, so they are cooler and contain fewer dissolved chemical constituents than water in aquifers with longer residence time. These springs are generally small, often ephemeral, and occur in the mountains.
- Local aquifer springs are generally warmer and contain higher concentrations of dissolved chemical constituents than mountain block aquifer springs. Also, springs fed by local aquifers are usually located on alluvial fans near the base of mountains, although they can occur in the central parts of some valleys, primarily in valleys without springs fed by regional aquifers.
- Regional aquifer springs have long residence times (generally hundreds to thousands of years) as well as high and constant discharge rates, warm temperatures, and elevated concentrations of dissolved chemical constituents. They generally occur on valley floors near the center of a valley.

A spring's size is generally a function of discharge, which can be affected by precipitation and evapotranspiration. Also, springs can be characterized as an endpoint in a continuous spectrum of groundwater discharge processes (Van der Kamp (1995, pp. 5–6), or points of focused groundwater discharge from groundwater flow systems. These flow systems transport groundwater from recharge areas to discharge areas under the influence of gravity. The rate of spring flow averaged over several years equals the average rate of recharge to the flow systems that feed the spring. The annual rate of groundwater recharge is always less than the annual precipitation, and can be estimated on the basis of precipitation and estimated evapotranspiration. For example, during prolonged dry periods, flow from springs with local or mountain block aquifer sources generally decrease more or less exponentially. Also, there may be significant water losses to evapotranspiration near undeveloped springs with heavy natural vegetation. Overall, any evapotranspiration loss results in reduced flow from springs, which is the principal reason why many small springs dry up entirely during hot, dry weather.

Within a spring's flow system, environmental characteristics (for example, temperature and dissolved oxygen (DO)) vary depending on proximity to the spring's main source of water, also called the springhead. Environmental variation is typically lowest near the springhead. Variation increases downstream from the springhead with higher variability in temperature, DO concentration, and other factors (Deacon and Minckley 1974, pp. 396–397). As a result, the composition of springhead and downstream communities is usually different, and many species of invertebrates become absent from downstream habitats (Hayford *et al.* 1995, p. 83; Hershler 1998, p. 11; O'Brien and Blinn 1999, p. 225). Water temperature at many springs varies little throughout the year while other factors vary considerably. The average water temperature and the variability of temperature are controlled by the geometry of the flow system, solar radiation, air temperature, season, and other factors. Groundwater temperatures about 10 m (33 ft) below the surface are typically constant, where the annual fluctuation of surface temperature does not penetrate.

Another environmental characteristic that can vary across different springs is water chemistry, which is strongly influenced by aquifer geology (Sada and Pohlmann 2002, p. 2). Unmack and Minckley (2008, pp. 28–29) describe the role that carbon dioxide, bicarbonate, and calcium carbonate provide in spring function. Groundwater often carries carbon dioxide from decomposing organics in strata through which it moves. Carbon dioxide combines with water to form weak carbonic acid, which dissolves calcium carbonate rocks to form the bicarbonate. Groundwater gas concentrations vary with pressure and temperature, which are often released when a spring emerges. A result of these processes is deposition of insoluble calcium carbonate as travertine, which produces the hard substrate that armors springbrooks, thus reducing bank erosion and prevents water from either entering or leaving the springbrook (Sada and Cooper, p. 18). Over time, a carbonate dam or mound may form as seen at Kiup Spring, where the Spring Mountains pyrg occurs, which in some instances could be extensive enough to modify or impound and isolate a spring or its outflow by changing flow or creating pools.

Riparian vegetation within and adjacent to arid springs such as those in Nevada and Utah exhibit unique characteristics due to their distinctive environments as well as colonization and extirpation dynamics that characterize these small, isolated habitats. Riparian vegetation associated with springs may be restricted to the immediate boundaries of a spring's aquatic habitat, or it may follow water that extends outward for substantial distances. Typical vegetation at larger and minimally disturbed springs includes sedges, rushes, grasses (e.g., *Distichlis* sp.), and woody phreatophytes (e.g., willows (*Salix* sp.) at middle to higher elevations, mesquite (*Prosopis* spp.) at lower elevations) while vegetation at seeps is typically limited to grasses and rushes (Sada and Pohlmann 2006, p. 7). The continually waterlogged condition of some springs creates anaerobic conditions that slow decomposition of plant material facilitating soil development (Coles-Ritchie *et al.* 2014, p. 2).

Freshwater springsnails are indicators of common inhabitats or conditions of spring ecosystems, most of which are characterized by permanent water with variable discharge and flow rates. Springs that harbor springsnails may have a high mineral content but must be relatively unpolluted (Mehlop and Vaughn 1984, p. 69). Where springsnails occupy a significant portion of a spring system, it is an indication that the spring ecosystem is functioning and intact (Mehlop and Vaughn 1994, p. 69).

3.3 Physical and Biological Needs of Springsnails

The current condition and potential future conditions of springsnail populations are most influenced by those species needs that are critical for survival and reproduction. Based on our review of the best available scientific and commercial information, and the knowledge and expertise of Service staff and other technical experts, we determined the following physical and biological needs to be most critical in influencing conditions at springs and spring provinces as they relate to springsnail populations: (1) sufficient water quality, (2) adequate substrate and vegetation, (3) free-flowing water, and 4) adequate spring discharge (Figure 3.2). When each of these physical and biological needs is present and functioning within a spring, stable populations of springsnails are expected. Following are descriptions of each species need and how we categorized each to evaluate current conditions (Chapter 5) and potential future conditions (Chapter 6) of the 14 springsnail species evaluated in this report.

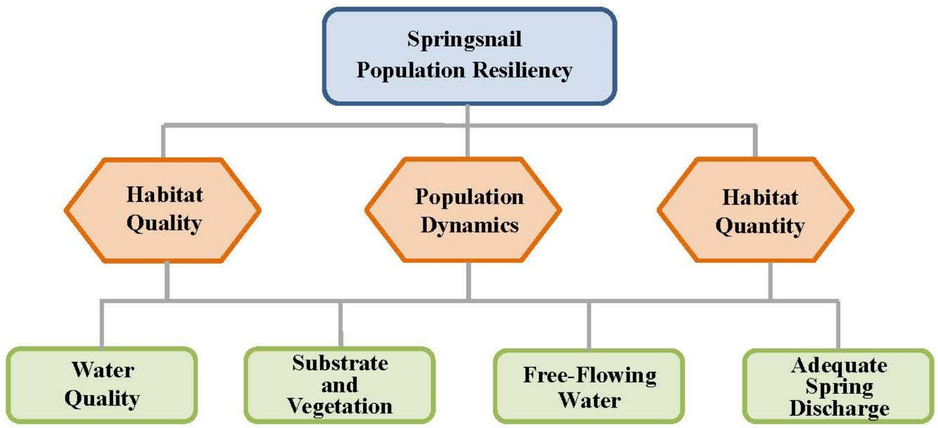


Figure 3.2. Physical and biological needs of 14 springsnail species that influence their populations, Nevada and Utah.

3.3.1 Adequate Water Quality

Pyrgulopsis and *Tryonia* species are sensitive to water quality and require specific parameters to thrive (Sada 2008, p. 59; Sada 2009, p. 3). Distribution of *Pyrgulopsis* within springs varies according to temperature, water chemistry (including carbon dioxide, DO, and conductivity), and flow regime (Hershler 1998, p. 11; Mladenka and Minshall 2001, pp. 209–211). Springsnails are typically most abundant at the spring source and less abundant farther away from the springhead, which may be due to decreased water quality or increased variability in the environment (Hershler 1998, p. 11; Hershler and Sada 2002, p. 256; Martinez and Rogowski 2011, pp. 218–220). This gradient in abundance is evident in small springs (Hershler 1998, p. 11), such as (but not limited to) Willow Spring and Kiup Spring. Spring sources contain relatively constant water temperature, discharge, and water chemistry, while these parameters are more variable downstream (Sada 2009, p. 3).

Springs contain various ranges in temperatures. Springsnails have been found to reside in conditions where water temperatures (for all inhabited springs) can range from 3 degrees Celsius (°C) to 36 °C (37 degrees Fahrenheit (°F) to 97 °F) (Sada 2009, p. 3). *Pyrgulopsis* species generally occur in colder water within this range, while *Tryonia* species always occur in thermal habitats (Sada 2009, p. 4). Mehler *et al.* (2015, p. 172) studied 27 springs throughout Nevada and found nitrate levels between 0.004 and 1.77 milligrams per liter (mg/L) or 0.004 and 1.77 parts per million (ppm) and soluble reactive phosphorus between 0.002 mg/L to 0.49 mg/L (0.002 to 0.49 ppm), which is indicative of good water quality.

Relatively low DO levels between 5.78 and 7.12 mg/L (5.78 and 7.12 ppm) were found to be negatively correlated with springsnail occurrence (Martinez and Thome 2006, pp. 13–14). Since water with low DO has high concentrations of carbon dioxide, there is greater primary productivity of periphyton (a primary food source) in these lower oxygen areas. Springsnails can be found in a variety of water quality conditions, including highly oxygenated waters, but the water must be relatively unpolluted (Melhop and Vaughn 1994, p. 69), meaning that it is essentially free from chemicals or other foreign substances that may cause harmful effects.

Adequate water quality is a habitat need of springsnails that may influence a population's condition (Hershler 1998, p. 11; Sada 2009, p. 3). Changes in temperature, DO, pH, conductivity, and other water quality metrics may impact the ability of a species to survive in a particular spring. For example, data for springs inhabited by the Page springsnail in Arizona documented lower DO (mean of 7.32 mg/L (7.32 ppm)) and lower conductivity (mean of 388 microSiemens per centimeter (µS/cm)) than springs without Page springsnails, and DO was directly correlated with pH (i.e., potential of hydrogen) (Martinez and Thome 2006, pp.11–12). We do not know, however, what the thresholds or limitations for these metrics are for the 14 springsnail species evaluated in this report. In the species sections under Chapter 5, we identify the observed ranges of temperature, DO, pH, conductivity, and other parameters as available for each species. To evaluate the current conditions of this factor, we assume that water quality parameters are adequate if the species is observed within a site.

3.3.2 Aquatic Vegetation and Substrate

Springs within perennial waters are surrounded with a riparian and wetland vegetation community that varies with elevation, soil type, discharge, and disturbance (Sada and Pohlman 2002, p. 4). Springs with minimal disturbance may be dominated by native sedges, rushes, grasses, willows, and mesquites (Sada and Pohlman 2002, p. 4), while springs with greater disturbance may have minimal to no native vegetation. There may be situations, though, where disturbed springs have varying abundance of nonnative aquatic vegetation, most common of which include (but is not limited to) tamarisk (*Tamarix* spp.), watercress, or Russian olive (*Elaeagnus* spp.).

Within a spring's source or downstream, *Pyrgulopsis* are commonly found among macrophytes (i.e., aquatic plants that grow in or near water), especially watercress that often forms dense mats (Hershler 1998, p. 14). In large thermal springs, *Tryonia* snails may be found on bladderwort (*Utricularia* spp.) or on the bases of spikerush or bulrush (*Scirpus* spp.) (Hershler 1998, p. 14). The amount of vegetation needed at a spring can be variable for springsnail species. While most springs contain vegetation, there are a few springs with springsnail populations that have minimal vegetation (but contain preferred substrate).

Substrate, the surface on which an organism lives, is another element of a springsnail's microhabitat that varies by species. *Pyrgulopsis* are rarely found on soft sediments. They generally occur on hard substrates such as bedrock, gravel, and cobble, as well as on macrophytes like watercress (Hershler and Sada 1987, p. 837; Hershler 1998, p. 14; Sada 2006, p. 8). Conversely, *Tryonia* occur on fine substrates such as sand along banksides (Sada 2006, p. 8; Sada 2008, p. 64). The occupied substrates not only contain sources of food for all life stages, but also sites for adults to lay eggs. Species-specific substrate information is described in Chapter 5 below.

Sufficient vegetation and substrate are species needs that may influence all life stages of a springsnail and its population's condition (Hershler and Sada 1987, p. 837; Hershler 1998, p. 14; Sada 2006, p. 8). To evaluate the current and potential future conditions of this factor, we categorized data from 2016 surveys (Sada 2016, entire; Sada 2017, entire). Since there is not enough known in literature to categorize each springsnail habitat by substrate type and vegetation species, we categorized the known data as follows:

High:	Spring dominated by suitable vegetation and substrate for the species
Moderate:	Spring contains some suitable vegetation and substrate for the species
Low:	Spring predominately lacks suitable vegetation and substrate for the speices

3.3.3 Free-Flowing Water

An important factor of water quantity for springsnails is the continuity of free-flowing water. Based upon local site conditions, springsnails appear to thrive in spring ecosystems that contain free-flowing water without barriers, as compared to those with physical alterations or barriers. We consider barriers to include anthropogenic barriers such as impoundments, and natural barriers such as high elevation areas, rocks, trees, and other obstacles that are out of water and do not provide habitat. Natural barriers may increase as water discharge decreases.

Free-flowing water is a habitat need of springsnails at all life stages that we assume may influence a population's condition (insert citations). To evaluate the current conditions of this factor, we categorized information from survey reports and other sources as follows:

Comment [CW5]: This is an assumption based on site conditions observed. There are no references.

- High: Water is free-flowing without barriers
- Moderate: Water flows with partial barriers
- Low: Water flows are mostly or entirely blocked

Water quantity (i.e., adequate spring discharge and free-flowing water) only relates to the mass of water and discharge. Equally important is the timing, frequency, and duration of the flow regime, since springsnails are restricted to perennial aquatic habitats throughout their life cycle (Hershler and Liu 2008, p. 92; Sada 2008, p. 59; Sada 2009, p. 2). Springsnails may be found in small seeps to large springs, so water depths can vary greatly (Hershler 1998, p. 11). The majority of springsnails occur in slow to moderate current (i.e., >0 centimeters per second (cm/sec) to <40 cm/sec) (>0 inch per second (in/sec) to 16 in/sec)). They also occupy springs with discharge rates ranging from <60 liters per minute (L/min) to 16,800 L/min (0.04 cubic feet per second (cfs) to 10 cfs) (Sada 2009, pp. 3–4). Spring discharge should be continuous and water should be free-flowing for these springs to persist.

Adequate spring discharge is a habitat need of springsnails that may influence a population's condition (Hershler and Liu 2008, p. 92; Sada 2008, p. 59; Sada 2009, p. 2). Adequate spring discharge is important and changes to discharge rates may impact the ability of a species to survive in a particular spring; however, we do not know what the thresholds or limitations for spring discharge are for the 14 springsnail species. In the species sections under Chapter 5, we identify the observed ranges of spring discharge as available for each species. To evaluate the current conditions of this factor, we assume that spring discharge is adequate if the species is observed within a site.

Comment [PME6]: Any plans for further study?

4 CURRENT CONDITIONS—FACTORS THAT MAY IMPACT SPECIES NEEDS

In order to analyze the current condition of springsnail habitat and springsnail populations, an understanding of potential factors impacting the physical and biological needs of springsnails is necessary. These potential factors include how groundwater and surface water are managed in Nevada and Utah, what sources of stress and stressors may be impacting springsnail needs, and how existing regulatory and voluntary conservation measures may reduce impacts from stressors.

4.1 Water Management

As described in the previous section, the 14 springsnail species evaluated in this SSA are dependent on perennial, freshwater spring ecosystems. These ecosystems are fed by groundwater aquifers located throughout the Great Basin Carbonate and Alluvial Aquifer System in Nevada and western Utah (Heilweil and Brooks (eds.) 2011). Because of this dependence, the management of water in Nevada and Utah has the potential to impact springsnails. For the purposes of this SSA, the term water management is used to encompass the administration and appropriation of surface water and groundwater resources.

Water management in Nevada and Utah is administered by State Engineers from the Nevada Division of Water Resources and the Utah Division of Water Rights (UDWRi), respectively. Groundwater management is divided into and administered by groundwater basin (Nevada Department of Conservation and Natural Resources (DCNRa) 2017, entire; Utah State Legislature, Utah State Code section 73-5-15). To ensure the amount of groundwater withdrawn from a basin over a period of time does not exceed the long-term recharge of the basin, the State

Engineers from Nevada and Utah give basins a designation to reflect water resource conditions based on the extent of water development and water use, and the appropriation of water rights (Nevada Division of Water Resources 2017, entire; Utah State Legislature, Utah State Code section 73-5-15(1)(b)). Any use of water requires a permit from the State Engineer with two exceptions. The first exception is that domestic wells do not require permits in either state, although in Nevada, this is true only if the well uses less than 1,800 gallons of water per day (Nevada Division of Water Planning 1999, p. 8-3). Even though domestic wells do not require a permit, some oversight is provided by the requirement of a permit to drill a new well (Welden 2003, p. 8). The second exception is relevant only in Nevada where permits are not required for those uses that pre-date water law requirements (DCNRb 2017, entire).

In Nevada, the State Engineer identifies basins as not designated or designated (Table 4.1) based on the concept of perennial yield. Perennial yield is defined as the maximum amount of groundwater that can be salvaged each year over the long term without depleting the groundwater reservoir (DCNR 2017b, entire) and is measured in acre feet per year (afy). Perennial yield cannot be more than the natural recharge of the groundwater reservoir and is usually limited to the maximum amount of natural discharge. In some areas, natural discharge in the form of spring discharge may be appropriated already as surface water, although the perennial yield estimate may still include this water (DCNR 2017b, entire). Groundwater seepage or discharge may help sustain ecosystems in other areas (DCNR 2017b, entire).

The Nevada State Engineer identifies a basin as designated if a determination is made that further administration of the basin is needed (Welden 2003, p. 8). This typically occurs when water use is approaching or exceeding water recharge (Welden 2003, p. 8). By identifying a basin as designated, the Nevada State Engineer is granted additional authority in the administration of the groundwater resources within the designated basin. In basins where groundwater is being depleted, the Nevada State Engineer may issue orders, regulations, or rules to ensure water use and recharge are balanced within the basin (Welden 2003, p. 8). Orders, regulations, and rules may include identifying preferred water uses, prohibiting the drilling of new domestic wells, monitoring pumping inventories, declaring critical management areas, and using other management tools (Welden 2003, p. 8; DCNR 2017b, entire). The majority of springs where the 14 springsnails occur in Nevada are within designated basins (Table 4.1).

In Utah, the State Engineer identifies basins as open, closed, or restricted based on the extent of groundwater development within each basin and the concept of safe yield. Safe yield is similar to the concept of perennial yield and is defined as the amount of groundwater that can be withdrawn from a groundwater basin over a period of time without exceeding the long-term recharge of the basin or unreasonably (not defined in Code) affecting the basin’s physical and chemical integrity (Utah State Legislature, Utah State Code section 73-5-15(1)(b)). The Utah State Engineer may issue new water rights in basins that are designated as open (UDWRi 2017, entire). In basins that are closed, no new water rights are issued; therefore, any new groundwater development occurs through State Engineer approval of the acquisition and change of an existing, valid water right (UDWRi 2017, entire). Where groundwater withdrawals consistently exceed safe yield, basins are designated as restricted. Typically in these areas, additional administration by the Utah State Engineer is provided through policies and guidelines that apply to all or part of a drainage basin or hydrographic area (Utah State Legislature, Utah State Code section 73-5-15; UDWRi 2011, entire).

Table 4.1. Hydrographic regions and areas currently or historically occupied by the 14 springsnail species.

Hydrographic Region	Hydrographic Area (Area Number)	State(s) of Hydrographic Area	Estimated Perennial or Safe Yield[a] (afy)	Currently Appropriated Groundwater Rights (afy)	Basin Designation[a] (Order Number)	Associated Springs and Spring Provinces	Spring Aquifer Source[b]	Springsnail Species Present
Colorado	Las Vegas Valley (212)	Nevada (NV)	25,000	90,122.16	Designated (0-833)	Corn Creek Springs Province	Local	-Corn Creek pyrg
Colorado	Las Vegas Valley (212)	Nevada (NV)	25,000	90,122.16	Designated (0-833)	Southeast of Corn Creek Spring	Local	-Corn Creek pyrg
Colorado	Las Vegas Valley (212)	Nevada (NV)	25,000	90,122.16	Designated (0-833)	Unnamed Spring near Corn Creek Springs	Local	-Corn Creek pyrg
Colorado	Las Vegas Valley (212)	Nevada (NV)	25,000	90,122.16	Designated (0-833)	Red Spring	Mountain block	-Spring Mountains pyrg
Colorado	Las Vegas Valley (212)	Nevada (NV)	25,000	90,122.16	Designated (0-833)	Willow Spring	Mountain block	-Spring Mountains pyrg
Death Valley	Pahrump Valley (162)	NV/California (CA)	20,000 (NV)	57,444.08 (NV)	Designated (0-1252)	Kiup Spring	Mountain block	-Spring Mountains pyrg
Death Valley	Pahrump Valley (162)	NV/California (CA)	20,000 (NV)	57,444.08 (NV)	Designated (0-1252)	Horse Springs Province	Mountain block	-Spring Mountains pyrg
Death Valley	Pahrump Valley (162)	NV/California (CA)	20,000 (NV)	57,444.08 (NV)	Designated (0-1252)	Manse Spring	Mountain block	-Spring Mountains pyrg (historic)
Death Valley	Pahrump Valley (162)	NV/California (CA)	20,000 (NV)	57,444.08 (NV)	Designated (0-1252)	Crystal Spring	Mountain block	-Spring Mountains pyrg
Death Valley	Pahrump Valley (162)	NV/California (CA)	20,000 (NV)	57,444.08 (NV)	Designated (0-1252)	South Rainbow Spring	Mountain block	-Spring Mountains pyrg (unsubstantiated)
Colorado	Muddy River Springs Area (219)	NV	100 – 36,000	16,544.21	Designated (0-1023)	Apcar Springs Province	Regional	-Moapa pebblesnail -Moapa Valley pyrg -Grated tryonia
Colorado	Muddy River Springs Area (219)	NV	100 – 36,000	16,544.21	Designated (0-1023)	Baldwin Spring	Regional	-Moapa pebblesnail -Moapa Valley pyrg -Grated tryonia
Colorado	Muddy River Springs Area (219)	NV	100 – 36,000	16,544.21	Designated (0-1023)	Cardy Lamb Spring	Regional	-Moapa pebblesnail -Moapa Valley pyrg -Grated tryonia
Colorado	Muddy River Springs Area (219)	NV	100 – 36,000	16,544.21	Designated (0-1023)	Muddy Spring	Regional	-Moapa pebblesnail -Moapa Valley pyrg -Grated tryonia
Colorado	Muddy River Springs Area (219)	NV	100 – 36,000	16,544.21	Designated (0-1023)	Pederson Springs Province	Regional	-Moapa pebblesnail -Moapa Valley pyrg -Grated tryonia
Colorado	Muddy River Springs Area (219)	NV	100 – 36,000	16,544.21	Designated (0-1023)	Plummer Springs Province	Regional	-Moapa pebblesnail -Moapa Valley pyrg

Hydrographic Region	Hydrographic Area (Area Number)	State(s) of Hydrographic Area	Estimated Perennial or Safe Yield[a] (afy)	Currently Appropriated Groundwater Rights (afy)	Basin Designation[a] (Order Number)	Associated Springs and Spring Provinces	Spring Aquifer Source[b]	Springsnail Species Present
								-Grated tryonia
Colorado	Black Mountains Area (215)	NV	1,300 (SY 7,000)	5,797.66	Designated (O-1018)	Blue Point Spring	Regional	-Blue Point pyrg
Colorado	Pahranagat Valley (209)	NV	25,000	10,743.76	Designated (O-1199)	Ash Springs Province	Regional	-Grated tryonia -Pahranagat pebblesnail
						Crystal Springs Province	Regional	-Hubbs pyrg -Grated tryonia
						Hiko Spring	Regional	-Hubbs pyrg
Colorado	White River Valley (207)	NV	37,000	35,458.21	Designated (O-1219)	Hot Creek Springs Province	Local	-Grated tryonia -Pahranagat pebblesnail
						Moon River Spring	Local	-Grated tryonia -Pahranagat pebblesnail
						Moorman Spring	Local	-Grated tryonia -Pahranagat pebblesnail
						Arnoldson Spring	Local	-White River Valley pyrg -Hardy pyrg (historic)
						Flag Springs Province	Regional[c]	-White River Valley pyrg -Flag pyrg
						Camp Spring	Local	-White River Valley pyrg
						Preston Big Spring	Local	-White River Valley pyrg
						Cold Spring	Mountain block	-White River Valley pyrg
						Nicholas Spring	Local	-White River Valley pyrg
						Indian Springs Province	Unknown	-White River Valley pyrg
						Lund Spring	Regional[c]	-White River Valley pyrg
						Butterfield Spring Province	Local	-Butterfield pyrg -Hardy pyrg

Hydrographic Region	Hydrographic Area (Area Number)	State(s) of Hydrographic Area	Estimated Perennial or Safe Yield[a] (afy)	Currently Appropriated Groundwater Rights (afy)	Basin Designation[a] (Order Number)	Associated Springs and Spring Provinces	Spring Aquifer Source[b]	Springsnail Species Present
						Emigrant Spring Province	Local	-Hardy pyrg
						Hardy Spring Province	Local	-Hardy pyrg
						Silver Springs Province	Unknown	-Hardy pyrg
						Ruppes Boghole Springs Province	Unknown	-Hardy pyrg
Colorado	Cave Valley (180)	NV	5,600	5,295.94	Not Designated	Parker Station Spring	Local	-Hardy pyrg
Colorado	Dry Lake Valley (181)	NV	15,000	12,631.48	Not Designated	Meloy Spring	Mountain block[d]	-Hardy pyrg
Colorado	Lake Valley (183)	NV	12,000	17,061.63	Designated (0-726)	Wambolt Springs Province	Local	-Lake Valley pyrg
Great Salt Lake Desert	Spring Valley (184)	NV	84,000	80,738.30	Not Designated	Turnley Spring	Mountain block	-Bifid duct pyrg
						Rock Spring	Mountain block	-Bifid duct pyrg
						Cache Springs Province	Mountain block	-Bifid duct pyrg
						Unnamed Spring near Sac Pass 1	Mountain block	-Bifid duct pyrg
						Unnamed Spring near Sac Pass 4	Mountain block	-Bifid duct pyrg
Great Salt Lake Desert	Snake Valley (195/254)	NV/Utah (UT)	25,000 (NV)	10,971.28 (NV)	Not Designated	Unnamed Springs N of Big Springs Province (NV)	Mountain block or local (?)	-Bifid duct pyrg
Sevier Lake	Sevier Desert (287)	UT	UK[e] but estimated recharge = 41,000[f]	UK[e] but well withdrawals = 55,000 in 2015[g]	Open/Restricted/Closed; Overlaps Sevier Desert Groundwater (GW) Policy Area 68	Antelope Spring	Mountain block	-Bifid duct pyrg
						Red Cedar Spring	Mountain block	-Bifid duct pyrg
						Big Spring	Mountain block	-Bifid duct pyrg
	Pavant Valley (286)	UT	60,000[h]	UK[e] but well withdrawals = 128,000 in	Closed; Overlaps Pahvant	Church Spring	Local	-Bifid duct pyrg
						Copley's Cove Spring	Mountain block	-Bifid duct pyrg

Hydrographic Region	Hydrographic Area (Area Number)	State(s) of Hydrographic Area	Estimated Perennial or Safe Yield[a] (afy)	Currently Appropriated Groundwater Rights (afy)	Basin Designation[a] (Order Number)	Associated Springs and Spring Provinces	Spring Aquifer Source[b]	Springsnail Species Present
				2015[g]	Valley GW Policy Area 67			
	Leamington Canyon (285)	UT	UK[e] but estimated recharge = 36,000[f]	UK[e] but maximum well withdrawal estimates = 10,000[i]	Closed; Overlaps Lower Sevier River GW Policy Area 66	Maple Grove Springs Province	Mountain block	-Bifid duct pyrg

[a] Further explanation of terms is provided in text
[b] Sada 2017, entire
[c] Service 2012, p. 75
[d] Golden *et al.* 2007, p. 168
[e] UK = Unknown
[f] Heilweil and Brooks (eds.) 2011, p. 170
[g] Burden *et al.* 2016, p. 5
[h] UDWRi 1994, p. 2
[i] Heilweil and Brooks (eds.) 2011, Auxili

4.2 Stressors and Sources of Stressors

4.2.1 Considered but not Carried Forward

We considered the potential impacts from parasitism, disease, and collection because they are known to impact similar springsnail species and therefore, may impact the springsnail species evaluated in this SSA. However, the best available scientific and commercial information does not indicate impacts from parasitism, disease, or collection specific to the 14 species evaluated in this SSA. Therefore, these topics are not carried forward in our evaluation.

4.2.1.1 *Parasitism and Disease*

Researchers have documented parasitism in other freshwater snail species, so logically it may also impact the 14 springsnail species in this SSA. Parasitic (e.g., trematode) infections can be prevalent in some freshwater snail species with impacts to the individuals and potentially to populations. For example, Taylor (1987, p. 47) found that trematode infestation and incidence of parasitic castration are high in dense populations of springsnails in New Mexico. However, following our evaluation of all potential springsnail stressors, we found no evidence that springsnails are affected by disease and no information was found to document impacts from parasitism as a stressor for the 14 species evaluated in this SSA Report.

4.2.1.2 *Collection*

Springsnails are occasionally collected for purposes associated with spring and springsnail surveys. Collection may be necessary to provide voucher specimens or verify the species' identity. Martinez and Sorenson (2007, p. 28) detected significant differences in the total size of springsnail populations across sampling periods. Sampling without replacement caused a transitory decline in total population size of each organism, though springsnails became locally abundant again the following year (Martinez and Sorenson (2007, p. 28). Springsnails may also be incidentally collected when vegetation or substrate is removed from springs or springbrooks. This likely occurs during restoration activities (e.g., removing dense vegetation within a spring) or from vegetation removal for personal use (e.g., removing watercress to eat). We did not discover any evidence or report to indicate collection occurs at any spring that affects the 14 springsnail populations. Therefore, we will not discuss collection as a potential stressor further in this report.

4.2.2 Considered and Carried Forward

We determined the following stressors may impact specific springsnails needs (Chapter 4) and ultimately the resiliency of springsnail populations (Chapters 5 and 6) Not all stressors have been documented at all springs. In each section, we identify at which springs stressors have been observed and which springsnail species may be impacted. We also describe the general potential effects of these stressors on the needs of springsnails. Additional specific information on impacts to each spring location and springsnail population, if applicable, is discussed in Chapters 5 and 6.

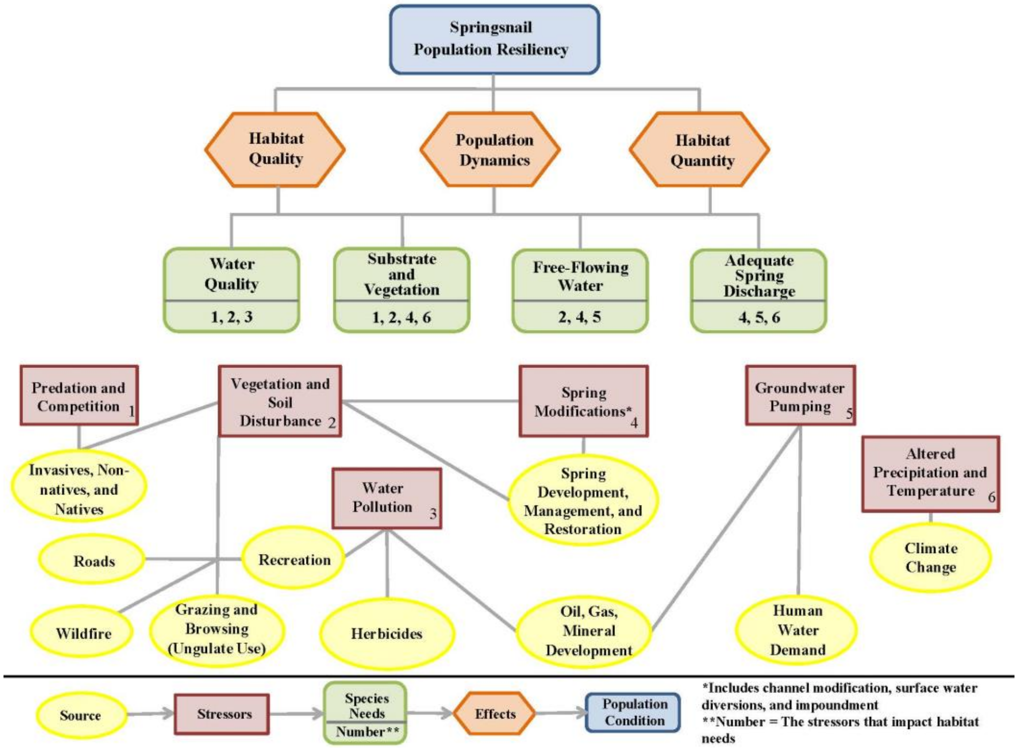


Figure 4.1. Illustration identifying stressors, sources of those stressors, species needs, effects, and population condition for the 14 springsnails evaluated in Nevada and Utah.

4.2.2.1 *Predation and Competition*

Predation or competition due to invasive, nonnative, and native species is documented at one or more springs or spring provinces, potentially impacting the following species: Moapa pebblesnail, Moapa Valley pyrg, grated tryonia, Blue Point pyrg, Pahranagat pebblesnail, Hubbs pyrg, White River Valley pyrg, Lake Valley pyrg, and bifid duct pyrg.

Invasive and nonnative species, and to a lesser degree native species, are known or presumed predators of springsnails and compete for resources, such as food and space. These species can indirectly affect springsnails by changing ecosystem function (Brown *et al.* 2008, p. 489; Lysne *et al.* 2008, pp. 466–467; Sada 2016, p. 11). Ecosystem changes include disruption of the algal component, nutrient recycling, and fluxes in bacterial production as described by Mehler and Acharya (2014, p. 93) at Rogers Spring (near Blue Point Spring). Invasive and nonnative competitors can also change the dominance relationships among gastropods and result in major losses of native species (Covich 2010, p. 191). Population- and rangewide-level effects typically occur only when high numbers or dense populations of these organisms exist in a spring, which currently does not occur in any spring in this assessment.

We found no documented observation of predation of any of the 14 species in this assessment; however, we assume predation may occur because it has been observed in another *Pyrgulopsis* species in similar environments with the same predator species. Many different types of predators can consume small snails that are typically less than 4 mm (0.2 in) shell length (Covich 2010, p. 195). Natural predators of springsnails include waterfowl, shorebirds, amphibians, fishes, crayfish, leeches, and aquatic insects (Martinez and Thome 2006, p. 9). Damselflies (Zygoptera) and dragonflies (Anisoptera) have been observed feeding on snails (Mladenka 1992, pp. 81–82). Important nonnative species that have extirpated spring-dwelling taxa in the southwestern U.S. include crayfish (mostly *Procambarus* spp.), mosquitofish (*Gambusia affinis*), red-rimmed melania (*Melanoides tuberculata*), mollies (*Poecellia* sp.), goldfish (*Carassius auratus*), cichlids, and bullfrogs (*Rana catesbeiana*) (Sada 2016, p. 11).

Pyrgulopsis species appear to be negatively affected in various parts of the West by introduced crayfishes that feed on aquatic snails (Hershler 1998, p. 14; Sada and Vinyard 2002, p. 277). In a study outside our analysis area (i.e., Ash Meadows, Nevada), Kilburn (2012, p. 43) found that springs containing crayfish consistently had fewer animal species and contained little to no endemic springsnails. Animal material was present in 93 percent of crayfish stomachs analyzed, with one gut filled entirely with native springsnails and native riffle beetle larvae (Kilburn 2012, p. 43). This level of predation could affect the population dynamics and substantially reduce the size of springsnail populations. Springs occupied by springsnails assessed in this report readily accessible by the public are most vulnerable to introduction of crayfish and other springsnail predators and competitors. Blue Point Spring and nearby Rogers Spring are sites with high public visitation and frequent release of aquarium fish and other pet trade species (Courtenay and Deacon 1983, p. 221; Relict Leopard Frog Conservation Team 2016, p. 32). Crayfish have been identified at Crystal Springs Province and Hiko springs (Golden *et al.* 2007, p. 199), where the grated tryonia and Hubbs pyrg occur. The effect these species have on springsnails is not known.

Johnson *et al.* (2013, p. 248) identified several families of fish known to prey on springsnails in the U.S and Canada, including the families Acipenseridae, Cyprinidae, Catostomidae, Ictaluridae, Centrarchidae, and Percidae. Field experiments in Cuarto Cienegas, Mexico, demonstrate that hydrobiid snails (such as *Mexipyrgus churinceaus*) increase threefold in density when predatory fishes were excluded (Covich 2010, p. 204). Remnants of Page springsnail shells have been reported in analyses of stomach content of mosquitofish from the Oak Creek Springs complex (= province) in Arizona (Raisanen 1991, p. 71). Within the analysis area, Sada (2017, p. 58-59) observed mosquitofish but not predation in Muddy River, Moapa Valley, and Pahranagat Valley springs. Additionally, nonnative fish are known to co-occur with the Moapa pebblesnail, Moapa Valley pyrg, grated tryonia, Blue Point pyrg, Pahranagat pebblesnail, Hubbs pyrg, White River Valley pyrg, and bifid duct. Although predation is possible in these areas, none has been documented to date. Additional research is needed to determine if there are any population-level effects of nonnative fish on these species.

Some predator species are known to kill snails by penetrating the shell opening, such as some leeches and aquatic insects (Covich 2010, p. 207), which are species known to occur within range of springsnails assessed in this report. When this type of predation occurs, they leave no trace and their impact on both individuals and populations is difficult to determine in remains of modern or fossil shells (Covich 2010, p. 207).

Brown *et al.* (2008, pp. 488–489) found that springsnails that co-occur in large spring systems with greater habitat heterogeneity appear to be facilitated by spatial habitat segregation; this segregation suggests a competitive basis for substrate use. For example, Sada (2008, p. 60) describes an assemblage of native springsnails and the nonnative red-rimmed melania in southern Nevada, which includes the Moapa pebblesnail and Moapa Valley pyrg. Each species of springsnail occupies a wide diversity of habitats, but each species also exhibits habitat preferences for a range of depths, velocities, temperatures, or substrates. Habitat niche overlap occurs, but varies among species. Thus, competitive interactions appear to minimally influence the structure and distribution of the Moapa pebblesnail and Moapa Valley pyrg, which may also apply to the other species of springsnail in this report.

Invasive snails affect native snails directly through competition for food and space or indirectly through changes in ecosystem function or parasite populations (Brown *et al.* 2008, p. 489). Additional stress from competition is posed by invasive gastropods including the red-rimmed melania and New Zealand mudsnail (*Potamopyrgus antipodarum*), which have recently spread across large portions of the West (Hershler *et al.* 2014, p. 5), including Crystal Springs Province (where the Hubbs pyrg and Grated tryonia occur) and Blue Point Spring (where Blue Point pyrg occurs). The red-rimmed melania may not have a large effect on Blue Point pyrg because heterogeneity in the springbrook environment is believed sufficient for these species to partition their habitat and coexist (Sada 2016, p. 67). Both of these invasive species primarily reproduce asexually and frequently achieve high densities at localities where they co-occur with springsnails (Hershler *et al.* 2014, p. 5). Red-rimmed melania are known to competitively displace native gastropods, posing concern for endemic populations of springsnails in New Mexico (New Mexico Aquatic Invasive Species Advisory Council 2008, p. 20). Riley *et al.* (2008, p. 509) showed that a significant reduction in the growth rate of the native Jackson Lake springsnail in the presence of the New Zealand mudsnail in the Snake River drainage. Although these two studies involve species of springsnail outside the analysis area, springs in our analysis area that harbor these invasive or nonnative competitors can result in one or more of the 14 springsnails being at greater risk of experiencing individual-level or possibly population-level impacts from predation.

Amphibians are known to co-occur with grated tryonia, Pahranagat pebblesnail, White River Valley pyrg, Spring Mountains pyrg, and Lake Valley pyrg. While amphibians have been identified as a potential predator of springsnails, the best available information did not indicate any of these species prey on springsnails.

In summary, springsnail predation and competition are potential stressors to 9 of the 14 springsnail species; 8 of the springsnail species co-occur with nonnative fish and 2 with crayfish. Leeches and aquatic insects are potential predators but no data were found to document abundance or effects on springsnail populations. The red-rimmed melania occurs at springs occupied by seven of the springsnails. Competition between melania and springsnails appear to minimally influence the structure and distributions of the Moapa pebblesnail and Moapa Valley pyrg in the analysis area, which may apply to the other springsnails in this report. The current level of predation and competition, and effects on springsnail populations, are not well-documented.

4.2.2.2 *Vegetation and Soil Disturbance*

The primary cause of imperilment for listed snail species is loss or alteration of habitat (Lysne *et al.* 2008, p. 464). Sources of stress such as wildfire, roads, recreation, and grazing and browsing (ungulate use) contribute to vegetation and soil disturbance at springsnail locations evaluated in this SSA Report. In this section, we generally describe how vegetation and soil disturbance can affect springsnail needs, which include water quality, substrate and vegetation, and free-flowing water, followed by specific ways each stressor affects springsnails. Abele (2011, p. 5) found that spring data collected in Nevada during the 1990s and again in 2007 and 2008 showed little difference in the overall condition of springs. However, by 2011, with greater surveying effort, few springs within the Great Basin were found to not be altered by diversion, recreation, or incompatible livestock use (Abele 2011. p. 5), and that characteristics of only 20 percent of springs were relatively natural (Abele 2011, p. 6).

Sada *et al*. (2015, p. 4) determined that there are few studies associated with spring systems and how they respond to human disturbance. Fleishman *et al.* (2006, p. 1,091) found that species richness (total number of taxa in a sample) of spring-associated perennial plants and cover of native plants tend to decrease as intensity of disturbance increases, whereas species richness (but not cover of nonnative plants) tend to peak with intermediate disturbance (disturbances including grazing, recreation, and water diversion). Spring-fed aquatic and riparian communities may be resistant to minor disturbance, but are affected by higher levels of disturbance (Sada *et al.* 2015, p. 3). This is consistent with a basic tenant of ecological processes whereby the effects of disturbance on a system is a function of its magnitude, duration, and frequency. Ecological systems are characteristically resistant and resilient to low magnitude disturbances that are short-term and infrequent, but they may be functionally altered when a disturbance is frequent, long lasting, or exceedingly large (Sada *et al.* 2015, p. 3). Anthropogenic disturbances may also modify material flow and nutrient cycling through food webs (Sada *et al.* 2015, pp. 2–4). Species needs affected by soil and vegetation disturbance include aquatic vegetation and substrate (including bank cover and canopy cover). Vegetation and substrate provide breeding, feeding, and cover for springsnails. Changes in bank or canopy cover may affect thermal protection and primary production for springsnail food and shelter needs.

In Colorado Plateau springs, Weissinger *et al.* (2012, p. 393) examined disturbance and biological and hydrological characteristics of springs impacted by livestock and vehicle use and found that taxonomic richness of vegetation was highest in moderately disturbed sites and lower in highly disturbed springs. They also observed that disturbance had no effect on nutrients, DO, pH, electrical conductance, or discharge (Weissinger *et al.* (2012, p. 393). In a similar study, Sada *et al.* (2015, p. 43) found no relationship between disturbance and taxonomic richness for Nevada springs. Therefore, within our analysis area, we considered the magnitude of potential impacts from vegetation and soil disturbance.

Sada and Lutz (2016, p. iii) found that moderately or highly degraded springs were most common on Bureau of Land Management (BLM) land, followed by private lands, U.S. Forest Service (USFS), and finally Service (National Wildlife Refuge) lands. Most of the springs in this assessment appear to have stabilized from anthropogenic disturbance or following restoration activities (Sada 2017, entire).

4.2.2.2.1 Disturbance from Roads

Vegetation and soil disturbance from roads has been documented at one or more spring or spring province, potentially impacting the following species: Moapa pebblesnail, Moapa Valley pyrg, grated tryonia, Blue Point pyrg, White River Valley pyrg, Flag pyrg, Hardy pyrg, and bifid duct pyrg. The species needs potentially affected include water quality, substrate and vegetation, and free-flowing water.

Springs and springbrooks may be affected by roads that pass through or nearby. Vehicles that enter or pass through springbrooks may crush springsnails, thus potentially affecting population dynamics. Vehicles may also crush or destroy springsnail vegetation and substrate, alter water flow patterns, or impact water quality through the addition of chemicals or oil. Roads may affect soil density, temperature, soil moisture content, light, dust, surface-water flow, run-off patterns, and sedimentation (Trombeck and Frissell 2000, p. 21). Roads modify natural drainage networks and accelerate erosion processes. These changes can alter physical processes in streams, leading to changes in streamflow regimes, sediment transport and storage, channel bank and bed configurations, substrate composition, and stability of slopes adjacent to streams (Furniss *et al.* 1991, p. 297). These changes can have important biological consequences for spring and springbrook ecosystem components (Furniss *et al.* 1991, p. 297). Any species-specific impacts that may exist are described in Chapter 5.

4.2.2.2.2 Disturbance from Wildfire

Vegetation and soil disturbance from wildfire has been documented in the Muddy River Springs Area and potentially impacts the following species: Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia. The potential for disturbance from wildlife may impact any species, since its occurrence cannot be predicted. The species needs potentially affected include water quality, substrate and vegetation, and free-flowing water.

Wildfire is a pulsed disturbance (occurring as a relatively discrete event in time), and the duration of its effects on freshwater ecosystems depends on terrestrial ecosystem recovery. Fires kill or damage vegetation and alter soil chemistry, thereby reducing nutrient transport (Bixby *et al.* 2015, p. 1,343). Wildfire effects on springsnails, both direct and indirect, depend on the extent and severity of fire, proximity of fire to springsnails, topography, and size of the watershed (Gresswell 1999, pp. 193–221). Smoke diffusion into water and ash flow can result in large amounts of phosphorus and nitrogen being mobilized into aquatic systems (Spencer and Hauer 1991, p. 24) that may be toxic to aquatic invertebrates. However, fire may benefit aquatic species under controlled conditions by providing the disturbance to riparian vegetation necessary to keep succession from eliminating the aquatic system (Hobbs and Huenneke 1992, pp. 326–327).

Fires modify the inputs of dissolved and particulate organic matter (e.g., ash and charcoal) into springs and streams by damaging or killing upland vegetation. Where riparian or wetland vegetation is destroyed or damaged by fire, the canopy opens (if one exists at the site), thereby decreasing allochthonous inputs (i.e., material that enters from outside, usually organic matter and nutrients) and increasing light and temperature levels. This promotes production of material within a spring or stream such as algae, with repercussions for aquatic communities and food webs (Bixby et al. 2015, pp. 1,343–1,344). Springs without a present canopy could experience fewer effects from wildfire, as it burns smaller fuels faster. Regardless of vegetation type burned, the loss of existing vegetation would likely result in bank erosion and increase of sedimentation into the system.

4.2.2.2.3 Disturbance from Grazing and Browsing (Ungulate Use)

Vegetation and soil disturbance from grazing and browsing (ungulate use) is documented at one or more spring or spring province, potentially impacting the following species: Spring Mountains pyrg, Hubbs pyrg, Blue Point pyrg, grated tryonia, Pahranagat pebblesnail, White River Valley pyrg, Butterfield pyrg, Hardy pyrg, Lake Valley pyrg, and bifid duct pyrg. The species needs potentially affected include water quality, substrate and vegetation, and free-flowing water.

There is little information describing the effects of grazing and ungulate disturbance on springsnails or spring ecology. Springsnails may be trampled by livestock resulting in springsnail mortality. Habitat impacts may include disturbance of substrates and aquatic vegetation where springsnails breed, feed, and shelter, as well as damaged or reduced stream bank and canopy cover.

Plant cover is an important measure of ecosystem health because it conserves soil, improves water quality, and is correlated with plant productivity. Thus, sustained grazing or browsing by ungulates could be detrimental to entire ecosystems. For example, a long-term grazing study in spring-fed wetlands of California found that sustained grazing at moderate or higher intensities is not desirable from an ecosystem conservation perspective to prevent significant erosion and prevent undesirable changes in species composition (Allen-Diaz *et al.* 2004, pp. 144–148). However, results also showed that occasional, moderate grazing does not significantly affect plant cover (Allen-Diaz *et al.* 2004, p. 144). Another example of potential negative effects as a result of improperly managed grazing is a study by Kauffman and Krueger (1984, p. 432) who identified impacts to streamside vegetation, stream channel morphology, shape and quality of the water column, and the structure of the streambank soils. They also found that improper livestock use of riparian ecosystems can change, reduce, or eliminate vegetation bordering the stream (Kauffman and Krueger 1984, p. 432). Overgrazing can cause bank erosion, accelerated sedimentation, and subsequent silt degradation (Kauffman and Krueger 1984, p. 432). In contrast, light to moderate grazing as observed at Wambolt Springs where the Lake Valley pyrg populations occur does not appear to result in adverse effects (Sada 2016, p. 111). Overall, based on the best available information, it appears that light to moderate disturbance may not adversely affect springsnail populations; however, moderate disturbance sustained over long periods may result in adverse effects.

4.2.2.2.4 Disturbance from Recreation

Vegetation and soil disturbance from recreation is documented at one or more spring or spring province, potentially impacting the following species: Spring Mountains pyrg, Moapa pebblesnail, Moapa Valley pyrg, grated tryonia, Pahranagat pebblesnail, Spring Mountains pyrg, White River Valley pyrg, and bifid duct pyrg. The species needs potentially affected by recreation activities include water quality, substrate and vegetation, and free-flowing water (if the springbrook is impounded).

Springs often provide the only shade and water in deserts, so they are popular among campers and bathers. Soil compaction, vegetation removal, and dam construction to create swimming pools are the most common impacts from recreation. Sada and Rosamond (2015, p. 2) found that the elongate Mud Meadows springsnail (*Pyrgulopsis notidicola*) occurred along flowing portions of a springbrook in the Nevada Black Rock Desert, but was absent from small impoundments devoid of vegetation that had been built by recreational bathers. Mehlhop and Vaughn (1994, p. 72) found that recreation is a threat to spring ecosystems if spring outflows are altered substantially, but swimmers and bathers only temporarily displaced freshwater snails. Sada (2001, p. 255) demonstrated that trampling caused by Death Valley National Park visitors reduced habitat quality and population size of the Badwater snail (*Assiminea infima*). Trampling and springsnail abundance were also negatively correlated and attributed this to direct mortality and habitat modification caused by people walking along springbrook banks at the park (Sada 2001, pp. 263-264). Overall, we found that disturbance due to recreational activities may have negative effects on springsnails at a given spring, but these are localized effects that do not reach the level of the population or species.

4.2.2.2.5 Disturbance Associated with Nonnative and Invasive Plants

Springs are typically characterized by vegetation type and condition to inform conservation and management. Aquatic plants are important to maintain aquatic ecosystem function through by influencing hydrological regime, sedimentation, nutrient cycling, and habitat of associated fauna. Introduction of nonnative or invasive species are considered a disturbance and can alter these functions (Santos *et al.* 2011, p. 443). Work by Fleishman and Sada (2006, p. 1092) in the Spring Mountains found that cascading effects may occur following replacement of dominant native plants by invasive nonnative plants. However, they also found that the response of native and nonnative spring biota to low-level disturbance is poorly understood.

Sada (2017, entire) identified nonative and invasive plants at several sites during his 2016 survey (e.g., watercress at multiple sites, palm trees at Baldwin Spring, and giant reed at Butterfield Springs Province) but did not determine that any springs was substantially affected by nonnative plants. Watercress was the most common species of nonnative aquatic plant identified by Sada (2017, entire), though he did not identify any adverse effects of watercress on any of the species in the SSA Report. Based on the best available information, we consider nonnative plants a source of vegetation and soil disturbance with negligible to minor effects on springsnails.

4.2.2.3 *Water Pollution*

Although hydrobiid snails as a group occur in a wide variety of aquatic habitats, each species is usually found within relatively narrow habitat parameters, and is likely sensitive to water quality (Sada 2008, p. 59). Potential sources of water pollution documented at springsnail locations within our analysis area that may impact current and future conditions of water quality include recreation and herbicide application. The level of effect these sources may have on water pollution has not been measured or sampled; however, we assume some level of water pollution is occurring if recreation or herbicide application has been documented at or near a spring.

4.2.2.3.1 Water Pollution from Recreation

Water pollution from recreation is documented at Muddy Spring, Ash Springs Province, Hot Creek Springs Province, and Lund Spring and therefore, may be potentially impacting the Moapa pebblesnail, Moapa Valley pyrg, grated tryonia, Pahranagat pebblesnail, and White River Valley pyrg.

In addition to habitat disturbance from recreation (described in Chapter 4.2.2.2.4), recreational activities may contribute to water pollution at springs that supports springsnail populations. Mehlhop and Vaughn (1994, p. 72) found that recreation, such as bathers, is a stressor to spring ecosystems if chemicals are added to the system. The source of these chemicals may include soap or sun protection products. We assume that if a spring is known to be used for recreational bathing, some level of water pollution is occurring, although no water quality sampling has been completed to evaluate this. The fact that springsnails have persisted suggests that at historical and current levels, no population-level impacts have occurred. In addition, Sada (2017, entire) reports that springsnails tolerate low to moderate levels of these activities with no apparent population- or species-level effect to their overall numbers and distribution, particularly if the impacts are short-term.

4.2.2.3.2 Water Pollution from Herbicides

Water pollution from herbicide application has been observed at Silver Springs Province, therefore, potentially impacting the Hardy pyrg.

The application of herbicides on lands administered by state or Federal agencies occurs under strict regulations and procedures (e.g., BLM 2007b, entire). Herbicide application on Federal land is also evaluated in accordance with the National Environmental Policy Act of 1970 (NEPA), while herbicide use on private land does not typically require NEPA analysis. Standard stipulations for herbicide use near riparian areas on Federal land typically require the use of a selective herbicide that is safe for uses in riparian zones and near aquatic sites using hand application methods (BLM 2007b, Chapter 4, p. 36). We expect any potential effects to springsnails from herbicides to occur at the individual level as opposed to population or rangewide impacts. The likely method of exposure would be from aerial drift or runoff from treated vegetation after a rain event, since aquatic herbicides are not typically applied to springs or streams. Herbicide effects on aquatic invertebrates are categorized as no to low risk for all four herbicides used near riparian areas, as analyzed in the BLM Environmental Impact Statement (BLM 2007b, Chapter 4, p. 87). We cannot assess the potential impact of herbicide on privately-owned springs, but we found no information that application of herbicide at springs assessed in this report has occurred other than in the Silver Springs Province.

4.2.2.4 *Spring Modifications*

Spring modifications include channel modification, surface water diversions, and impoundment at springs. Such modifications may occur for development, management, or restoration purposes and have been documented at the majority of springs and spring provinces, and therefore, all 14 springsnail species have one or more population potentially impacted from this stressor.

Human alterations of springheads, to concentrate or divert discharge, negatively impact spring systems and invariably result in loss of biota (Unmack and Minckley 2008, p. 20). Spring developments may result in water diversion, impoundments, or channel modification. For example, a number of springs in Death Valley National Park are developed for municipal water use, which have changed aquatic and riparian habitats and eliminated several populations of endemic macroinvertebrates (Sada and Herbst 2006, p. 1). Many springs evaluated in this report are or have been affected to some degree by development.

Surface water diversions are sources of multiple stresses to springs including: altering physical integrity, creating conditions that favor nonnative aquatic species, or degrading habitat conditions for native riparian vegetation. Additionally, the presence of pipes, dikes, dams, impoundments, channel modifications and dredging, or spring boxes indicate further stress in the form of spring diversions and loss of occupancy at some sites. For example, an impoundment created by dredging and filling at Hardy Springs resulted in the separation of Hardy pyrgs at that site, with springsnails continuing to occupy the springbrook upstream of the impoundment and extirpation of the species downstream of the impoundment (Sada 2016, p. 22). Although surface water diversions can cause stress to springs and springsnails, as indicated above, populations of springsnails in historically disturbed habitats can recover if the disturbance is low in magnitude and infrequent (Sada 2016, p. 22).

Spring systems can also recover from vegetation and soil disturbances that occur from restoration activities. For example, historical impoundments can be removed in order to restore habitat for aquatic species. This entails removal of the impoundment often followed by channel modification in order to get the system to return to its natural channel, which may no longer be present. While restoration is a large source of stress to a spring system and springsnails, there is usually an overall benefit to springsnails by improving all of the species needs within a spring (water quality, substrate and vegetation, free-flowing water, and adequate spring discharge).

Although some spring-dependent species may prefer deeper water habitats that impoundments provide, many of these species, such as springsnails, primarily rely upon the natural physical integrity of an undammed system. All impounded springs are considered highly disturbed because flow has been interrupted and functional characteristics of the aquatic system have been highly altered.

Contrary to impoundment and ponding of water, spring discharge in the western U.S. has been primarily affected by surface diversion from spring sources and springbrooks that causes reduced spring discharge. In extreme cases, springs and springbrooks are dried and all aquatic life is extirpated. Springs and springbrooks may not completely dry when diversions leave water in the system, but decreased discharge affects springbrook habitat and the structure and functional characteristics of the benthic macroinvertebrate community, which includes springsnails.

Aquatic habitat and productivity are affected by diversion in a number of ways. As discharge is reduced, springbrook length and wetted width and depth decrease. Decreasing the volume of water also alters thermal characteristics of the springbrook, as well as aspects of water chemistry such as pH and DO concentration. Consequences of these incremental changes include reduced productivity, habitat heterogeneity, and benthic macroinvertebrate microhabitat availability (Sada *et al.* 2015, pp. 45–46).

Riparian vegetation has an early and evident response to a reduction in spring flow. Plants occurring in spring outflows are adapted for life in waterlogged soil; however, as water levels decline, soil dries and becomes aerated, which facilitates invasion of forbs, shrubs, and trees. New water depths and soil conditions may also allow stands of cattails (*Typha* spp.) and reeds (*Phragmites* spp.) to expand, sometimes reducing or eliminating open water (Unmack and Minckley 2008, p. 24).

In summary, spring modifications may include surface water diversion, impoundment, or channel modification, including dredging. These spring modifications affect springsnail needs by reducing springbrook discharge length, wetted width and depth (unless ponded), and open water needed for plant productivity, which provides food and shelter. Because the thermal and chemical properties of water are influenced by water depth and flow, alteration of these properties may affect water quality. The level and effect of spring developments across all the locations analyzed in this report range from an absence of spring modifications to potentially significant impacts. Details related to specific locations and species are presented in Chapter 5 where applicable.

4.2.2.5 *General Impacts from Groundwater Pumping*

Increased groundwater pumping in Nevada and western Utah is primarily driven by human water demand for municipal purposes, irrigation, and development for oil, gas, and minerals. In this section, we first describe general impacts from groundwater pumping on springsnails and their habitat. We use the term *human water demand* to describe groundwater pumping and withdrawal to support residential and metropolitan development. We then describe *additional impacts from oil, gas, and mineral development*, a phrase we use to encompass all phases (i.e., exploration, development, production, and reclamation) of these types of projects. Finally, we describe specific projects that have occurred or are proposed that may impact springs in which one or more of the 14 springsnail species occur.

Many factors associated with groundwater pumping can affect whether or not an activity will impact a spring. These factors include the amount of groundwater to be pumped, period of pumping, the proximity of pumping to a spring, depth of pumping, and characteristics of the aquifer being impacted. Depending on the level of these factors, groundwater withdrawal may result in no measureable impact to springs, reduce spring discharge, reduce free-flowing water, dry springs, alter springsnail habitat size and heterogeneity, or create habitat that is more suited to nonnative species than to native species (Sada and Deacon 1994, p. 6). Reduced spring discharge may also reduce springbrook length and wetted width as well as the total area of substrate and amount of primary and secondary production, thus affecting food resources for springsnails (Sada 2017, pp. 7–8). Excessive groundwater withdrawal can lower the water table, which in turn will likely affect riparian vegetation (Patten *et al.* 2008, p. 399).

Excessive groundwater withdrawal can be difficult to monitor and reverse due to inherent delays in detection of pumping impacts and the subsequent lag time required for recovery of discharge at a spring (Bredehoeft 2011, p. 808). Groundwater pumping initially captures stored groundwater near the pumping area until water levels decline and a cone of depression expands potentially impacting water sources to springs or streams (Dudley and Larson 1976, p. 38). Spring aquifer source and other aquifer characteristics influence the ability and rate at which a spring fills and may recover from groundwater pumping (Heath 1983, pp. 6 and 14). Depending on aquifer characteristics and rates of pumping, recovery of the aquifer is variable and may take several years or even centuries to be balanced or recover (Heath 1983, p. 32). Yet where reliable records exist, most springs fed by even the most extensive aquifers are affected by exploitation, and spring flow reductions relate directly to quantities of groundwater removed (Dudley and Larson 1976, p. 51).

The effects of groundwater withdrawal on springsnails are that a completely dry spring will result in extirpation. If groundwater withdrawal occurs but does not cause a spring to go dry, alternative results could include cumulative impacts (see Section 4.4) associated with altered precipitation and temperature from climate change, and a delay in groundwater recharge, which may result in a greater effect to springsnails than the effects of the individual stressors acting alone.

4.2.2.5.1 Impacts from Municipal Purposes and Irrigation

Groundwater pumping for human water demand and associated development projects could impact springs and spring provinces where springsnails occur. Following are descriptions of known or anticipated projects that may potentially impact springs within the range of the springsnails. The springs and species affected are specified for each project.

Comment [CSE7]: NOTE TO REVIEWERS. What, if any, additional groundwater or oil and gas projects are you aware of or your agency is permitting that may impact springs identified in this SSA?

4.2.2.5.1.1 Domestic Water Use in Nevada

The current rate of groundwater being withdrawn from a hydrographic area indicates where water demands may increase in the future. Increased demands and use of water could impact all springs where springsnails occur. These trends may also indicate spring impacts due to historical events. Estimates for the amount of groundwater pumped by residential or domestic wells provide some trend information.

Groundwater pumping in Las Vegas and Pahrump Valleys has resulted in reductions to groundwater elevations, which have impacted springs and springsnails in the past (Deacon *et al.* 2007, p. 688). Groundwater elevation declines of up to 30 m (98 ft) in Pahrump Valley (Harrill 1986, p. 22) and up to 91 m (299 ft) in Las Vegas Valley (Burbey 1995, p. 9) were documented in 1975 and 1990, respectively. As a result of pumping events, several springs went dry in Pahrump Valley during the 1970s, including Manse springs, which led to extirpation of a local population of the Spring Mountains pyrg in 1975 (Hershler 1998, p. 25). Examples such as this indicate that groundwater pumping may be an important stressor to all springs and springsnail populations.

While some variability in well withdrawal trends exists, in general an increase in groundwater withdrawals has occurred in most hydrographic areas since the1950s (insert citation). This likely reflects increasing populations and water demands for human use. Because populations in Nevada are expected to continue to increase (Garfin *et al.* 2014, p. 470), water demand would likely also increase. This demand represents a potential added pressure to the water that provides habitat for all springsnails in this report. Since we cannot predict where new domestic wells would be drilled or the amount of water new and existing wells would pump, we recognize that this is a potential future stressor, but do not analyze it in the spring descriptions.

4.2.2.5.1.2 Southern Nevada Water Authority Groundwater Development Project

The Southern Nevada Water Authority (SNWA) proposed the Clark, Lincoln, and White Pine Counties Groundwater Development Project (GWD Project) to provide a backup water supply for municipal water use in Southern Nevada. The proposed GWD Project includes development and conveyance of up to approximately 4.9 cubic meter per second (m^3/s) (125,000 afy) of groundwater from Lincoln and White Pine counties in eastern Nevada to Clark County in southern Nevada using a system of pumps and pipelines stretching over 482 km (300 mi). Details about the project are described in the BLM's

Comment [PME8]: The BLM's what?

SNWA completed the necessary permitting for the GWD Project in 2012, which included 3.3 m^3/s (83,988 afy) of new groundwater rights in Spring, Cave, Dry Lake, and Delamar valleys from the Nevada Division of Water Resources, Office of the State Engineer (Nevada State Engineer (NSE)); a right-of-way grant from the BLM (BLM 2012a, entire); and issuance of a biological opinion under Section 7 of the ESA to the BLM (Service 2012, entire) for adverse effects from the project on several listed fish, plant, and riparian bird species.

Comment [PME9]: Nevada Division of Water Resources has now been mentioned a couple of times in the text, consider abbreviating.

In its analysis of the project, the BLM determined that flow reductions at Big Springs in Snake Valley could result in loss of bifid duct pyrg populations at this location (BLM 2012b, p. 3.7-91). They identified that flow rates at the following springs (Hydrographic Basin; percent decrease) would decrease from current rates after full build out plus 75 years (BLM 2012b, p. 3.3-187):

- Butterfield (White River Valley; 6),
- Flag Springs (White River Valley; 6),
- Hot Creek Spring (White River Valley; 1),
- Moorman Spring (White River Valley; 1);
- Keegan Spring (Spring Valley; 98),
- North Millick Spring (Spring Valley; 52),
- South Millick Spring (Spring Valley; 86), and
- Big Springs (Snake Valley; 25).

The BLM also determined at full build-out plus 75 years, the project is not anticipated to result in decreased flow rates at other springs (BLM 2012 – DEIS, p. 3.3-183).

Additionally, the Service determined in the biological opinion (Service 2012, pp.163-164, 180, 19-191, 194) that the following specific impacts would likely occur. In Cave, Dry Lake, and Delamar valleys, the groundwater withdrawals would likely result in widespread and measurable declines in groundwater levels (reductions in groundwater storage), accompanied by reductions in natural discharge (capture of evapotranspiration and spring and stream flows), within and possibly beyond the project basins over time (BLM 2012c, Chapter 2; Service 2012, p. 163). The hydrology at the following springs and spring provinces (hydrographic basin of occurrence in parentheses) are expected to be measurably impacted:

- Discharge of springs comprising the Flag Springs Province (White River Valley) (Service 2012, p. 164)
- Discharge of Pahranagat warm springs including Hiko, Crystal, and Ash springs (Pahranagat Valley) (Service 2012, p. 180)
- Surficial water levels in the area of the Key Pittman Wildlife Management Area (Pahranagat Valley) (Service 2012, p. 180)
- Riparian habitat in the Pahranagat Wash (Pahranagat Valley) (Service 2012, p. 180)
- Discharge of Shoshone Ponds flowing artesian wells (Spring Valley) (Service 2012, p. 190)

- Riparian habitat throughout Hamlin, Spring, and Snake valleys including but not limited to South Little Spring, Big Springs / Big Springs Pond, Unnamed 1 Spring (north of Big Springs), Unnamed 2 Spring (north of Big Springs), Big Spring / Lake Creek, and Clay Spring in southern Snake Valley, and springs and Gandy Salt Marsh (Spring Valley) (Service 2012, pp. 190–191, 194)

Currently, the GWD Project is on hold due to legal challenges stemming from the NSE's 2012 issuance of new groundwater rights to SNWA. In 2013, a Senior District Court Judge ruling required the NSE to recalculate how much water could safely be pumped without causing conflicts with the environment and other water rights holders (*White Pine County et al. v. Jason King* 2013). In response to the rulings, the NSE ordered new administrative hearings on SNWA's monitoring, management, and mitigation plans, which will likely occur in Fall 2017 (Office of the Nevada State Engineer 2016, entire). Currently, the project is on hold, and we are uncertain if it will be implemented as originally proposed or if a new analysis of impacts to springs will be required (see Chapters 5 and 6 for further evaluation).

4.2.2.5.1.3 Order 1169—Groundwater Pumping in the Coyote Springs Basin of the White River Flow System

SNWA and Coyote Springs Investment, LLC (CSI) hold water rights applications in Coyote Spring Valley totaling 5.3 m^3/s (135,000 afy). The NSE held hearings on these applications in July and August 2001 and issued Order 1169 in 2002 (Service *et al*. 2013, p.1). The Order held in abeyance carbonate-rock aquifer system groundwater applications pending or to be filed in Coyote Spring Valley (HA 210) and several adjacent basins including Garnet Valley (HA 216), Hidden Valley (HA 217), Muddy River Springs Area (HA 219), Lower Moapa Valley (HA 220), and the Black Mountains Area (HA 215). There are 2 HAs that have springs with springsnails that are part of this SSA Report that may be affected by Order 1169. The Muddy River Springs Area (HA 219) contains Apcar Springs Province, Baldwin Spring, Cardy Lamb Spring, Muddy Spring, Pederson Springs Province, and Plummer Springs Province, all of which have Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia populations. The Black Mountains Area (HA 215) contains Blue Point Spring that has a Blue Point pyrg population. The Order also required entities with existing or pending water rights applications to participate in a 5-year study to pump at least 50 percent of the water rights currently permitted for 2 consecutive years. These entities include the Las Vegas Valley Water District, SNWA, CSI, Nevada Energy (NVE), and Moapa Valley Water District (MVWD). The pump test started November 15, 2010 and ended December 31, 2012. The pump rate was approximately one-third of the existing permitted amounts. All data are available from the NSE website (http://water.nv.gov/mapping/order1169/) or the USGS website (http://waterdata.usgs.gov/nv/nwis/sw).

Results from the pump test suggest the presence of flow barriers between parts of the Coyote Spring Valley HA and the other HAs. In contrast to this, the southern portion of Coyote Spring Valley HA, Garnet Valley HA, Hidden Valley HA, California Wash HA, and the Black Mountains Area HA are apparently hydraulically interconnected. This suggests that pumping at any location within these five hydrographic basins will affect groundwater levels throughout the area. Results from the pump test pertaining to the springs and springsnails in this SSA Report (Service *et al*. 2013, entire) include the following:

- Discharge at Pederson Spring (Spring C), the highest elevation spring, declined 63 percent during the pump test, which was a historic low flow; this spring could be dry in 1.5 years if pumping continued at pump test rates. Drying at this spring within the Pederson Springs Province would result in individual-level effects to Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia through the loss of all individuals, since none of the species needs would be met.
- Discharge at Pederson East Spring (Spring A), the second highest elevation spring, declined 45 percent during the pump test; this spring could be dry in 2.5-3 years if pumping continued at pump test rates. Individual –level effects would also apply to the 3 springsnail species within this spring due to the loss of all species needs.
- At other lower elevation springs, flows declined 4 percent at Jones Spring (in Apcar Springs Province) and Baldwin Spring, and increased 19 percent at Muddy Springs (most likely due to a combination of increased precipitation in 2010 and upstream effects from the July 2010 fire). These declines or increases should not result in any significant effects to individuals or populations of the 3 springsnail species.
- Discharge at Blue Point Spring did not see noticeable change from the pumping test, and there should be no impacts to the Blue Point pyrg.

In summary, the following conclusions were drawn from the pump test results:

- Local groundwater level trends are driven by pumping and hydrologic or climatic conditions.
- There is no scientific justification for managing the five hydrographic basins (Coyote Spring Valley, Garnet Valley, Hidden Valley, California Wash, Black Mountains) separately as they appear to be hydraulically connected. Pumping anywhere in the carbonate rock aquifer lowers groundwater levels uniformly throughout the basins in a relatively short time.
- All available water in the Coyote Springs Valley appears to be already appropriated and the basin may currently be over-appropriated.
- Full impacts of pumping existing permitted water rights were not observed, since approximately only one-third (0.2 m^3/s (5,400 afy)) of the currently permitted volume (0.6 m^3/s (16,300 afy)) was pumped during the test. However, even this reduced volume of groundwater pumping appears to have adverse impacts to springs, endangered fish, Federal trust resources, and downstream senior water rights (senior water rights are those entities that historically first used the water for beneficial use and then acquired the right to use the water first afterward).
- The Muddy River Springs Area supports multiple endemics (Moapa speckled dace (*Rhinichtthys osculus moapae*), Moapa pebblesnail, and Moapa Valley pyrg) and federally listed species (Moapa dace (*Moapa coriacea*), are all dependent on discharge from the carbonate rock aquifer. Pumping appears to reduce spring discharge and streamflow and will also likely impact downstream water right holders. Therefore, there is no additional groundwater available for appropriation.

4.2.2.6 *General Impacts from Oil, Gas, and Mineral Development*

We have no information on future project locations. Oil, gas, and mineral development on public land would likely occur in areas administered by the BLM. In Nevada, the analysis area includes lands managed by the Sounthern Nevada and Ely district offices.

The best available information indicates that hydraulic fracturing, commonly known as fracking, is an important source of water pollution and groundwater withdrawal stressors due to oil and gas development (Al-Bajalan 2015, pp. 4–6). Fracking is sometimes used as part of oil and gas development projects, and it has the potential to both contaminate and consume water resources (Al-Bajalan 2015, pp. 4–6; Mehany and Guggemos 2015, p. 172). Fracking is a process that occurs after a well is drilled but before it begins producing oil or gas. During fracking, an oil and gas company fractures the geologic formation containing the oil or gas with concentrated explosions. Subsequently, a proprietary mixture of chemicals and water is pumped at high pressure into the formation along with sand to open the pore space of the rock and release the oil and gas.

Most fractured wells will consume 10.2 to 14.7 million liters (2.7 to 3.9 million gallons) of pressurized water along with dozens of chemicals constituting 2 to 3 percent of the total volume (Sovacool 2014, p. 257). Water resource contamination can occur as a result of unlined and leaky storage pits of fracturing liquids, accidental blowouts (uncontrolled escape of fluid from well to surface), improper disposal of fracking fluids, faulty well cementing, release of natural gas (methane), and the possible connection of deep fractures with surface water (Mehany and Guggemos 2015, pp. 172–173; Al-Bajalan 2015, pp. 3–4).

Hydrofracking and shale gas production can contribute to increased seismicity and earthquakes, though on a smaller scale than major catastrophic earthquake (Sovacool 2014, p. 260); however, the effects of increased seismic activity and earthquakes on springs and springsnails are not known.

Springs may be impacted by oil and gas development if fracking is used and groundwater pumping occurs; the effects of groundwater pumping on springsnails are discussed above. If contaminants from fracking enter the groundwater and emerge at spring sources, springs and springsnails would likely be adversely affected. Al-Bajalan (2015, p. 6) identified a considerable number of organic and inorganic compounds that have been detected in shallow and deep drinking water outside the analysis area due to fracking chemicals. We know BLM parcels have been proposed for lease sales in the vicinity of springs occupied by the White River Valley pyrg, Hardy pyrg, Butterfield pyrg, grated tryonia, and Pahranagat pebblesnail and therefore, oil and gas development is likely (BLM 2015, entire). We are uncertain what extraction methods (e,g., hydraulic fracturing) will be used or how springs and springsnails would be affected by the developments if they occur.

4.2.2.7 *Altered Precipitation and Temperature from Climate Change*

The Southwest region where springsnail sites occur is one of the hottest and driest areas of the United States, and climate change is likely to exacerbate these conditions. Changes in climate have already been observed in this region and are expected to continue. Average annual temperatures have increased almost 1.1 °C (2 °F) over the last century (Garfin *et al.* 2014, p.

464), and an additional increase of 1.9 to 5.3 °C (3.5 to 9.5 °F) is predicted to occur by the year 2100 (Walsh *et al.* 2014, p. 23). In recent decades, reductions in precipitation and winter snowpack have been observed, and this pattern is expected to continue (Garfin *et al.* 2014, p. 465; Figure 4.2). The frequency and intensity of these reductions have increased on a global scale (IPCC 2014, p. 51), and climate change is projected to reduce surface and groundwater resources in most subtropical deserts (IPCC 2014, p. 69). The majority of model simulations based upon future climatic conditions predict a drying trend throughout the Southwest during the 21st century (Seager *et al.* 2007, pp. 1181–1184). Overall anticipated climate change impacts for the region include: warmer temperatures, decreased precipitation, fewer frost days, longer dry seasons, reduced snowpack, and increased frequency and intensity of extreme weather and disturbance events (heat waves, droughts, storms, flooding, wildfires, insect outbreaks; Archer and Predick 2008, pp. 23–25; Seager *et al.* 2007, p. 1,183; USGCRP 2009, p. 131; Garfin *et al.* 2014, p. 463; Walsh *et al.* 2014, p. 36). GCM projections indicate a marked reduction in spring snow accumulation in mountain watersheds across the southwestern United States (Figure 4.2, top panel) (Garfin *et al.* 2013, pp. 117–118). More rain and less snow, earlier snowmelt, and to some extent, drying tendencies, cause a reduction in late-spring and summer runoff (Figure 4.2, middle panel). These effects, along with increases in evaporation, result in lower soil moisture by early summer (Figure 4.2, bottom panel).

Both human settlements and natural ecosystems in the southwestern U.S. are largely dependent on groundwater resources, and decreased groundwater recharge may occur as a result of climate change (USGCRP 2009, p. 133). Furthermore, the human population in the southwest is expected to increase 70 percent by mid-century (Garfin *et al.* 2014, p. 470). Resulting increases in urban development, agriculture, and energy production facilities will likely place additional demands on already limited water resources. Climate change will likely increase water demand while at the same time shrink water supply, since water loss may increase evapotranspiration rates and run-off during storm events (Archer and Predick 2008, p. 25).

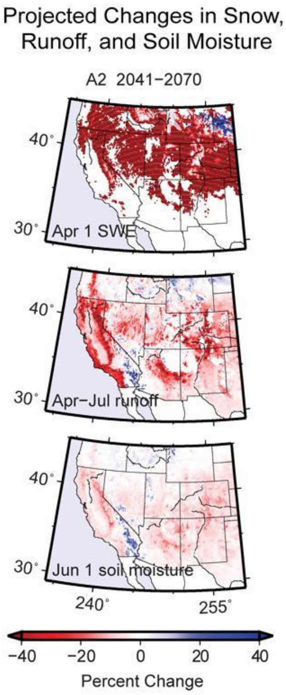


Figure 4.2. Mid-century (2041–2070) percent changes from the simulated historical median values from 1971–2000 for: (1) April 1 snow water equivalent (SWE, or snowpack, top), (2) April-July runoff (middle), and (3) June 1 soil moisture content (bottom), as obtained from the median of 16 Variable Infiltration Capacity (VIC) simulations under the high-emissions (A2) scenario (Garfin *et al.* 2013, p. 118).

In order to identify changing climatic conditions more specific to sites where the 14 springsnail species occur in Nevada and Utah, we conducted a climate analysis using Climate Wizard (Service 2016, unpublished data). Climate Wizard is a freely available, web based tool that incorporates historical and modeled future climate information to examine projected change (The Nature Conservancy (TNC) 2017, no page number). Climate Wizard is designed for a wide range of users and can provide simple tables and graphical representations summarizing future temperature and precipitation conditions as well as customized analyses that predict changes in ecologically relevant climate variables (for example, number of cold nights or consecutive dry days) for specified geographic areas (Girvetz *et al.* 2009, p. 1). Future climate projections are analyzed under one of three emissions scenarios (High A2, Medium A1B, LowB1), and the tool can calculate ensemble averages using multiple general circulation models (GCMs). High resolution climate data are obtained from downscaling techniques that allow for precise projections of climate change at small scales (Girvetz *et al.* 2009, p. 14).

For our analysis, we used the mapping tool to delineate the geographic area encompassing springsnail hydrographic areas. We chose mid-century (2046–2065) as the future time period for projection because models that go further into the future become less reliable. We selected emission scenario Medium A1B. For GCM selection, we chose the ensemble average since this option combines results from multiple GCM model outputs and often yields more accurate predictions than any individual climate projection alone.

Results from our Climate Wizard analysis predict increased temperatures and decreased precipitation where the springs in this SSA Report occur (Figure 4.2 and Figure 4.3). Annual temperature is projected to increase between 2.2 and 3.3 °C (4 and 6 °F) throughout our delineated geographic area by the 2050s (Figure 4.2) (Service 2016, unpublished data). Projections related to annual precipitation vary more across the region, with most areas showing expected decreases of up to 7 percent by the 2050s (Service 2016, unpublished data). A smaller number of areas within our analysis area project no change in annual precipitation while an increase (up to 7 percent) in annual precipitation is predicted for a handful of spring locations (Figure 4.3) (Service 2016, unpublished data).

Comment [CSE10]: We need to update this with spring names.

Comment [CSE11]: We need to update this with spring names.

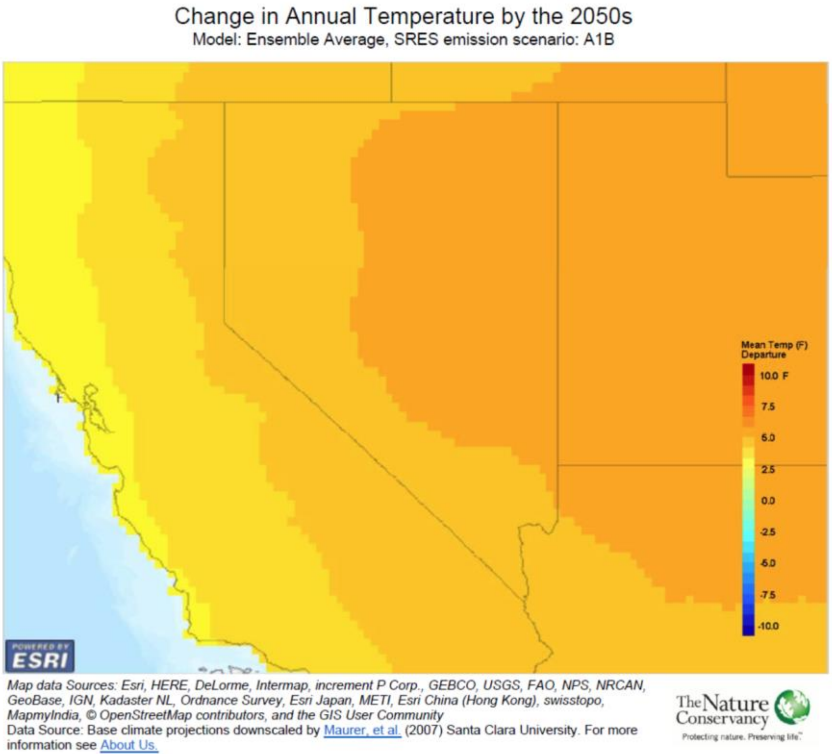


Figure 4.3. Map showing changes in average annual temperature predicted for the time period 2046–2065 as compared to the 1961–1990 baseline average. The map forecast future temperature using a Medium A1B emission scenario and a GCM ensemble average (i. e., half of the models project a greater amount of change and half of the models project less change as compared to the 1961–1990 baseline average) (Service 2016, unpublished data)

Comment [PME12]: Would be more useful if this included a border or inset box of the areas being described if possible.

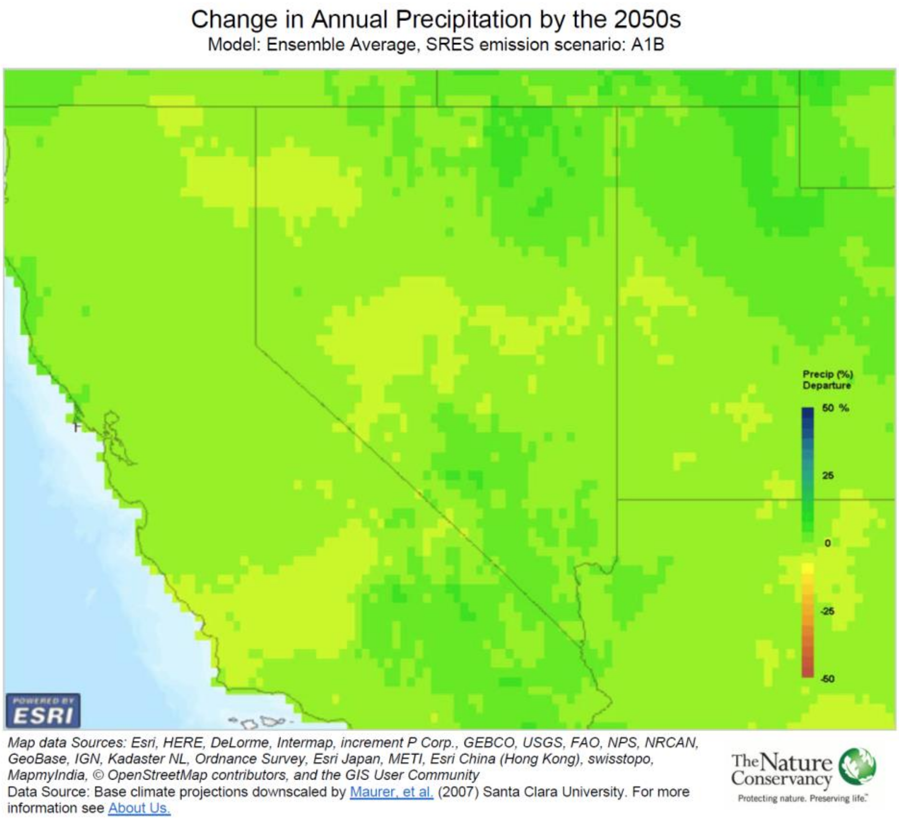


Figure 4.4. Map showing changes in average annual precipitation predicted for the time period 2046–2065 as compared to the 1961–1990 baseline average. The map forecast future precipitation using a Medium A1B emission scenario and a GCM ensemble average (i. e., blue areas projected to increase by at least half of the models and light green to red areas expected to decrease in precipitation by at least half of the models) (Service 2016, unpublished data).

Comment [PME13]: See comment for Figure 4.3.

Although it seems certain that climate change in conjunction with increased demands on water resources from a growing human population will result in lowered groundwater levels (Jaeger *et al.* 2014, p. 13,895), little is known about how and when spring flows may be affected by changes in climate. Direct hydrological connections have not been established in most cases, and for many areas, these connections remain difficult to make. The large number of springsnail species endemic to one or few locales speaks to the consistency and reliability of these aquatic habitats over millions of years. For example, although discharge and geographic extent of springs at Ash Meadows, Nye County, Nevada were higher 3 million years ago, Ash Meadows springs continue to discharge from the deep aquifer to this day (Deacon *et al.* 2007, p. 690). Naturally occurring climatic variation results in changes in Ash Meadows groundwater levels, including a 9 m (29.5 ft) decline in groundwater 15,000 years ago as part of the drying trend that occurred at the end of the Pleistocene Epoch (Deacon *et al.* 2007, p. 690). However, this climatic decline is minor in comparison to more recent reductions in groundwater levels that are a result of pumping in the Las Vegas and Pahrump Valleys (Deacon *et al.* 2007, p. 688). Groundwater level declines of up to 30 m (98.4 ft) in Pahrump Valley (Harrill 1986, p. 22) and up to 91 m (298.6 ft) in Las Vegas Valley (Burbey 1995, p. 9) were documented in 1975 and 1990, respectively. As a result of pumping events, several springs went dry in Pahrump Valley during the 1970s, including Manse springs which led to extirpation of a local population of the Spring Mountains pyrg in 1975 (Hershler 1998, p. 25). Examples such as this indicate that groundwater pumping, rather than climate change, may be a greater stressor to spring snails.

Comment [PME14]: This figure was rounded to 98 ft above. Consider just using whole numbers (i.e. 98 ft) rather than 98.4 ft.

Comment [PME15]: This figure was rounded to 299 ft above. For consistency, stay with 299 ft.

Ultimately, the degree to which spring flows are affected by climate change largely depends on influences on surface water processes and precipitation, since aquifers are recharged through exchanges with surface water (Green *et al.* 2011, p. 541). Components of surface water systems that may be altered by climate change include atmospheric water vapor, precipitation patterns, rates of evapotranspiration, snow cover and melting of glaciers, soil temperature, and surface runoff and stream flows (Green *et al.* 2011, p. 538). Changes to these components will likely result in changes to groundwater systems, but climate change impacts on groundwater resources are poorly understood (Green *et al.* 2011, p. 533). Relationships between climate and groundwater are considered more complicated than those between climate and surface water (Holman 2006, p. 638). Interpretation of potential impacts is further complicated by a lack of data and background studies necessary to determine the magnitude and direction of possible groundwater changes (Kundzewicz *et al.* 2008, p. 7). Furthermore, groundwater level responses are highly variable across a landscape due to spatial differences in sediment permeability and recharge characteristics. For example, increased precipitation often leads to higher groundwater levels at some testing locations but not at others nearby (Chen *et al.* 2002, p. 106). Accordingly, some studies have shown a decrease in groundwater recharge rate, while others have predicted positive effects or concluded that it is not known whether overall groundwater recharge will increase, decrease, or stay the same throughout the western U.S. as a result of climate change (Jyrkama and Sykes 2007, p. 248; Herrera-Pantoja and Hiscock 2008, p. 12; Gurdak and Roe 2010, pp. 1,762–1,763).

Climate change may impact springsnails and their habitats in two main ways: (1) Reductions in spring flow as a result of changes in the amount, type, and timing of precipitation, increased evapotranspiration rates, and reduced aquifer recharge; and (2) reductions in spring flow as a result of changes in human behavior in response to climate change (e.g., increased groundwater pumping as surface water resources disappear). Impacts vary geographically, but identifying which springs may be more or less vulnerable is challenging. For example, a study examining different springs over a 14-year period at Arches National Park found that each spring responded to local precipitation and recharge differently, despite similarities in topographic setting, aquifer type, and climate exposure (Weissinger *et al.*, p. 9).

Some springsnail sites are fed by mountain block aquifers located at higher elevations (e.g., 1,119–1,619 m (3,671–5,312 ft) compared to those at the base of mountains or in valleys. In general, mountain block aquifers are small (often a single drainage basin) (Sada and Pohlmann 2006, p. 5; Sada 2017, p. 4) and have a local recharge source fed by precipitation often in the form of snowpack covering a small area. These springs may be more vulnerable to predicted changes in temperature and precipitation than springs fed by older, larger local and regional aquifers. Recharge to mountain aquifers, particularly those located in the southwestern U.S., may decrease as a result of: (1) Warm temperatures that lead to high evapotranspiration rates, particularly in spring time; (2) decreased spring precipitation leading to less total snowpack and snowmelt; and (3) decreased snow fraction of precipitation and thus smaller snowpack depths (Meixner *et al.* 2016, p. 133). However, these higher-elevation springs may also be less susceptible to impacts of increased groundwater pumping if most of the pumping is located on valley floors.

Local and regional springs are typically fed by older and larger aquifers (compared to mountain block aquifers) that have relatively longer residence times (sometimes hundreds to thousands of years for regional aquifers) (Sada 2017, p. 4). Local and regional springs also tend to occur in low elevation alluvial fans and valley floors where production wells are typically located. In this case, effects to these aquifers may be more driven by increased groundwater extraction rather than climate-driven decreases in recharge.

Predicting individual spring response to climate change is further complicated by the minimal information available about the large hydrological connections for most sites and the high degree of uncertainty inherent in future precipitation models. Regardless, the best available data indicate that all springsnail sites in the analysis area may be vulnerable to climate change to an unknown degree, but we cannot say with any certainty where impacts may be manifested or the greatest.

4.3 Land Management and Conservation Plans

A variety of regulatory and voluntary conservation measures are currently in place to help reduce the potential impacts from some of the potential stressors. Many spring stressors are historical (e.g., spring modifications), have stabilized over time, and have little effect on springsnail species needs, and there are current stressors (e.g., vegetation and soil disturbance) that also have little to no impact to springsnail species needs. There are also potential stressors that may occur in the future (e.g., groundwater pumping and altered precipitation and temperature). While we cannot definitively know to what extent these future stressors may impact springs or spring provinces (and thus springsnail species), we do know that there are land management and conservation plans in place on various lands that should provide protections for springsnail species and their needs. These range from laws, regulations, policies, and management plans on federal lands, to state plans in Nevada and Utah, to other agreements and plans that cover federal, state, or private lands. Plans may include specific conservation actions for springsnail species and protecting species needs, while others may include more broad protections for aquatic and riparian species habitat or protections from future water withdrawals. Such protections provide some assurances that current individual-level stressor impacts will not become population-level impacts and that potential future stressors will not occur or impact springsnail species needs.

These conservation measures are described in detail in Appendix A. Additionally, these conservation measures are indentified and discussed in Chapters 5 and 6 when they are resulting in reduced impacts to the species needs.

4.4 Cumulative Effects

Current and potential future stressors may act together to affect springsnails at springs or spring provinces. Predation and competition, vegetation and soil disturbance, water pollution, spring modifications, groundwater pumping, and altered precipitation and temperature may adversely affect a site if one, some, or all stressors occur concurrently (both now and in the future). Many of the stressors are either historic and have stabilized over time or are current with low-level or individual-level impacts. Potential future stressors such as groundwater pumping or altered precipitation and temperature could also produce individual-level effects, but may rise to population-level impacts at specific springs depending the on the severity of effects to free-flowing water and spring discharge and whether or not current stressors are concurrently impacting the springs in the future.

We conclude that the magnitude of cumulative effects to springsnails is low to moderate with individual-level effects depending upon the spring or spring province, with potential for population-level effects in the future for some springsnail species. All historic, current, and potential future stressors are discussed in Chapters 4, 5, and 6.

4.5 Summary

This chapter provided a general discussion of the potential stressors, sources of stress, and the potential impacts they may have to the 14 springsnail species or their habitat. Stressors and their impacts vary by spring and spring province and by historic or current effects. In some instances, historical stressors have stabilized at some springs (e.g., historic dredging with recovered riparian vegetation), where as at other locations stressors continue to impact the species or habitat currently (e.g., impoundment, recreation). Stressors including predation and competition; vegetation and soil disturbance; water pollution; and spring development, management, and restoration are historical to current stressors that may cause only individual-level impacts to springsnails.

Potential future stressors, including groundwater pumping for human water demand; oil, gas, and mineral development; and altered precipitation and temperature, are likely to have the greatest impact on springsnail species needs and cause population-level impacts to springsnails. Those springs with land management and conservation plans in place will see the greatest protections from these potential future impacts.

Cumulatively, these stressors affect current and future conditions of the springs and spring provinces. In conjunction with current distribution and abundance, current and future effects determine springsnail viability and vulnerability to extinction. Stressors and land management and conservation plans (see Appendix A) that may ameliorate these stressors are discussed for each spring and spring province in Chapters 5 and 6.

5 CURRENT CONDITIONS—SPRINGSNAIL HABITAT AND POPULATIONS

In this chapter, we provide information on each springsnail species and the springs and spring provinces they inhabit. We include the quantity and quality of springsnail habitat that is present at a spring or spring province, any information on individual needs that is unique to a particular species, the historical and current distribution of the species, the relative abundance of each springsnail population, and finally, the current conditions of each species' population(s). We also describe the historic and current conditions of each springsnail species and its habitat. We grouped the springs and spring provinces, and the springsnail species by geographic area and present them from the west and south to the east and north.

5.1 Las Vegas Valley HA (212) and Pahrump Valley HA (162) – Springs and Spring Provinces and Current Habitat Conditions

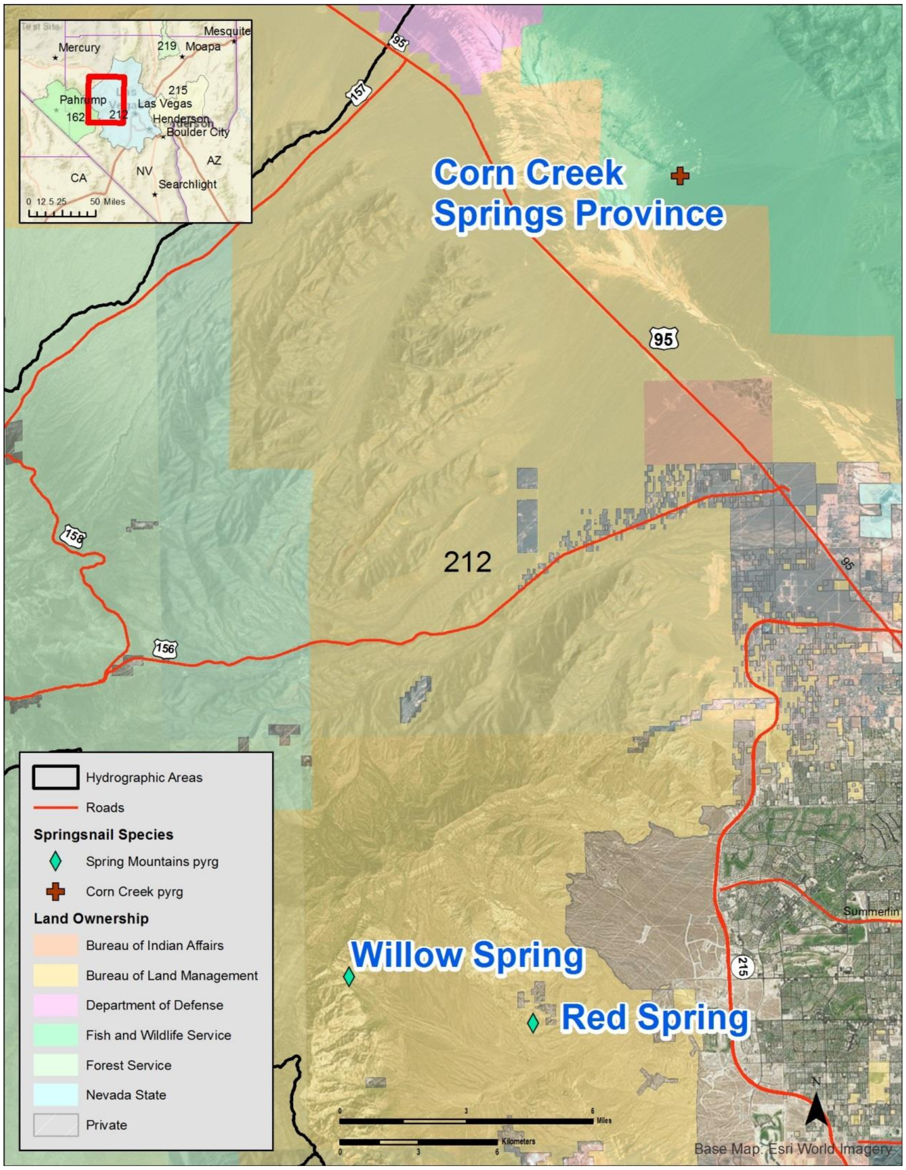


Figure 5.1. Map of the land ownership and general location for Corn Creek Springs Province where the Corn Creek pyrg occurs, and Willow Spring and Red Spring where the Spring Mountains pyrg occurs, Las Vegas Valley HA (212), Clark County, Nevada. The two springs known as Southeast of Corn Creek Spring and Unnamed Spring near Corn Creek Springs occur in close proximity to Corn Creek Springs Province, so they do not appear as separate points on this map. The Spring Mountains pyrg also occurs in Crystal Spring, Horse Springs Province, and Kiup Spring (Figure 5.2).

5.1.1 Corn Creek Springs Province, Southeast of Corn Creek Spring, Unnamed Spring near Corn Creek Springs

Springsnail species present in Corn Creek Springs Province, Southeast of Corn Creek Spring, and Unnamed Spring near Corn Creek Springs (which for the purposes of this discussion may also be described as "Corn Creek area springs") include the Corn Creek pyrg.

The source of water for Corn Creek Springs Province, Southeast of Corn Creek Spring, and Unnamed Spring near Corn Creek Springs is from a local aquifer that emanates at similar elevations of approximately 900 m (2,953 ft) as rheocrene springs or an unknown spring type for Unnamed Spring near Corn Creek Springs (Sada 2016, entire; Sada 2017, entire). The source of water for Corn Creek Springs Province, which has been studied the most, is likely the same as that for Southeast of Corn Creek Spring and Unnamed Spring near Corn Creek Springs because of their close proximity and similar water characteristics. Water emerging at Corn Creek Springs Province is unlikely to be from the regional aquifer based on chemical characteristics that are different from known regional springs (Hershey *et al.* 2010, p. 1,021). Water at Corn Creek Springs comes from precipitation falling in the Sheep Range to the northeast that flows westward as groundwater through carbonate and alluvial aquifers toward the valleys (Fiero 1975, p. 6; Thomas *et al.* 1996, pp. C33 and C39). The amount of water flowing from the Corn Creek area into the northern Las Vegas Valley is likely a small amount because it is impeded by geologic structural controls such as non-carbonate rock barriers (Thomas *et al.* 1996, pp. C27 and C30). Corn Creek Springs was among the largest springs, along with Tule, Kyle, Las Vegas, Grapevine, and Stevens springs, in the Las Vegas Valley; currently, Corn Creek Springs is the only one of these that still flows (Wood 2000, p. 8). The other five springs in Las Vegas Valley stopped flowing in the 1960s after groundwater withdrawals exceeded recharge (Wood 2000, p. 32).

Corn Creek Springs Province consists of three springs (A, B, C) with short springbooks that are tributary to a single springbrook flowing into a concrete pool (Sada 2017, p. 76). There is a trail and footbridge crossing the springbrook near the concrete pool (Sada 2017, p. 76). Springs in this province are heavily disturbed from past activities, including restoration by removing old concrete channels so water flow now follows historical routes (Sada 2017, p. 76). When water flowed through concrete channels springsnails were historically scarce and in 2016 they were found only in the spring sources (Sada 2017, p. 76). However, at this time springsnail abundance remains low at all springs in this province because restoration did not attempt to mimic historic habitat conditions required by the Corn Creek pyrg (Sada 2017, p. 76).

Comment [PME16]: Is there a diagram showing which spring is which?

Corn Creek Spring A is the largest spring in this province although it has a relatively short springbrook length of 10 m (32.8 ft) (Sada 2017, p. 76). Mean wetted width (see Glossary) for this spring is 210.8 cm ((83 in)) and mean wetted depth is 20.8 cm (8.2 in) (Sada 2017, pp. 76–77). Corn Creek Spring B is the longest springbrook in the province with a length of 23 m (75.5 ft). Mean wetted width is 91.7 cm (36.1 in) and mean wetted depth is 10.3 cm (4.1 in); Spring B is also densely covered and shaded by reeds (Sada 2017, p. 77). Corn Creek Spring C has a springbrook length measuring 8 m (26.2 ft) (Sada 2017, p. 77). Wetted width and wetted depth were not measured due to extremely dense cattails preventing access to the springbrook (Sada 2017, p. 77).

Comment [PME17]: Double parentheses?

Southeast of Corn Creek Spring is a small spring located on a spring mound near a mesquite tree that was removed (Sada 2017, p. 77). The spring is in near reference condition (see Glossary) and was hidden by dead grass (Sada 2017, p. 77). Springbrook length is 1 m (3.3 ft), mean wetted width is 10 cm (3.9 in), and mean wetted depth is 1 cm (0.39 in) (Sada 2017, p. 78).

Unnamed Spring near Corn Creek Springs is the type locality for the Corn Creek pyrg and consists of a small circular helocrene spring (see Glossary). Springbrook length is 18 m (59.1 ft), mean wetted width is 23.3 cm (9.17 in), and mean wetted depth is 0.4 cm (0.16 in) (Sada 2017, p. 77).

We compiled information on water quality and quantity at springs from several sources of data (Table 5.1). Measurements and estimates of flow at springs occupied by the Corn Creek pyrg have ranged between 0.5 and 858 L/min (0.0003 and0.5 cfs) (Sada 2016, entire; USGS 2016, entire; Sada 2017, pp.76–78). Measurements of water quality at springs occupied by the Corn Creek pyrg have ranged between 18.8 and 23.0 ºC (65.8 and 73.4 ºF) for temperature, 3.6–5.0 mg/l (ppm) for DO, 6.5–7.7 for pH, and 320–1003 µS/cm for conductivity (Sada 2016, entire; USGS 2016, entire; Sada 2017, entire). Estimates of substrate composition in springs occupied by the Corn Creek pyrg are typically dominated by silt followed by gravel (Sada 2016, entire; Sada 2017, entire).

Comment [PME18]: Some of the text above describing wetted widths and depths could also be condensed into a table.

Comment [PME19]: Not sure of the utility of summarizing what can easily be found in the table below.

Table 5.1. Attribute measurements for Corn Creek Springs Province, Southeast of Corn Creek Spring, and Unnamed Spring near Corn Creek Springs.

Spring or Spring Province	Temperature °C (ºF)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Corn Creek Spring A	21.0–23.0 (69.8–73.4)	7.4–7.7	408–1,003	3.6–5.0	10–100 (0.01–0.06)	1.8 (0.7)
Corn Creek Spring B	21.2–21.3 (70.1–70.3)	6.5	410–1,003	3.6	70 (0.04)	7.3 (2.9)
Corn Creek Spring C	21.3 (70.3)	-	407	-	15 (0.01)	NA
Southeast of Corn Creek Spring	18.8 (65.8)	-	320	-	0.5 (<0.01)	-
Unnamed Spring near Corn Creek Springs	20.1–23.0 (68.2–73.4)	7.5	120–500	2	2.0–3.0 (<0.01)	-

Data is compiled from the following sources: Hershey 1989, USGS 2016, and Sada 2017.

Comment [PME20]: Spring or springs? Both have been used in the text.

Overall, substrate at the Corn Creek area springs in 2016 was dominated by silt (≥ 50 percent) followed by gravel and cobble (Sada 2017, entire). Vegetative bank cover ranged from 44 to 100 percent (Sada 2017, entire). Emergent cover ranged from 0 to 100 percent (Sada 2017, entire). In 2016, vegetation at Corn Creek area springs included willow, mesquite, reeds, cattails, and watercress (Sada 2017, entire).

The stressor (see Table 5.2) affecting Corn Creek Springs (A,B,C) is spring modification, which stems from channel modification, impoundment, water diversion, and historical restoration activities (Sada 2017, entire). These stressor sources are currently affecting a moderate amount (11–30 percent) of the exposed population at a moderate intensity (Sada 2017). The stressor (see Table 5.3) impacting the Unnamed Spring near Corn Creek Springs is residual impacts from historical restoration activities (vegetation and soil disturbance, effects realized), which are affecting a small portion (< 10 percent) of the population (Sada 2017, entire). Finally, Southeast of Corn Creek Spring (see Table 5.4) is experiencing extremely low estimated levels of water flow at a small amount (<10 percent) of the population. The best available information suggests this low water flow may be resulting from exposure to drought conditions (i.e., decreased precipitation); however, the immediacy and intensity of this stressor is unknown (Sada 2017, entire), since little is known about the history of the population or hydrology at this specific spring. We expect that future conditions at all three of the Corn Creek area springs will likely remain similar to current conditions as the best available information does not indicate an increase or decrease in effects associated with spring modifications.

Table 5.2. Stressors for Corn Creek Springs A, B, C.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Restoration)	current	moderate	moderate	unknown	NC	L
Spring Modifications from the following Sources						
Surface Water Diversion	current	moderate	moderate	unknown	NC	L
Channel Modification	current	moderate	moderate	unknown	NC	L
Impoundment	current	moderate	moderate	unknown	NC	L

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Table 5.3. Stressors for Southeast of Corn Creek Springs.

Comment [PME21]: Springs or spring?

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Altered Precipitation and Temperature (Drought)	unknown	unknown	small	unknown	NC	L

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Table 5.4. Stressors for Unnamed Spring near Corn Creek Springs.

Stressor	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future**	**Confidence of Trend**[2]

					Trend[1]	
Vegetation and Soil Disturbance (Restoration)	historic	low	small	unknown	NC	L

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

The Service manages all of the Corn Creek area springs in accordance with the Desert Refuge Complex Comprehensive Conservation Plan (USFWS 2009, entire; see Appendix A). There are no specific activities being implemented that address spring modifications. In addition, there are no specific management activities being implemented that address drought conditions stemming from altered precipitation and temperature.

5.1.2 Willow Spring

Springsnail species reviewed in this SSA present in Willow Spring include the Spring Mountains pyrg (Figure 5.1), although an additional species not evaluated in this report— Southeast Nevada pyrg (*Pyrgulopsis turbatrix*)—is also present. This is a small spring adjacent to a picnic area on BLM land in the Red Rock Canyon National Conservation Area (Sada 2017, p. 71) within the Las Vegas Valley hydrographic basin. The primary source of water is mountain block (perched) aquifers that emanate at elevations of 1,119–1,619 m (3,671–5,312 ft) as rheocrene springs (Sada 2016, entire). In the 1970s, the Southeast Nevada pyrg and Spring Mountains pyrg were first collected at this spring by J. Landye (NMNH 2016, entire; Sada 2017, p. 71). By 1995, springsnails were extirpated (Sada and Nachlinger 1996, p. 17), although both species were reintroduced in 2001 (Sada 2002, p. 5). Unless otherwise noted, current condition information for Willow Spring is primarily from 2016 surveys as documented in Sada (2017, entire).

This spring was historically modified when its source was boxed in by a concrete trough-like structure (a type of impoundment) and water was diverted through channels (Sada and Nachlinger 1996, pp. 22, 29, and Figure 3). Restoration began in 1998 when a fence was installed around the spring and water was returned to its historic channel (Sada 2002, p. 5). Additional restoration occurred in 2012 when fence was improved to protect the entire upper riparian area, nonnative plants were removed, native plants were planted, and a walking bridge installed for the public to cross above the springbrook (Jones 2017, entire; Poff and Savage 2017, p. 1). Public use of the spring and its springbrook now appears minimal, and ongoing vegetation maintenance occurs to remove nonnative plants.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.5). Maximum springbrook length was 50 m (164 ft). Wetted width ranged from 15 to 30 cm (5.9 to 11.8 in) and wetted depth ranged from 0.5 to 5 cm (0.2 to 2 in).

Comment [PME22]: As with the other information presented in the text above, this might do better in a table rather than in the text.

Table 5.5. Attribute measurements for Willow Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Willow	15.0–25.0	5.3–8.0	210–300	4.3–7.3	0–17.0	0

Comment [PME23]: How can you have flow but a velocity of 0? Was this meant to be a range?

	(59–77)				(0–0.01)	

Data is compiled from the following sources: BLM 2016; Hughes 1966; Sada 2016, 2017; USGS 2016

Surveys conducted in 2016 estimated the substrate to be 20 percent silt, 40 percent sand, and 40 percent gravel. In 2016, riparian vegetation included rushes, spikerushes, grapevine (*Vitis* spp.), and watercress. There are also nonnative grasses throughout the springbrook. Bank cover was estimated at 98.3 percent and emergent vegetation at 13.3 percent.

Several stressors have been documented at Willow Spring (Table 5.6). Historically, vegetation and soil disturbance from recreation activities were large impacts when the spring was not protected from the public. After fencing was installed, allowing the channel to resume its historic path, impacts to springsnails from recreation are minimal. Another current stressor to Willow Spring includes spring modification (i.e., surface water diversion, channel modification, and impoundment). Historic channel modification, surface water diversion, and impoundment likely had a great impact on springsnails in Willow Spring that resulted in past extirpation of the Spring Mountain pyrg in this location although it has since been reintroduced (see 5.2.1 for further discussion). After restoration and even with current impoundment, impacts to springsnails appear negligible.

We expect that future conditions at this spring will likely remain similar to current conditions as the best available information does not indicate any increase or decrease in stressor intensisty.

Table 5.6. Stressors for Willow Spring.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Recreation)	current	low	small	basic need	NC	L
Spring Modifications from the following Sources						
Impoundment	unknown	unknown	unknown	unknown	NC	L
Channel Modification	unknown	unknown	unknown	unknown	NC	L
Surface Water Diversion	unknown	unknown	unknown	unknown	NC	L

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

This area is covered under the BLM Red Rock Canyon National Conservation Area Resource Management Plan (BLM 1998, entire; see Appendix A). Management activites conducted to reduce recreation-related impacts include fencing and weed removal discussed above. Additional information regarding this management plan is found in Appendix A.

5.1.3 Red Spring

Springsnail species present in Red Spring include the Spring Mountains pyrg (Figure 5.1). Red Spring is on BLM land in Red Rock Canyon National Conservation Area within the Las Vegas Valley hydrographic basin. The primary source of water is a mountain block (perched) aquifer that emanates at elevations of 1,119–1,619 m (3,671–5,312 ft) as rheocrene springs (Sada 2016, entire). Unless otherwise noted, current condition information for Red Spring is primarily from 2016 surveys, as documented in Sada (2017, entire).

This area was historically used as a recreational area (Sada and Nachlinger 1996, p. IV-5). The spring was dammed and the wet meadow was turned into a recreation field, allowing visitors to drive up to the dammed spring area (Poff and Savage 2012, p. 1). Restoration of the area around Red Spring was completed and reopened to the public in November 2005 (BLM 2005, p. 1). The spring area was undammed and allowed to restore to its original wet meadow condition. A raised boardwalk was installed to keep people above the wet meadow and outside of the spring area (Poff and Savage 2012, p. 1). A picnic area, restrooms, parking lot, interpretive panels, and new trails were also installed for the public away from the spring (BLM 2005, p. 1).

Red Spring is a small spring with a small springsnail population (see also section 5.2.1). Its source is an historical adit (a horizontal entrance into a mine) that extends approximately 10 m (32.8 ft) deep into a sandstone hillside. The adit is stabile and appears to have no current effect on springsnail individuals (or abundance) within the adit. The overall condition of this spring has improved since initial surveys in 1995 as reported by Sada and Nachlinger (1996, entire), although the length of occupied habitat has remained relatively constant. Springsnails occupied 23 m (75.5 ft) of springbrook and 30.2 square meters (m^2) of habitat (325 square feet (ft^2)) during the 2016 surveys.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.7). This data was compiled restoration occurred in 2005. Springbrook length extended a maximum of 30 m (98.4 ft). Wetted width ranged from 30 cm to 76 cm (12 to 30 in) and wetted depth ranged from 2.0 to 3.0 cm (0.8 to 1.2 in).

Table 5.7. Attribute measurements for Red Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Red Spring	19.0–21.7 (66.2–71)	7.1–7.9	310–875	4.4–7.5	10.0–51.0 (0.01–0.03)	3.4 (1.3)

Data is compiled from the following sources: BLM 2016; Hershey 1989; Hughes 1966; Sada 2016a,b; Thomas *et al.* 1996; and USGS 2016.

Surveys conducted in 2016 estimated the substrate to be 10 percent silt, 20 percent sand, 40 percent gravel, and 30 percent cobble with slight variations among the previous surveys. In 2016, riparian vegetation included ash trees (*Fraxinus* spp.), rushes, and watercress. There was 50 percent vegetative bank cover and 58 percent emergent vegetation cover.

The only stressor for Red Spring is vegetation and soil disturbance from recreation (Table 5.8). Historically, the habitat impacts from recreation were more severe, in part, due to easy vehicular access near the spring (Sada and Nachlinger, p. IV-5). Currently, after restoration which reduced access, the impact is minor (Sada 2017, pp. 70–71). The cable barrier and boardwalk keep most of the public above the wet meadow and out of the springbrook (Sada 2017, entire). Some people bypass the boardwalk and cable barrier to see the spring or adit and do not appear to enter the springbrook, which is minimally impacted (Sada 2017, p. 71). We expect that future conditions at this spring will likely remain similar to current conditions as the best available information does not indicate any increase or decrease in stressor intensisty.

Table 5.8. Stressors for Red Spring.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Recreation)	historic	high	high	mortality	NC	L
Vegetation and Soil Disturbance (Recreation)	current	negligible	insignificant	unknown	NC	L

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

This area is managed under the BLM Red Rock Canyon National Conservation Area Resource Management Plan (BLM 2000, entire; see Appendix A). Management activites conducted to reduce recreation-related impacts were discussed above. Additional information regarding this management plan is found in Appendix A.

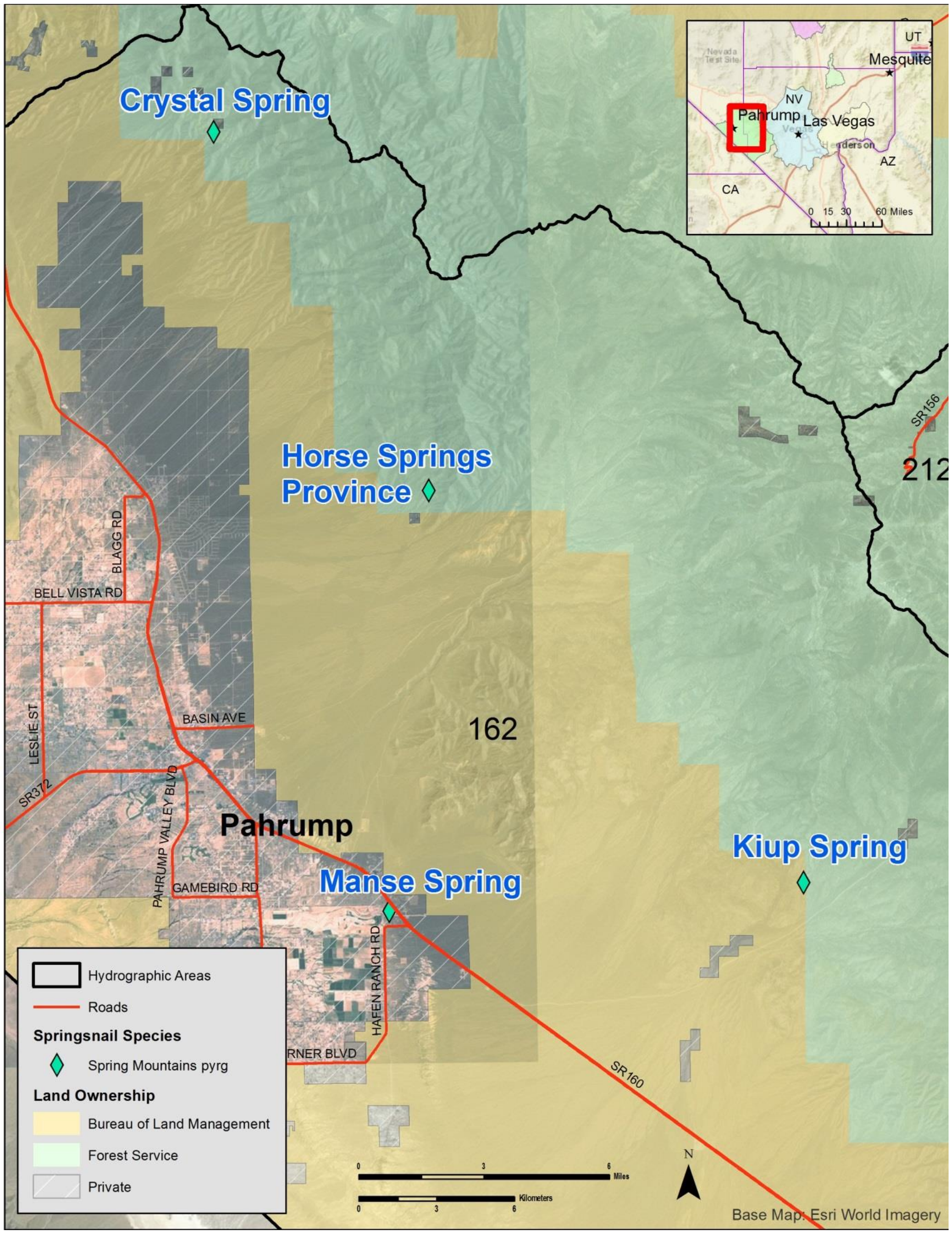


Figure 5.2. Map of the land ownership and general location for Crystal Spring, Horse Springs Province, Kiup Spring, and Manse Spring where the Spring Mountains pyrg occurs or has occurred, Pahrump Valley HA (162), Clark County, Nevada. The Spring Mountains pyrg also occurs in Willow Spring and Red Spring (Figure 5.1).

5.1.4 Crystal Spring

Springsnail species present in Crystal Spring include the Spring Mountains pyrg (Figure 5.2). Crystal Spring is in the SMNRA on USFS land within the Pahrump Valley hydrographic basin. The primary source of water is mountain block (perched) aquifers that emanate at elevations of 1,119– 1,619 m (3,671– 5,312 ft) as a rheocrene spring (Sada 2016). The spring is located in primarily shale bedrock. This spring is very difficult to access and is heavily overgrown with sumac (*Rhus* spp.), baccharis (*Baccharis* spp.), and willows (*Salix* spp.). Riparian species include willow (*Salix* spp.), sedges, (*Carex* spp.), rushes, and spikerushes. Recent genetic studies indicate it is occupied by Spring Mountains pyrg and Southeast Nevada pyrg (Pilgrim and Schwartz 2013, p. 7). The channel is 0.4 m wide (1.3 ft) (Springer *et al.* 2012, pp. 43–47). Instream transects from 2012 show substrate consisting of gravel, cobble, boulder, and bedrock (Springer *et al.* 2012, pp. 43–47). Crystal spring could not be accessed in 2016.

The only water quality and quantity information at Crystal Spring is from 2012 (Table 5.9; Springer *et al.* 2012, pp. 43–47).

Table 5.9. Attribute measurements for Crystal Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Crystal Spring	12.7 (54.9)	7.4	617.3	7.6	14.5 (0.01)	not available

The most recent data from this spring is from Springer *et al.* (2012, pp. 43-47). No hydrology disturbance was noted, but there was significant channel erosion (incised about 2 m (6.6 ft)) (Springer *et al.* 2012, pp. 43–47). Vegetation and soil disturbance from ungulate use was mentioned in the 2012 survey report because of evidence of trampling and browsing (Springer *et al.* 2012, pp. 43–47). This is the only potential stressor documented. We expect that future conditions at this spring will likely remain similar to current conditions as the best available information does not indicate and increase or decrease in stressor intensisty.

This spring is provided protections under the National Forest Management Act, the USFS Spring Mountains National Recreation Area Act, and the General Management Plan for the Spring Mountains National Recreation Area (USFS 1996, entire). There are no specific management activities being implemented at this spring. Additional information regarding this management plan is found in Appendix A.

5.1.5 Horse Springs Province

Springsnail species present in Horse Springs Province include the Spring Mountains pyrg (Figure 5.2). The three springs of this province are widely dispersed on USFS land in the Spring Mountains National Recreation Area within the Pahrump Valley hydrographic basin. The primary source of water is mountain block (perched) aquifers that emanate at elevations of 1,119–1,619 m (3,671–5,312 ft) as rheocrene springs (Sada 2016, entire). The springbrooks have been channelized and diverted approximately 1 km (0.6 mi) below to private property (Sada 2017, pp. 72–73). Spring travertine deposits have stabilized the springbrooks and indicate no recent disturbance (Sada 2017, pp. 72–73). Access to the spring sources in 2016 was inhibited by dense grapevines (Sada 2017, pp. 72–73). In 2016, all springs were reported to be used by ungulates that have degraded springbrook habitat quality; however, springsnail relative abundance was still high (Sada 2017, pp. 72–73). The three springs in this province and their respective characteristics are as follows:

- Horse Spring A- This is the southwestern spring in the province. In 2016, its springbrook was 95 m (312 ft) long, and springsnails occupied 35 m (115 ft) of the springbrook (13.3 m^2 (143.2 ft^2) of habitat).
- Horse Spring B- In 2016, its springbrook was 250 m (820 ft) long, and springsnails occupied 120 m (394 ft) of the springbrook (61 m^2 (657 ft^2) of habitat).
- Horse Spring C- This is the northeastern spring in the province. In 2016, its springbrook was 342 m (1122 ft) long, and springsnails occupied 342 m (1,122 ft) of the springbrook (194.3 m^2 (2091 ft^2) of habitat)" (Sada 2017, p. 73).

We compiled information on water quality and quantity at springs from several sources of data (Table 5.10). Maximum springbrook length was 1,500 m (4,921 ft). Wetted width ranged from 25 to 75 cm (9.8 to 30 in) and wetted depth ranged from 1.8 to 20 cm (0.7 to 7.9 in).

Table 5.10. Attribute measurements for Horse Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Horse Springs Province	16.3–23.0 (61.3–73.4)	6.3–8.5	376–1150	5.5–7.4	30.0–200 (0.02–0.12)	13–25 (5.1–9.8)

Data is compiled from the following sources: Sada 2016a,b; USFS 2013

Comment [PME24]: Seems like some somewhat large ranges between pH, conductivity, DO, and flow. Consider breaking this out into one line for each Horse Springs A, B, and C.

Surveys conducted in 2016 estimated the substrate to be 20 percent sand and 80 percent gravel in Horse Springs A and C, and substrate was 50 percent silt, 30 percent gravel, and 20 percent cobble in Horse Springs B. In 2016, riparian vegetation contained rushes, grapevine, saltgrass (*Distichlis* spp.), yerba mansa (*Anemopsis* spp.), and watercress. Bank vegetation cover was 45-60 percent and emergent vegetation was 0–13.3 percent.

Stressors for Horse Springs Province include spring modifications as a result of surface water diversion and vegetation and soil disturbance from ungulate species use (Table 5.11; Sada 2017, pp. 72–73). The channelized sections of springbrook for water diversion downstream have natural deposition of travertine along them that stabilizes the springbrooks (Sada 2017, pp. 72–73). The stabilized springbrook and large relative abundance (discussed below) of springsnails indicate that impacts from stressors is small due to the change in substrate composition. Disturbance to the spring source is reduced by dense vegetation (Sada 2017, pp. 72–73). We expect that future conditions at this spring will likely remain similar to current conditions as the best available information does not indicate and increase or decrease in stressor intensisty.

Table 5.11. Stressors for Horse Springs Province.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and	current	moderate	small	unknown	NC	L

Soil Disturbance (Grazing and Browsing)						
Spring Modifications (Surface Water Diversion)	current	moderate	small	unknown	NC	L

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

This spring is provided protections under the National Forest Management Act, the USFS Spring Mountains National Recreation Area Act and the General Management Plan for the Spring Mountains National Recreation Area (USFS 1996, entire). There are no specific management activities being implemented that address spring modification or grazing and browsing. Additional information regarding this management plan is found in Appendix A.

5.1.6 Kiup Spring

Springsnail species present in Kiup Spring is the Spring Mountains pyrg. Kiup Spring is on BLM land in the Southern Nevada District, Las Vegas Field Office within the Pahrump Valley hydrographic basin. The primary source of water is mountain block (perched) aquifers that emanate at elevations of 1,119–1,619 m (3,671–5,312 ft) as rheocrene springs (Sada 2016, entire). Unless otherwise noted, current condition information for Kiup Spring is from 2016 and 2017 surveys (Sada 2016, entire; Sada 2017, pp entire).

Kiup Spring emanates from a travertine mound and the springbrook is lined with travertine (Sada 2017, p. 72). The spring was altered when a springbox was installed but has naturalized and does not appear to have negative effects on springsnail habitat and abundance (Sada 2017, p. 72). In 1996, the spring was described as “high quality” (Sada and Nachlinger 1996, Figure 16). In 2013 and 2014, the spring was treated as a restoration project to remove dense native vegetation (RECON 2014) and is recovering from short-term vegetation and soil disturbance impacts (Sada 2017, p. 72). Most recently in 2017, Sada (2017, p. 72) recommended monitoring treatments as necessary for invasives during recovery from the restoration.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.12). Maximum springbrook length was 70 m (230 ft). Wetted width ranged from 10 to 25.2 cm (3.9 to 9.9 in) and wetted depth ranged from 1.0 to 3.0 cm (0.4 to 8.7 in).

Table 5.12. Attribute measurements for Kiup Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Kiup Spring	15.9–19.9 (60.6–67.8)	6.8–8.5	506–778	3.3–11.5	6.0–30.6 (0–0.02)	8.4 (3.3)

Data is compiled from the following sources: Hughes, 1966; Kingsley 2007; Sada 2016a,b; USGS 2016

Surveys conducted in 2016 estimated the substrate to be 30 percent silt, 20 percent sand, 20 percent gravel, and 30 percent bedrock. The channel is formed by travertine. In 2016, riparian vegetation contained rushes and grapevine. Bank vegetation cover was 45 percent and emergent vegetation was 2 percent.

The only stressor at Kiup Spring is spring modification as a result of surface water diversion (Table 5.13). There is an historic springbox at the spring source which has an insignificant effect on springsnails. We expect that future conditions at this spring will likely remain similar to current conditions as the best available information does not indicate and increase or decrease in stressor intensity.

Table 5.13. Stressors for Kiup Spring.

Stressor	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Spring Modifications (Surface Water Diversion)	current	negligible	insignificant	unknown/ basic need	NC	L

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Kiup Spring is covered in the BLM Southern Nevada District's Resource Management Plan (BLM 1998, entire; see Appendix A). There are no specific management activities being implemented that address spring modification. Additional information regarding this management plan is found in Appendix A.

5.1.7 Manse Spring

Manse Spring is on private land within the Pahrump Valley hydrographic basin (Figure 5.2). It was approximately 15m (49 ft) wide, 18m (59 ft) long, and 2m (6.6 ft) deep (Williams 1996, p. 272). Its water was clear with a consistent temperature of approximately 24 ºC (75.2 ºF) (Maxey and Jameson 1948; Appendix II; Hughes 1966, p. 70; Williams 1996, p. 272). Manse Spring went dry in 1975 due to excessive groundwater pumping for agriculture (Harrill 1986, p. 22). The Spring Mountains pyrg population that occurred at this spring was extirpated (Hershler 1998, p. 25).

Comment [PME25]: I was out there a couple of years ago and found that Manse Spring was not dry. I took a couple of discharge measurements, which can be found in NWIS. I did not evaluate the spring for the presence of springsnails at the time, but I imagine that they're still gone since the spring was dry for a number of years in 1975 onward. Not sure when it started flowing again.

5.1.8 South Rainbow Springs

This spring is on BLM land in Red Rock Canyon National Conservation Area within the Pahrump Valley HA (162). *Pyrgulopsis* species have been reported at South Rainbow Springs, suspected to be Spring Mountains pyrg, but have not been identified (Sada and Nachlinger 1998, p. 28). Reports of *Pyrgulopsis* species at South Rainbow Springs are unlikely because conditions of the spring are not adequate to provide habitat (Sada 2017, p. 72). The historic presence of the Spring Mountains pyrg was, therefore, unlikely. Springsnails were absent from this spring during 2016 surveys and all BLM surveys from 2010 to present (BLM 2016, entire; Sada 2017, p. 72).

5.2 Las Vegas and Pahrump Valleys – Springsnail Species and Current Population Conditions

5.2.1 Spring Mountains pyrg

The Spring Mountains pyrg is small with a sub-globose shell reported to range from 1.5–1.9 mm (0.06–0.07 in) in height, 1.3 to 1.7 mm (0.05–0.07 in) in width, and having 3.5 to 3.8 whorls (Hershler 1998, p. 15 and 23). The periostracum ("skin-like" outer coating of the shell) is a light tan (Hershler 1998, p. 35).

The Spring Mountains pyrg has been reported to occur at a total of nine springs in the Spring Mountains area, Clark and Nye Counties, Nevada; however, its identity and subsequent presence has only been confirmed at eight of the nine springs. The presence of Spring Mountains pyrg has been confirmed at Crystal Spring, Horse Springs Province (A, B, and C), Kiup Spring, Manse Spring, Red Spring, and Willow Spring through morphological or molecular genetic methods (Figures 5.1 and 5.2; Hershler 1998, p. 25; Sada 2002, p. 3; Pilgrim and Schwartz 2013, p. 10). The identity of a *Pyrgulopsis* species reported at South Rainbow Spring has not been confirmed (Sada 2017, p. 72) through morphological or molecular genetic methods. Because up to 4 species may exist within the Spring Mountains (McKelvey *et al.* 2017, pp.), it is uncertain which species was detected at South Rainbow Spring. Therefore, South Rainbow Spring is excluded from further analyses in this SSA Report. Populations of Spring Mountains pyrg were reported to have been extirpated from Manse Spring in the early 1970's and from Willow Spring (including Southeast Nevada pyrg) sometime prior to 1995 (Hershler 1998, p. 25; Sada 2002, p. 4). Sada (2002, pp. 5–6) reintroduced springsnails to Willow Spring in 2001, Spring Mountains pyrg from Red Spring (along with Southeast Nevada pyrg from Lost Creek Spring). Thus there are currently seven populations of Spring Mountains pyrg.

All survey records for Spring Mountains pyrg found spring temperatures ranged between 12.7 and 25.0 ºC (54.9–77 ºF), DO between 3.3 and 11.5 mg/l (ppm), pH between 5.3 and 8.5, and conductivity between 210 and 1,150 µS/cm (Hughes 1966, p. 52; Kingsley 2007, 4–5; BLM 2016, entire; Sada 2016, entire; USGS 2016, entire). Discharge measurements across all sampling dates were highly variable between 1 and 200 L/min (0–0.12 cfs) and 0.0–25.0 cm/sec (0-9.8 in/sec) (BLM 2016, entire; Sada 2016, entire; USGS 2016, entire).

Little is known about substrate requirements of Spring Mountains pyrg. The Spring Mountains pyrg has been recorded to be present on hard substrates such as gravel, cobble, and bedrock at Red, Willow, and Kiup Springs (Sada 2017, entire). BLM data also show Spring Mountains pyrg at Red and Willow Springs attached to watercress.

Surveys of Spring Mountains pyrg at six extant locations (BLM 2015, entire; Sada 2016, entire; Sada 2017, entire) indicate that its downstream extent and abundance in a springbrook fluctuate during and between years. Spring Mountains pyrg may occur throughout the entire springbrook length but are typically most abundant near the spring source and decrease in abundance further downstream (BLM 2015, entire; Sada 2016, entire; Sada 2017, entire). Populations of Spring Mountains pyrg have typically been abundant or common during surveys in recent years at Horse

Spring A, Horse Spring B, Horse Spring C, Kiup Spring, Red Spring, and Willow Spring[2] (Table 5.14). Relative abundance estimates of Spring Mountains pyrg at Willow Spring may be high because individuals of sympatric populations of Southeast Nevada pyrg and other freshwater pond snails (*Physa* spp.) could be included in some counts since 2001. The presence of Spring Mountains pyrg at Willow Spring was confirmed by genetic analysis in 2015 (Pilgrim and Schwartz 2015, p. 8). The population of Spring Mountains pyrg at Crystal Spring was identified using genetic analysis in 2013 (Pilgrim and Schwartz 2013, p. 10). The Crystal Spring population appears to be scarce in 2013 because there was only 1 individual identified from genetic analysis among 16 collected (Pilgrim and Schwartz 2013, p. 6).

Table 5.14. Relative abundance and springbrook data of Spring Mountains pyrg.

Spring or Spring Province	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance	Source
Manse Spring	1970s	-	-	Extirpated	1, 2
Crystal Spring	4/5/2013 5/26/2012	-	-	Scarce[1]	3, 4
Horse Spring A	5/20/2009	400	400	Common	5
	5/12/2016	95	35	Abundant	5
Horse Spring B	11/21/1998	200	0	None	5
	5/20/2009	25	25	Common	5
	5/12/2016	250	120	Common	5
Horse Spring C	12/28/1991	-	-	Unknown	5
	11/21/1998	150	-	Abundant	5, 6
	5/20/2009	1500	800	Common	
	5/12/2016	342	342	Abundant	5
Kiup Spring	7/25/1988	-	-	Scarce	6
	6/22/1991	-	-	Abundant	5
	7/18/1994	20	-	Scarce	5
	1/5/2001	-	-	Scarce	6
	9/5/2007	-	-	Scarce	7
	5/20/2009	50	30	Common	5, 6
	Spring 2011	-	5	Common	8
	Fall 2011	-	-	-	8
	Spring 2012	-	7.5	Abundant	8
	Fall 2012	-	7.5	Common	8
	Spring 2013	-	10	Common	8
	Fall 2013	-	12.5	Abundant	8
	Spring 2014	-	10	Abundant	8
	Fall 2014	-	15	Abundant	8

[2] The relative abundance was estimated from collection records in the National Museum of Natural History for collections made by J. Landye, R. Hershler, and D. Sada when no other data was available. Classified as abundant for collections of 100 or more individuals which is similar to descriptions by (Hershler 1995, p. 2). Collections of 50 to 100 were classified as common and collections less than 50 were scarce.

	Spring 2015	-	12.5	Abundant	8
	5/10/2016	70	35	Abundant	5
Red Spring	5/1/1977	-	-	-	6
	7/11/1986	-	-	Scarce	6
	7/26/1988	-	-	Common	6
	1/2/1992	-	-	Common	5, 6
	5/17/1995	150	-	Common	5, 6
	1/5/2001	-	-	-	6
	5/14/2008	30	8	Scarce	5, 6
	Spring 2010	-	17.5	Abundant	8
	Fall 2010	-	25	Abundant	8
	Spring 2011	-	17.5	Abundant	8
	Fall 2011	-	12.5	Abundant	8
	Spring 2012	-	25	Abundant	8
	Fall 2012	-	12.5	Abundant	8
	Spring 2013	-	17.5	Abundant	8
	Fall 2013	-	12.5	Abundant	8
	Spring 2014	-	15	Abundant	8
	Fall 2014	-	12.5	Abundant[2]	8
	Spring 2015	-	15	Abundant	8
	5/4/2016	23	23	Common	5
Willow Spring	8/28/1973[3]	-	-	Abundant	6
	4/24/1977	-	-	-	6
	5/1/1977	-	-	-	6
	12/30/1991	-	-	Scarce	5, 6
	5/17/1995	50	0	Extirpated	5
	8/20/2001	-	-	Scarce[4]	5
	11/9/2005	-	-	Common	5
	5/28/2008	25	20	Common	5, 6
	Spring 2010	-	5	Scarce[5]	8
	Fall 2010	-	5	Scarce[5]	8
	Spring 2011	-	2.5	Scarce[5]	8
	Fall 2011	-	2.5	Scarce[5]	8
	Spring 2012	-	7.5	Abundant[5]	8
	Fall 2012	-	10	Scarce[5]	8
	Spring 2013	-	15	Scarce[5]	8
	Fall 2013	-	15	Common[5]	8
	Spring 2014	-	20	Common[5]	8
	Fall 2014	-	17.5	Common[6]	8
	Spring 2015	-	20	Common	8
	5/4/2016	29	29	Scarce	5

[1] Inferred from proportion of genetics sample from Pilgrim and Schwartz (2013, p. 6) and observation from USFS.
[2] One individual pond snail was detected among a sample of 30 snails collected for a *Pyrgulopsis* genetics analysis (Pilgrim and Schwartz 2015, p. 3). It is unknown if pond snails were differentiated in earlier BLM 2016 counts.
[3] This location is identified as "Hidden Lakes, In Spring In Runoff from; Red Rock Area" and is presumed to be Willow Spring.
[4] Reintroduced
[5] Counts of *Pyrgulopsis* (Spring Mountains pyrg and Southeast Nevada pyrg) at this spring between 2010 and 2014 may have included pond snails. Thus Spring Mountains pyrg represents an unknown percentage less than the total gastropods counted at the location.
[6] There were 2 Spring Mountains pyrgs among a sample of 10 snails collected for genetic analysis (Pilgrim and Schwartz 2015, p. 4), thus counts of Pyrgulopsis include pond snails and it is unknown if the genera were differentiated in earlier counts.
Sources of data: (1) Hershler 1998, (2) Sada 2002, (3) USFS 2012, (4) Pilgrim and Schwartz 2013, (5) Sada 2016, (6) National Museum of Natural History 2016, (7) Kingsley 2007, and (8) BLM 2015.

Table 5.15. Current conditions of Spring Mountains pyrg.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Red Spring	Adequate	High	High	Adequate	High
Willow Spring	Adequate	High	Moderate	Adequate	High/Moderate
Kiup Spring	Adequate	High	High	Adequate	High
Horse Springs (A, B, and C) Province	Adequate	High	High	Adequate	High
Crystal Spring	Adequate	High	High	Adequate	High

Comment [PME26]: May want to consider re-evaluating Manse Spring. I wonder if the owner of the land would be amenable to reestablishing a population if the spring has continued to flow?

The springs listed in the above table contain populations of the Spring Mountains pyrg. We have assumed that if the species is present within a spring or spring province, the water quality and discharge are adequate. Substrate and vegetation was ranked high for those springs with multiple meters of occupied habitat. Crystal Spring was also ranked high, since surveys showed substrate and vegetation suitable for the Spring Mountains pyrg. Free-flowing water was ranked high if it flowed without any barriers. Free-flowing water was ranked moderate for Willow Spring due to the concrete trough-like impoundment at its source.

5.2.1 Corn Creek pyrg

The Corn Creek pyrg is small with sub-globose shells reported to range from 1.4–1.7 mm (0.06–0.07 in) in height, 1.3 to 1.5 mm (0.05–0.06 in) in width, and having 3.25 to 3.75 whorls (Hershler 1998, pp. 15 and 23). The periostracum ("skin-like" outer coating of the shell) is a light tan (Hershler 1998, p. 35).

There are three populations of the Corn Creek pyrg that occur at five spring source lcoations in Clark County, Nevada, which are within the Desert National Wildlife Refuge managed by the Service (Figure 5.1; Sada 2017, pp. 76–79). The Corn Creek pyrg population at the Corn Creek Springs Province area inhabits three separate but hydrologically interconnected spring sources, Corn Creek Spring A, B, and C Sada 2017, pp. 76–79). The other two Corn Creek pyrg populations, Unnamed Spring near Corn Creek Springs and Southeast of Corn Creek, occur approximately 0.3 km (0.19 mi) and 0.6 km east southeast and southeast from Corn Creek Springs respectively.

Survey records for the Corn Creek pyrg for measurements of flowing water have ranged between 0.5 and 858 L/min (0.0003–0.5 cfs) (Sada 2016, entire; USGS 2016, entire). Measurements of water quality at springs occupied by the Corn Creek pyrg have ranged between 18.8 and 23.0 ºC (65.8–73.4 ºF) for temperature, 3.6–5.0 mg/l (ppm) for DO, 6.5–7.7 for pH, and 320–1003 µS/cm for conductivity (Sada 2016, entire; USGS 2016, entire).

Estimates of substrate composition in springs occupied by the Corn Creek pyrg have typically been dominated by silt followed by gravel (Sada 2016, entire). Surveys in 2016 estimated substrate at Corn Creek A and Southeast of Corn Creek as 50 percent silt and 50 percent gravel (Sada 2017, entire). Substrate at Corn Creek B in 2016 was 50 percent fines, 40 percent gravel and 10 percent cobble, and substrate at Corn Creek C and Unnamed Spring near Corn Creek was 100 percent silt (Sada 2017, entire).

The relative abundance of Corn Creek pyrg has varied between sites and surveys (Table 5.16). At the largest area of habitat, Corn Creek Springs, the Corn Creek pyrg has typically been scarce since it was first observed during the earliest collections in the 1970s (Sada 2002, p. 4, 2017; National Museum of Natural History 2016, entire). In 2016, the Corn Creek pyrg was scarce at Corn Creek Springs and found in 10.5 m^2 (113.0 ft^2) area that was 5 m (16.4 ft) in length of the total 41 m (134.5 ft) springbrook length (Sada 2017, entire). At Southeast Corn Creek and Unnamed Spring near Corn Creek Springs the Corn Creek pyrg was common in 2016 but only occupied 0.1 m^2 (1.1ft^2) and 3.5 m^2 (37.7 ft^2) along a 1 m (3.28 ft) and 15 m (49.2 ft) length of springbrook respectively (Sada 2017, entire).

Table 5.16. Relative abundance and springbrook data of Corn Creek pyrg.

Spring or Spring Province	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance	Source(s)
Corn Creek Springs[1]	9/16/1975	-	-	Common[2]	1
Corn Creek Springs[1]	1/16/1976	-	-	-	1
Corn Creek Springs[1]	7/7/1986	-	-	Scarce[2]	1
Corn Creek Springs[1]	5/13/1987	-	-	Scarce[2]	1
Corn Creek Springs[1]	7/24/1988	-	-	Scarce[2]	1
Corn Creek Springs[1]	7/1/2000	-	-	Scarce[2]	1
Corn Creek Springs[1]	9/8/2004	-	-	Scarce[2]	1
Corn Creek Spring A	1/1/1992	-	-	Scarce	2
Corn Creek Spring A	6/6/1992	50	-	Scarce	2
Corn Creek Spring A	5/15/2008	35	-	Scarce	1, 2
Corn Creek Spring A	5/5/2016	10	5	Scarce	2
Corn Creek Spring B	5/15/2008	-	-	Scarce	2
Corn Creek Spring B	5/5/2016	23	-	Scarce	2
Corn Creek Spring C	5/5/2016	8	-	Scarce	2
Southeast of Corn Creek Spring	5/5/2016	1.0	1.0	Common	2

Unnamed Spring near Corn Creek Springs	9/16/1975	-	-	Scarce	1
Unnamed Spring near Corn Creek Springs	6/6/1992	3.0	0.0	Common	1, 2
Unnamed Spring near Corn Creek Springs	6/5/2016	18.0	15.0	Abundant	2

[1] The spring source at Corn Creek Springs Province could not be determined.
[2] The relative abundance was estimated from collection records in the National Museum of Natural History for collections made by J. Landye, R. Hershler, and D. Sada. when no other data was available. Classified as abundant for collections of 100 or more individuals which is similar to descriptions by (Hershler 1995, p. 2). Collections of 50 to 100 were classified as common and collections less than 50 were scarce.
Sources of data: 1) National Museum of Natural History 2016, p. 2) Sada 2016, entire.

Three poulations of Corn Creek pyrg occur, each contained within one spring (Table 5.17). We assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. Substrate and vegetation was ranked high for those springs with highly occupied habitat or suitable habitat. Corn Creek Springs A, B, and C and Unnamed Spring near Corn Creek Springs were ranked moderate due to marginal springsnail habitat filled with cattails and reeds. Free-flowing water was ranked high if it flowed without any barriers. Unnamed Spring near Corn Creek Springs was ranked moderate because the spring has changed to flow down the side of a spring mound filled with cattails. The Southeast of Corn Creek Spring is ranked low since it is a small spring with low flow.

Table 5.17. Current conditions of Corn Creek pyrg.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Corn Creek Springs A, B, C	Adequate	Moderate	High	Adequate	High/Moderate
Unnamed Spring near Corn Creek Springs	Adequate	Moderate	Moderate	Adequate	Moderate
Southeast of Corn Creek Spring	Adequate	High	Low	Adequate	Moderate

5.3 Muddy River Springs Area HA (219), Black Mountains Area HA (215), and Pahranagat Valley HA (209) – Springs and Spring Provinces and Current Habitat Conditions

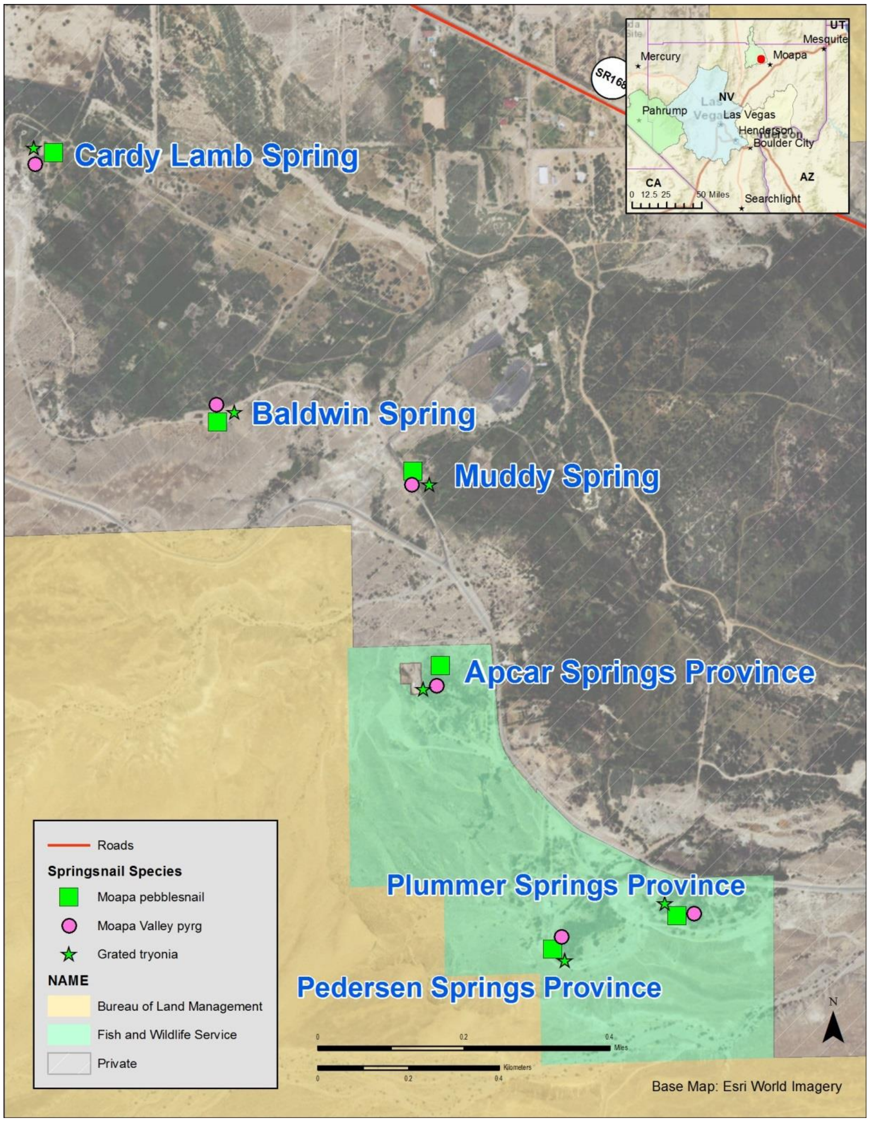


Figure 5.3. Map of the land ownership and general location for springs and spring provinces of the Upper Muddy River where the Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia occur, Muddy River Springs Area HA (219), Clark County, Nevada. The grated tryonia also occurs in Ash Springs Province and Crystal Springs Province (Figure 5.5), and Moon River Spring, Hot Creek Springs Province, and Moorman Spring (Figure 5.6).

5.3.1 Cardy Lamb Spring

Springsnail species present in Cardy Lamb Spring include one population each of Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia (Figure 5.3). Springsnails only inhabit the small area where the source flows into the concrete-lined pond. This spring is near Baldwin Spring, is privately owned, and was dredged and modified into a gravel-bottom swimming pool in the mid-1980s. It is within the Warm Springs Natural Area owned by Southern Nevada Water Authority and is in the Muddy River Springs Area Hydrographic basin (219). The spring is a rheocrene, alluvial slope spring originating from an unconfined local basin fill aquifer. The Muddy River Springs Province contains several of these local aquifers which are underlain by a regional carbonate aquifer. The regional carbonate rock aquifer is confined. Its source and water are now ponded within concrete walls (approximately 1.5 m (4.9 ft) high) that encompass an irregularly shaped area that is approximately 60 by 50 m (197 by 164 ft) (Sada 2017, p. 58). There is no surface discharge from the pool and no evidence where its water is taken. Therefore, its springbrook was 0 m long and it was not possible to estimate discharge (Sada 2017, p. 58). It is likely that a pipe from Cardy Lamb Spring discharges water into the north bank of Baldwin Spring. There is a small peninsula of water that extends out of the pond from its southeastern corner. This area is warmer than the pond, indicating that this is the 'spring source' and is densely covered by cattails.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.18). Wetted width and wetted depth were not measured in 2016, since the springsnails occupy an area within the pool and not a springbrook.

Table 5.18. Attribute measurements for Cardy Lamb Spring.

Spring or Spring Province	Temperature °C (ºF)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Cardy Lamb Spring	32–32.3 (89.6–90.1)	7.3–7.7	974–1134	2.7—4.1	0–25 (0–0.01)	0 (ponded)

Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; Sada 2016, entire; and Sada 2017, entire.

Surveys conducted in 2016 estimated the substrate to be 100 percent silt. In 2016, riparian vegetation contained mesquite, cottonwoods (*Populus* spp.), and palm trees. Riparian vegetation also included cattails and grapevine. There was no bank vegetation cover due to the concrete walls containing this spring, and emergent vegetation was a minimal patch of cattails. Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected. This information also provides a range of historical to current conditions and a reference that may be used as a comparison to future data collected.

Stressors to Cardy Lamb Spring include water diversion, impoundment, channel modification, predation and competition from invasive aquatic species (mosquitofish and red-rimmed melania), and possible vegetation and soil disturbance from recreation (Table 5.19). Mosquitofish and red-rimmed melania can impact springsnails through predation and competition for resources. Recent survey data show that the intensity of invasive aquatics is high, which may be why the most recent springsnail surveys documented scarce abundance of Moapa pebblesnail and Moapa Valley pyrg.

Table 5.19. Current stressors for Cardy Lamb Spring.

Stressors	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Predation and Competition	current	high	unknown	basic need	NC	L
Vegetation and Soil Disturbance (Recreation)	current	low	insignificant	unknown	NC	M
Spring Modifications from the following Sources						
Surface Water Diversion	current	high	unknown to very high	basic need	NC	M
Impoundment	current	high	unknown to very high	basic need	NC	M
Channel Modification	current	high	unknown to very high	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Cardy Lamb Spring is currently impounded by concrete walls and was historically used as a swimming pool. There is no discharge from the pool into a natural channel, and a pipe diverts water from the pool to another area (likely Baldwin Spring). There is very little flow into the pool, which cannot be measured, since it comes from underneath the surface into one corner of the pool. Due to these alterations, there is very little habitat for springsnails, which likely accounts for the scarce abundance of Moapa pebblesnail and Moapa Valley pyrg in 2016. Recreation was identified as another stressor in 2016 as scientists' tents were set up nearby to do research. The public is not allowed access to this spring, and researchers do not use the spring in any way. The impacts to springsnails due to recreation are negligible.

Tetra Tech (2012, entire) evaluated modeling simulations of groundwater systems in southeastern Nevada under seven scenarios in 12 hydrographic areas. Cardy Lamb Spring, within Muddy River Springs Area HA (219), is included in this study. Modeling scenario 1 is based existing groundwater rights that are currently pumped. After 50 years of pumping under the current pumping scenario 1, aquifer drawdown is 0.6 to 1.5 m (2 to 5 feet), and simulated spring discharges are reduced but still adequate (Tetra Tech 2012, pp. 13; Figure 3.1-2a). Modeling scenario 2 is based on all existing groundwater rights, both pumped and unpumped. After 50 years of pumping under the pumping scenario 2, aquifer drawdown would be 3 to 6 m (10 to 20 feet) and simulated spring discharges reduced (Tetra Tech 2012, p. 52; Figure 3.2-2a).

Comment [CSE27]: This may need to be incorporated into the future conditions section.

SNWA and CSI hold water rights applications in Coyote Spring Valley totaling 135,000 afy. Executive Order 1169 required multiple entities in five hydrographic basins (including 219 where Cardy Lamb Spring is) to conduct a pump test of all existing water rights (see Chapter 4 for more details). The study began in November 2010 and ended the last day of 2012. The test was supposed to pump 50% of existing water rights, but the study was ended after only pumping one-third of the permitted rights. Groundwater levels decreased 0.76 to 1.1 m (2.5 to 3.5 feet).

Springs in the Muddy River Springs hydrographic area saw a decline in discharge, though not at rates that would result in complete drying of these springs.

Comment [CSE28]: We still need to evaluate what this mean in terms of impacts to the habitat/species occurring there

We expect that the province future conditions will likely remain similar to current conditions as the best available information does not indicate an increase or decrease in effects associated with the stressors.

SNWA developed the Warm Springs Natural Area has a Stewardship Plan to establish a long-term management direction for the Warm Springs Natural Area that will foster relations between SNWA and the property neighbors, while preserving the important ecological integrity of the property. The purpose of the property is to protect Moapa dace and its habitat, which will also provide protections for Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia, as free-flowing water and adequate discharge would be maintained. Water diversion, channel modification, impoundment, and recreation are stressors that have already occurred and have stabilized as much as possible. If funding were to become available, Cardy Lamb Spring would greatly benefit from restoration from impoundment, which SNWA would likely support. The mission statement for the Warm Springs Natural Area is "To manage the property as a natural area for the benefit of native species and for the recovery of the endangered Moapa dace – consistent with the Southern Nevada Water Authority's commitments to the Southern Nevada Public Land Management Act funding of the property. Agreements and stipulations in place as discussed on Service land (e.g., Apcar Spring Province) could also provide protections for this spring by preventing extensive groundwater pumping that could result in the lowering of water discharge.

Comment [PME29]: As?

Additional protections have been provided under the Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem. The Service prepared a recovery plan for Moapa dace in 1983, which specified research-related tasks to guide recovery. This revised plan incorporates research data and addresses the species (then) current status, threats, and recovery needs. It also addresses the (then) current status, potential threats, and recovery needs of the seven other rare aquatic species (including Moapa pebblesnail and grated tryonia), which occur with Moapa dace in the Muddy River ecosystem. Conservation measures include protecting Cardy Lamb Spring through conservation agreements, easements, or management plans. Implementation of tasks in this recovery plan should reduce potential threats to springsnails by protecting instream flows, protecting habitat, and minimizing nonnative species, but we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.3.2 Baldwin Spring

Springsnail species present in Baldwin Springs include one population each of Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia (Figure 5.3). This spring is in the Muddy River Springs Area Hydrographic basin (219) and is in the headwaters of the Muddy River in Clark County, Nevada, and it is currently the source of the South Fork Muddy River. It is within the Warm Springs Natural Area owned by Southern Nevada Water Authority and has been highly disturbed by diversion and dredging. It is a rheocrene, fluvial deposit spring originating from an unconfined local basin fill aquifer. The Muddy River Springs Province contains several of these local aquifers which are underlain by a regional carbonate aquifer. The regional carbonate rock aquifer is confined. Historically, the spring discharged from bedrock at the base of a hillside and was diverted northward into a concrete channel. In the late 1990s, the source was captured in a Moapa Valley Water District (MVWD) pump house and its springbrook channelized toward the east and into the South Fork Muddy River. MVWD has a water diversion at the pump house, and the water MVWD does not divert is allowed to flow into a deep, slow-moving channel with fine substrate (SNWA 2008, p. 3-99). Discharge is supplemented by water from a pipe that appears to bring water from the Cardy Lamb Spring area. Southern banks of the upper reaches of the springbrook were channelized within the trunks of palm trees that were laid horizontally parallel to the flow of water.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.20). Springbrook length was 200 m (656 ft). Wetted width ranged from 50 to 300 cm (19.7 to 118 in) and wetted depth ranged from 3 to 55.6 cm (1.2 to 22 in).

Table 5.20. Attribute measurements for Baldwin Spring.

Spring or Spring Province	Temperature °C (ºF)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Baldwin Spring	31–31.7 (87.8–89)	7.5–7.7	976–1143	3.8–4.3	700–1000 (0.4–0.59)	16.6 (6.5)

Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; Sada 2016, entire; and Sada 2017, entire.

Additional measurements from the Moapa Valley Water District indicate that the average monthly discharge rate from 2002 to 2016 ranged from 1,699 to 7,136 L/min (1.0 to 4.20 cfs) (USGS 2016, entire).

Surveys conducted in 2016 estimated the substrate to be 80 percent silt and 20 percent sand. In 2016, riparian vegetation contained mesquite and palm trees. Riparian vegetation also included cattails, grapevine, and green algae. Bank cover was estimated at 50 percent and emergent vegetation at 12 percent. The north bank was densely covered by vegetation and was also dense beginning approximately 70 m downstream from the pump house. Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected. This information also provides a range of historical to current conditions and a reference that may be used as a comparison to future data collected.

Stressors to Baldwin Spring (Table 5.21) include water diversion, channel modification, predation and competition from invasive aquatic species (mosquitofish and red-rimmed melania), and vegetation and soil disturbance from roads. Mosquitofish and red-rimmed melania can impact springsnails through predation and competition for resources. Recent survey data show that the intensity of invasive aquatics is high, which may be why the most recent springsnail surveys documented scarce abundance of Moapa pebblesnail and Moapa Valley pyrg.

Table 5.21. Current stressors for Baldwin Spring.

Stressors	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Predation and Competition	current	high	high	basic need	NC	M

Vegetation and Soil Disturbance (Roads)	current	low	high	basic need	NC	M
Spring Modifications from the following Sources						
Surface Water Diversion	current	high	high	basic need	NC	M
Channel Modification	current	high	high	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2]L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Baldwin Spring has undergone channel modification and is a water diversion, resulting from the human demand for water. It includes a pumping facility for the Moapa Valley Water District (MVWD), which captures some discharge for diversion while the rest flows into the modified channel where springsnails occur. While the spring water comes out of a pipe, it flows into a modified channel lined with palm trees that has become habitat for springsnails. This stressor should not impact springsnails, unless water flows are cut off or dramatically reduced. Roads are another stressor at Baldwin Springs, since there is an access road and parking area adjacent to the south springbrook bank. Potential effects to springsnails from road traffic include vegetation or soil disturbance, sediment transport and storage, and stability of slopes adjacent to streams. The roads in this area are not heavily traveled, since they are not accessible to the public. Therefore, intensity and exposure to springsnails should be low and insignificant (instead of high as stated in the 2016 survey).

Tetra Tech (2012, entire) evaluated modeling simulations of groundwater systems in southeastern Nevada under seven scenarios in 12 hydrographic areas. Cardy Lamb Spring, within Muddy River Springs Area HA (219), is included in this study. Modeling scenario 1 is based existing groundwater rights that are currently pumped. After 50 years of pumping under the current pumping scenario 1, aquifer drawdown is 0.6 to 1.5 m (2 to 5 feet), and simulated spring discharges are reduced but still adequate (Tetra Tech 2012, pp. 13; Figure 3.1-2a). Modeling scenario 2 is based on all existing groundwater rights, both pumped and unpumped. After 50 years of pumping under the pumping scenario 2, aquifer drawdown would be 3 to 6 m (10 to 20 feet) and simulated spring discharges reduced (Tetra Tech 2012, p. 52; Figure 3.2-2a).

Comment [CSE30]: This may need to be incorporated into the future conditions section.

Comment [PME31]: Agree with this assessment. Also, seems like it is just repeating the info from the last section that presented this info.

SNWA and CSI hold water rights applications in Coyote Spring Valley totaling 135,000 afy. Executive Order 1169 required multiple entities in five hydrographic basins (including 219 where Cardy Lamb Spring is) to conduct a pump test of all existing water rights (see Chapter 4 for more details). The study began in November 2010 and ended the last day of 2012. The test was supposed to pump 50% of existing water rights, but the study was ended after only pumping one-third of the permitted rights. Groundwater levels decreased 0.76 to 1.1 m (2.5 to 3.5 feet). Springs in the Muddy River Springs hydrographic area saw a decline in discharge, though not at rates that would result in complete drying of these springs.

Comment [CSE32]: We still need to evaluate what this mean in terms of impacts to the habitat/species occurring there

We expect that the province future conditions will likely remain similar to current conditions as the best available information does not indicate an increase or decrease in effects associated with the stressors.

SNWA developed the Warm Springs Natural Area has a Stewardship Plan to establish a long-term management direction for the Warm Springs Natural Area that will foster relations between SNWA and the property neighbors, while preserving the important ecological integrity of the property. The purpose of the property is to protect Moapa dace and its habitat, which will also provide protections for Moapa pebblesnail, Moapa Valley pyrg, and Grated tryonia, as free-flowing water and adequate discharge would be maintained. Water diversion, channel modification, and roads are stressors that have already occurred and have stabilized. This Plan would likely prevent the building of future diversions, modifications and roads, since they would greatly impact Moapa dace, and therefore, springsnails. The mission statement for the Warm Springs Natural Area is "To manage the property as a natural area for the benefit of native species and for the recovery of the endangered Moapa dace – consistent with the Southern Nevada Water Authority's commitments to the Southern Nevada Public Land Management Act funding of the property. Agreements and stipulations in place as discussed on Service land (e.g., Apcar Spring Province) could also provide protections for this spring by preventing extensive groundwater pumping that could result in the lowering of water discharge.

Comment [PME33]: As?

Comment [PME34]: This paragraph is a repeat of the above paragraph on SNWA's Warm Springs Natural Area. Can it be condensed into a single section?

Additional protections have been provided under the Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem. The Service prepared a recovery plan for Moapa dace in 1983, which specified research-related tasks to guide recovery. This revised plan incorporates research data and addresses the species (then) current status, threats, and recovery needs. It also addresses the (then) current status, potential threats, and recovery needs of the seven other rare aquatic species (including Moapa pebblesnail and grated tryonia), which occur with Moapa dace in the Muddy River ecosystem. Conservation measures include protecting Baldwin Spring through conservation agreements, easements, or management plans. Implementation of tasks in this recovery plan should reduce potential threats to springsnails by protecting instream flows, protecting habitat, and minimizing nonnative species, but we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.3.3 Muddy Spring

Springsnail species present in Muddy Spring include one population each of Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia (Figure 5.3). This spring is in Clark County, Nevada and is in the Muddy River Springs Area Hydrographic basin (219). Its confluence is with the Muddy River and is privately owned by the Mormon Church. It is a rheocrene, alluvial slope spring originating from an unconfined local basin fill aquifer. The collective Muddy River Springs Province contains several of these local aquifers which are underlain by a regional carbonate aquifer. The regional carbonate rock aquifer is confined. The spring source is adjacent to a house and its patio, where it was historically impounded and used for recreation. Reportedly, it is no longer impounded and the spring flows into its brook without obstruction (Sada 2017, p. 54). The best available information indicates that the spring likely continues to support a large amount of springsnail habitat, which was documented by Sada (2017, p. 54) in 2000. Current condition of this spring is unknown since access was denied during 2016 survey efforts.

Comment [PME35]: The LDS church has been redeveloping the swimming pool and have been holding back water and then releasing it. Not sure of what impact sudden pulses of water would have on the springsnails.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.22). In 2016, the private landowners did not permit access to Muddy Spring. Springbrook length extended a maximum of 600 m (1,969 ft). Wetted width was 1,500 cm (591 in) and wetted depth was 0.5 cm (0.2 in). Summary statistics (USGS 2016, entire) for the time period 1984–2016 give a daily discharge mean of 13,252 L/min (7.8 cfs), median of 13,252 L/min (7.8 cfs), maximum of 14,442 L/min (8.5 cfs) (in 1997) and minimum of 11,213 L/min (6.6 cfs) (in 2007).

Table 5.22. Attribute measurements for Muddy Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Muddy Spring	31.7 (89)	7.8	1,070	4.7	12,000 (7.1)	not available

Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; Sada 2016, entire; and Sada 2017, entire.

Comment [PME36]: Paragraph above cites USGS and gives and average daily Q of 7.8 cfs. This table says 7.1?

Comment [CSE37]: To be verified.

Information on spring vegetation is not available, but substrate during a 1991 survey was 25 percent silt, 25 percent sand, and 50 percent gravel (CITATION). Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected. This information also provides a range of historical to current conditions and a reference that may be used as a comparison to future data collected.

Stressors for Muddy Spring include impoundment and vegetation and soil disturbance and water pollution from recreation (Table 5.23). These are historic stressors and do not currently impact springsnails. Vegetation at springs that includes nonnative plants such as palm trees increases the risk of wildfire. In July 2010, a major wildfire occurred in the Moapa area springs and streams that was fueled largely by palm trees, which burned the Muddy Spring area. The affected riparian vegetation has recovered at this spring. Wildfire still remains a potential stressor for all springs in the entire Muddy River area.

Comment [PME38]: Apparently LDS is going to open up the camp again at some point, we learned through a casual conversation with a caretaker out there.

Table 5.23. Historic stressors for Muddy Spring.

Stressors	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Spring Modifications (Impoundment)	historic	moderate	unknown	unknown	NC	L
Vegetation and Soil Disturbance and (Recreation)	historic	moderate	unknown	unknown	NC	L
Water Pollution (Recreation)	historic	moderate	unknown	unknown	NC	L

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Tetra Tech (2012, entire) evaluated modeling simulations of groundwater systems in southeastern Nevada under seven scenarios in 12 hydrographic areas. Cardy Lamb Spring, within Muddy River Springs Area HA (219), is included in this study. Modeling scenario 1 is based existing groundwater rights that are currently pumped. After 50 years of pumping under the current pumping scenario 1, aquifer drawdown is 0.6 to 1.5 m (2 to 5 feet), and simulated spring discharges are reduced but still adequate (Tetra Tech 2012, pp. 13; Figure 3.1-2a). Modeling scenario 2 is based on all existing groundwater rights, both pumped and unpumped. After 50 years of pumping under the pumping scenario 2, aquifer drawdown would be 3 to 6 m (10 to 20 feet) and simulated spring discharges reduced (Tetra Tech 2012, p. 52; Figure 3.2-2a).

Comment [CSE39]: This may need to be incorporated into the future conditions section.

SNWA and CSI hold water rights applications in Coyote Spring Valley totaling 135,000 afy. Executive Order 1169 required multiple entities in five hydrographic basins (including 219 where Cardy Lamb Spring is) to conduct a pump test of all existing water rights (see Chapter 4 for more details). The study began in November 2010 and ended the last day of 2012. The test was supposed to pump 50% of existing water rights, but the study was ended after only pumping one-third of the permitted rights. Groundwater levels decreased 0.76 to 1.1 m (2.5 to 3.5 feet). Springs in the Muddy River Springs hydrographic area saw a decline in discharge, though not at rates that would result in complete drying of these springs.

Comment [CSE40]: We still need to evaluate what this mean in terms of impacts to the habitat/species occurring there

We expect that the province future conditions will likely remain similar to current conditions as the best available information does not indicate an increase or decrease in effects associated with the stressors.

While Muddy Spring is privately owned spring, agreements and stipulations in place as discussed on Service land (e.g., Apcar Springs Province) would also provide this spring protections. Additional protections have been provided under the Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem. The Service prepared a recovery plan for Moapa dace in 1983, which specified research-related tasks to guide recovery. This revised plan incorporates research data and addresses the species (then) current status, threats, and recovery needs. It also addresses the (then) current status, potential threats, and recovery needs of the seven other rare aquatic species (including Moapa pebblesnail and grated tryonia), which occur with Moapa dace in the Muddy River ecosystem. Conservation measures have included the restoration of Muddy Spring, which eliminated the impoundment and reduced recreation. We are not aware of any current management actions specific to spring or springsnail conservation that are being implemented at this site.

5.3.4 Apcar Springs Province

Springsnail species present in Apcar Springs Province include one population each of Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia (Figure 5.3). Apcar Springs Province is in the Muddy River Springs Area Hydrographic basin (219) and located near the Muddy River in Clark County, Nevada about 80.5 km (50 mi) northeast of Las Vegas and is owned and managed by the Service. There are six spring sources in this rheocrene, alluvial slope system originating from an unconfined local basin fill aquifer. The Muddy River Springs Province contains several of these local aquifers which are underlain by a regional carbonate aquifer. The regional carbonate rock aquifer is confined. All of the Apcar Province springs flow into a common springbrook that leaves Moapa Valley National Wildlife Refuge (MVNWR) and flows onto SNWA's Warm Springs Natural Area property.

- *Apcar Spring A*: This is the northernmost spring in the province. In 2016, its springbrook was 108 m (354 ft) long, and springsnails occupied 82 m (269 ft) of the springbrook (50.5 m^2 (545 ft^2) of habitat).

Comment [PME41]: Would be nice to see a figure of the area which A-F labeled.

- *Apcar Spring B:* The springbrook was 48 m (157 ft) long in 2016, and springsnails occupied 42 m (138 ft) of the springbrook (19.3 m^2 (208 ft^2) of habitat).
- *Apcar Springs C and D confluence:* The sources of springs C and D could not be accessed in 2016 due to dense vegetation. The springbrook (28 m (92 ft) long) below the confluence of these two springs was sampled, and springsnails occupied 26 m (85 ft) of the springbrook (18.9 m^2 (203 ft^2) of habitat).
- *Apcar Spring E:* This springbrook was 18 m (59 ft) long in 2016, with springsnails occupying all 18 m (59 ft) of the springbrook (16.7 m^2 (180 ft^2) of habitat).
- *Apcar Spring F:* This is the southernmost spring in the province and the largest. All of its discharge comes from a pipe that captures the spring in a pump house. The springbrook has recovered from restoration, and it is a large, swift aquatic habitat. Its springbrook flows onto SNWA property and into a channelized ditch. Springsnails occupied 252 m (827 ft) of the springbrook (424.4 m^2 (4,568 ft^2) of habitat) and were found on green algae species (*Chara* spp.) during 2016 surveys.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.24). Springbrook length extended a maximum of 2,000 m (6,562 ft). Wetted width ranged from 30 cm to 168.3 cm (12 to 66 in) and wetted depth ranged from 2.8 to 19.1 cm (1.1 to 7.5 in).

Table 5.24. Attribute measurements for Apcar Springs Province.

Spring or Spring Province	Temperature °C (ºF)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Apcar Springs Province	31–32.2 (87.8– 90)	7.4–7.6	880–1163	2.1–4.3	15–1000 (0.009–-0.59)	3.4–59 (1.3–23)

Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; Sada 2016, entire; and Sada 2017, entire.

The condition of all springs and springbrooks is similar in this province. Substrate composition is dominated by fines, sand, and gravel. Surveys conducted at the confluence of C and D springs estimated the substrate to be 40 percent silt, 10 percent sand, and 50 percent gravel, with slight variations among the remaining spring survey locations. Apcar Spring F, however, was the only site to have cobble (80 percent) with 20 percent gravel. In 2016, riparian vegetation was dominated by shrub willow and arrow weed (*Pluchea* spp.), which was often dense. Native mesquite (*Prosopis* spp.) and ash trees were scarce. Riparian vegetation also included cattails, rushes, saltgrass, sawgrass (*Cladium* spp.), green algae (*Chara* spp.), and cottonwood trees. All five sampling locations had 100 percent bank cover and low percentages of emergent vegetation. Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected. This information also provides a range of historical to current conditions and a reference that may be used as a comparison to future data collected.

Stressors for Apcar Springs A through F include predation and competition from invasive aquatic species (mosquitofish (*Gambusia affinis*) and red-rimmed melania (*Melanoides tuberculata*)), vegetation and soil disturbance from roads, and vegetation and soil disturbance and channel modification from restoration (Table 5.25). Mosquitofish and red-rimmed melania can impact springsnails through predation and competition for resources. Recent survey data show that the intensity of invasive aquatics is low, thereby making the current impact to springsnails low. Other sources of stress are restoration and roads. Restoration activities in 2007 and 2008 resulted in channel modification and disturbance to vegetation and soil, which may have resulted in the loss of some individuals. Site conditions have since stabilized and impacts to springsnails from this restoration are negligible. Road traffic on gravel and dirt roads near the spring may contribute to vegetation or soil disturbance, sediment transport and storage, and stability of slopes adjacent to streams. Impacts to springsnails at Apcar Springs Province from roads are negligible.

Table 5.25. Current stressors for Apcar Springs Province.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Roads)	current	negligible	insignificant	unknown	NC	M
Predation and Competition (Invasive Aquatics)	current	low	unknown	unknown	NC	M
Spring Modifications from the following Sources						
Surface Water Diversion	current	moderate	unknown	unknown	NC	H
Channel Modification	current	moderate	moderate	basic need	NC	H
Restoration	current	moderate	moderate	basic need	NC	H

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Apcar Spring F is also a water diversion, a stressor resulting from the human demand for water. It includes a pumping facility for the Moapa Valley Water District (MVWD), which captures discharge from the largest spring in the province and delivers a portion of its water to downstream agriculture. While the spring water comes out of a pipe, it flows into a restored channel that is habitat for springsnails. This stressor should not impact springsnails, unless water flows are cut off or dramatically reduced.

Tetra Tech (2012, entire) evaluated modeling simulations of groundwater systems in southeastern Nevada under seven scenarios in 12 hydrographic areas. Cardy Lamb Spring, within Muddy River Springs Area HA (219), is included in this study. Modeling scenario 1 is based existing groundwater rights that are currently pumped. After 50 years of pumping under the current pumping scenario 1, aquifer drawdown is 0.6 to 1.5 m (2 to 5 feet), and simulated spring discharges are reduced but still adequate (Tetra Tech 2012, pp. 13; Figure 3.1-2a). Modeling scenario 2 is based on all existing groundwater rights, both pumped and unpumped. After 50 years of pumping under the pumping scenario 2, aquifer drawdown would be 3 to 6 m (10 to 20 feet) and simulated spring discharges reduced (Tetra Tech 2012, p. 52; Figure 3.2-2a).

Comment [CSE42]: This may need to be incorporated into the future conditions section.

SNWA and CSI hold water rights applications in Coyote Spring Valley totaling 135,000 afy. Executive Order 1169 required multiple entities in five hydrographic basins (including 219 where Cardy Lamb Spring is) to conduct a pump test of all existing water rights (see Chapter 4 for more details). The study began in November 2010 and ended the last day of 2012. The test was supposed to pump 50% of existing water rights, but the study was ended after only pumping one-third of the permitted rights. Groundwater levels decreased 0.76 to 1.1 m (2.5 to 3.5 feet). Springs in the Muddy River Springs hydrographic area saw a decline in discharge, though not at rates that would result in complete drying of these springs.

Comment [CSE43]: We still need to evaluate what this mean in terms of impacts to the habitat/species occurring there

We expect that the province future conditions will likely remain similar to current conditions as the best available information does not indicate an increase or decrease in effects associated with the stressors.

Apcar Springs Province occurs within a third piece of property purchased by the Service to create the MVNWR and conserve the endangered Moapa dace. These springs have been altered for recreation, but never used as a resort. The springs were restored in 2007 and 2008, and the riparian community along all springbrooks remains in an early seral stage of recovery. The Service manages Apcar Springs Province in accordance with the Desert Refuge Complex Comprehensive Conservation Plan. This Plan states that it is a goal to protect and restore, when possible, healthy populations of endemic and special status species, which includes Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia. Such restoration would not only favor these native springsnails, but should also discourage nonnative species, identified as a stressor in Apcar Springs Province. Agreements or stipulations in place to further protect Apcar Springs Province include Coyote Spring Valley Stipulation and Monitoring, Management, and Mitigation Plan for Existing and Future Permitted Groundwater Development in Coyote Spring; Memorandum of Agreement for Coyote Spring Valley and California Wash Hydrographic Basins; Water Settlement Agreement for Coyote Spring Valley and California Wash Hydrographic Basins; and Kane Springs Amended Stipulation. All of these agreements and stipulations would assist in preventing extensive groundwater pumping that could result in the lowering of water discharge in Apcar Springs Province in the future. Details of these agreements and stipulations can be found in Appendix A.

Additional protections have been provided under the Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem. The Service prepared a recovery plan for Moapa dace in 1983, which specified research-related tasks to guide recovery. This revised plan incorporates research data and addresses the species (then) current status, threats, and recovery needs. It also addresses the (then) current status, potential threats, and recovery needs of the seven other rare aquatic species (including Moapa pebblesnail and grated tryonia), which occur with Moapa dace in the Muddy River ecosystem. Conservation measures include protecting Apcar Springs Province through conservation agreements, easements, or management plans. Implementation of tasks in this recovery plan should reduce potential threats to springsnails by protecting instream flows, protecting habitat, and minimizing nonnative species, but we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.3.5 Plummer Springs Province

Springsnail species present in Plummer Springs Province include one population each of Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia (Figure 5.3). There are three springs in this province that are in the Muddy River Springs Area HA (219). All of the springs in this rheocrene system flow into a common springbrook that leaves the MVNWR and flows onto SNWA land. They are rheocrene, alluvial slope springs originating from an unconfined local basin fill aquifer. The Muddy River Springs Province contains several of these local aquifers which are underlain by a regional carbonate aquifer. The regional carbonate rock aquifer is confined. There is no confluence between this springbrook and the springbrook leaving Pederson springs. This property was purchased for the MVNWR. Similar to the Pederson property, it was managed as a warm-springs resort that included swimming pools and bath houses. Some springs were impounded within concrete walls and springbrooks were lined with pea-size gravel. Palm trees were the only riparian vegetation, aquatic vegetation was dominated by invasive eelgrass, and the gastropod assemblage was dominated by red-rimmed melania. Native fish were scarce, and the springs exhibited little resemblance to natural conditions. A Moapa dace restoration program was initiated; eelgrass was eradicated; artificial pools were removed; and Moapa dace, Moapa White River springfish, and native benthic macroinvertebrate communities returned.

These springs provide an interpretive focus for MVNWR with a visitor parking area, walking trails through the riparian area, bridges over springbrooks, and a flow-through viewing chamber where a springbrook is diverted to allow the public to observe fish and invertebrates in a quasi-natural setting. This facility appears to have no discernable negative effect on springsnail abundance.

- *Plummer Spring A:* This spring discharges above the viewing chamber and flows beneath it into a naturalized springbrook. Its springbrook flowed 37 m (121 ft) before combining with spring B and C springbrooks. This was considered to be the 'primary' Plummer springbrook that captured discharge from springs B and C before flowing under Warm Springs Road and onto SNWA property. Springsnails occupied a total of 87 m (285 ft) of this springbrook (96.6 m^2 (1,040 ft^2) of habitat). Below this confluence, springsnails occupied an additional 50 m (164 ft) of springbrook (67.5 m^2 (727 ft^2) of habitat) on SNWA property (dense vegetation prevented surveying additional habitat in this springbrook).
- *Plummer Spring B:* This spring supports the public viewing chamber. Its springbrook was 110 m (361 ft) long before combining with discharge from springs A and C. Springsnails occupied all 110 m (361 ft) of springbrook (139.4 m^2 (1,500 ft^2) of habitat).
- *Plummer Spring C:* This spring is in good condition. Its springbrook was 100 m (328 ft) long and springsnails occupied 70 m (230 ft) of springbrook (76.3 m^2 (821 ft^2) of habitat). The source of this spring was dredged into a circular pool, which was probably not characteristic of its natural form. It is a stable system that has naturalized from restoration and is still recovering.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.26). Springbrook length extended a maximum of 110 m (361 ft). Wetted width ranged from 40 cm to 127 cm (15.7 to 50 in) and wetted depth ranged from 5 cm to 20 cm (2 to 7.96 in).

Comment [PME44]: Map of A-C?

Table 5.26. Attribute measurements for Plummer Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Plummer Springs Province	30.9–32.1 (87.6–-89.8)	7.4	936–1207	2.1–2.5	40–300 (0.02–0.18)	21.5–30.2 (8.5–11.9)

Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; Sada 2016, entire; and Sada 2017, entire.

Periodic discharge measurements for Plummer Main (downstream from Plummer Springs A, B, C: USGS 2016, entire; Beck *et al.* 2006 Appendix B, p. 54) for the time period 1982–2004 give a daily discharge maximum of 6,626 L/min (3.9 cfs) and minimum of 850 L/min (0.5 cfs).

Substrate composition varied between the springs. Springs A and B were dominated by gravel with some silt, sand, and cobble. Spring C was dominated by silt with some sand and gravel. The riparian community at these springs differs demonstrably from the Pederson springs. Willow and arrow weed are sparse, and springbrooks are bordered mostly by mesquite, cottonwoods, palm trees, rushes, and bulrushes. This vegetation appears to be in a later seral stage of ecological change than vegetation at either the Pederson or Apcar spring provinces. Bank cover at all springs is over 89 percent and emergent vegetation cover is less than 42 percent. Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected. This information also provides a range of historical to current conditions and a reference that may be used as a comparison to future data collected.

Stressors for springs A through C include predation and competition from invasive red-rimmed melania, vegetation and soil disturbance from roads and restoration (Table 5.27). Red-rimmed melania can impact springsnails through predation and competition for resources. Recent survey data show that the intensity of invasive aquatics is low, thereby making the current impact to springsnails low. Traffic on gravel and dirt roads near the spring may contribute to vegetation or soil disturbance, sediment transport and storage, and stability of slopes adjacent to streams. Impacts to springsnails at Plummer Springs Province are negligible. Another source of stress is restoration, which resulted in vegetation and soil disturbance. Restoration activities occurred in 2007 and 2008, which may have resulted in the loss of some individuals. Site conditions have since stabilized and impacts to springsnails from this restoration are negligible.

Table 5.27. Current stressors for Plummer Springs Province.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Predation and Competition (Invasive Aquatics)	current	low	small	unknown	NC	M
Vegetation and Soil Disturbance	current	negligible	small	unknown	NC	M

(Roads)						
Spring Modifications from the following Sources						
Surface Water Diversion	current	negligible	insignificant	unknown	NC	H
Restoration	current	moderate	moderate	unknown	NC	H

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Plummer Spring B is a water diversion, due to the public viewing chamber. While the course of the water did change, the habitat has been restored. Impacts to springsnails are negligible and springsnail abundances are scarce to common.

Tetra Tech (2012, entire) evaluated modeling simulations of groundwater systems in southeastern Nevada under seven scenarios in 12 hydrographic areas. Cardy Lamb Spring, within Muddy River Springs Area HA (219), is included in this study. Modeling scenario 1 is based existing groundwater rights that are currently pumped. After 50 years of pumping under the current pumping scenario 1, aquifer drawdown is 0.6 to 1.5 m (2 to 5 feet), and simulated spring discharges are reduced but still adequate (Tetra Tech 2012, pp. 13; Figure 3.1-2a). Modeling scenario 2 is based on all existing groundwater rights, both pumped and unpumped. After 50 years of pumping under the pumping scenario 2, aquifer drawdown would be 3 to 6 m (10 to 20 feet) and simulated spring discharges reduced (Tetra Tech 2012, p. 52; Figure 3.2-2a).

Comment [CSE45]: This may need to be incorporated into the future conditions section.

SNWA and CSI hold water rights applications in Coyote Spring Valley totaling 135,000 afy. Executive Order 1169 required multiple entities in five hydrographic basins (including 219 where Cardy Lamb Spring is) to conduct a pump test of all existing water rights (see Chapter 4 for more details). The study began in November 2010 and ended the last day of 2012. The test was supposed to pump 50% of existing water rights, but the study was ended after only pumping one-third of the permitted rights. Groundwater levels decreased 0.76 to 1.1 m (2.5 to 3.5 feet). Springs in the Muddy River Springs hydrographic area saw a decline in discharge, though not at rates that would result in complete drying of these springs.

Comment [CSE46]: We still need to evaluate what this mean in terms of impacts to the habitat/species occurring there

We expect that the province future conditions will likely remain similar to current conditions as the best available information does not indicate an increase or decrease in effects associated with the stressors.

Plummer Springs Province occurs within the second piece of property purchased by the Service to create the MVNWR and conserve the endangered Moapa dace. The Service manages Plummer Springs Province in accordance with the Desert Refuge Complex Comprehensive Conservation Plan. This Plan states that it is a goal to protect and restore, when possible, healthy populations of endemic and special status species, which includes Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia. Such restoration would not only favor these native springsnails, but should also discourage nonnative species, identified as a stressor in Apcar Springs Province. Agreements or stipulations in place to further protect Apcar Springs Province include Coyote Spring Valley Stipulation and Monitoring, Management, and Mitigation Plan for Existing and Future Permitted Groundwater Development in Coyote Spring; Memorandum of Agreement for

Coyote Spring Valley and California Wash Hydrographic Basins; Water Settlement Agreement for Coyote Spring Valley and California Wash Hydrographic Basins; and Kane Springs Amended Stipulation. All of these agreements and stipulations would assist in preventing extensive groundwater pumping that could result in the lowering of water discharge in Plummer Springs Province in the future. Details of these agreements and stipulations can be found in Appendix A.

Additional protections have been provided under the Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem. The Service prepared a recovery plan for Moapa dace in 1983, which specified research-related tasks to guide recovery. This revised plan incorporates research data and addresses the species (then) current status, threats, and recovery needs. It also addresses the (then) current status, potential threats, and recovery needs of the seven other rare aquatic species (including Moapa pebblesnail and grated tryonia), which occur with Moapa dace in the Muddy River ecosystem. Conservation measures include protecting Plummer Springs Province through conservation agreements, easements, or management plans. Implementation of tasks in this recovery plan should reduce potential threats to springsnails by protecting instream flows, protecting habitat, and minimizing nonnative species, but we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.3.6 Pederson Springs Province

Springsnail species present in Pederson Springs Province include one population each of Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia (Figure 5.3). There are eight springs in this province in Clark County, Nevada that are in the Muddy River Springs Area Hydrographic basin (219). All of these springs flow into a common springbrook that leaves the MVNWR and flow onto SNWA land. The springs are rheocrene, alluvial slope springs originating from an unconfined local basin fill aquifer. The Muddy River Springs Province contains several of these local aquifers which are underlain by a regional carbonate aquifer. The regional carbonate rock aquifer is confined. This was the first piece of property purchased by the Service in 1979 to create the MVNWR and conserve the endangered Moapa dace. Prior to this purchase, it was managed as a warm springs resort that included an Olympic-sized swimming pool and bath houses. Some springs were impounded within concrete walls, and springbrooks were lined with pea-sized gravel. Palm trees were the only riparian vegetation, aquatic vegetation was dominated by invasive eelgrass (*Vallisneria* spp.), and the gastropod assemblage was dominated by red-rimmed melania. Native fish were scarce, and the springs exhibited little resemblance to natural conditions. A Moapa dace restoration program was initiated and springs were restored in 2007 and 2008. Eelgrass was eradicated; artificial pools were removed; and native Moapa dace, Moapa White River springfish, and native benthic macroinvertebrate communities returned. The riparian community along all springbrooks is currently in an early seral stage of recovery.

- *Pederson Spring A:* All Pederson springs are tributary to this springbrook. Discharge is continuously measured by a USGS weir that is located near the spring source. Approximately 400 m (1,312 ft) of this springbrook lies on the MVNWR (including 419.2 m^2 (4,512 ft^2) of springsnail habitat) before crossing Warm Springs Road and entering SNWA property.
- *Pederson Spring C:* Discharge from this spring is also monitored by a USGS weir and recorder. This springbrook was 65 m (213 ft) long (32.9 m^2 (354 ft^2) of habitat) and

Comment [PME47]: Map?

flowed into the west side of the Spring A springbrook. The source of this spring was dredged into a circular pool, which is probably not characteristic of its natural form. It is a stable system that has naturalized from restoration and is still recovering.

- *Pederson Spring D:* Dense vegetation prevented surveying access to the source of this spring in 2016. Its springbrook was 52 m (171 ft) long (54.1 m^2 (582 ft^2) of habitat), relatively wide, and had swift current.
- *Pederson Spring F:* This spring and its springbrook were also densely covered by woody riparian vegetation, which limited access. Its springbrook was 53 m (174 ft) long (249.1 m^2 (2681 ft^2) of habitat).
- *Pederson Spring G:* This spring and its springbrook were also densely covered by woody riparian vegetation, which limited access. Its springbrook was 58 m (190 ft) long (39.6 m^2 (426 ft^2) of habitat).
- *Pederson Spring H:* Vegetation was extremely dense at this spring source and all along its 35 m long springbrook, and sampling was not possible without removing vegetation. Proximity to other Pederson springs, and its connection with the Spring A springbrook, suggests that it also supports a springsnail population that is similar in abundance to other springs in the province. Habitat metrics were not evaluated in this spring.
- *Pederson Spring I:* This spring flowed into the east side of the Spring A springbrook and approximately 10 m downstream from the Spring A source. Its springbrook was 5 m (16 ft) long (2.8 m^2 (30 ft^2) of habitat). The source of this spring was dredged into a circular pool, which is probably not characteristic of its natural form. It is a stable system that has naturalized from restoration and is still recovering.
- *Pederson Spring J:* This spring flowed into the west side of the Spring A springbrook, approximately 9 m (29.5 ft) downstream from the Spring A source. Its springbrook was 8 m (26 ft) long (9.5 m^2 (102 ft^2) of habitat). This spring has been minimally altered by restoration, is stable, and appears to be characteristic of its natural form.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.28). Springbrook length extended a maximum of 2,000 m (6,562 ft). Wetted width ranged from 40 cm to 470 cm (16 to 185 in) and wetted depth ranged from 3 cm to 30 cm (1 to 12 in).

Table 5.28. Attribute measurements for Pederson Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Pederson Springs Province	30.9–32.2 (87.6–90)	7.4–7.8	640–1207	2.1–5.2	15–10,000 (0.01–5.9)	2.5–44.1 (1–17.4)

Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; Sada 2016, entire; and Sada 2017, entire.

Summary statistics (USGS 2016, entire) for the time period 1986-2016 give a daily discharge mean of 323 L/min (0.19 cfs), median of 340 L/min (0.20 cfs), maximum of 442 L/min (0.26 cfs) (in 1998) and minimum of 136 L/min (0.08 cfs) (in 2013). The condition of all springs and springbrooks is similar in this province. Substrate composition is mostly dominated by gravel or cobble. Spring J, however, as surveyed in 2016, was dominated by silt.

Comment [PME48]: USGS also?

Comment [PME49]: The stats aren't consistent with the Q ranges presented in the table above. Was this a difference of using daily values versus instantaneous values?

The riparian community at these springs remains in early seral stages of recovery following restoration. It is dominated by shrub willow and arrow weed, which is often dense and prevented access to one spring and its springbrook. Native mesquite, cottonwoods, and palm trees are present. Emergent vegetation consists of rushes, sparse cattails, and bulrushes Bank cover at all springs is over 50 percent and emergent vegetation cover is less than 35 percent. Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected. This information also provides a range of historical to current conditions and a reference that may be used as a comparison to future data collected.

Stressors for springs A through J (Table 5.29) include predation and competition from invasive red-rimmed melania, vegetation and soil disturbance from roads, and channel modification and vegetation and soil disturbance from restoration. Red-rimmed melania can impact springsnails through predation and competition for resources. Recent survey data show that the intensity of invasive aquatics is low, thereby making the current impact to springsnails low. Restoration activities in 2007 and 2008 resulted in channel modification and disturbance to soil and vegetation, which may have resulted in the loss of some individuals. Site conditions have since stabilized and impacts to springsnails from this restoration are negligible. Another source of stress is roads. Traffic on gravel and dirt roads near the spring may contribute to vegetation or soil disturbance, sediment transport and storage, and stability of slopes adjacent to streams. Impacts to springsnails at Pederson Springs Province are negligible.

Table 5.29. Current stressors for Pederson Springs Province.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Predation and Competition (Invasive Aquatics)	current	low	unknown	unknown	NC	M
Vegetation and Soil Disturbance (Roads)	current	negligible	insignificant	unknown	NC	M
Spring Modifications from the following sources						
Channel Modification	current	moderate	moderate	unknown	NC	H
Restoration	current	moderate	moderate	unknown	NC	H

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Tetra Tech (2012, entire) evaluated modeling simulations of groundwater systems in southeastern Nevada under seven scenarios in 12 hydrographic areas. Cardy Lamb Spring, within Muddy River Springs Area HA (219), is included in this study. Modeling scenario 1 is based existing groundwater rights that are currently pumped. After 50 years of pumping under the current pumping scenario 1, aquifer drawdown is 0.6 to 1.5 m (2 to 5 feet), and simulated spring discharges are reduced but still adequate (Tetra Tech 2012, pp. 13; Figure 3.1-2a). Modeling scenario 2 is based on all existing groundwater rights, both pumped and unpumped. After 50 years of pumping under the pumping scenario 2, aquifer drawdown would be 3 to 6 m (10 to 20 feet) and simulated spring discharges reduced (Tetra Tech 2012, p. 52; Figure 3.2-2a).

Comment [CSE50]: This may need to be incorporated into the future conditions section.

SNWA and CSI hold water rights applications in Coyote Spring Valley totaling 135,000 afy. Executive Order 1169 required multiple entities in five hydrographic basins (including 219 where Cardy Lamb Spring is) to conduct a pump test of all existing water rights (see Chapter 4 for more details). The study began in November 2010 and ended the last day of 2012. The test was supposed to pump 50% of existing water rights, but the study was ended after only pumping one-third of the permitted rights. Groundwater levels decreased 0.76 to 1.1 m (2.5 to 3.5 feet). Springs in the Muddy River Springs hydrographic area saw a decline in discharge, though not at rates that would result in complete drying of these springs.

Comment [CSE51]: We still need to evaluate what this mean in terms of impacts to the habitat/species occurring there

We expect that the province future conditions will likely remain similar to current conditions as the best available information does not indicate an increase or decrease in effects associated with the stressors.

The Service manages Pederson Springs Province in accordance with the Desert Refuge Complex Comprehensive Conservation Plan. This Plan states that it is a goal to protect and restore, when possible, healthy populations of endemic and special status species, which includes Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia. Such restoration would not only favor these native springsnails, but should also discourage nonnative species, identified as a stressor in Apcar Springs Province. Agreements or stipulations in place to further protect Apcar Springs Province include Coyote Spring Valley Stipulation and Monitoring, Management, and Mitigation Plan for Existing and Future Permitted Groundwater Development in Coyote Spring; Memorandum of Agreement for Coyote Spring Valley and California Wash Hydrographic Basins; Water Settlement Agreement for Coyote Spring Valley and California Wash Hydrographic Basins; and Kane Springs Amended Stipulation. All of these agreements and stipulations would assist in preventing extensive groundwater pumping that could result in the lowering of water discharge in Pederson Springs Province in the future. Details of these agreements and stipulations can be found in Appendix A.

Additional protections have been provided under the Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem. The Service prepared a recovery plan for Moapa dace in 1983, which specified research-related tasks to guide recovery. This revised plan incorporates research data and addresses the species (then) current status, threats, and recovery needs. It also addresses the (then) current status, potential threats, and recovery needs of the seven other rare aquatic species (including Moapa pebblesnail and grated tryonia), which occur with Moapa dace in the Muddy River ecosystem. Conservation measures include protecting Pederson Springs Province through conservation agreements, easements, or management plans. Implementation of tasks in this recovery plan should reduce potential threats to springsnails by protecting instream flows, protecting habitat, and minimizing nonnative species, but we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

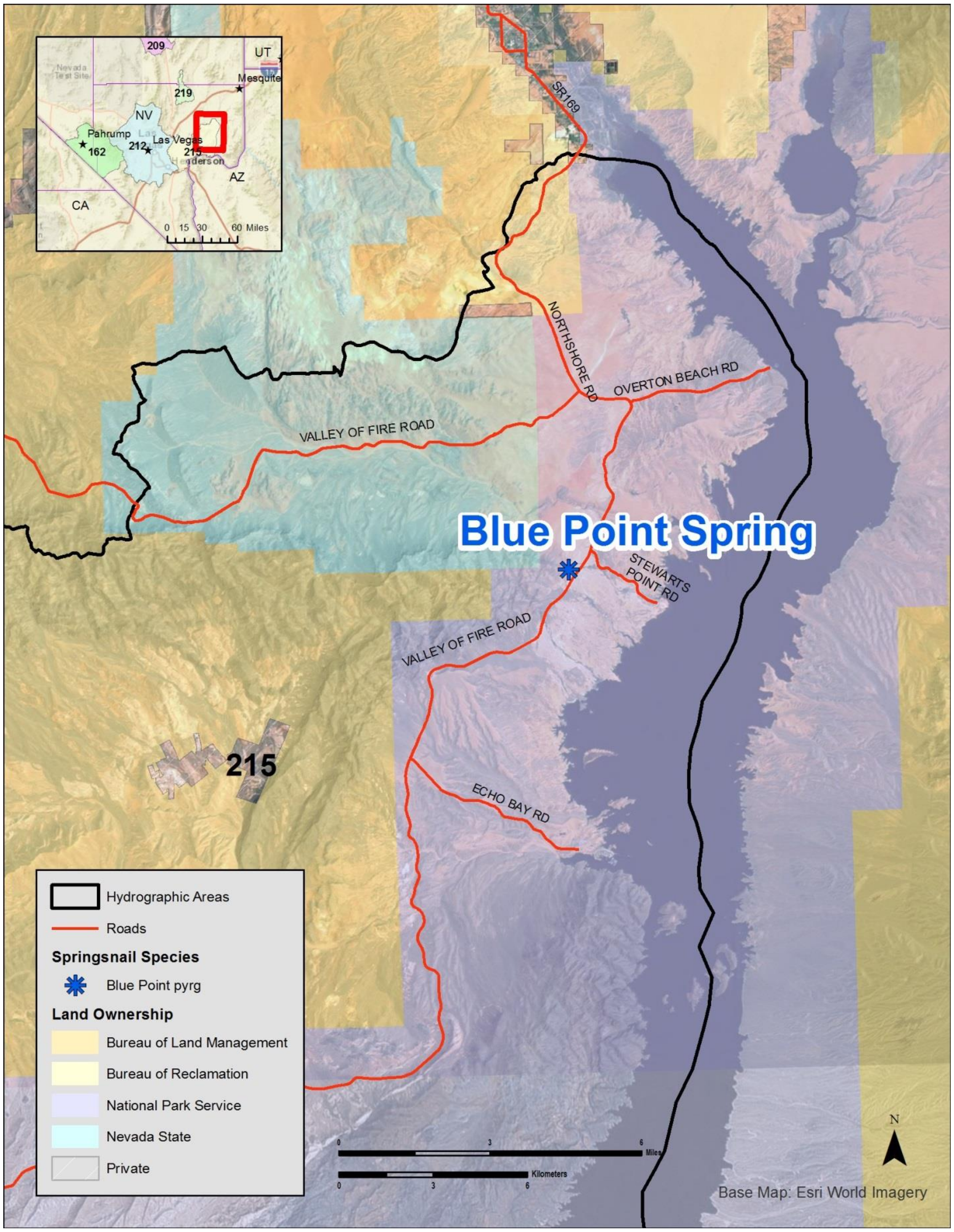


Figure 5.4. Map of the land ownership and general location for Blue Point Spring where the Blue Point pyrg occurs, Black Mountains Area HA (215), Clark County, Nevada.

5.3.7 Blue Point Spring

Springsnail species present in Blue Point Spring is the Blue Point pyrg (Figure 5.4). This spring is located in the Colorado River Basin HA (13) region and Black Mountains Area HA (215). Blue Point Spring's source of water is from a regional confined aquifer near the Roger Springs Fault that emanates at an elevation of 470 m (1,542 ft) as a rheocrene spring (Laney and Bales 1996, p. 5 and 21; Pohlman *et al*. 1998, p. 33; Sada 2016, entire). Pohlmann *et al.* (1998, p. 43) found that groundwater flow systems to Blue Point Spring extend north to Weiser Wash and the Mormon Mountains and appeared to be more strongly related than those to the White River Flow System or Virgin River basin. In addition, Pohlmann (1998, pp. 16–17) indicate there is not a direct relationship between discharge at Blue Point Springs and Muddy River Springs based on temperatures and stable isotopic data.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.30). The water discharging from Blue Point spring measured in 2016 created a springbrook that had a width, depth, and velocity of 76.4 cm (30.1 in), 28.6 cm (11.3 in), and 4.3 cm/sec (1.7 in/sec). Continuous measurements of water flowing from Blue Point Spring were made from October 1999 - October 2012 and have ranged between 765 to 1,138 L/min (0.45 to 0.67 cfs) and averaged 939 L/min (0.55 cfs) (Laney and Bales 1996, p. 5 and 21; USGS 2016, entire). Measurements of water quality at Blue Point Spring have ranged between 29.0 ºC to 30.8 ºC (84.2– to 87.4 ºF) for temperature, 1.5 to 5.6 mg/l (ppm) for DO, 6.9 to 8.1 for pH, and 1,800 to 4,351 µS/cm for conductivity (Thomas *et al*. 1991, pp. 5–14; 1996, p. C88; Laney and Bales 1996, p. 21; Sada and Jacobs 2008, p. 43; Sada 2016, entire; USGS 2016, entire).

Comment [PME52]: I believe NPS still monitors streamflow at Blue Point Spring. May want to talk to Gary Karst for updated flow rates through present.

Comment [PME53]: Not sure how useful it is to restate information from a table. Suggest just presenting the table.

Table 5.30. Attribute measurements for Blue Point Spring.

Spring or Spring Province	Temperature °C (ºF)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Blue Point	29.0–30.8 (84.2–87.4)	6.9–8.1	1,800–4,351	1.5–5.6	765–1,137 (0.45–0.67)	4.3 (1.7)

Data is compiled from the following sources: Thomas *et al.* 1991, Sada and Jacobs 2008, Sada 2016, and USGS 2016.

Substrate can be an important physical factor in spring systems that influences the distribution of biotic assemblages therein (Sada 2008, p. 59), however little is known about the Blue Point Spring system. The substrate recorded for Blue Point Spring has historically been predominantly silt and sand; however, in recent 2016 surveys there was a larger proportion of gravel (Sada 2016 entire; Sada 2017, entire) for unknown reasons. Estimates of substrate particle size composition at Blue Point Spring have tended to be small (silt, sand, and gravel) and changes therein may influence shifts in springsnail distributions but more information is need to understand the dynamics of these relationships.

In 2016, the Blue Point spring system and the vegetation in the area was reported to appear in nearly reference condition even though ongoing disturbances and stressors continue to occur in the area (Sada 2017, pp. 67–68).The riparian and aquatic vegetation recorded at Blue Point spring includes mesquite, cattails, rushes, reeds, salt grass, and sedges (Sada 2017, entire).

Stressors at Blue Point Spring include spring modifications, predation and competition, and vegetation and soil disturbance (Table 5.31; Sada 2017, entire). The Blue Point Spring area is easily accessible from Nevada State Highway 167 where there is a dirt road that parallels the springbrook, but there are no apparent effects from the road and human disturbance on springsnails (Sada and Jacobs 2008, p. 19; Sada 2017; entire). Of potential stressors identified at Blue Point Spring, invasive aquatics, particularly convict cichlids, are thought to have the most detrimental effect on the springsnail population as a result of direct mortality (Sada and Jacobs 2008, p. 26; Sada 2017, p. 68). The decline of springsnails at Blue Point Spring coincided with the appearance of convict cichlids in the 1990s and is considered the greatest stressor to Blue Point pyrg (Sada and Jacobs 2008, p. 26; Sada 2017, entire).

We have little information to predict future change in trend to stressors at Blue Point Spring however we expect the following based upon information we do have. We do not have information on proposed actions which could affect Blue Point Spring. We expect that because of the policies and direction of the National Park Service to protect resources that there can be a moderate confidence of no change in trend from water diversion or roads. Surveys by Sada indicate that past stressors from ungulate species are recovering; therefore we are moderately confident that this will continue to decrease. We are moderately confident that stressors from aquatic invasives will increase at Blue Point Spring because of historic introductions and easy access to the spring from a paved road.

Table 5.31. Current stressors for Blue Point Spring.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Predation and Competition (Aquatic Invasives)	current	high	all	mortality	I	M
Vegetation and Soil Disturbance from the following sources						
Roads	current	negligible	insignificant	unknown	NC	M
Grazing and Browsing	historic	low	low	unknown	D	M
Spring Modifications (Surface Water Diversion)	current	negligible	insignificant	unknown	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

SNWA and CSI hold water rights applications in Coyote Spring Valley totaling 135,000 afy. Executive Order 1169 required multiple entities in five hydrographic basins (including 219 where Cardy Lamb Spring is) to conduct a pump test of all existing water rights (see Chapter 4 for more details). The study began in November 2010 and ended the last day of 2012. The test was supposed to pump 50% of existing water rights, but the study was ended after only pumping one-third of the permitted rights. Groundwater levels decreased 0.76 to 1.1 m (2.5 to 3.5 feet).

Springs in the Muddy River Springs hydrographic area saw a decline in discharge, though not at rates that would result in complete drying of these springs.

Comment [CSE54]: We still need to evaluate what this mean in terms of impacts to the habitat/species occurring there

Springsnail species present in Blue Point Springs include Blue Point pyrg. Other native gastropod species recorded at Blue Point Spring are the Badwater snail, *Tryonia infernalis*, and pond snails (Hershler *et al*. 2015, p. 107; Sada 2017, entire).

Within Lake Mead National Recreation Area LAME NRA, Blue Point Spring and Blue Point pyrg are managed under the policies and directives of the National Park Service which is directed under 16 U.S.C. 1 "(T)o conserve the scenery and the natural and historic objects and wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." The establishment of Lake Mead National Recreation Area (Public Law 88-639) identifies the general purpose of public recreation but also directs that it be done in a manner to preserve important features which would include Blue Point Spring. Under the general management plan, the area near Blue Point Spring was identified to be improved for recreation, monitored, and corrective action taken if impacts to the spring community habitat occur (NPS 1986, p. 291).

Comment [CSE55]: This needs to be incorporated into Appendix A still.

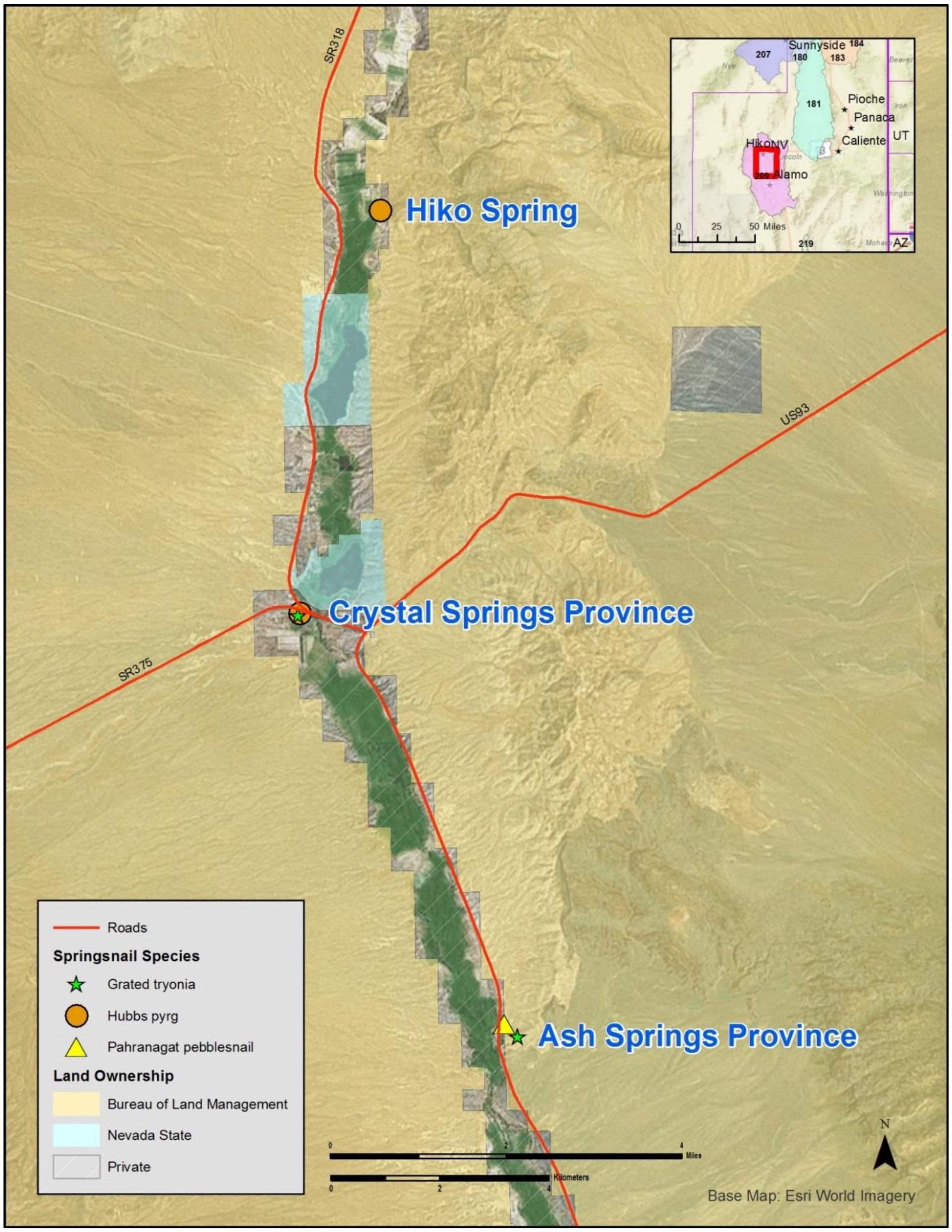


Figure 5.5. Map of the land ownership and general location for Ash Springs Province, Crystal Spring Province, and Hiko Spring where the Hubbs pyrg, grated tryonia, and Pahranagat pebblesnail occur, Pahranagat Valley HA (209), Lincoln County, Nevada. The grated tryonia also occurs in Cardy Lamb Spring, Baldwin Spring, Muddy Spring, Apcar Springs Province, Plummer Springs Province, and Pederson Springs Province (Figure 5.3), and Moon River Spring, Hot Creek Springs Province, and Moorman Spring (Figure 5.6).

5.3.8 Ash Springs Province

Springsnail species present at Ash Springs Province include one population each of Pahranagat pebblesnail and grated tryonia (Figure 5.5). This spring is located in the Pahranagat Valley hydrographic basin (209) in Lincoln County, Ash Springs, Nevada and is a province of at least six springs. Most springs in this rheocrene system and regional aquifer have very short springbrooks (< 1 m (3.3 ft)), which flow immediately into an impoundment. This spring is composed of many spring orifices along the north-south-trending Hiko Fault (SNWA 2016, p. 2-11). Some of its sources, and approximately 70 m (230 ft) of its upper springbrook, are on BLM land. All habitat downstream from this is privately owned. The aquatic habitat bears little resemblance to natural condition. The largest spring source (on BLM land) now discharges from a pipe into a brick-lined pool that is approximately 1.5 m (4.9 ft) deep. The natural spring source no longer exists. Until recently, this area was heavily used for recreational bathing, which has been suspended while BLM determines how to more effectively manage the area. Bathers may have reduced Pahranagat pebblesnail and grated tryonia abundance by walking on the substrate and removing vegetation, causing mortality. This would have most recently affected habitat on BLM land. A dam located immediately upstream from Highway 93 (and approximately 500 m (1,640 ft) downstream from BLM land) impounds the springbrook and creates a long wide pool. There is a headgate where flow can be diverted into another channel to be used for irrigation (SNWA 2008, p. 3-76). Historically this part of the spring was a commercial enterprise where people camped and swam. This activity ended in the 1990s and the area is now lightly used by the current owners, who have cleaned up trash and created a park-like setting with large ash trees, native grasses, and wetland plants. It appears that the system has naturalized from past disturbance. Springsnails occupied 3,885 m^2 (41,817 ft^2) of habitat.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.32). Springbrook length extended a maximum of 2,000 m (6,562 ft). Wetted width ranged from 8 to 4,800 cm (3 to 1,890 in) and wetted depth ranged from 4 to 150 cm (1.6 to 59 in).

Table 5.32. Attribute measurements for Ash Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Ash	33.4–35.7 (92.1–96.3)	7.11–7.5	457–619	1.97–7.8	3–38,990 (0.002–23)	1.1 (0.4)

Data is compiled from the following sources: Garside and Schilling 1979, Golden *et al.* 2007, Albrecht *et al.* 2008, SNWA 2008, and Sada 2016.

The condition of all springs is similar in this province. Substrate composition in 2008 surveys documented relatively even distribution of silt, sand, and gravel. Surveys conducted in 2016 recorded 90 percent silt and 10 percent gravel. In 2016, riparian vegetation was dominated by cottonwood trees, saltgrass rushes, and green algae. The survey location in 2016 had 95 percent bank cover and 13 percent emergent vegetation cover. Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected. This information also provides a range of historical to current conditions and a reference that may be used as a comparison to future data collected.

Stressors for Ash Springs Province on BLM and private land include impoundment, predation and competition from invasive aquatic red-rimmed melania, and vegetation and soil disturbance and water pollution from recreation (Table 5.33). Red-rimmed melania can impact springsnails through predation and competition for resources. Recent survey data show that the intensity of invasive aquatics is high for grated tryonia, which may be why the most recent springsnail surveys documented scarce abundance.

Table 5.33. Current and historic stressors for Ash Springs Province.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Predation and Competition from the following Sources						
Invasive Aquatics—on Pahranagat pebblesnail	current	negligible	insignificant	basic need	NC	L
Invasive Aquatics--on grated tryonia	current	high	very high	basic need	NC	L
Vegetation and Soil Disturbance (Recreation)	historic	moderate	moderate	basic need	I	M
Water Pollution (Recreation)	historic	moderate	moderate	basic need	I	M
Spring Modifications from the following Sources						
Impoundment—on Pahranagat pebblesnail	current	negligible	insignificant	unknown	I	M
Impoundment—on grated tryonia	current	high	high	basic need	I	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Ash Springs Province is currently impounded by brick walls and a dam, which was historically done for water demand and recreation. The impact to Grated tryonia is currently high, since the shallow habitat preferred by Grated tryonia is limited. Recreation was an historic stressor, as the spring was heavily used for recreational bathing and potentially contributed to vegetation and soil disturbance and water pollution. This has not occurred since 2013 and impacts have likely recovered.

Other potential sources of stress include groundwater pumping and oil and gas development. Based on the analyses and conclusions in the biological opinion for the GWD Project (Chapter 4), the discharge of Pahranagat warm springs including Ash Springs Province (Pahranagat Valley hydrographic basin) has the potential to be impacted should the project be implemented as proposed (Service 2012, p. 180). In addition, Ash Springs Province is in close proximity to BLM land in the Ely District, which processes permit applications for oil and gas development. While there may be a possibility for oil and gas development in the area, there is no way to predict whether or not future oil and gas development may affect this spring province.

Ash Springs Province has officially been closed to the public since the summer of 2013, with BLM Caliente Field Office citing public health and safety concerns. They are currently in the process of drafting an environmental assessment to determine how to best manage this site. The proposed alternatives for analysis will likely include: (1) recreation development, (2) recreation and habitat conservation (conserving habitat with no water recreation), (3) recreation and habitat conservation (conserving habitat with recreational bathing in soaker pools), (4) management of natural resources (no public access), and (5) no action. While we currently cannot predict which alternative will be selected, it seems likely that BLM would select an alternative that provides for multiple uses as stated in their mission. Alternatives 1 and 3 (multiple use) would likely disturb springsnail habitat through altering the impoundment and increasing recreation. While there may be additional disturbance to the system in the future, BLM does plan to address sensitive species habitat. This would likely mean that the system would naturalize to new conditions and recreation would be kept separate from springsnail habitat. The confidence of this trend is moderate (BLM 2017, entire).

The portion of the Ash Springs Province on BLM land is covered under the Ely Resource Management Plan (BLM 2007a, entire), which provides protections of springs and native spring-dependent species, such as Pahranagat pebblesnail and grated tryonia. Stipulations and best management practices that would provide conservation for these springsnail species include: (1) Protection of springs and their associated stream segments is part of management for native spring-dependent species, and (2) for streams currently occupied by any special status species, do not allow extraction of water from ponds or pools if stream inflow is minimal (i.e., during drought situations) and extraction of water would lower the existing pond or pool level (BLM 2007, Appendix F) . Ash Springs is also in the NEPA process for the management of the Ash Springs Recreation Site. A preliminary draft environmental assessment is currently being drafted and includes alternatives that would protect Pahranagat pebblesnail and grated tryonia habitat and populations. Other alternatives may result in sustaining or increasing current stressors. The NEPA process will identify such potential impacts. Additional information on conservation on BLM land can be found in Appendix A.

The Recovery Plan for the Aquatic and Riparian Species of Pahranagat Valley (Service 1998, entire) also mentions conservation and restoration of habitat. The objective of the Recovery Plan is to recover and maintain the aquatic and riparian habitats of the Pahranagat Valley so that the three endangered fish species may be removed from the Federal list of endangered and threatened species. Because this Plan addresses an ecosystem, actions taken to improve the status of the native fishes should also improve the status and condition of other endemic species (including Pahranagat pebblesnail and grated tryonia). Recovery actions include: (1) maintain and enhance aquatic and riparian habitats in Pahranagat Valley (which includes Ash Spring), and (2) develop and implement monitoring plan for the native aquatic invertebrates. To what degree this occurs at Ash Springs will remain to be seen after BLM completes the NEPA process and selects an alternative. We are not aware, howver, of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.3.9 Crystal Springs Province

Springsnail species present in Crystal Springs Province include one population each of Hubbs pyrg and grated tryonia (Figure 5.5). This spring is located in the Pahranagat Valley hydrographic basin (209) in Lincoln County, 7.2 km (4.5 mi) south of Hiko and 8.9 km (5.5 mi) north of Ash Springs, Nevada. Crystal Springs Province is in the Colorado River Basin (13) region and Pahranagat Valley (209) designated groundwater basin administered by the Nevada Department of Conservation and Natural Resources, Office of the State Engineer, Division of Water Resources. This province is on private land and permission to survey in 2016 was not granted. The source of water for Crystal Springs Province and Hiko Spring is from a regional carbonate aquifer that emanates from an unknown (Crystal Spring A) and rheocrene spring (Crystal Spring B and Hiko Spring) types at elevations of approximately 1,161 m (3,806 ft) and 1,182 m (3,878 ft) respectively. There are two springs in this province:

- *Crystal Springs A*: This is the northern spring in the province. The spring source is completely enclosed in a metal box. Water is ponded, captured in pipes, and diverted into channelized ditches. There is no springbrook.
- *Crystal Springs B:* Water is impounded and diverted into channelized ditches.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.34). Springbrook length (Spring B) extended a maximum of 2,000 m (6,562 ft). Wetted width ranged from 150 to 2,900 cm (59 to 1,142 in) and wetted depth ranged from 15 to 152 cm (5.9 to 59.8 in).

Table 5.34. Attribute measurements for Crystal Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Crystal Province	27.1–27.5 (80.8–81.5)	7.4–7.6	520–536	1.02–5.8	200–22,087 (0.12–-13.0)	n/a

Data is compiled from the following sources: Eakin 1963, entire; Sada 2016, entire; USGS 2016, entire; and Sada 2017, entire.

Surveys conducted at Spring A in 2008 estimated the substrate to be 60 percent silt, 30 percent sand, and 10 percent gravel. Substrate compositions were varied for Spring B. Surveys in 2008 documented substrate to be 35 percent silt, 30 percent sand, 20 percent gravel, 10 percent cobble, and 5 percent bedrock. Substrate surveyed in 2008 at Spring B found 100 percent cobble. Surveys were not completed in 2016, but distant observation noted cottonwood trees and saltgrass surrounding the springs. Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected. This information also provides a range of historical to current conditions and a reference that may be used as a comparison to future data collected.

Stressors for Crystal Springs Province include predation and competition from invasive aquatic species (convict cichlids, carp (*Cyprinus carpio*), red swamp crayfish, western mosquitofish, shortfin mollies, bullfrogs, and red-rimmed melania), water diversion, impoundment, and channel modification (Table 5.35). Aquatic invasives can impact springsnails through predation and competition for resources. The presence of convict cichlids in the spring system also likely causes direct mortality since they are known to consume gastropods.

Table 5.35. Current stressors for Crystal Springs Province.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Predation and Competition (Invasive Aquatics)	unknown	unknown	all	basic need and mortality	NC	L
Spring Modifications from the following Sources						
Surface Water Diversion	current	high	all	basic need	NC	L
Impoundment	current	high	all	basic need	NC	L
Channel Modification	current	high	all	basic need	NC	L

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Both springs have been highly altered by impoundment, diversion, and water management for human water demand. It now consists of north and south artificial ponds that are connected by a short (approximately 7 m (23 ft) long) ditch. Water flows from the north pond into the south pond. Springs feeding the north pond all discharge into its pool, and water discharges into the south pond from a bedrock outcrop that is partially elevated above the impoundment. Water from the south pond irrigates a number of agricultural lands; one set is watered from a ditch that can be watered when the pond level is high, and another set from water is released through a gate that regulates flow into the Pahranagat River that is below the two ponds. Over the past 15 years, springsnails have only occurred on the bedrock outcrop and in the ditch that joins the north and south ponds. Such alterations likely impacted springsnails historically when they occurred. While the intensity is still high, impacts may have stabilized.

The GWD Project may also impact Crystal Springs Province in the future (see Chapter 4—*Southern Nevada Water Authority Groundwater Development Project* for more details). Based on the analyses and conclusions in the biological opinion for the GWD Project, the discharge of Pahranagat warm springs including Crystal Springs Province (Pahranagat Valley hydrographic basin) has the potential to be impacted should the project be implemented as proposed (Service 2012, p. 180).

Crystal Springs Province is in close proximity to BLM land in the Ely District, which processes permit applications for oil and gas development. While there may be a possibility for development in the area, there is no way to predict whether or not future oil and gas development may affect this spring province.

We expect that the province future conditions will likely remain similar to current conditions as the best available information does not indicate an increase or decrease in effects associated with the stressors.

The primary conservation and management factor that may benefit springsnails at Crystal Springs Province is the intermittent trapping and removal of invasive aquatic fish and red swamp crayfish that has occurred since 2002 for the benefit of the endangered Hiko White River springfish (*Crenichthys baileyi grandis*). In addition, the spring province area is private and posted to deter public use of the area which could prevent recreational disturbances and impacts.

The Recovery Plan for the Aquatic and Riparian Species of Pahranagat Valley (Service 1998, entire) also mentions conservation and restoration of habitat. The objective of the Recovery Plan is to recover and maintain the aquatic and riparian habitats of the Pahranagat Valley so that the three endangered fish species may be removed from the Federal list of endangered and threatened species. Because this Plan addresses an ecosystem, actions taken to improve the status of the native fishes should also improve the status and condition of other endemic species (including grated tryonia). Recovery actions include: 1) maintain and enhance aquatic and riparian habitats in Pahranagat Valley (which includes Crystal Springs Province) and 2) develop and implement monitoring plan for the native aquatic invertebrates. Any actions undertaken at Crystal Springs Province will be completed according to the landowner's decisions, but we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.3.10 Hiko Spring

Springsnail species historically occurring in Hiko Spring include Hubbs pyrg (Figure 5.5). This spring is located in the Pahranagat Valley hydrographic basin (209) in Lincoln County, Hiko, Nevada. This large rheocrene spring is on private land. The spring discharges from the base of a hill, but it is now captured in a spring box that is submerged in a large impoundment. All of its water is diverted into pipes to irrigate pasture and cropland. There is no springbrook, and there is no natural character to this aquatic system. A private home is nearby, and the pond is used for recreational swimming. Native riparian vegetation is sparse, and it does not appear that swimming has an adverse effect of the current aquatic system. Hershler (1998, entire) first collected springsnails from Hiko Spring in1986, and this spring is the type locality for Hubbs pyrg. Sada (1992, field notes) reported springsnails were abundant near the spring source in 1992 but in 2000, Sada (2000, field notes) found that the spring box had been modified and springsnails could not be found. Nevada Department of Wildlife biologists have also unsuccessfully looked for Hubbs pyrg during recent springfish surveys (Burg and Guadalupe 2015b). Hubbs pyrg could not be found during the 2016 survey effort, and are now believed to be extirpated (CITATION). Hubbs pyrg was likely extirpated at Hiko Spring sometime between 1992 and 2000 since four subsequent surveys have failed to detect it between 2000 and 2015 (Golden *et al*. 2007, p. 198; Burg and Guadalupe 2015b, p. 4; NMNH 2016, entire; Sada 2016, entire; 2017, entire).

We compiled information on water quality and quantity at springs from several sources of data (Table 5.36). Wetted width ranged from 200 to 5,100 cm (78.7 to 2,008 in) and wetted depth ranged from 100 to 273 cm (39.4 to 107 in).

Table 5.36. Attribute measurements for Hiko Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Hiko	26.0–26.7 (78.8–80.1)	6.8–7.3	513–525	3.6–7.2	6,779–11,485[A] (3.99–6.8)	n/a

Data is compiled from the following sources: Eakin 1963, Sada 2016, and USGS 2016.
[A] Outlier values from 1912 and 1931 measurements excluded.

Surveys conducted in 2016 recorded 100 percent silt. In 2016, riparian vegetation was dominated by cottonwood trees and willows. The survey location in 2016 had 100 percent bank cover and zero percent emergent vegetation cover.

Stressors for Hiko Spring on BLM and private land include water diversion, impoundment, channel modification, predation and competition from invasive aquatics (mosquitofish, mollies, cichlids, crayfish, and red-rimmed melania, and vegetation and soil disturbance from recreation.

The GWD Project may also impact Crystal Springs Province in the future (see Chapter 4—*Southern Nevada Water Authority Groundwater Development Project* for more details). Based on the analyses and conclusions in the biological opinion for the GWD Project, the discharge of Pahranagat warm springs including Hiko Spring (Pahranagat Valley hydrographic basin) has the potential to be impacted should the project be implemented as proposed (Service 2012, p. 180).

Hiko Spring is in close proximity to BLM land in the Ely District, which processes permit applications for oil and gas development. While there may be a possibility for development in the area, there is no way to predict whether or not future oil and gas development may affect this spring.

There are no known conservation or management actions being undertaken at this privately owned spring.

5.4 Muddy River Springs Area, Black Mountains Area, and Pahranagat Valley – Springsnail Species and Current Population Conditions

5.4.1 Moapa pebblesnail

The Moapa pebblesnail has a medium-sized shell with four whorls. The shell is 2.4 to 4.3mm (0.09 to 0.17 in) in length and 3.1 mm (0.12 in) in diameter. The Moapa pebblesnail has a central radular tooth with four to five lateral cusps (the central cusp is pointed), and one short basal cusp (Pilsbry 1935, p. 92; Hershler 1994, p. 19; Hershler 1998, p. 29).

The Moapa pebblesnail is an endemic springsnail that occurs in Apcar Springs Province, Baldwin Spring, Cardy Lamb Spring, Muddy Spring, Pederson Springs Province, and Plummer Springs Province of the upper Muddy River system in Clark County, Nevada (Figure 5.3). It was described by Pilsbry (1935) and Hershler (1998). This species can be identified with microscopic examination, but it cannot be differentiated from the Moapa Valley pyrg in the field. Their abundance and distribution vary temporally and in response to restoration. For example, the Moapa pebblesnail was absent from the Apcar Springs province during February 2008, following disturbance from restoration (Albrecht *et al.* 2008, p. 13), but it was present during earlier and later studies (Sada 2017, p. 58). Studies by Sada (2017, p. 52) and Albrecht *et al.* (2008, p. 13) found that either Moapa pebblesnail and Moapa Valley pyrg were both absent from a sample or both species occurred when any sample included a *Pyrgulopsis* spp. All of the springs inhabited by the Moapa pebblesnail are also inhabited by the Moapa Valley pyrg and grated tryonia.

A study of Baldwin Spring, Muddy Spring, Apcar Springs Province, Pederson Springs Province, and Plummer Springs Province (Sada 2008, p. 64) found that the Moapa pebblesnail selected relatively deep water (from 30 to 40 cm (11.8 to 15.7 in)) and avoided shallow water (< 15 cm (5.9 in)) and deeper water (> 45 cm (17.7 in)). It selected mean water velocities greater than 50 cm/sec (19.7 in/sec), mostly between 70 to 110 cm/sec (27.6 to 43.3 in/sec) (Sada 2008, p. 64). The Moapa pebblesnail was most abundant in mid-channel habitats where substrates are larger and depths and current velocities are greatest (Sada 2008, p. 64). All survey data for Moapa pebblesnail found spring temperatures ranged between 30.9 and 32.3 ºC (87.6 and 90.1 ºF), DO between 2.1 and 5.2 mg/L (2.1 and 5.2 ppm), pH between 7.3 and 7.8, and conductivity between 640 and 1207 µS/cm. Discharge measurements across all sampling dates were highly variable between 15 and 12,000 L/min (0.009 to 7.1 cfs). Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; Sada 2016, entire; and Sada 2017, entire.

Relative abundance and springbrook data has varied by spring and year (Table 5.37). Biologists conducted surveys for the species and documented habitat conditions as recently as 2016 (Sada 2017, entire). During these surveys, emergent and bank vegetation was documented at all springs. Landye (1973, p. 14) located Moapa pebblesnails on rocks and submergent vegetation (vegetation not identified), while Sada (2008, p. 64) found the species occurred on gravel, and less frequently on cobble, and rarely on fines, sand, and coarse particulate organic material (CPOM).

Table 5.37. Relative abundance and springbrook data of Moapa pebblesnail.

Spring or Spring Province	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance	Source
Apcar Springs A	2016	108	82	scarce	Sada 2017
Apcar Springs B	2016	48	42	common	Sada 2017
Apcar Springs C & D confluence	2016	28	26	common	Sada 2017
Apcar Springs E	2016	18	18	common	Sada 2017
Apcar Springs F	2016	252 and continues onto SNWA land (~2000 total)	252	common	Sada 2017
Apcar (at 5 locations)	2008	-	-	none	Albrecht *et al.* 2008
Baldwin Spring	2016	200	43	scarce	Sada 2017
Baldwin Spring (at 5 locations)	2008	-	-	common to abundant	Albrecht *et al.* 2008
Cardy Lamb Spring	2016	not measurable	-	scarce	Sada 2017
	2008	-	-	none	Albrecht *et al.* 2008
Muddy Spring	2016	-	-	access denied	
Muddy Spring (at 10 locations)	2008	-	-	common to abundant	Albrecht *et al.* 2008
Muddy Spring	2000	-	-	common to abundant	Sada 2016
	1991	600	-	-	Sada 2016
Pederson A	2016	400 and continues onto SNWA land for 1600	409	common	Sada 2017
Pederson C	2016	65	65	common	Sada 2017
Pederson D	2016	52	52	abundant	Sada 2017
Pederson F	2016	53	53	abundant	Sada 2017
Pederson G	2016	58	58	scarce	Sada 2017
Pederson H	2016	35	unknown	not accessible	Sada 2017
Pederson I	2016	5	5	common	Sada 2017
Pederson J	2016	8	8	abundant	Sada 2017
Pederson (5 locations)	2008	-	-	common to abundant	Albrecht *et al.* 2008
Plummer A	2016	87	87	common	Sada 2017
Plummer B	2016	110	110	common	Sada 2017
Plummer C	2016	100	70	common	Sada 2017
Plummer (5 locations)	2008	-	-	abundant	Albrecht *et al.* 2008

The Moapa pebblesnail occurs in springs of the Upper Muddy River (Table 5.38). For this SSA Report, we assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. Substrate and vegetation was ranked high for those springs with multiple meters of occupied habitat. Cardy Lamb Spring was ranked moderate, since it only has one very small portion of springsnail habitat. Free-flowing water was ranked high if it flowed without any barriers. Baldwin Spring was ranked moderate due to the highly modified channel lined with palm trees. Cardy Lamb Spring was ranked low because it is a ponded system with minor flow entering into one corner underneath the ponded water.

Table 5.28. Current conditions of Moapa pebblesnail.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Apcar Springs Province	Adequate	High	High	Adequate	High
Baldwin Spring	Adequate	High	Moderate	Adequate	High/Moderate
Cardy Lamb Spring	Adequate	Moderate	Low	Adequate	Moderate/Low
Muddy Spring	Adequate	High	High	Adequate	High
Pederson Springs Province	Adequate	High	High	Adequate	High
Plummer Springs Province	Adequate	High	High	Adequate	High

5.4.2 Moapa Valley pyrg

The Moapa Valley pyrg has a medium-sized shell with four to five whorls. The shell is 3.8 to 5.0 mm (0.15 to 0.2 in) in length and 4 mm (0.16 in) in diameter. The Moapa Valley pyrg has a central radular tooth with four to five lateral cusps (the central cusp is pointed), and one short basal cusp (Pilsbry 1935, p. 93; Hershler 1994, p. 26; Hershler 1998, p. 31).

The Moapa Valley pyrg is an endemic springsnail that occurs in Baldwin Spring, Cardy Lamb Spring, Muddy Spring, and the Apcar, Pederson, and Plummer Spring provinces of the upper Muddy River system in Clark County, Nevada (Figure 5.3). It was originally described by Pilsbry (1935, p. 93) and Hershler (1998, pp. 29-31). This species can be identified with microscopic examination, but it cannot be differentiated from Moapa pebblesnail in the field. Their abundance and distribution vary temporally and in response to restoration. For example, the Moapa Valley pyrg was absent from the Apcar Springs province during February 2008, following disturbance from restoration (Albrecht *et al.* 2008, p. 13) but was present during earlier and later studies (Sada 2017, p. 58). Studies by Sada (2017, p. 52) and Albrecht *et al.* (2008, p. 13) found that either Moapa pebblesnail and Moapa Valley pyrg were both absent from a sample or both species occurred when any sample included a *Pyrgulopsis* spp. All of the springs inhabited by the Moapa pebblesnail are also inhabited by the Moapa Valley pyrg and grated tryonia. Both studies found that Moapa Valley pyrg was typically more abundant than Moapa pebblesnail in the assemblage. Examining samples collected during a 1999 survey found that Moapa Valley pyrg was more abundant than Moapa pebblesnail in upper Muddy River

Springs (including Muddy Spring and the Apcar, Pederson, and Plummer Spring provinces). Sada sampled during spring and summer of 1998 and 1999 and also found that Moapa Valley pyrg dominated the springsnail assemblage. All of the springs inhabited by Moapa Valley pyrg are also inhabited by Moapa pebblesnail and grated tryonia.

A study of Baldwin, Muddy, Apcar, Pederson, and Plummer springs Sada (2008, p. 64) found that the Moapa Valley pyrg selected shallow habitats (< 10 cm (3.9 in)) and avoided depths over 30 cm (11.8 in). It occupied various currents, but was found mostly in moderate current velocities between 30 to 40 cm/sec (11.8 to 15.7 in/sec) and avoided current velocities > 50 cm/sec (19.7 in/sec) (Sada 2009, p. 4). The Moapa Valley pyrg was found equally distributed in the mid-channels and banks of springs (Sada 2008, p. 64). The Moapa Valley pyrg selected gravel substrate, avoided sand and coarse particulate organic material (CPOM), and strongly avoided fines and cobbles. Greater availability of slow moving, shallow habitats in the area may contribute to the greater abundance of Moapa Valley pyrg in these systems compared to Moapa pebblesnail. The Moapa Valley pyrg prefers water temperatures near 32 C (89.6 F) and avoids cooler water (Sada 2008, p. 64). All survey data for Moapa Valley pyrg found spring temperatures ranged between 30.9 and 32.3 ºC (87.6 and 90.1 ºF), DO between 2.1 and 5.2 mg/L (2.1 and 5.2 ppm), pH between 7.3 and 7.8, and conductivity between 640 and 1207 µS/cm. Discharge measurements across all sampling dates were highly variable between 15 and 12,000 L/min (0.009 to 7.1 cfs), and velocity measurements were all below 59 cm/sec (23.2 in/sec). Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; Sada 2016, entire; and Sada 2017, entire.

Relative abundance and springbrook data has varied by spring and year (Table 5.39). Biologists conducted surveys for the species and documented habitat conditions as recently as 2016 (Sada 2017, entire). During these surveys, emergent and bank vegetation was documented at all springs. Sada (2008, p. 64) found the species selected gravel substrate, avoided sand and coarse particulate organic material (CPOM), and strongly avoided fines and cobbles.

Table 5.39. Relative abundance and springbrook data for Moapa Valley pyrg.

Spring or Spring Province	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance	Source
Apcar Springs A	2016	108	82	scarce	Sada 2017
Apcar Springs B	2016	48	42	common	Sada 2017
Apcar Springs C & D confluence	2016	28	26	common	Sada 2017
Apcar Springs E	2016	18	18	common	Sada 2017
Apcar Springs F	2016	252 and continues onto SNWA land (~2000 total)	252	common	Sada 2017
Apcar (at 5 locations)	2008	-	-	none	Albrecht *et al.* 2008
Baldwin Spring	2016	200	43	scarce	Sada 2017
Baldwin Spring (at 5 locations)	2008	-	-	none	Albrecht *et al.* 2008
Cardy Lamb Spring	2016	not measurable	-	scarce	Sada 2017
	2008	-	-	none	
Muddy Spring (at 10 locations)	2008	-	-	abundant	Albrecht *et al.* 2008
Muddy Spring	2000	-	-	common to abundant	Sada 2016
	1991	600	-	-	Sada 2016
Pederson A	2016	400 and continues onto SNWA land for 1600	409	common	Sada 2017
Pederson C	2016	65	65	common	Sada 2017
Pederson D	2016	52	52	abundant	Sada 2017
Pederson F	2016	53	53	abundant	Sada 2017
Pederson G	2016	58	58	scarce	Sada 2017
Pederson H	2016	35	unknown	not accessible	Sada 2017
Pederson I	2016	5	5	common	Sada 2017
Pederson J	2016	8	8	abundant	Sada 2017
Pederson (5 locations)	2008	-	-	abundant	Albrecht *et al.* 2008
Plummer A	2016	87	87	common	Sada 2017
Plummer B	2016	110	110	common	Sada 2017
Plummer C	2016	100	70	common	Sada 2017
Plummer (5 locations)	2008	-	-	none to abundant	Albrecht *et al.* 2008

The Moapa Valley pyrg occurs in springs of the Upper Muddy River (Table 5.40). For this SSA Report, we assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. Substrate and vegetation was ranked high for those springs with multiple meters of occupied habitat. Cardy Lamb Spring was ranked moderate, since it only has one very small portion of springsnail habitat. Free-flowing water was ranked high if it flowed without any barriers. Baldwin Spring was ranked moderate due to the highly modified channel lined with palm trees. Cardy Lamb Spring was ranked low because it is a ponded system with minor flow entering into one corner underneath the ponded water.

Table 5.40. Current conditions of Moapa Valley pyrg.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Apcar Springs Province	Adequate	High	High	Adequate	High
Baldwin Spring	Adequate	High	Moderate	Adequate	High/Moderate
Cardy Lamb Spring	Adequate	Moderate	Low	Adequate	Moderate/Low
Muddy Spring	Adequate	High	High	Adequate	High
Pederson Springs Province	Adequate	High	High	Adequate	High
Plummer Springs Province	Adequate	High	High	Adequate	High

5.4.3 Grated Tryonia

The grated tryonia has a medium to large-sized conical shell with 5.75 to 8.75 whorls, and the shell length is 2.9 to 7.0 mm (0.1 to 0.28 in). The grated tryonia has a radula with 56 rows of teeth. The central radular teeth have six to eight lateral cusps (central cusps narrowly pointed) and two to three basal cusps (Hershler 1999, p. 331; Hershler 2001, pp. 7–8).

The grated tryonia is an endemic springsnail that occurs in warm springs in the pluvial White River System of southern and eastern Nevada (Moapa, Pahranagat, and White River Valleys; Figures 5.3, 5.5, and 5.6). It also inhabits springs occupied by Pahranagat pebblesnail or by Moapa pebblesnail and Moapa Valley pyrg. Grated tryonia has a wider distribution than these *Pyrgulopsis* species. It occurs in headwaters of the Muddy River (Moapa Valley), Pahranagat Valley, and White River Valley. In the upper Muddy River, its springs are on land owned by the SNWA, the Mormon Church, and the MVNWR. In the Pahranagat Valley, it occupies springs managed by BLM that flow onto private land. One of its habitats in White River Valley is on land owned by the State of Nevada (Nevada Department of Wildlife, Wayne E. Kirch Wildlife Management Area), and all other springs in this valley are privately owned.

Hershler (1999, p. 331) examined grated tryonia material found in Crystal Springs that Landye found and collected in 1969 and 1973 (Herschler 2016, pers. comm.). Golden *et al.* (2007, p. 200) observed that Crystal Springs was highly disturbed by diversion and did not document grated tryonia at Crystal Springs during their 2005 surveys, but did document nonnative species (Golden *et al.* 2007, pp. 195–197). Grated tryonia was detected again at Crystal Springs during surveys in 2014 and 2015 by NDOW biologists (Burg and Guadalupe 2015a, p. 3).

Knowledge of grated tryonia ecology, abundance, and distribution comes from benthic macroinvertebrate studies (including springsnails) in the upper Muddy River over the past 20 years (Sada 2008, entire; Albrecht *et al.* 2008, entire). In all studies, springsnails were sampled over a much larger area than that sampled in 2016, but each study found grated tryonia in many of the Muddy River headwater springs. Sada (2008, p. 63) and Albrecht *et al.* (2008, p. 12) also found grated tryonia was often uncommon and comprised a relatively small part of the gastropod assemblage in most Muddy River springs and springbrooks. Its scarcity may be primarily attributed to the effects of human and natural factors on its selected habitat and/or interactions with red-rimmed melania an invasive, parthenogenetic aquarium gastropod that is native to Asia.

Sada (2008, p. 65) found that red-rimmed melania preferred habitat with fine substrate and current velocities less than 10 cm/sec (3.9 in/sec), which is also the habitat that grated tryonia prefers. This habitat is scarce in many of its springs (particularly in the upper Muddy River), and activities that affect the presence of this habitat type will influence grated tryonia abundance. Sada (2008) also concluded that, at least in Muddy River springs, grated tryonia and red-rimmed melania avoided interactions by partitioning habitats, albeit slightly. This partitioning may not occur in systems with more homogeneous habitats where there is little diversity in water depth, current velocity, and substrate composition.

Restoration programs for Moapa dace (*Moapa coriaceae*) have been initiated on most Muddy River springs and all springs on Moapa Valley National Wildlife Refuge. This has improved the quality of aquatic habitats since earlier distribution studies were conducted. It is assumed that restoration has improved habitat and that grated tryonia abundance and distribution is greater now than before restoration. This does not suggest, however, that they are more abundant. They were not found in some Muddy River springs during the 2016 surveys, but it is doubtful that this indicates they were absent. It is more likely that their scarcity is due to the relatively small amount of grated tryonia microhabitat in these springs, which contain mostly swift water with large substrates. Grated tryonia was found in all of the single Muddy River springs and in all of the spring provinces. Springs in each province are all tributary to one another, and their occurrence in each province suggests that they have not been extirpated from any spring. Its scarcity makes it difficult to determine the total amount of habitat occupied by grated tryonia, but its consistent, co-occurrence with Moapa pebblesnail and Moapa Valley pyrg suggests that it occupied approximately the same 11,000 m^2 (2.7 ac) of habitat.

Relative abundance and springbrook data has varied by spring and year (Table 5.41). All survey records for grated tryonia found spring temperatures ranged between 30.8 and 36.8 ºC (87.4 and 98.2 ºF), DO between 1.0 and 7.8 mg/L (1.0 and 7.8 ppm), pH between 7.05 and 7.8, and conductivity between 457 and 1207 µS/cm. Discharge measurements across all sampling dates were highly variable between 3 and 32,900 L/min (0.002 and 19.4 cfs), and velocity measurements were all below 59 cm/sec (23.2 in/sec). Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; Sada 2016, entire; and Sada 2017, entire. During the 2016 surveys, emergent and bank vegetation was documented at all springs. Sada (2008, p. 64) found that grated tryonia selected shallow habitats (< 5 cm (2 in)). It mostly occupied slower currents less than 20 cm/sec (7.9 in/sec) and was found mostly on the banks of springs (Sada 2008, pp.64–65). Grated tryonia selected sand, fines, algae and coarse particulate organic material (CPOM), and strongly avoided gravel and cobbles (Sada 2008, p. 65; Sada 2009, p. 4).

Table 5.41. Relative abundance and springbrook data of grated tryonia.

Spring or Spring Province	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance	Source
Apcar Springs A	2016	108	82	scarce	Sada 2017
Apcar Springs B	2016	48	42	scarce	Sada 2017
Apcar Springs C & D confluence	2016	28	26	scarce	Sada 2017
Apcar Springs E	2016	18	18	scarce	Sada 2017
Apcar Springs F	2016	252 and continues onto SNWA land (~2000 total)	252	scarce	Sada 2017
Apcar (at 5 locations)	2008	-	-	none to abundant	Albrecht *et al.* 2008
Baldwin Spring	2016	200	43	common	Sada 2017
Baldwin Spring (at 5 locations)	2008	-	-	abundant	Albrecht *et al.* 2008
Cardy Lamb Spring	2016	not measurable	-	common	Sada 2017
	2008	-	-	none to scarce	Albrecht *et al.* 2008
Muddy Spring (at 10 locations)	2008	-	-	common to abundant	Albrecht *et al.* 2008
Muddy Spring	2000	-	-	none to common	Sada 2016
	1991	600	-		Sada 2016
Pederson A	2016	400 and continues onto SNWA land for 1600	409	scarce	Sada 2017
Pederson C	2016	65	65	scarce	Sada 2017
Pederson D	2016	52	52	scarce	Sada 2017
Pederson F	2016	53	53	scarce	Sada 2017
Pederson G	2016	58	58	scarce	Sada 2017
Pederson H	2016	35	unknown	not accessible	Sada 2017
Pederson I	2016	5	5	scarce	Sada 2017
Pederson J	2016	8	8	scarce	Sada 2017
Pederson (5 locations)	2008	-	-	none to abundant	Albrecht *et al.* 2008
Plummer A	2016	87	87	scarce	Sada 2017
Plummer B	2016	110	110	scarce	Sada 2017
Plummer C	2016	100	70	scarce	Sada 2017
Plummer	2008	-	-	abundant	Albrecht *et al.*

(5 locations)					2008
Ash Springs Province	2016	555	555	scarce	Sada 2017
	2015	-	-	abundant	NDOW 2015
	2014	-	-	scarce	NDOW 2015
	1992	-	-	scarce	Sada 2016
Crystal Springs Province	2015	-	-	scarce	NDOW 2015
Hot Creek Springs Province	2016	5000	440	common	Sada 2017
Moon River Spring	2016	2000	300	scarce	Sada 2017
Moorman Spring	2016	200	95	scarce	Sada 2017

The grated tryonia occurs in ten springs and spring provinces (Table 5.42). For this SSA Report, we assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. Substrate and vegetation was ranked high for those springs with multiple meters of occupied habitat. Cardy Lamb Spring was ranked moderate, since it only has one very small portion of springsnail habitat. Crystal Springs Province was ranked moderate due to large ponds with limited habitat and the presence of invasives such as convict cichlids. Free-flowing water was ranked high if it flowed without any barriers. Ash Springs was ranked moderate because there is a brick-lined impounded pool and a dam impounding the springbrook. Baldwin Spring was ranked moderate due to the highly modified channel lined with palm trees. Cardy Lamb Spring was ranked low because it is a ponded system with minor flow entering into one corner underneath the ponded water. Crystal Springs Province was ranked moderate due to highly altered impoundments with manipulated water levels for irrigation.

Table 5.42. Current conditions of grated tryonia.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Apcar Springs Province	Adequate	High	High	Adequate	High
Ash Springs Province	Adequate	High	Moderate	Adequate	High/Moderate
Baldwin Spring	Adequate	High	Moderate	Adequate	High/Moderate
Cardy Lamb Spring	Adequate	Moderate	Low	Adequate	Moderate/Low
Crystal Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate
Hot Creek Springs Province	Adequate	High	High	Adequate	High
Moon River Spring	Adequate	High	High	Adequate	High
Moorman Spring	Adequate	High	High	Adequate	High
Muddy Spring	Adequate	High	High	Adequate	High
Pederson Springs Province	Adequate	High	High	Adequate	High

5.4.4 Blue Point Pyrg

The Blue Point pyrg is small with low trochoid to ovate-conic shells reported to range from 1.2 to 1.6 mm (0.05 to 0.06 in) in height, 1.0 to 1.3 mm (0.04 to 0.05 in) in width, and having 2.8 to 3.5 whorls (Hershler 1998, p. 29). The periostracum ("skin-like" outer coating of the shell) is a light tan (Hershler 1998, p. 29).

The Blue Point pyrg is only known to occur in Blue Point Spring (Figure 5.4; Hershler 1998, p. 29), Clark County, Nevada within the Lake Mead National Recreation Area managed by the National Park Service. It is possible that the Blue Point pyrg or another *Pyrgulopsis* sp. also inhabited Rogers Spring, 1.6 km (1 mi) southwest of Blue Point Spring, because shells similar to Blue Point pyrg were found there (Sada 2002, p. 2). However, the identity of the *Pyrgulopsis* species at Rogers Spring cannot be confirmed without live specimens (Sada 2002, p. 2) which typically cannot be identified to species with confidence based on empty shells alone (Hershler 1998, p. 3). *Pyrgulopsis* sp. are reported to have been extirpated from Rogers Spring (Sada and Jacobs 2008, pp. 1 and 18).

Survey records for Blue Point pyrg for measurements of flowing water made between October 1999 and October 2012 have ranged between 765 to 1,138 l/min (0.45 to 0.67 cfs) and averaged 939 L/min (0.55 cfs) (Laney and Bales 1996, p. 21; USGS 2016a, entire). Measurements of water quality at Blue Point Spring have ranged between 29.0 to 30.8 ºC (84.2 to 87.4 ºF) for temperature, 1.5 to 5.6 mg/L (ppm) for DO, 6.9 to 8.1 for pH, and 1,800 to 4,351 µS/cm for conductivity (Thomas et al. 1991, pp. 5–14, 1996, p. C88; Laney and Bales 1996, pp. 21 and 31; Sada and Jacobs 2008, p. 43; Sada 2016, entire; USGS 2016a, entire).

Substrate can be an important physical factor in spring systems that influences the distribution of biotic assemblages therein (Sada 2008, p. 59); however, little is known about the Blue Point Spring system. The substrate recorded for Blue Point Spring has been predominantly silt and sand, but in recent 2016 surveys there was a larger proportion of gravel (Sada 2017, entire) for unknown reasons. Estimates of substrate particle size composition at Blue Point Spring have tended to be small (silt, sand, and gravel) and changes therein may influence shifts in springsnail distributions. More information is needed to understand the dynamics of these relationships. Surveys in 2016 estimated substrate as 10 percent silt, 30 percent sand, and 60 percent gravel (Sada 2017, entire).

The range of the Blue Point pyrg is limited to Blue Point Spring. Its relative abundance is typically characterized as scarce and its distribution within the spring system is narrow (Table 5.43). The Blue Point pyrg is reported to have been limited in abundance since it was first observed at Blue Point Spring, however its reported to have become increasingly scarce in the early 1990's (Hershler 1998, p. 29; Sada and Jacobs 2008, p. 26). The Blue Point pyrg was thought to be extinct after not being detected during several intensive surveys prior to 2001 (Sada 2002, p. 2); however, in December 2006, the Blue Point pyrg was observed and collected (Sada 2016, entire). The Blue Point pyrg was scarce during surveys in 2008, 2009, 2012, (Sada 2016, entire) and apparently scarce in 2014 based on low numbers collected (Hershler et al. 2015, p. 110; NMNH 2016, entire). In 2016, the Blue Point pyrg was not observed during springsnail surveys of Blue Point Spring (Sada 2017, p. 67). Similar to other *Pyrgulopsis* species, the Blue Point pyrg occupies the upper portions of the springbrook near the spring source. The

Blue Point pyrg was observed in 2007 in an area extending approximately 5 m (16.4 ft) from an area above a USGS weir (Sada n.d., field notes as cited in Sada and Jacobs 2008, p. 26). All springsnails including Blue Point pyrg are documented as most frequently observed within 5 m (16.4 ft) of the spring source (Sada 2016, entire). Springsnails in the Blue Point Spring springbrook are documented to have been detected as far as 10 m (33 ft) and 30 m (98 ft) from the spring source (Sada 2016, entire).

Table 5.43. Relative abundance and springbrook data of Blue Point pyrg.

Spring or Spring Province	Survey Date	Springbrook Length (m)	Occupied* Length of Springbrook (m)	Relative Abundance	Source
	7/11/1988	-	-	Scarce[1]	1
	7/24/1988	-	-	Common[1]	1
	6/23/1992	-	-	Scarce[1]	2
	12/17/1992	-	-	Scarce[1]	1
	10/10/1993	-	-	Scarce[1]	1
	8/20/1997	1500	0	None[2]	2
	12/6/2006	-	4	Scarce	1, 2
	5/29/2008	2000	5	Scarce	2
	12/11/2009	-	30	Scarce	2
	5/26/2012	3000	5	Scarce	2
	5/15/2014	-	-	Scarce[1]	1, 3
Blue Point Spring	5/31/2016	5000	10	None	2

* Distances include *Pyrgulopsis* and *Tryonia.*
[1] The relative abundance was estimated from collection records in the National Museum of Natural History for collections made by J. Landye, R. Hershler, and R. Hovingh. when no other data was available. The number of individuals collected can be adjusted to the size of the population (Hershler 1995, p. 2). Collections of 50 to 100 were classified as common and collections less than 50 were scarce.
[2] *Pyrgulopsis* and *Tryonia* were considered extirpated after no detection but were later found to be extant.
Source: (1) National Museum of Natural History 2016, (2) Sada 2016, and (3) Hershler *et al.* 2015

Blue Point Spring contains the only extant population of Blue Point pyrg. For this SSA Report, we assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. Sada (2017, pp. 67–68) summarizes conditions at Blue Point Spring for the Blue Point pyrg. Substrate and vegetation was ranked high, since conditions present provide habitat that would support springsnails. Free-flowing water was ranked moderate due to the installation of the weir, which causes a slight obstruction to flow.

Table 5.44. Current conditions of Blue Point pyrg.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Blue Point Spring	Adequate	High	Moderate	Adequate	High/Moderate

5.4.5 Hubbs Pyrg

Hubbs pyrg is medium to large, with globose to low-conical shells reported to range from 2.5 to 3.8 mm (0.1 to 0.15 in) in height, 2.2 to 3.4 mm (0.09 to 0.13 in) in width, and having 3.3 to 3.8

whorls (Hershler 1998, pp. 33–35). The periostracum ("skin-like" outer coating of the shell) is a light brown (Hershler 1998, p. 35).

Hubbs pyrg has been reported from two spring areas, Hiko Spring and Crystal Springs Province (Figure 5.5; Hershler 1998, pp. 35–37; Sada 2017, pp. 80–81) located on private lands in Pahranagat Valley, Lincoln County, Nevada. Hubbs pyrg was last observed at Hiko Spring in 1992 when it was reported to be abundant, however it has not been observed in subsequent searches since 2000 and it is thought to have been extirpated (Golden *et al.* 2007, p. 198; Sada 2017, p. 80). The current range of Hubbs pyrg is limited to Crystal Springs province where it is restricted to a channel between two pond like areas between sources Crystal Springs A and Crystal Springs B (Burg and Guadalupe 2015a, p. 2; Sada 2016, entire) and near the source area of Crystal Springs B (Sada 2016, entire). There is no information to specify changes that have occurred in the distribution of Hubbs pyrg at Crystal Springs province, however based upon the areas it currently occupies with hard substrate and faster flow, its distribution has likely been reduced from changes to the spring system.

All survey records for Hubbs pyrg found spring temperatures ranged between 26.0 and 27.5 ºC (78.8 and 81.5 ºF), DO between 1.2 and 7.2 mg/l (ppm), pH between 6.8 and 7.6, and conductivity between 513 and 533 µS/cm (Eakin 1963, Table 5; Sada 2016, entire; USGS 2016, entire). Discharge measurements across all sampling dates were highly variable between 6,779 and 22,087 L/min (3.99 and 12.99 cfs) (Eakin 1963, p. 20; USGS 2016, entire)

Little is known about substrate requirements of Hubbs pyrg; however, based on the limited descriptions available of the spring areas it has been found, it does appear to select primarily hard substrates with flowing water. Hubbs pyrg has been recorded to be present on hard substrates such as rocks and bedrock at Crystal Springs province and Hiko Spring in areas where water flows faster (NMNH 2016, entire; Sada 2016, entire). Characterizations of substrate at Crystal Springs A with 60, 30, and 10 percent of silt, sand, and gravel respectively with a source that is impounded (Sada 2016, entire).This could partially explain the absence of Hubbs pyrg from this area.

The relative abundance and distribution or range of Hubbs pyrg has changed since first records of its collection in 1969 at Crystal Spring province and in 1973 at Hiko Spring–29 and 25 years respectively before formal publication and recognitions as a species (Table 5.45). Four records of Hubbs pyrg at Hiko Spring between 1973 and 1992 indicate that its relative abundance may have ranged from scarce to abundant during this time based on collections and surveys (NMNH 2016, entire; Sada 2016, entire). The last observations of Hubbs pyrg reported at Hiko Spring in 1992 reported it as abundant at the spring source (Sada 2017, p. 80). Hubbs pyrg was likely extirpated at Hiko Spring sometime between 1992 and 2000 since four subsequent surveys have failed to detect it between 2000 and 2015 (Golden et al. 2007, p. 198; Burg and Guadalupe 2015b, p. 4; NMNH 2016, entire; Sada 2016, entire; 2017, p. 80). Larger scientific collections of individual springsnails between 1969 and 1988 from the Crystal Springs province may indicate that it was historically more abundant there than at Hiko Spring (Hershler 1995, p. 2; NMNH 2016, entire). In 1992 at Crystal Springs B, springsnails were recorded as abundant at the spring source and *Pyrgulopsis* sp. was present in the "ditch connecting the two upper ponds" (Sada 2016, entire) which has a length of approximately 7 m (23 ft) (Sada 2017, p. 81). In 2005, Golden *et al.* (2007,

p. 198) sampled 31 locations–heads, pools, and springbrooks–in Crystal Springs province and springsnails were found at only one location for which they were scarce. In 2008 at Crystal Springs B, Hubbs pyrg was only found above an impoundment on bedrock source where it was estimated it occupied an area of approximately 30 m^2 (323 ft^2) (Sada 2016, entire). Burg and Guadalupe (2015a, pp. 2–3) reported they sampled Hubbs pyrg in the area connecting Crystal Springs A and B and the average density they observed was comparable to an abundance category of common assigned during 2016 surveys by Sada (Sada 2017, pp. 24–25). Permission was denied to survey Crystal Springs province in 2016 (Sada 2017, p. 80) so no current abundance or distribution data are available.

Table 5.35. Relative abundance and springbrook data of Hubbs pyrg.

Spring or Spring Province	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance	Source(s)
	9/9/1969	-	-	Abundant[1]	1
	9/1/1973	-	-	Abundant[1]	1
	3/6/1977	-	-		1
	7/9/1986	-	-	Common[1]	1
	7/24/1988	-	-	Abundant[1]	1
	6/30/2000	-	-	Scarce[1]	1
	6/13/2005	-	-	Scarce	2
Crystal Springs	6/22/2015	-	-	Common[2]	3
Crystal Spring A	6/24/2008	-	-	None	4
	6/1/1992	2000	1.5	Scarce	1, 4
	6/24/2008	2000	1.5	Scarce	4
Crystal Spring B	9/15/2008	-	-	Abundant	4
	9/1/1973	-	-	Scarce[1]	1
	7/9/1986	-	-	Common[1]	1
	7/24/1988	-	-	Common[1]	1
	6/1/1992	-	-	Abundant	1, 4
	6/30/2000	-	-	None	4
	9/12/2006	-	-	None	2
Hiko Spring	6/23 & 30/2015	-	-	None	5
Hiko Spring	6/6/2016	-	-	None	4

[1] The relative abundance was estimated from collection records in the National Museum of Natural History for collections made by J. Landye, R. Hershler, and D. Sada when no other data was available. Classified as abundant for collections of 100 or more individuals which is similar to descriptions by (Hershler 1995, p. 2). Collections of 50 to 100 were classified as common and collections less than 50 were scarce.
[2] The area connecting Crystal Springs A and B was sampled.
Sources: (1)National Museum of Natural History 2016, (2) Golden *et al.* 2007, (3)Burg and Guadalupe 2015a, (4)Sada 2016, and (5)Burg and Guadalupe 2015b.

Crystal Springs Province contains the only extant population of Hubbs pyrg. For this SSA Report, we assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. Sada (2017 pp. 80–81) summarizes conditions at Crystal Spring province for Hubbs pyrg (Table 5.46). Substrate and vegetation was ranked moderate due to large ponds with limited habitat and the presence of invasives such as convict cichlids. Free-flowing water was ranked moderate due to highly altered impoundments with manipulated water levels for irrigation.

Table 5.46. Current conditions of Hubbs pyrg.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Crystal Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate

5.4.6 Pahranagat Pebblesnail

The Pahranagat pebblesnail has a small to medium-sized conical shell with about four whorls, and the shell length is about 3 mm (0.1 in). The Pahranagat pebblesnail has a central radular tooth with five lateral cusps (central cusp pointed) and two very short basal cusps (Hershler 1994, p. 49).

The Pahranagat pebblesnail is an endemic springsnail that occurs in warm springs in the Pahranagat Valley and the White River Valley in the pluvial White River System of southern and eastern Nevada (Figures 5.5 and 5.6; Hershler 1994, p. 49). Most of its populations are on private land (Hot Creek, Moorman, and Moon River Springs), with the sources of one spring system on BLM land (Ash Springs). Its springs are also inhabited by grated tryonia, which is also endemic to the pluvial White River system (Hershler 2001, p. 8). Previous survey records and documents show the distribution of Pahranagat pebblesnail included Crystal and Hiko springs in the Pahranagat Valley (Landye 1973, p. 16; Deacon *et al.* 1980, p. 110; Williams *et al.* 1985, p. 36). No records have shown the presence of Pahranagat pebblesnail in these springs since 1973. It is likely that identification of this species was incorrect (since Hubbs pyrg is now documented in surveys). In Landye (1973, p. 16), the Pahranagat pebblesnail was documented in Ash, Hiko, and Crystal Springs, while he stated that a different unknown species was found in Hot Creek and Moorman Springs. This is incorrect, since Ash, Hot Creek, and Moorman all have Pahranagat pebblesnail populations.

All of the Pahranagat pebblesnail's habitats are also occupied by the White River springfish and usually by nonnative fish (mosquitofish, mollies (*Poecillia* spp.), and/or convict cichlids). Red-rimmed melania, an invasive parthenogenetic aquarium gastropod that was only found in Asia and Africa prior to 1940 (Facon *et al.* 2005, p. 526), currently occurs in all of the springs occupied by Pahranagat pebblesnail. This invasive species can live out of water for extended periods and may be readily transported into springs by recreational bathers and birds. Pointier *et al.* (1993, p. 40) found that it detrimentally impacted native gastropod abundance.

Landye (1973, p. 16) found that Pahranagat pebblesnail selected habitats with rocks and submergent vegetation. There is no preference for water velocity identified in the literature. However, since Pahranagat pebblesnail and grated tryonia co-exist at springs, it can be assumed that the Pahranagat pebblesnail also avoids swift water and prefers slow moving waters. There is also no information on selected water depth or channel location. During the 2016 surveys, all emergent and bank vegetation was documented. The Pahranagat pebblesnail was most abundant on submerged aquatic vegetation, particularly green algae, where as many as 368 individuals were collected in a single grab sample (Sada 2017, p. 93).

The 2016 surveys (Sada 2017, p. 93) found that the Pahranagat pebblesnail occurred in all of its historic habitats (occupying more than 4,100 m^2 (44,132 ft^2) of habitat). All of its habitats had been altered by dredging, impoundment, and/or diversion or recreation. Although none of its springs are in natural condition or resemble natural characteristics, physical alteration of these habitats has all been historical, and the springs have all naturalized to a stable condition.

Relative abundance and springbrook data have varied by spring and year (Table 5.47). All survey records for Pahranagat pebblesnail found spring temperatures ranged between 30.8 and 36.8 ºC (87.4 and 98.2 ºF), DO between 1.0 and 7.8 mg/L (1.0 and 7.8 ppm), pH between 7.05 and 7.8, and conductivity between 457 and 657 µS/cm. Discharge measurements across all sampling dates were highly variable between 3 and 32,900 L/min (0.002 and 19.4 cfs), and velocity measurements were all below 59 cm/sec (23.2 in/sec).

Table 5.47. Relative abundance and springbrook data of Pahranagat pebblesnail.

Spring or Spring Province	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance	Source
Ash Springs Province	2016	555	555	scarce	Sada 2017
	2015	-	-	abundant	NDOW 2015
	2014	-	-	common	NDOW 2015
	1992	-	-	scarce	Sada 2016
Hot Creek Springs Province	2016	5000	440	common	Sada 2017
Moon River Spring	2016	2000	300	scarce	Sada 2017
Moorman Spring	2016	200	95	scarce	Sada 2017

Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; SNWA 2008, entire; Sada 2016, entire; and Sada 2017, entire

The Pahranagat pebblesnail occurs in four springs and spring provinces, each of which contains one population of the species (Table 5.48). For this SSA Report, we assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. Substrate and vegetation was ranked high for those springs with multiple meters of occupied habitat. Free-flowing water was ranked high if it flowed without any barriers. Ash Springs was ranked moderate because there is a brick-lined impounded pool and a dam impounding the springbrook.

Table 5.48. Current conditions of Pahranagat pebblesnail.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Ash Springs Province	Adequate	High	Moderate	Adequate	High/Moderate
Hot Creek Springs	Adequate	High	High	Adequate	High

Province					
Moon River Spring	Adequate	High	High	Adequate	High
Moorman Spring	Adequate	High	High	Adequate	High

5.5 White River Valley HA (207), Cave Valley HA (180), and Lake Valley HA (183) – Springs and Spring Provinces and Current Habitat Conditions

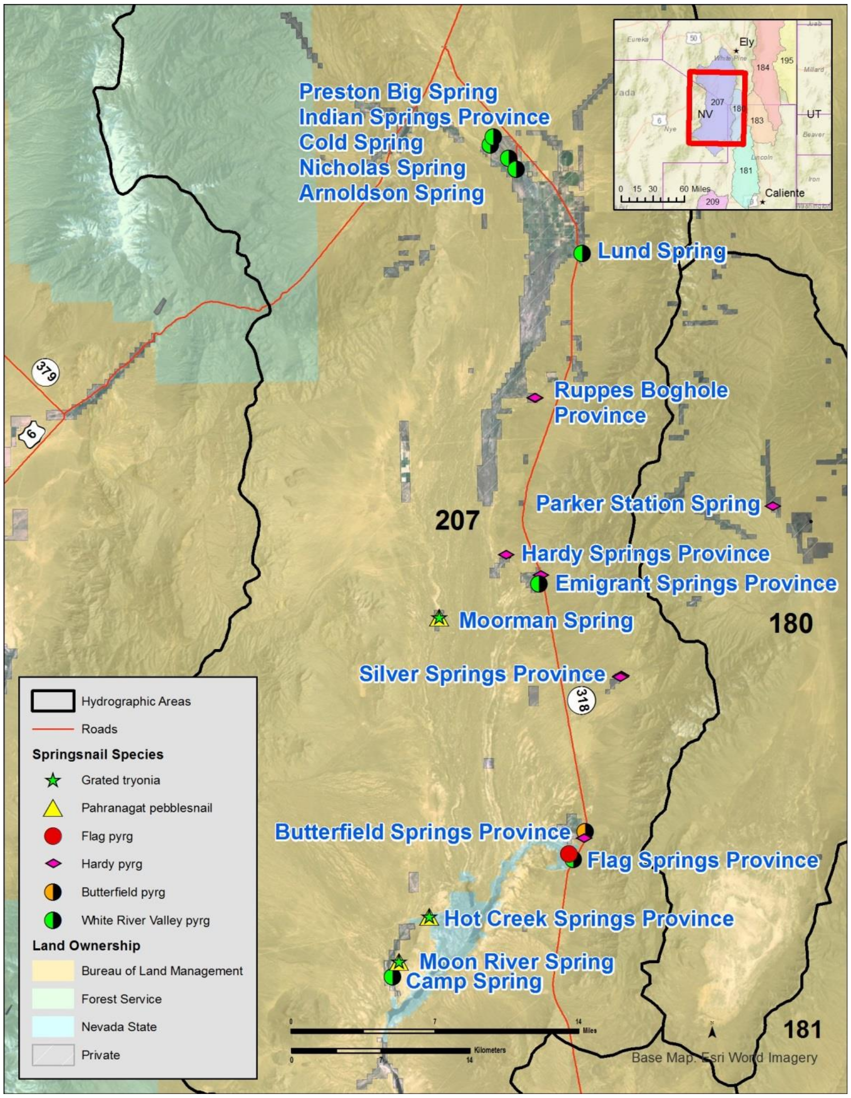


Figure 5.6. Map of the land ownership and general location for springs and spring provinces where the grated tryonia, Pahranagat pebblensnail, Flag pyrg, Hardy pyrg, Butterfield pyrg, and White River Valley pyrg occur, White River Valley HA (207), Cave Valley HA (180), and Lake Valley HA (183), Nye and White Pine counties, Nevada. The grated tryonia also occurs in Cardy Lamb Spring, Baldwin Spring, Muddy Spring, Apcar Springs Province, Plummer Springs Province, and Pederson Springs Province (Figure 5.3), and Ash Springs Province and Crystal Springs Province (Figure 5.5).

5.5.1 Camp Spring

The only springsnail species present in Camp Spring is the White River Valley pyrg.

Camp Spring is on private land in the White River Valley HA (207), which is a designated hydrographic basin in White Pine County, Nevada (Figure 5.6). The source of water for this spring is a local aquifer that emanates at 1,580 m (5,184 ft) elevation as a rheocrene spring (Sada 2016, entire). The springbrook length is 250 m (820 ft), which is diverted onto pastures. The spring is moderately disturbed due to dredging and cattle. The spring has been dredged, apparently a number of times, and the source and upper reaches of the springbrook (approximately 70 m (xx ft)) discharge from a deeply incised gravel channel. It does not appear to have been dredged recently, and has naturalized from past dredging activity.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.48). Maximum springbrook length was 250 m (820 ft). Wetted width ranged from 126 to 200 cm (49.6 to 78.7 in) and wetted depth ranged from 3 to 18 cm (1.2 to 7.1 in). Springsnails occupy 55 m (180 ft) of springbrook (69.5 m^2 (748 ft^2) of habitat). Speckled dace also occur at this spring (Scoppettone *et al.* 2004, p. 49).

Table 5.48. Attribute measurements for Camp Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Camp Spring	17.8-18.8 (64-65.8)	8.1	511	4.9	100 (0.06)	5.6 (2.2)

Data is compiled from Golden *et al.* 2007, pp. 146-147; Sada 2016, entire; and Sada 2017.

Surveys conducted in 2016 (Sada 2017, entire?) estimated the substrate to be 100 percent fines. Rushes, spikerush, reeds, and watercress are present at this spring. Bank cover is 71.3 percent and emergent cover is 46.3 percent. We determined that Camp Spring provides the species needs and habitat conditions are appropriate for the White River Valley pyrg.

Stressors identified in the 2016 survey include spring modifications from water diversion and channel modification, and vegetation and soil disturbance from grazing and browsing (ungulate use) (Table 5.49) (Sada 2017, entire?). The spring has been dredged and the source and upper reaches of springbrook discharge from a deeply incised channel. Dredging does not appear to be recent and has naturalized. Livestock use does not appear to have a discernable effect of springsnails.

Table 5.49. Current and historic stressors for Camp Spring.

Stressors (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Vegetation and Soil Disturbance from the following Sources						
Grazing and Browsing	current	low	high	basic need	NC	M
Roads	current	moderate	moderate	basic need	NC	M
Spring Modifications from the following Sources						

Surface Water Diversion	current	moderate	moderate	basic need	NC	M
Channel Modification	historic	low	moderate	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Camp Spring occurs entirely on private land not managed in accordance with any management or conservation plan. Camp Spring has one population of White River Valley pyrg. We expect that future conditions at this spring will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

5.5.2 Moon River Spring

Springsnail species present at Moon River Spring include one population each of Pahranagat pebblesnail and grated tryonia.

Moon River Spring is located on private land in the White River Valley HA (207), which is a designated hydrographic basin in Nye County, Nevada (Figure 5.6). This thermal rheocrene spring is the largest single spring in the White River Valley. The spring originates from fluvial deposits and is a local aquifer. This is one of the few large springs in the valley where there are no nonnative fish. The spring and its springbrook have been dredged, but it does not appear that dredging has been recent. All of its diverted water is delivered to pastures and cropland. Although the site currently bears little resemblance to natural conditions, it appears to have recovered and naturalized from this disturbance.

We compiled information on water quality and quantity at springs from 1992 and 2016 surveys (Table 5.50). Springbrook length extended a maximum of 2,000 m (6,562 ft) and springsnails occupied 300 m (984 ft) of the springbrook (807.6 m^2 (8,693 ft^2) of habitat). Wetted width ranged from 269 to 700 cm (106 to 276 in) and wetted depth ranged from 3 to 52.4 cm (1 to 21 in).

Table 5.50. Attribute measurements for Moon River Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Moon River Spring	31.3–33.0 (88.3–91.4)	7.7	544–550	3.3	2718–8699 (1.6–5.12)	5.1 (2)

Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; SNWA 2008, entire; Sada 2016, entire; and Sada 2017, entire.

The 2016 survey documented a substrate composition of 100 percent silt and riparian vegetation was rushes and bulrushes. The survey location in 2016 had 42 percent bank cover and no emergent vegetation cover. Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected. This information also provides a range of historical to current conditions and a reference that may be used as a comparison to future data collected.

Stressors for Moon River Spring include water diversion, channel modification, and vegetation and soil disturbance from grazing from ungulate species (Table 5.51). The spring was historically dredged and channels modified in order to divert water for pasture and cropland irrigation. The system appears to have recovered from these disturbances. These stressors should not have an impact on the current condition of springsnails. Grazing and browsing (ungulate use) were also identified as an historic source of stress, which may have contributed to vegetation and soil disturbance and direct mortality through trampling. Grazing and browsing (ungulate use) do not appear to be occurring presently and should not have an impact on the current condition of springsnails. Grazing has also been documented as an historic stressor at Moon River Spring, and should no longer impact springsnail species.

Table 5.51. Historic stressors for Moon River Spring.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Grazing and Browsing)	historic	moderate	moderate	basic need	NC	L
Spring Modifications from the following Sources						
Surface Water Diversion	historic	moderate	moderate	basic need	NC	L
Channel Modification	historic	moderate	moderate	basic need	NC	L

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Another potential stressor that has been assessed for Moon River Spring is groundwater pumping. The Central Carbonate-Rock Province model simulations completed for the GWD Project suggest that drawdown due to pumping may affect portions of White River Valley. The regional model simulations suggest that drawdown in the regional aquifer at the location of Moon River Spring due to pumping in southern Cave Valley (to 75 years after FBO) would be negligible (Service 2012, Appendix B, p. 12).

There are no known conservation or management actions being undertaken at this privately owned spring. Moon River Spring is in close proximity to BLM land in the Ely District, which processes permit applications for oil and gas development. While there may be a possibility for development in the area, there is no way to predict whether or not future oil and gas development may affect this spring. We expect that the province future conditions will likely remain similar to current conditions as the best available information does not indicate an increase or decrease in effects associated with the stressors.

5.5.3 Hot Creek Springs Province

Springsnail species present at Hot Creek Springs include one population each of Pahranagat pebblesnail and grated tryonia.

Hot Creek Springs Province is in the White River Valley HA (207), which is a designated groundwater basin in Nye County, Nevada (Figure 5.6). This is a thermal limnocrene (see *Glossary*) system and local aquifer in the Kirch Wildlife Management Area (WMA), owned by the State of Nevada and managed by Nevada Department of Wildlife. It consists of many springs that discharge into a long impounded springbrook that flows into the Adams-McGill Reservoir. The system was first impounded during the 1970s to protect White River springfish by creating a vertical barrier to prevent largemouth bass (*Micropterus salmoides*) from migrating upstream from the reservoir. The major source of water discharges from a large limnocrene that is located near the northwestern extent of the impoundment. Additional discharge is supplied by many small springs (most with springbrooks < 1 m (3.3 ft) long) that are scattered along its banks and near the source. The system appears to have recovered from disturbance attributed to impoundment. It has naturalized to this new condition, and springsnails occur throughout the upper 440 m (1,444 ft) of the springbrook (4,300 m^2 (46,285 ft^2) of habitat). A USGS weir and public swimming disturb the aquatic system at the downstream extent of springsnails, but it does not appear that these disturbances adversely affect them.

Comment [PME56]: We don't have a weir at Hot Creek, just a gage (09415558). If there is a weir on-site, it is not owned/operated by the USGS.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.52). Springbrook length extended a maximum of 5,000 m (16,404 ft). Wetted width ranged from 80 to 6,000 cm (31 to 2,362 in) and wetted depth ranged from 8 to 488 cm (3 to 192 in).

Table 5.52. Attribute measurements for Hot Creek Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Hot Creek Springs Province	30.8–31.9 (87.4–89.4)	7.06–7.8	511–657	1.0–2.2	130–26,000 (0.08–15.3)	0.5 (0.2)

Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; SNWA 2008, entire; Sada 2016, entire; and Sada 2017, entire.

The 2016 survey documented a substrate composition of 90 percent silt and 10 percent sand. Riparian vegetation included rushes, bulrushes saltgrass and reeds. The survey location in 2016 had 100 percent bank cover and 14 percent emergent vegetation cover. Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected. This information also provides a range of historical to current conditions and a reference that may be used as a comparison to future data collected.

Stressors for Hot Creek Springs Province (Table 5.53) include impoundment, predation and competition from invasive aquatic species (red-rimmed melania, bullfrogs, mosquitofish), and vegetation and soil disturbance and water pollution from recreation. Mosquitofish, bullfrogs, and red-rimmed melania can impact springsnails through predation and competition for resources.

Recent survey data show that the intensity of invasive aquatics is negligible, which may be why the most recent springsnail surveys documented common abundance.

Table 5.53. Current stressors for Hot Creek Springs Province.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Predation and Competition (Invasive Aquatics)	current	negligible	insignificant	unknown	NC	M
Vegetation and Soil Disturbance (Recreation)	current	negligible	insignificant	unknown	NC	L
Water Pollution (Recreation)	current	negligible	insignificant	unknown	NC	L
Spring Modification (Impoundment)	current	negligible	insignificant	unknown	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Hot Creek Springs Province was impounded in the 1970s to protect White River springfish. The system has recovered since this disturbance and there appears to be no impacts to springsnails. Recreation is a current source of stress, as the downstream extent is used for swimming. Soil compaction, vegetation removal, water pollution, and dam construction to create swimming pools are likely impacts due to recreation. Due to the common of abundance of springsnails in this spring, it does not seem that this recreation is affecting the springsnails.

Hot Creek Springs Province occurs within a hydrographic basin (White River Valley) identified to be impacted by the GWD Project (see Chapter 4—*Southern Nevada Water Authority Groundwater Development Project* for more details). BLM identified a 1 percent decrease in spring flow at Hot Creek Springs as a result of the proposed alternative for the project 75 years after full build out (BLM 2012, Chapter 3, Section 3.3 Water Resources, p. 183).

Hot Creek Springs Province is in close proximity to BLM land in the Ely District, which processes permit applications for oil and gas development. While there may be a possibility for development in the area, there is no way to predict whether or not future oil and gas development may affect these springs.

Hot Creek Springs Province has one population each of Pahranagat pebblesnail and grated tryonia. We expect that the province future conditions will likely remain similar to current conditions as the best available information does not indicate an increase or decrease in effects associated with the stressors. While springsnails are not state protected, there are provisions in the Nevada State Wildlife Action Plan (WAP) that protect springs, such as increasing naturally functioning springs by 2022 and no net loss of spring-springbrook-dependent species. Hot Creek

Springs Province is also managed by NDOW in accordance with The Wetland Conservation Plan for Wildlife Management Areas (WCP) (Huffman *et al.* 1998, p. 13-14). The overall goal of the WCP is no net loss of wetlands on WMAs and to increase wetland quantity and quality within WMAs with emphasis on sensitive species and control of tamarisk.

Hot Creek Springs Province is also managed under the Kirch WMA Conceptual Management Plan. The NDOW developed the Kirch WMA Conceptual Management Plan (NDOW 2000, entire) to guide the management of species, habitats and programs on the W.E. Kirch WMA. Four endemic fish species occur on the Kirch WMA. They are the White River spinedace (*Lepidomeda albivalis*), the Moorman White River springfish (*Crenicthys baileyi thermophilus*), the Wite River speckled dace (*Rhinichthys osculus velifer*), and the White River desert sucker (*Catostomus clarki intermedius*). They inhabit Hot Creek Springs Province, which are also occupied by the Pahranagat pebblesnail and grated tryonia. Wildlife population and habitat goals for Kirch WMA include maintaining and enhancing native fish and their habitat. Although management specific to springsnail conservation is not provided in the Kirch WMA Conceptual Management Plan, objectives and strategies identified in the plan for native fish management at Hot Creek Springs Province, such as securing appropriated continued flow of water, maintaining stability of undercut banks and riparian vegetation through control of livestock grazing, encouragement of the recruitment of gravels and seasonal flows, avoiding disturbance activities in stream channels and adjacent riparian and upland habitats, controlling invasive weeds, and acquiring important wildlife habitat and water rights from willing sellers (NDOW 2000, pp. 66, 72, and 74), may also provide conservation benefits for the springsnails. We are not aware, however, of any management actions specific to spring or springsnail conservation that are being implemented at this site.

Details of the Nevada WAP, WCP, and Kirch WMA Conceptual Management Plan can be found in Appendix A.

5.5.4 Flag Springs Province

Springsnail species present in Flag Springs Province include the White River Valley pyrg and Flag pyrg.

The province consists of three springs with relatively cold water on Kirch Wildlife Management Area (WMA) in the White River Valley (207), which is a designated groundwater basin in Nye County, Nevada (Figure 5.6). The source of water for all springs in this province is a regional aquifer that emanates at 1,610–1,622 m (5,282–5,322 ft) elevation as rheocrene springs.

Flag Springs support populations of native speckled dace (*Rhinichthys osculus*) and desert sucker (*Catostomus clarki intermedius*), and the only population of the endangered White River spinedace (*Lepidomeda albivallis*); and the predacious largemouth bass (*Micropterus salmoides*) (Scoppettone *et al.* 2004, p. 49). Flag Springs A springbrook has been modified to increase spinedace habitat but has naturalized. All of the Flag Springs are in near reference condition.

Flag springs are near WMA headquarters where there are maintenance and office buildings and access roads. Flag Spring A is the northern spring, Flag Spring B is the middle spring, and Flag

Spring C is the southern spring. Although these facilities and roads springs are near, they have no apparent effect on springsnails or ecological health of these spring systems.

- *Flag Spring A*: Springbrook length is 2,000 m (6,562 ft) long, and springsnails occupied 170 m (558 ft) of springbrook (380.5 m^2 (4,096 ft^2)) of habitat). It is cool with swift flow.
- *Flag Spring B*: Springbrook length is 600 m (1,969 ft). Springsnails occupy 60 m (197 ft) of springbrook (152.6 m^2 (1,643 ft^2)) of habitat. It is also cool with swift flow. Bank cover is 73.6 percent and emergent cover is 8.6 percent. Riparian vegetation present includes wild rose, grapevine, and ash. A USGS gauge pond occurs in the upper 2.5 m (8.2 ft) of springbrook, but this has little effect on the spring or springsnail habitat.
- *Flag Spring C*: Springsnails were present at this spring in 2009 but no springsnails were found or data collected in 2016. Temperature and conductivity measurements for this spring was higher than Flag Springs A and B. Flow at this spring is swift.

Comment [PME57]: Not USGS. I believe this is an SNWA gage. The USGS does streamflow measurements twice a year on Flags A-C approximately in April or May and September, data can be found on NWIS.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.54). Maximum springbrook length was 2,000 m (6,562 ft). Surveys conducted in 2016 estimated the wetted width from 70 to 1,500 cm (28 to 591 in) and wetted depth from 12 to 100 cm (5 to 39 in). Substrate is 20 percent gravel, 60 percent cobble, and 20 percent boulder in Flag Spring A; and 10 percent sand, 80 percent gravel, and 10 percent cobble in Flag Spring B. In 2016, riparian vegetation present includes grapevine, willow, wild rose, and ash. Bank cover ranged from 73.6–100 percent and emergent cover ranged from 8.6–36.3 percent. We determined that Flag Springs provide the species needs and habitat conditions are appropriate for the White River Valley and Flag pyrgs.

Table 5.54. Attribute measurements for Flag Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Flag Spring A	16.3–16.5 (61.3–61.7)	7.2–7.8	301–390	6.7	2000–3609 (1.18–2.12)	46.8 (18.4)
Flag Spring B	19.7–20.0 (67.5–68)	7.3–7.5	348–446	5.4	1500–5329 (0.88–3.14)	53.9 (21.2)
Flag Spring C	22.4–22.6 (72.3–72.7)	7.4–7.6	421–482	4.6	1400–2039 (0.82–1.2)	-

Data is compiled from Sada 2016, entire; Sada 2017; and Golden *et al.* 2007, pp. 146-147.

Current stressors identified were identeified during 2016 surveys and include spring modifications and vegetation and soil disturbance (Table 5.55) (Sada 2017, entire?).

Table 5.55. Current stressors for Flag Springs Province.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Roads)	current	negligible	insignificant	basic need	NC	H

Spring Modification (Surface Water Diversion)	current	negligible	insignificant	basic need	NC	H

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

We expect that future conditions at this province will increase for groundwater pumping in consideration of the proposed SNWA GWD project (see Chapter 4—*Southern Nevada Water Authority Groundwater Development Project* for more details), and other stressors are likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. The springs in this province are managed by NDOW in accordance with The Wetland Conservation Plan for Wildlife Management Areas (WCP) (Huffman *et al.* 1998, entire). The overall goal of the WCP is no net loss of wetlands on WMAs and to increase wetland quantity and quality within WMAs.

5.5.5 Butterfield Spring Province

Springsnail species present in the Butterfield Springs Province include the Butterfield and Hardy pyrgs. Two populations of each species occur at this province, Butterfield Springs C and D and Butterfield Spring E. These populations are separated by 0.4 km (0.2 mi) of upland area (Figure 5.6).

Butterfield Springs Province occurs on private land in Nye County, Nevada. This province is in the White River Valley HA (207), which is a designated hydrographic basin. The source of water is a local aquifer. Butterfield Springs Province waters emanate at 1,619–1,622 m (5,312–5,325 ft) elevation as rheocrene springs (Sada 2016, entire). This province is 1.5 km (0.9 mi) north of Flag Springs Province).

The Butterfield Springs Province currently consists of three springs (Butterfield Spring C, D, and E). Butterfield Springs C and D are connected and support a single population of Butterfield and Hardy pyrgs. Butterfield Spring E supports a second population of the pyrgs. This province supports the only know population of the Butterfield pyrg.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.56). Butterfield C and D: maximum springbrook length 40 m (131 ft); wetted width 120 cm (47.2 in); and wetted depth 28.6 cm (1.3 in); and Butterfield E: maximum springbrook length 2,000 m (6,562 ft); wetted width 105 cm (41.3 in); and wetted depth 28.6 cm (11.3 in).

- *Butterfield Springs A and B*: Sada could not locate these springs during the 2016 survey, thus no current data are available for these springs.
- *Butterfield Springs C and D:* These springs are tributary to one another. The springbrook length is 40 m (131 ft). The springbrook of one is less than 3 m (10 ft) long. Substrate is 80 percent gravel and 20 percent cobble. Bank cover is 100 percent and emergent cover is 96.0 percent. Both springbrooks are densely covered by giant reed, which rapidly

Comment [CSE58]: Double check this.

colonizes disturbed aquatic systems. Other vegetation present includes wild rose and watercress.

- *Butterfield Spring E*: Springbrook length is 2,000 m (6,562 ft). Substrate is 10 percent sand, 80 percent gravel, and 10 percent boulder. Bank cover is 92.5 percent and emergent cover is 34.0 percent. The south springbrook bank is densely vegetated by wild rose and the north bank is grassy. Other vegetation present includes mesquite, rushes, spikerush, reeds, yerba mansa, and watercress.

Comment [PME59]: Maps would be helpful. USGS also measures this spring twice a year (similar timing as with Flag Springs) and the data can be found on NWIS. I'm not sure which spring of A-E that we are measuring though.

Table 5.56. Attribute measurements for Butterfield Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Butterfield Springs Province	16.5 (61.7)	7.9	384	6.6	-	-
Butterfield A & B	16.7 (62.1)	8.2	379	6.9	600 (0.35)	-
Butterfield C	16.5 (61.7)	7.9	384	6.6	-	-
	16.7 (62.1)	7.9	373	7.2	240 (0.14)	-
Butterfield C & D	16.8 (62.2)	-	322	-	70 (0.04)	30.6 (12)
Butterfield D	16.9 (62.4)	7.8	376	6.7	200 (0.12)	28.6 (11.3)
Butterfield E	16.3 (61.3)	-	310	-	150 (0.09)	18.3 (7.2)

Data is compiled from Sada 2016, entire; Sada 2017; and Golden *et al.* 2007, pp. 146-147.

Sada (2017) observed that all three of the springs had been dredged to maximize water collection for agriculture, and the springbrooks of two tributary springs have been impounded.

Current stressors identified at Butterfield Springs C and D in the 2016 surveys include vegetation and soil disturbance, and spring modification (Table 5.57) (Sada 2017, entire?). These are moderately disturbed springs. The springs are adjacent to a ranch house, repair shop, and a network of access roads that are associated with these facilities. The roads do not appear to affect these springs. Both springs have been dredged to remove vegetation and direct water into two impoundments where water is collected then diverted to downstream pastures. Springsnails do not occur in the impoundments, or the downstream ditch that delivers water to pastures. A pump is at the upper impoundment to deliver water to tanker trucks. Springsnails occupy 40 m (131 ft) of springbrook (44.8 m^2 (482.2 ft^2) of habitat).Giant reed density and high current velocity throughout the habitat may be adversely affecting the springsnail population. Due to dense giant reeds and high springbrook velocity, habitat conditions at Butterfield Springs C and D are marginally appropriate to meet springsnail species needs.

Table 5.57. Current stressors for Butterfield Springs C and D.

Stressors (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]

Spring Modifications (Surface Water Diversion)	current	moderate	high	basic need	NC	M
Vegetation and Soil Disturbance (Grazing and Browsing)	current	moderate	high	basic need	NC	M
Vegetation and Soil Disturbance (Invasive Plants)	current	unknown	moderate	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Current stressors identified at Butterfield Spring E in the 2016 surveys include vegetation and soil disturbance, and spring modification (Table 5.58) (Sada 2017, entire?). This spring is moderately disturbed from cattle, diversions, and channel modification. Water discharges from a springbox that does not divert water from the springbrook. The upper approximately 200 m (656 ft) of springbrook has naturalized from dredging but exhibits moderate use by cattle. A fence isolates this upper reach of springbrook. Downstream from this, the brook is contained within a straight, channelized ditch that is actively used by cattle. Woody vegetation is absent from this reach of springbrook. Springsnails occupy 400 m (1,312 ft) of springbrook (420 m^2 (4,521 ft^2)) of habitat. Habitat conditions at Butterfield Spring E are appropriate to meet springsnail species needs.

Table 5.58. Current and historic stressors for Butterfield Spring E.

Stressors	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Vegetation and Soil Disturbance (Grazing and Browsing)	current	moderate	moderate	mortality	NC	M
Spring Modification (Surface Water Diversion)	historic	moderate	moderate	mortality	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Butterfield Springs Province occurs entirely on private lands and not managed in accordance with any management or conservation plan. We determined that overall habitat conditions at this province are appropriate to meet springsnail species needs. We expect that future conditions at this province may be impacted by groundwater pumping if the proposed SNWA GWD project is implemented (see Chapter 4—*Southern Nevada Water Authority Groundwater Development Project* for more details). Other stressors will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

5.5.6 Silver Springs Province

Springsnail species present in the Silver Springs Province include the Hardy pyrg.
Silver Springs consists of three springs occur on private land in Nye County, Nevada (Figure 5.6). This spring province is in the White River Valley HA (207), which is a designated hydrographic basin. The source of these springs is a local aquifer. Silver Springs emanate at 1,821–1,826 m (5,974–5,991 ft) elevation are rheocrene springs (Sada 2016, entire).

The landowner did not provide access to Silver Springs in 2016. We compiled information on water quality and quantity at springs from several sources of data (Table 5.59). Maximum springbrook length was 500 m (1,641 ft). Wetted width ranged from 70 to 1,500 cm (28 to 591 in) and wetted depth ranged from 12 to 100 cm (5 to 39 in).

- *Silver Spring A*: The springbrook length is 110 m (361 ft); wetted width is 40 cm (16 in); and wetted depth is 3.0 cm (1.2 in). Substrate is comprised of 10 percent fines, 60 percent sand, and 30 percent gravel. Bank cover is 60 percent and emergent cover is 30 percent. A residence is present with disturbance, mowing, and herbicide use affecting the site. Springsnails were not found in 2008.
- *Silver Spring B*: The springbrook length is 45.0 m (147.6 ft); wetted width is 20.0 cm (7.9 in); and wetted depth is 2.0 cm (0.8 in). Substrate is comprised of 10 percent fines, 15 percent sand, and 75 percent gravel. Bank cover is 30 percent and emergent cover is 20 percent. A residence is present with disturbance, mowing, and herbicide use affecting the site. Springsnails are found in 2008.
- *Silver Spring C*: The springbrook length is 45.0 m (147.6 ft); wetted width is 15.0 cm (5.9 in); and wetted depth is 1.0 cm (0.8 in). Substrate is comprised of 10 percent fines, 15 percent sand, and 75 percent gravel. Bank cover is 30 percent and emergent cover is 20 percent. Only flow data are available for this spring. A residence is present with disturbance, mowing, and herbicide use affecting the site. Water volume was too low for data collection. Springsnails were found in 2008.

Table 5.59. Attribute measurements for Silver Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Silver Springs Province	14.9 (58.8)	-	446	-	-	-
Silver Spring A	15.2 (59.4)	8.2	376	7.4	75 (0.04)	-
Silver Spring B	15.5 (59.9)	8.0	387	7.2	5 (>0)	-
Silver Spring C	-	-	-	-	2 (>0)	-

Sada 2016

Comment [CSE60]: Need to check if this is the correct citation.

Current stressors identified for the Silver Springs Province in the 2016 surveys include water pollution from herbicide application, and vegetation and soil disturbance (Table 5.60) (Sada 2017, entire?).

Table 5.60. Current stressors for Silver Springs Province.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Water Pollution (Herbicides)	current	high	very high	basic need	NC	M
Vegetation and Soil Disturbance	current	high	very high	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Silver Springs Province occurs entirely on private lands not managed in accordance with any management or conservation plan. Silver Springs Province has one population of Hardy pyrg. We are uncertain if the habitat conditions at this province are appropriate to meet springsnail species needs. We expect that future conditions at this province will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

5.5.7 Moorman Spring

Springsnail species present at Moorman Spring include one population each of Pahranagat pebblesnail and grated tryonia. This thermal spring is located on private land in the White River Valley hydrographic basin (207) 32.2 km (20 mi) south of Lund in Nye County, Nevada (Figure 5.6). It is a limnocrene spring, a local aquifer, and is a tufa mound cut by several trending faults (SNWA 2008, p. 3-57). Moorman Spring discharges from the alluvium along a fault scarp and is set in a highly dissected alluvial fan. The spring and its springbrook have been dredged, but the presence of large woody shrubs (*Mahonia fremontii*) on the spoil piles indicate that dredging occurred in the distant past. Moorman Spring forms a small pool behind an old irrigation diversion structure, and the pool has a partial man-made berm around it (SNWA 2008, p. 3-57). An old and presently non-functional control valve is located approximately 45 m (148 ft) downstream from the source. It had been used to divert water into a currently unused irrigation ditch. Although the site currently bears little resemblance to natural conditions, the site appears to have recovered and naturalized from this disturbance. It is characterized by a relatively homogeneous habitat with little diversity in current velocity, water depth, and substrate composition. This is the warmest spring occupied by springsnail species in the White River Valley.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.61). Springbrook length extended a maximum of 500 m (1640 ft) and springsnails occupied 95 m (312 ft) of springbrook (218.5 m^2 (2352 ft^2) of habitat). Wetted width ranged from 75 to 230 cm (30 to 91 in) and wetted depth ranged from 11 to 50 cm (4.3 to 20 in).

Table 5.61. Attribute measurements for Moorman Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Moorman Spring	35.4–36.8 (95.7–98.2)	7.15–7.7	558–631	3.6	150–25,995 (0.09–15.3)	7.8 (3)

Data is compiled from the following sources: Garside and Schilling 1979, entire; Golden *et al.* 2007, entire; Albrecht *et al.* 2008, entire; SNWA 2008, entire; Sada 2016, entire; and Sada 2017, entire.

Comment [PME61]: USGS also measures this spring twice a year.

The 2016 survey documented a substrate composition of 80 percent silt, 15 percent sand, and 5 percent gravel. Riparian vegetation included rushes, bulrushes spikerushes and sedges. The survey location in 2016 had 100 percent bank cover and 45 percent emergent vegetation cover. Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected. This information also provides a range of historical to current conditions and a reference that may be used as a comparison to future data collected.

Stressors for Moorman Spring include water diversion, channel modification, impoundment, predation and competition from invasive aquatic species (red-rimmed melania), and vegetation and soil disturbance from grazing from ungulate species (Table 5.62). Red-rimmed melania can impact springsnails through predation and competition for resources. Recent survey data show that the intensity of invasive aquatics is moderate, which may be why the most recent springsnail surveys documented scarce abundance.

Table 5.62. Current and historic stressors for Moorman Spring.

Stressors (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Predation and Competition (Invasive Aquatics)	current	moderate	moderate	mortality confirmed	NC	L
Vegetation and Soil Disturbance (Grazing and Browsing)	historic	moderate	moderate	basic need	NC	L
Spring Modifications from the following Sources						
Surface Water Diversion	historic	low	small	basic need	NC	L
Impoundment	historic	low	small	basic need	NC	L
Channel Modification	historic	low	small	basic need	NC	L

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

The spring was historically dredged and impounded with channels modified in order to divert water for irrigation. The system appears to have recovered from these disturbances. Grazing and browsing (ungulate use) were also identified as an historic source of stress, which may have contributed to vegetation and soil disturbance and direct mortality through trampling. Grazing and browsing (ungulate use) do not appear to be occurring presently and should not have an impact on the current condition of springsnails.

Moorman Spring occurs within a hydrographic basin (White River Valley) identified to be impacted by the SNWA Groundwater Development Project (see Section 4.5.1.1). BLM identified a 1 percent decrease in spring flow at Moorman Spring as a result of the proposed alternative for the project 75 years after full build out (BLM 2012, Chapter 3, Section 3.3 Water Resources, p. 183).

Moorman Spring is in close proximity to BLM land in the Ely District, which processes permit applications for oil and gas development. While there may be a possibility for development in the area, there is no way to predict whether or not future oil and gas development may affect this spring.

There are no known conservation or management actions being undertaken at this privately owned spring. We expect that the province future conditions will likely remain similar to current conditions as the best available information does not indicate an increase or decrease in effects associated with the stressors.

5.5.8 Emigrant Spring Province

Springsnail species present in the Emigrant Springs Province include the Hardy pyrg. Emigrant Springs occur on private land in Nye County, Nevada (Figure 5.6). This spring province is in the Colorado River Basin (13) region and White River Valley (207) designated groundwater basin. The source of these springs is a local aquifer. Butterfield Springs emanate at 1,664–1,674 m (5,459–5,492 ft) elevation as rheocrene springs (Sada 2017).

Springs in this province have been disturbed by dredging, channelization, and horse and cattle use. Compared to other springsnail habitats that have been altered by these uses, these all appeared to be suitable springsnail habitat. Surveys in 2008 documented springsnails in five springs within this province. Sada (2017, p. XX) found springsnails only at Emigrant Springs I.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.63). Maximum springbrook length ranged from 35 m (115 ft) to 300 m (984); wetted width ranged from 60 cm (23.6 in) to 160 cm (63 in); and wetted depth from 3 cm (11.3 in) to 10.0 cm (3.9 in).

- *Emigrant Spring A*: The springbrook flows for 70 m (230 ft) before entering an impoundment. Substrate is 100 percent gravel. This spring is highly disturbed due to diversion and dredging. No bank cover is present and emergent cover is 65 percent. Watercress is present at this spring. This spring and springbrook have also been dredged a number of times. Even with this disturbance, the aquatic habitat appears to be suitable springsnail habitat and provides the overall needs of the Hardy pyrg. Springsnails were found in 2008 but not in 2016. Reasons for their apparent absence are unclear.

- *Emigrant Spring B*: The springbrook length is 120 m (394 ft). Substrate is 100 percent gravel. No bank cover is present and emergent cover is 30 percent. Watercress is present at this spring. This spring is highly disturbed due to diversion, channel modification, and dredging. The springbrook flows into a collection ditch. Springsnails were not found in this spring during 2008 and 2016 surveys although the spring provides the overall needs of the Hardy pyrg. Reasons for their apparent absence are unclear.
- *Emigrant Spring D*: The springbrook length is 150 m (492 ft). Substrate is 100 percent gravel. Bank cover is 40 percent and emergent cover is 30 percent. Watercress and Russian olive are present. The spring flows through a pasture. This spring is highly disturbed due to dredging. Even with this disturbance, the aquatic habitat appears to be suitable springsnail habitat. Springsnails were found in 2008 and but not in 2016. Reasons for their apparent absence are unclear. The spring provides the overall needs of the Hardy pyrg.
- *Emigrant Spring E:* The springbrook length is 150 m (492 ft). Substrate is 100 percent fines. Bank cover is 30 percent and emergent cover is 30 percent. Watercress and Russian olive are present. This spring is in a horse pasture and badly trampled, but it appears to be suitable springsnail habitat and the species' needs are represented, even with this disturbance. Springsnails were found in 2008 but not in 2016. Reasons for their apparent absence are unclear.
- *Emigrant Spring F*: The springbrook length is 75 m (246 ft). Substrate is 100 percent fines. Bank cover is 70 percent and emergent cover is 40 percent. Rushes, watercress, and Russian olive are present. This spring is in a horse pasture and badly trampled, but it appears to be suitable springsnail habitat and the species' needs are represented, even with this disturbance. Springsnails were not found in this spring in either 2008 or 2016.
- *Emigrant Spring H*: The springbrook length is 35 m (114 ft). Substrate is 100 percent fines. Bank cover is 100 percent and emergent cover is 90 percent. Rushes, spikerush, wild rose, and watercress are present. This spring is in a pasture used by cattle and badly trampled, but it appears to be suitable springsnail habitat and the species' needs are represented, even with this disturbance. Springsnails were found in 2008 but not in 2016. Reasons for their apparent absence are unclear.
- *Emigrant Spring I*: The springbrook length is 300 m (984 ft) and substrate is mixed (30 percent fines, 20 percent sand, and 50 percent gravel). This spring is moderately disturbed due to cattle. Bank cover is 58.3 percent and emergent cover is 91.7 percent. Watercress and Russian olive are present at this spring. The spring is in a pasture and moderately disturbed by cattle. Hardy pyrgs and Emigrant pyrgs (*P. gracilis*) occupy 85 m of springbrook (52.4 m^2 (564.0 ft^2) of habitat). This spring provides the overall needs of the species.
- *Emigrant Spring J*: The springbrook length is 70 m (753 ft) and substrate is 100 percent fines. This spring is moderately disturbed due to cattle. Bank cover is 90 percent and emergent cover is 40 percent. Watercress is present at this spring. It appears to be suitable springsnail habitat and the species' needs are represented, even with this disturbance. Springsnails were found in 2008 and but not in 2016. Reasons for their apparent absence are unclear.

Comment [PME62]: Map?

Table 5.63. Attribute measurements for Emigrant Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Emigrant A	17.5–19.6 (63.5–67.3)	7.7	340–469	5.2	100–300 (0.06–0.18)	36 (14.2)
Emigrant B	19.9–20.0 (67.8–68)	7.7	407–472	4.8	40–60 (0.02–0.04)	-
Emigrant D	20.2 (68.4)	-	402	-	120 (0.07)	-
Emigrant E	21.0 (69.8)	-	407	-	7 (>0)	-
Emigrant F	20.9 (69.6)	-	372	-	15 (0.01)	-
Emigrant H	17.7–17.8 (63.9-64.0)	-	375–426	5.1	3–100 (>0–0.06)	-
Emigrant I	16.8 (62.2)	-	359	-	80 (0.05)	5 (2.0)
Emigrant J	18.0 (64.4 ºF)	-	355	-	30 (0.02)	-

Sada 2016, 2017

Current stressors identified during 2016 surveys include vegetation and soil disturbances, and spring modifications (Tables 5.64-5.69) (Sada 2017, entire?).

Table 5.64. Current stressors for Emigrant Springs A and B.

Stressors (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Spring Modifications from the following Sources						
Surface Water Diversion	current	high	high	basic need	NC	M
Channel Modification	current	high	high	basic need	NC	M
Impoundment	current	unknown	unknown	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Table 5.65. Current stressors for Emigrant Spring D.

Stressors (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Spring Modifications (Channel Modification)	current	moderate	high	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Table 5.66. Current stressors for Emigrant Springs E and F.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Grazing and Browsing)	current	moderate	high	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Table 5.67. Current stressors for Emigrant Springs H and J.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Grazing and Browsing)	current	moderate	high	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Table 5.68. Current and historic stressors for Emigrant Spring I.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance from the following Sources						
Browsing and Grazing	current	high	all	basic need	NC	M
Roads	historic	low	small	basic need	NC	M
Spring Modifications from the following Sources						
Surface Water Diversion	current	high	all	basic need	NC	M
Channel Modification	current	high	all	basic need	NC	M
Impoundment	current	high	all	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Emigrant Spring Province occurs entirely on private land not managed in accordance with any management or conservation plan. Emigrant Springs A and B have one population of Hardy pyrg. Although springsnails were found in 2016 at only Emigrant Spring I, we determined the habitat conditions at this province are appropriate to meet springsnail species needs. We expect that future conditions at this province will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

5.5.9 Hardy Spring Province

Springsnail species present in the Hardy Springs Province include the Hardy pyrg.
Hardy Springs occur on private land in Nye County, Nevada (Figure 5.6). This spring province is in the Colorado River Basin (13) region and White River Valley (207) designated groundwater basin. The source of these springs is a local aquifer. Hardy Springs emanate at 1,631–1,634 m (5,351–5,361 ft) elevation. Hardy Springs A, C, and E are rheocrene springs, Hardy Spring B is a limnocrene spring, and Hardy Spring D is a helocrene spring (Sada 2016, entitre).

Surveys in 2008 documented springsnails in seven springs within this province. Hardy pyrgs were found in all six springs during 2016. Surveyors could not locate Hardy Springs G and L in 2016, where they were found in 2008. Most springs in this province are moderately disturbed by dredging, channelization, and/or cattle. One spring is highly disturbed by heavy cattle use. Speckled dace were observed in Hardy Spring A springbrook, and they were also recorded in these springs by Scoppettone *et al.* (2004, p. 49).

Hardy Springs A-E are close to one another and flow westward into a single springbrook that is impounded approximately 70 m (230 ft) downstream from the eastern-most spring source. Water has been withdrawn (surface water diversion) from this impoundment as indicated by the presence of a water tank and stand and extensive vehicle use of the road for access to the impoundment. The impoundment is approximately 30 m (98 ft) west of Hardy Spring E. Springsnails occurred in the Hardy Spring E springbrook until the impoundment, and no further downstream. Sources of these springs are fenced, but they are also moderately disturbed by cattle. Two other springs are isolated from Hardy Springs A-E, which are located west of this springbrook, and their springbrooks terminated before connecting to other water. The sources, and much of these two springbrooks, are also fenced and protected from grazing. A number of additional springs are in the province, but they are located distantly to the west of springsnail habitats, and their habitat is not suitable for springsnails.

- *Hardy Springs A*: The springbrook length is 72 m (230 ft). This spring is moderately disturbed by cattle. Bank cover is 82.8 percent and emergent cover is 50.9 percent. Springsnails occupy 72 m (236 ft) of springbrook (79.3 m^2 (853.6 ft^2) of habitat).
- *Hardy Springs B*: The springbrook length is 45 m (148 ft). This spring is moderately disturbed due to cattle. Bank cover is 82.5 percent and emergent cover is 81.7 percent. The habitat is moderately disturbed by cattle. Springsnails occupy 45 m (148 ft) of springbrook (58.0 m^2 (624.3 ft^2) of habitat).
- *Hardy Springs C*: The springbrook length is 11 m (36 ft). This spring is highly disturbed due to cattle. Bank cover is 67.8 percent and emergent cover is 62.9 percent. The habitat is slightly disturbed at the source and the springbrook is highly disturbed by cattle. In spite of this disturbance, springsnails occupy 11 m (36 ft) of springbrook (5.3 m^2 (57.0 ft^2) of habitat).
- *Hardy Springs D*: The springbrook length is 21 m (69 ft). The habitat is moderately disturbed by cattle. Bank cover is 100 percent and emergent cover is 82.5 percent. Springsnails occupy 21 m of springbrook (25.7 m^2 (276.6 ft^2) of habitat).

- *Hardy Springs E*: The springbrook length is 12 m (39 ft). This spring is moderately disturbed due to cattle. Bank cover is 56.6 percent and emergent cover is 68.0 percent. Springsnails occupy 12 m of springbrook (7.9 m^2 (85.0 ft^2) of habitat).
- *Hardy Springs F*: The springbrook length is 60 m (197 ft). Bank cover is 67.8 percent and emergent cover is 62.9 percent. The spring source and approximately 30 m (323 ft) of springbrook are fenced and protected from cattle, and the habitat downstream from the fence is highly disturbed by cattle. This spring is isolated from the other springs in the province and the impoundment further isolates Hardy Spring F from the other springs. Springsnails occupy 55 m (180 ft) of springbrook (73.1 m^2 (786.8 ft^2) of habitat).

Comment [PME63]: Map?

We compiled information on water quality and quantity at springs from 2016 surveys (Table 5.69) (Sada 2016, entire; and Sada 2017, p. XX). Maximum springbrook length 72 m (236 ft); wetted width from 52.5 cm (20.7 in) to 132 cm; and wetted depth 2.9 cm (1.1 in) to 13.8 cm (5.4 in).

Table 5.69. Attribute measurements for Hardy Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Hardy Spring A	13.7–14.2 (56.7–57.6)	7.5	382–452	6.9	70–285 (0.04–0.17)	25.2 (9.9)
Hardy Spring B	13.8–13.9 (56.8–57.0)	7.5	333–385	7.6	40–75 (0.02–0.04)	-
Hardy Spring C	14.5–14.9 (58.1–58.8)	8.0	335–412	2.6	3–5 (>0)	0.25 (0.1)
Hardy Spring D	13.7–14.0 (56.7–57.2)	7.6	341–384	7.1	20–50 (0.01–0.03)	2.25 (0.89)
Hardy Spring E	19.9–20.0 (67.8–68)	7.7	408–472	4.8	40–60 (0.02–0.04)	-
Hardy Spring F	14.0–14.2 (57.2–57.6)	7.8	297–389	7.5	90–100 (0.05–0.06)	3.7 (1.5)
Hardy Spring G	14.1 (57.4)	7.7	397	8.5	10 (0.01)	-
Hardy Spring L	14.4 (57.9)	7.9	389	6.8	8 (>0)	-

Surveys conducted in 2016 (Sada 2017, pp. XX) estimated the substrate to 50 percent fines and 50 percent gravel in Hardy Spring A; 100 percent fine in Hardy Spring B and F; 80 percent fines, 15 percent sand, and 5 percent gravel at Hardy Spring D; and 80 percent fines, 10 percent sand, and 10 percent gravel at Hardy Spring E. In 2016, riparian vegetation present includes rushes, reeds, wild rose, spikerush, watercress, salt cedar, and Russian olive. Bank cover ranged from 56.6–100 percent and emergent cover ranged from 50.9–82.53 percent.

Stressors for this province affect all springs in the province (Table 5.70) (Sada 2017, p. XX). Overall, the species' needs are provided by the Hardy Springs. We expect that future conditions at this province will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

Table 5.70. Current stressors for Hardy Springs Province.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance from the following Sources						
Invasive Aquatics	current	low	low	basic need	NC	M
Browsing and Grazing	current	moderate	moderate	basic need	NC	M
Roads	current	moderate	moderate	basic need	NC	M
Spring Modifications from the following Sources						
Surface Water Diversion	current	low	moderate	basic need	NC	M
Impoundment	current	moderate	all	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Hardy Spring Province occurs entirely on private lands not managed in accordance with any management or conservation plan. Based on 2016 survey data, Hardy Spring Province supports a single population of Hardy pyrgs. We determined that the habitat conditions at this province are appropriate to meet springsnail species needs.

5.5.10 Parker Station Spring

Springsnail species present in Parker Station Spring include the Hardy pyrg.

This spring occurs on private land in Lincoln County, Nevada (Figure 5.7). This spring is in the Colorado River Basin (13) region and Cave Valley (180) designated groundwater basin. The source of the spring is a local aquifer. Parker Statuion Spring emanates at 1,677 m (5,502 ft) elevation as a limnocrene spring (Sada 2017, p. XX).

This, valley floor spring is wide, deep, and characterized by deep, fine sediments (100 percent of substrate) that prevented surveyor access to the channel in 2016. Access is also restricted for livestock that could easily become mired and trapped in the mud. The springbrook length is 400 m (1,312 ft).

The banks of the spring and springbrook are moderately disturbed by cattle and horses, but deep muck prevented them from entering the channel that is densely covered by watercress. Springsnails could only be sampled along the banks where they occurred only in patches of watercress, which suggests that springsnails also occupy this vegetation in the channel. They did not occupy grasses, rushes and spikerush growing along at least 75 cm (29.5 in) along each side of the springbrook. Springsnails occupy 150 m (492 ft) of springbrook to the fence crossing this reach of springbrook and an estimated 525 m^2 (5,651 ft^2) of habitat, which does not include springbrook margins with grasses, rushes, and spikerush.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.71). Surveys estimated the wetted width to be 478 cm (188 in) and wetted depth >30 cm (>11.8 in). Bank cover is 86.1 percent and emergent cover is 100 percent.

Table 5.71. Attribute measurements for Parker Station Spring.

Spring or Spring Province	Temperature °C (ºF)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Parker Station Spring	13.9–14 (57.0–57.2)	7.7	436–454	3.2	200 (0.12)	0

Golden *et al.* 2007; Sada 2017

Stressor impacts on Parker Station Springs are low and include vegetation and soil disturbance (Table 5.72).

Table 5.72. Current stressors for Parker Station Spring.

Stressors (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Vegetation and Soil Disturbance (Grazing and Browsing)	current	low	small	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Parker Station Spring occurs entirely on private land not managed in accordance with any management or conservation plan. Parker Station Spring has one population of Hardy pyrg. We determined that the habitat conditions at this spring are appropriate to meet springsnail species needs. We expect that future conditions at this province will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

5.5.11 Ruppes Boghole Springs Province

Springsnail species present in Ruppes Boghole Springs Province include the Hardy pyrg. This province consists of two connected springs on private land in Lincoln County, Nevada (Figure 5.6). A third spring, Ruppes Boghole C, was reported dry in 2012 (Sada 2016, entire). This spring province is in the Colorado River Basin (13) region and White River Valley (207) designated groundwater basin. The source of these springs is a local aquifer. Ruppes Boghole Springs emanate at 1,677 m (5,502 ft) elevation as helocrene springs (Sada 2016, entire).

The landowner did not provide access to Ruppes Boghole Springs Province in 2016. No springbrook length data were found for the two springs. The springs in this province are dug out and heavily disturbed mostly due to cattle use of the aquatic area. The site provides poor quality springsnail habitat. Spring data were found for the province and Ruppes Boghole Spring A, but not for Ruppes Boghole B.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.73). The estimated wetted width is 1,000 cm (393.7 in) and wetted depth is 100.0 cm (39.4 in). Substrate is 100 percent fines for both springs. Bank cover is 75–95 percent and emergent cover is 85–90 percent.

Table 5.73. Attribute measurements for Ruppes Boghole Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Ruppes Boghole Province	13.2 (55.8)	-	550	-	5 (>0)	-
Ruppes Boghole A	12.6–18.3 (54.7–64.9)	7.8–7.9	526–547	3.9	1 (>0)	-

Golden *et al.* 2007, Sada 2016

Comment [CSE64]: Need to verify this citation is correct.

Stressors for this spring include vegetation and soil disturbance and spring modification (Table 5.74) (Sada 2017, p. XX).

Table 5.74. Current stressors for Ruppes Boghole Springs Province.

Stressors (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Vegetation and Soil Disturbance (Grazing and Browsing)	current	high	all	basic need	NC	M
Spring Modification (Channel Modification)	current	high	all	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Ruppes Boghole Springs Province occurs entirely on private land not managed in accordance with any management or conservation plan. Ruppes Boghole Springs Province has one populations of Hardy pyrg. We determined that Ruppes Boghole Springs Province currently does not provide the species' needs and conditons are not adequate. We anticipate these conditions will be similar in the future. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

5.5.12 Lund Spring

Springsnail species present in Lund Spring includes the White River Valley pyrg.

Lund Spring occurs occur on private land in White Pine County, Nevada (Figure 5.6). This spring is in the White River Valley HA (207), which is a designated hydrogaphic basin. The source of this spring is a regional aquifer. Lund Spring emanates at 1,708 m (5,604 ft) elevation as a rheocrene spring (Sada 2016 (entire).

This spring has been highly altered by impoundment and diversions. All of the springbrook is captured in pipes approximately 65 m (213 ft) from its source. Lund spring historically supported the full complement of native fishes in upper White River Valley springs (Courtney *et al.* 1985, p. 508). Construction of the diversion facilities and the subsequent drying of the springbrook occurred after 1983. More recent surveys found desert suckers and speckled dace in the spring, but White River spinedace and White River springfish have been extirpated (Scoppettone *et al.* 2004, p. 50).

The spring is also used for recreational bathing, at least during warm months. Springsnails are absence from the substrate in a 15 m x 15 m (49 ft x 49 ft) area in the center of the pond where people actively swim but common on substrate that is on the periphery of the pond. Springsnails occupy 65 m (213 ft) of springbrook (262 m^2 (2,815 ft^2)) of habitat) and there is 486.6 m^2 (5,238 ft^2) of potential habitat outside of the area impacted by swimmers.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.75). Maximum springbrook length 65 m (820 ft); wetted width 219.1 cm (86.3 in); and wetted depth 39.5 cm (15.6 in). Surveys conducted in 2016 (Sada 2017, pp. XX) estimated the substrate to be 10 percent sand, 80 percent gravel, and 10 percent cobble. Bank cover is 100 percent and emergent cover is 31.1 percent. Willow and spikerush are present at the spring.

Table 5.75. Attribute measurements for Lund Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Lund Spring	18.0–19.3 (64.4–66.7)	7.6–7.9	391–442	5.2–5.6	500–2000 (0.29–1.18)	3.8 (1.5)

Golden 2007; Sada 2016, 2017

Comment [PME65]: Flows of 1.18 cfs seem a bit low. USGS measures Lund Spring twice a year, consider checking out NWIS.

Although several stressors are present at this spring, the overall impact on the species is low (Table 5.76).

Table 5.76. Current stressors for Lund Spring.

Stressors (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Predation and Competition (nonnative fish)	current	unknown	unknown	basic need	NC	M
Vegetation and Soil Disturbance (Recreation)	current	moderate	moderate	basic need	NC	M
Spring Modifications from the following sources						
Surface Water Diversion	current	moderate	moderate	basic need	NC	M

Channel Modification	current	moderate	moderate	basic need	NC	M
Impoundment	current	moderate	moderate	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Lund Spring occurs entirely on private land not managed in accordance with any management or conservation plan. We determined that habitat conditions at this spring are appropriate to meet springsnail species needs. Lund Spring has one population of White River Valley pyrg. We expect that future conditions at this province will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

5.5.13 Arnoldson Spring

Springsnail species present in Arnoldson Spring include the White River Valley pyrg but historically, Hardy pyrgs also occurred at the spring. Arnoldson Spring occurs in the White River Valley HA (207), White Pine County, Nevada (Figure 5.6). The source of water is a local aquifer that emanates at 1,715 m (5,627 ft) elevation as a rheocrene spring. No surveys were performed at this spring in 2016. No suitable springsnail habitat appeared to be present in 2016 based on visual observation (Sada 2017, p. XX), therefore, the species needs are not represented at Arnoldson Spring.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.77). Estimates for springbrook length are 50 m (164 ft). Although several stressors are present at this spring, the overall impact on the species is low and the White River Valley pyrg's needs are represented at this spring. Surveys estimated the wetted width to be from 75 cm (30 in) to 12.5 m (41 ft) and wetted depth from 8 cm (1.2 in) to 86 cm (34 in). The substrate was 100 percent fines. No bank cover was present and emergent cover is 20 percent. Watercress is present at this spring.

Table 5.77. Attribute measurements for Arnoldson Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Arnoldson Spring	22.4–22.9 (72.3–73.2)	7.4–7.9	410–428	3.5–4.4	90 (0.05)	-

Golden *et al.* 2007, Sada 2016

Comment [PME66]: We also measure this spring twice a year if you need to verify data.

Stressors for Arnoldson Spring include predation and competition, vegetation and soil disturbance, and spring modifications (Table 5.78).

Table 5.78. Current stressors for Arnoldson Spring.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend[1]**	**Confidence of Trend[2]**

Predation and Competition (nonnative fish)	current	unknown	unknown	basic need	NC	M
Vegetation and Soil Disturbance (Roads)	current	unknown	unknown	basic need	NC	M
Spring Modifications from the following Sources						
Surface Water Diversion	current	unknown	unknown	basic need	NC	M
Channel Modification	current	unknown	unknown	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Arnoldson Spring occurs entirely on private land not managed in accordance with any management or conservation plan. Arnoldson Spring has one population of White River Valley pyrg. Because the landowner has not provided access to the spring, we are uncertain whether habitat conditions at this spring are appropriate to meet springsnail species needs. Habitat conditions were appropriate to meet springsnail species needs when the spring was surveyed in 1992. We expect that future conditions at this spring will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors.

5.5.14 Nicholas Spring

Springsnail species present in Cold Spring includes the White River Valley pyrg.

Nicholas Spring is a single spring on private land in White Pine County, Nevada (Figure 5.6). This spring is in the Colorado River Basin (13) region and White River Valley (207) designated groundwater basin. The source of this spring could not be determined. Cold Spring emanates at 1,714 m (5,623 ft) elevation as a rheocrene spring (Sada 2016, entire).

The landowner did not provide access for the 2016 survey at this spring. Golden (2007, p. 160) reported that springsnails occupied 38 m (125 ft) of the springhead and springbrook prior to the entire system going into a pipe. Dr. Robert Hershler at the Smithsonian Museum of Natural History identified these snails as White River Valley pyrgs (Golden 2007, p. 160). Local landowners stated that springbrooks are short due to pipes capturing their discharge for irrigation (Sada 2017, p. XX).

We compiled information on water quality and quantity at springs from one source (Table 5.79). The springbrook length is 38 m (125 ft). Golden *et al.* (2007, pp. 146-147) estimated the weeted width to be 4.0 m (13.1 ft) and maximum depth 37 cm (14.6 in). No estimates were available for cover and substrate. Rabbit-foot grass (*Polypogon monspeliensis*), redtop (*Agrostis gigantean*), red willow (*Salix laevigata*), saltgrass horsehair algae (*Chlorophyceae* sp.), water speedwell (*Veronica anagallis*), and watercress are present at the spring.

Table 5.79. Attribute measurements for Nicholas Spring.

Spring or Spring Province	Temperature °C (ºF)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Nicholas Spring	21.7–22.1 (71.1–71.8)	7.8–7.9	404–409	3.46–3.73	-	-

Golden *et al.* 2007

Comment [PME67]: We measure this spring twice a year, so you can find flow data on NWIS.

No recent surveys have been performed at Nicholas Spring, thus our analysis of stressors is based on data from Golden *et al.* (2007, pp. 146-147) and Sada (2016, entire) (Table 5.80).

Table 5.80. Current stressors for Nicholas Spring.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Predation and Competition (nonnative fish)	current	unknown	unknown	basic need	NC	M
Vegetation and Soil Disturbance (Grazing and Browsing)	current	unknown	unknown	basic need	NC	M
Spring Modifications from the following Sources						
Surface Water Diversion	current	high	high	basic need	NC	M
Channel Modification	current	unknown	unknown	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Nicholas Spring occurs entirely on private land not managed in accordance with any management or conservation plan. Nicholas Spring has one population of White River Valley pyrg. Because the landowner has not allowed recent access to the spring to perform assessment of conditions, we are uncertain whether habitat conditions at this spring are appropriate to meet springsnail species needs. We expect that future conditions at this spring will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

5.5.15 Cold Spring

Springsnail species present in Cold Spring includes the White River Valley pyrg.

Cold Spring is a single spring on private land in White Pine County, Nevada (Figure 5.6). This spring is in the Colorado River Basin (13) region and White River Valley (207) designated groundwater basin. The source of water for this spring is a mountain block aquifer that emanates at 1,724 m (5,656 ft) elevation as a rheocrene spring (Sada 2016, entire).

The landowner did not provide access for the 2007 or 2016 survey at this spring and no prior spring data are available. The White River Valley pyrg was found at this spring during surveys prior to 2007. Local landowners stated that springbrooks are short due to pipes capturing their discharge for irrigation (Sada 2017, p. XX).

Comment [PME68]: We measure this spring twice a year, so you can at least grab flow data from NWIS.

No recent surveys have been performed, thus our analysis of stressors is based on Sada (2016, entire) data and anecdotal observations (such as?) (Table 5.81).

Table 5.81. Current stressors for Cold Spring.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance from the following Sources						
Invasive Aquatics	current	unknown	unknown	basic need	NC	M
Grazing and Browsing	current	unknown	unknown	basic need	NC	M
Spring Modifcations from the following Sources						
Surface Water Diversion	current	high	high	basic need	NC	M
Channel Modification	current	unknown	unknown	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Cold Spring occurs entirely on private land not managed in accordance with any management or conservation plan. Cold Spring has one population of White River Valley pyrg. We are uncertain whether habitat conditions at this spring are appropriate to meet springsnail species needs. We expect that future conditions at this spring will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

5.5.16 Indian Springs Province

Indian Springs Province consists of two connected spring. Golden (2007, p. 160) performed a survey of Indian Springs and found only shells of springsnails, which could not be identified to species; however, Sada (2016, p. XX) identified the White River Valley pyrg as the species of springsnail present at Indian Springs. Indian Springs occur on private land in White Pine County, Nevada (Figure 5.6). These springs are in the Colorado River Basin (13) region and White River Valley (207) designated groundwater basin. The source of the springs could not be determined. Indian Springs emanate at 1,744 m (5,722 ft) elevation as a rheocrene spring (Sada 2016, p. XX).

The landowner did not provide access for the 2016 survey at this spring province. Because recent assessment information is unavailable, our analysis of stressors is based on data from Golden *et al.* (2007, pp. 146-147) (Table 5.82). The maximum springbrook length was 207 m (679 ft).

Springbrook flow is swift. Spring discharge is diverted onto pastures. Golden *et al.* (2007, pp. 146-147) estimated the wetted width to be 10 m (32.8 ft) and wetted depth 107 cm (42.1 in). Rushes, spikerush, saltgrass water speedwell, and monkeyflower (*Mimulus guttatus*) are present at the spring.

Table 5.82. Attribute measurements for Indian Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Indian Springs Province	21.5–22.3 (70.7–72.1)	8.0–8.1	342–314	3.186–3.27	2,525 (1.49)	-

Golden 2007

No recent surveys have been performed at Indian Springs Province, thus our analysis of stressors is based on Sada (2017, p. XX) data and anecdotal observations (such as?) (Table 5.83).

Table 5.83. Current stressors for Indian Springs Province.

Stressors (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Predation and Competition (red-rimmed melania)	current	moderate	all	basic need	NC	M
Vegetation and Soil Disturbance (Grazing and Browsing)	current	unknown	unknown	basic need	NC	M
Spring Modifications from the following Sources						
Surface Water Diversion	current	moderate	moderate	basic need	NC	M
Channel Modification	current	moderate	moderate	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings
Source: Golden (2007, pp. 163-164).

Indian Springs Province occurs entirely on private land not managed in accordance with any management or conservation plan. We are uncertain whether habitat conditions at this province are appropriate to meet springsnail species needs. We expect that future conditions at this province will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

5.5.17 Preston Big Spring

Springsnail species present in Preston Big Spring includes the White River Valley pyrg.

Preston Big Spring is a single spring on private land in White Pine County, Nevada (Figure 5.6). This spring is in the Colorado River Basin (13) region and White River Valley (207) designated groundwater basin. The source of water for this spring is a local aquifer that emanates at 1,747 m (5,732 ft) elevation as a limnocrene spring (Sada 2016, entire). The springbrook length is 550 m (1,804 ft). The spring is moderately disturbed due to cattle and diversion. The spring has been dredged and channelized in the past and it appears to have naturalized from this disturbance. This spring also supports White River springfish, and White River speckled dace (*Rhinichthys osculus* ssp.), but White River spinedace and desert suckers have been extirpated (Scoppettone *et al.* 2004, p. 49). Courtney *et al.* (1985, p. 505) suggested that extirpation of the sucker occurred following the use of copper sulfate to eradicate vegetation in the spring. A drum that was used to meter copper sulfate into the springbrook is still present during the 2016 survey.

We compiled information on water quality and quantity at springs from several sources of data (Table 5.84). Springsnails occupy 300 m (984 ft) of springbrook (657 m^2 (7,072 ft^2) of habitat). Springsnails were found only on cobble substrate, and absent from vegetation or other types of habitat. Springsnail habitat may be improved in this spring by adding some cobble substrate (Sada 2017, p. XX). Maximum springbrook length was 550 m (820 ft). Wetted width 219.1 cm (86.3 in) and wetted depth 39.5 cm (15.6 in).

Table 5.84. Attribute measurements for Preston Big Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Preston Big Spring	20.6–21.9 (69.1–71.4)	8.1–8.2	338–415	2.4–2.7	8,500–16,464 (5.0–9.69)	13.5 (5.3)

Golden 2007; Sada 2016, 2017

Comment [PME69]: USGS has a continuous gage on this site, consider referencing.

Surveys conducted in 2016 estimated the substrate to be 20 percent fines, 30 percent sand, 40 percent gravel, and 10 percent cobble. Bank cover is 35.9 percent and emergent cover is 43.6 percent. Willow, rushes, reeds, and Russian olive are present at this spring. Although several stressors are present at this spring, the overall impact on the species is low and the White River Valley pyrg's needs are represented at this spring.

Stressors occurring at Preston Big Spring include vegetation and soil disturbances, and spring modifications (Table 5.85).

Table 5.85. Current and historic stressors for Preston Big Spring.

Stressors (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Vegetation and Soil Disturbance from the following Sources						
Invasive Aquatics	current	low	moderate	basic need	NC	H
Grazing and Browsing	current	low	high	basic need	NC	H
Spring Modifications from the following Sources						
Water Diversion	current	moderate	moderate	basic need	NC	H
Channel	historic	low	moderate	basic need	NC	H

Modification						

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Preston Big Spring occurs entirely on private land not managed in accordance with any management or conservation plan. Preston Big Spring has one population of White River Valley pyrg. We expect that future conditions at this spring will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is high although there is uncertainty associated with private land uses. The presence of endangered fish in the spring will provide some protection from declines in condition.

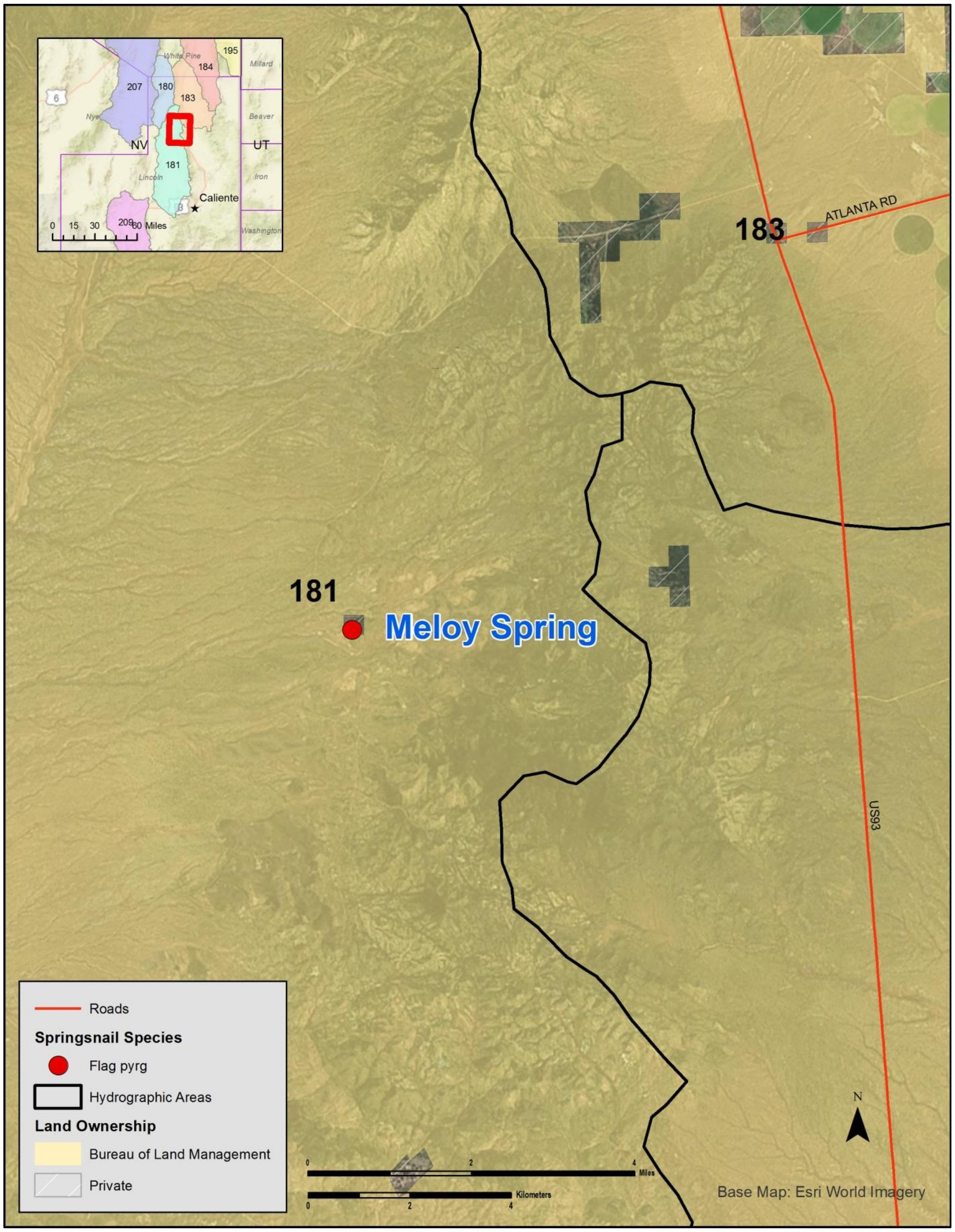


Figure 5.7. Map of the land ownership and general location where the Flag pyrg occurs at Meloy Spring, Dry Lake Valley HA (181), Lincoln County, Nevada. The Flag pyrg also occurs at Flag Springs Province (Figure 5.6).

5.5.18 Meloy Spring

Springsnail species present in Meloy Spring include the Flag pyrg.

This spring occurs on private land in Lincoln County, Nevada (Figure 5.7). This spring is in the Dry Lake Valley HA (181), which is a designated hydrographic basin. The source of these springs is a mountain block aquifer. Meloy Spring emanates at 1,867 m (6,125 ft) elevation as a rheocrene spring (Sada 2016, entire).

We compiled information on water quality and quantity at springs from one source (Table 5.86). The springbrook length is 35 m (115 ft). Surveys estimate the wetted width to be 94.3 cm (37.1 in) and wetted depth is 8.4 cm (3.3 in). Substrate is 10 percent fines, 20 percent sand, and 70 percent gravel. Bank cover is 100 percent and emergent cover is 55.7 percent. Rushes, spikerush, and watercress are present at this spring.

Table 5.86. Attribute measurements for Meloy Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Meloy Spring	14.2–14.6 (57.6–58.3)	7.4	398–507	9.3	60 (0.04)	8.4 (3.3)

Sada 2016

Stressors at this spring result in an overall low impact on the species and include spring modifications (Table 5.87). Although the spring has been altered by diversion and impoundment that have probably reduced springsnail habitat, it does not appear there have been recent activities affecting springsnails or the spring environment. The system has not changed since early surveys in the 1990s, and the aquatic habitat has naturalized from the past disturbance.

Table 5.87. Current stressors for Meloy Spring.

Stressors	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Spring Modifications from the following Sources						
Surface Water Diversion	current	low	small	basic need	NC	M
Impoundment	current	low	small	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Meloy Spring occurs entirely on private lands not managed in accordance with any management or conservation plan. Meloy Spring has one populations of Flag pyrg. We determined that the habitat conditions at this spring are appropriate to meet springsnail species needs. We expect that future conditions at this province will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

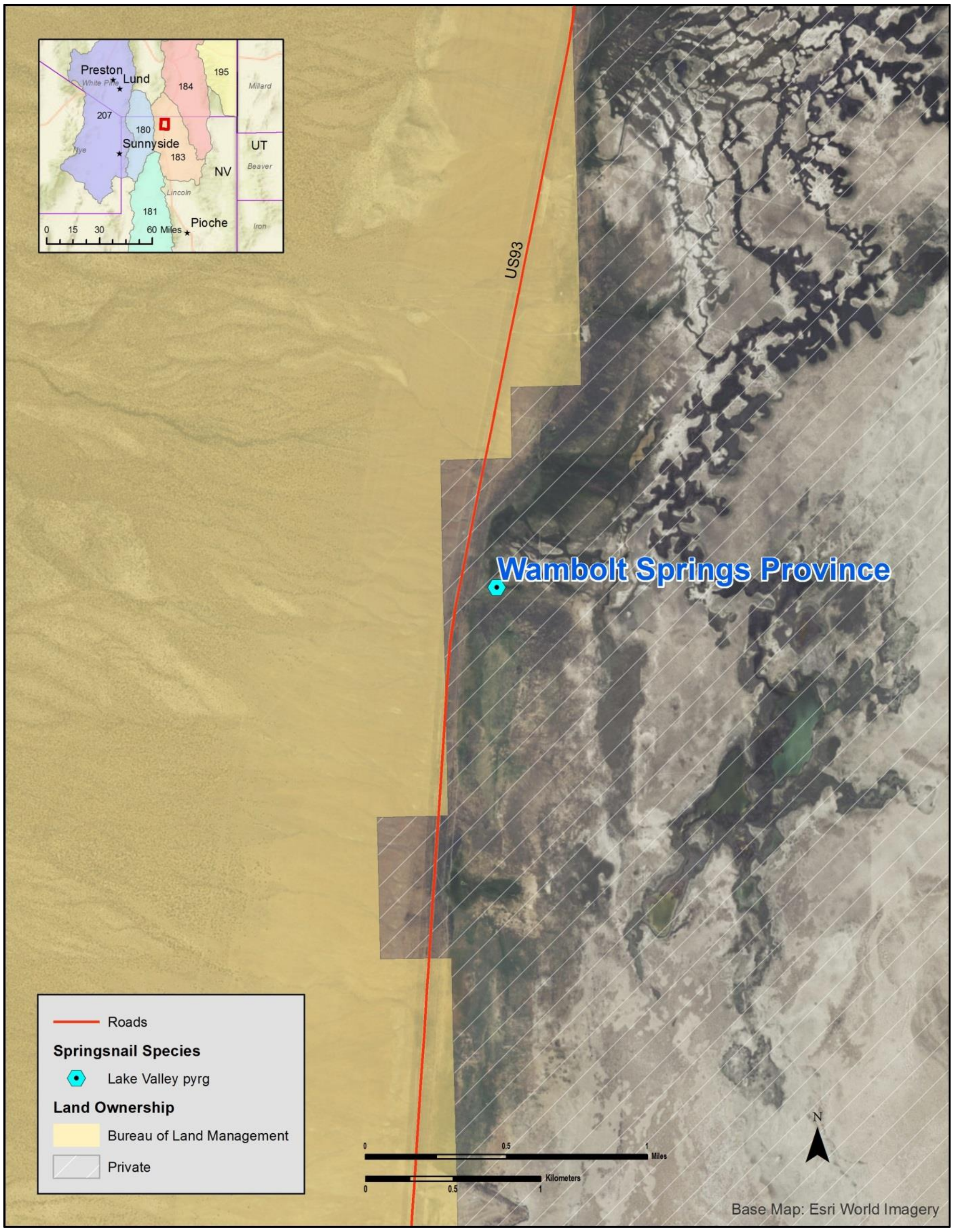


Figure 5.8. Map of the land ownership and general location where the Lake Valley pyrg occurs at Wambolt Springs Province, Lake Valley HA (183), Lincoln County, Nevada.

5.5.19 Wambolt Springs Province

Springsnail species present in Wambolt Springs Province include the Lake Valley pyrg.

This spring occurs on private land in Lincoln County, Nevada (Figure 5.9). This spring province is in the Lake Valley HA (183), which is a designated hydrographic basin. The source of this province is a local aquifer. Wambolt Springs Province waters emanate at 1,815 m (5,955 ft) elevation. Wambolt Springs C and D are helocrene springs and Wambolt Spring B discharge from an old well casing and spring type where the spring (Sada 2017, p. XX).

This province currently consists of three connected springs (Wambolt Springs B, C, and D) and potentially two other springs (Wambolt Spring A and E) that support the only known population of Lake Valley pyrg. Wambolt Springs A and E were not located or surveyed in 2016. Golden *et al.* (2007, record number 69la18) surveyed a spring identified in their database as the "south wet meadow", which we determined is Wambolt Spring E. The Wambolt Springs Province appeared to be produced by groundwater from the mountainside being pushed out of the alluvial fan at the base of the mountains (Golden *et al.* 2007, p. 133). The source for springs in this province is the local aquifer. No other springsnails evaluated in this document are anticipated to occur in Lake Valley.

Surveys of Wambolt Springs B, C, and D were performed in 2004, 2009, and 2016. Lake Valley pyrgs were found in 2009 at Wambolt Spring A and 2004 at Wambolt Spring E.

- *Wambolt Spring B:* The springbrook length is 200 m (656 ft). Water discharges from the base of an old well casing. This spring is slightly disturbed by cattle grazing. Cattle activity has removed all riparian and aquatic vegetation immediately around the casing and appears to have little influence on springsnail abundance. Springsnails occupy 70 m (230 ft) of springbrook (163.4 m^2 (1,758.9 ft^2) of habitat).
- *Wambolt Spring C:* The springbrook length is 300 m (984 ft). This spring is in good condition and slightly disturbed by cattle grazing. Springsnails occupy 33 m (108 ft) of springbrook (75.2 m^2 (809.4 ft^2) of habitat).
- *Wambolt Spring D:* The springbrook length is 200 m (656 ft). This spring is in good condition and slightly disturbed by cattle grazing. Springsnails occupy 20 m (66 ft) of springbrook (33.3 m^2 (355.2 ft^2) of habitat).

Comment [PME70]: Map?

We compiled information on water quality and quantity at springs from several sources (Table 5.88). Maximum springbrook length was 300 m (984 ft). Surveys conducted in 2016 estimated the substrate to be 100 percent fines for Wambolt Springs B and C and 10 percent sand and 90 percent gravel for Wambolt Spring D. Wetted width ranged from 166.7 (65.6 in) to 233.3 cm (91.9 in) and wetted depth from 2.0 cm (0.8 in) to 3.4 cm (1.3 in). Bank cover ranged from 50 to 100 percent and emergent cover is from 64 to 100 percent. Cattails, rushes, spikerush, reeds, sedges, and watercress are present at this spring.

Table 5.88. Attribute measurements for Wambolt Springs Province.

Spring or Spring Province	Temperature °C (ºF)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)

Wambolt Spring A	16.9 (62.4)	-	297	-	8 (>0)	-
Wambolt Spring B	17.1–18.9 (62.8–66.0)	7.8	309–312	-	30–60 (0.02–0.04)	5.3 (2.1)
Wambolt Spring C	13.6–18.3 (56.5-65)	7.1–7.3	325–348	3.2	30–100 (0.02–0.06)	0.8 (0.3)
Wambolt Spring D	18.4–19.1 (65.1-66.4)	7.4–7.6	305–331	3.9	15–100 (0.01–0.06)	0

citation

Stressors present at this province include vegetation and soil disturbance, and spring modifications (Tables 5.89 and 5.90). The overall impact is low.

Table 5.89. Current and historic stressors for Wambolt Springs B and D.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Grazing and Browsing)	current	low	moderate	basic need	NC	M
Spring Modifications (Surface Water Diversion)	historic	low	small	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Table 5.90. Current stressors for Wambolt Spring C.

Stressors (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Grazing and Browsing)	current	low	small	basic need	NC	M

[1] D = Decreasing, I = Increasing, or NC = No Change
[2] L = Low, M = Moderate, H = High
See methodology section for explanation of column headings

Wambolt Springs Province occurs entirely on private lands not managed in accordance with any management or conservation plan. Wambolt Springs Province has two populations of Lake Valley pyrg. We determined that the habitat conditions at Wambolt Springs Province are appropriate to meet springsnail species needs. We expect that future conditions at this province will likely remain similar to current conditions as we have no information to indicate a change in trend or the addition of new stressors. Our confidence is moderate due mostly to the uncertainty associated with private land uses.

5.6 White River, Cave, and Lake Valleys – Springsnail Species and Current Population Conditions

5.6.1 White River Valley Pyrg

The White River Valley pyrg occurs in 7 springs or provinces in Nye and White Pine counties, Nevada. We determined that the White River Valley pyrg occurs in 7 populations that are synonymous with the springs and provinces identified in Table 5.91 below. It is an unusually large springsnail with 3.25 to 5.25 whorls. The shell is tan-brown and measures 1.4 to 4.6 mm (0.05 to 0.18 in) in height and 1.2 to 3.5 mm (0.05 to 0.14 in) in width. The White River Valley pyrg was described by Hershler (1998, pp. 37-39) who reported it from six springs in White River Valley, within Nye, Lincoln, and White Pine Counties, Nevada. The current distribution of this species includes Arnoldson Spring, Flag Springs, Camp Spring, Lund Spring, Preston Big Spring, Nicholas Spring, Cold Spring, and Indian Spring (though not confirmed) (Figure 5.6). All spring locations occur on private land except Flag springs, which occur on Kirch Wildlife Management Area (WMA; owned by Nevada Department of Wildlife). The Flag pyrg also occupies springs on Kirch WMA (Sada 2017).

All survey records for the White River Valley pyrg found spring temperatures ranged between 15.6 and 22.4 ºC (60.0 and 72.3 ºF), DO between 3.5 and 6.5 mg/L (ppm), pH between 7.45 and 8.4, and conductivity between 300 and 511 µS/cm. Discharge measurements across all sampling dates were highly variable between 2 and 8,500 L/min (0.001 and 5.0 cfs), and velocity measurements were between 0 and 54 cm/sec (21.2 in/sec).

Sada (2017) sampled five of the springs where this species occurred in 2016. In total, the White River Valley pyrg were documented in 650 m (2,133 ft) of springbrook, including 1,485 m^2 (15,984 ft^2) of habitat in 2016.

The private landowner did not give permission to sample Arnoldson Spring in 2016, but observation of Arnoldson Spring from the highway indicated that its discharge was reduced from years past, and the spring was highly disturbed, which suggests springsnails may be extirpated from this site. Hershler sampled this spring in 1992 and found White River Valley pyrg to be common (Sada 2016, entire).

Surveyors sampled Flag Springs in 1992, 2009, and 2016. The White River Valley pyrg and Flag pyrg have been recorded in Flag Springs A and Flag Springs B during all surveys but were not found in the Flag Spring C (southern) spring during the 2016 survey. Sada (2017, p. XX) found 210 springsnails at Flag Spring A in 2016, which consisted of 36 percent White River Valley pyrg and 64 percent Flag pyrg.

Surveyors sampled Camp Spring in 1992 and 2016. During the surveys, surveyors determined that White River Valley pyrg were abundant but found no Flag pyrgs in at Camp Spring in 2016.

Lund Spring is a relatively large spring and was sampled in 2008 and 2016. White River Valley pyrgs were absent in the area where bathing occurs, but occur on substrate on the periphery and along the banks of the spring and springbrook where they were abundant.

Preston Big Spring was surveyed in 1992, 2005, and 2016. Springsnails occupied 300 m (984 ft) of springbrook (657 m^2 (7,072 ft^2) of habitat), which was approximately 50 m (164 ft) upstream from a USGS gauge. They were found only on cobble substrate, and absent from vegetation or other types of habitat. Sada (2017, p. XX) considered White River Valley pyrgs to be common at this spring.

The landowner for Nicholas and Cold Springs did not permit surveyors access the springs in 2016. Springsnails were present at Cold Spring in 1999 but not collected and identified to species. No survey data was available for Cold Spring other than a record that White River Valley pyrg was detected in 1999, when the species was also detected at Nicholas Spring. Golden (2007, p. 161) found only hydrobiids shells of unknown species at Nicholas Spring. No recent abundance estimates are available for these springs.

Table 5.91. Relative abundance and springbrook data of White River Valley pyrg.

Spring or Spring Province	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance	Source
Arnoldson	6/29/1992	-	-	common	Hershler 1992
	9/12/2006	121	-	common	Sada 2005
	7/2/2016	50	-	none	Sada 2017
Flag Spring A	3/2/2005	603	170	abundant	Sada 2005
	7/9/2009	500	90	common	Sada 2016
	6/6/2016	2000	170	abundant	Sada 2016
Flag Spring B	3/2/2005	88	-	common	Sada 2005
	7/9/2009	500	80	common	Sada 2016
	6/6/2016	600	60	common	Sada 2017
Flag Spring C	3/2/2005	105	-	common	Sada 2005
	7/9/2009	65	1	scarce	Sada 2016
	6/6/2016	-	-	none	Sada 2017
Camp Spring	6/28/1992	-	-	abundant	Sada 2016
	6/8/2016	250	55	abundant	Sada 2017
Lund Spring	7/22/2008	60	-	abundant	Sada 2016
	5/4/2016	65	65	abundant	Sada 2017
Preston Big Spring	6/29/1992	-	-	scarce	Sada 2016
	6/14/2005	217	-	common	Sada 2016
	2007	217	50	common	Golden 2007
	7/2/2016	550	300	common	Sada 2017
Nicholas Spring	9/9/1999	-	-	(present)	Sada 2016
	2007	-	38	common *	Golden 2007
Cold Spring	9/9/1999	-	-	(present)	Sada 2016

*identity of species not confirmed

We expect each spring where the White Rivery Valley pyrg occurs contains a population of the species (Table 5.92). Arnoldson Spring is the only spring where White River Valley springsnail presence or absence could not be confirmed in 2016. Other than Arnoldson Spring, we assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. Substrate and vegetation was ranked moderate or high for those springs with abundant or common determinations of springsnail abundance. There is insufficient data on springsnail abundance at Cold and Nicholas springs to determine substrate and vegetation condition.

Table 5.92. Current conditions of White River Valley pyrg.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Flag Spring Province	Adequate	High	High	Adequate	High/Moderate
Camp Spring	Adequate	High	High	Adequate	High/Moderate
Lund Spring	Adequate	High	High	Adequate	High/Moderate
Preston Big Spring	Adequate	High	High	Adequate	Moderate
Arnoldson	Unknown	Low	Low	Inadequate	Low
Cold Spring	Adequate	Insuff. data	Low	Adequate	Low
Nicholas Spring	Adequate	Insuff. data	Low	Adequate	Low

White River Valley pyrg in Flag Springs was ranked high/moderate due to their large spring sizes, high spring discharge, and reference condition of Flag Springs A and B and extent of habitat occupied by springsnails in these springs; however, springsnails were not detected at Flag Spring C in 2016. Camp Spring was ranked high/moderate due to abundant populations in 1992 and 2016, extent of habitat occupied by springsnails, and moderate disturbance. Lund was ranked high/moderate due to its large size, high spring discharge, abundant populations in 2008 and 2016, extent of habitat occupied, and stressors present. Preston Big Spring was ranked moderate due to its large size; high spring discharge; scarce abundance in 1992 but common in 2005, 2007, and 2016; extent of habitat occupied; and stressors present. Arnoldson Spring is ranked low due to low discharge and flow, presumed low abundance, low extent of habitat estimated to be occupied by springsnails, and stressors present. Cold and Nicholas springs were ranked low due to observed impacts to the spring and springbrook and other stressors present.

We determined the overall current condition of the White River Valley pyrg at all sites is high to moderate. Although three populations are low condition, the White River Valley pyrg in Flag Springs, Camp Spring, Lund Spring, and Preston Big Spring appears to be thriving.

5.6.2 Butterfield Pyrg

The Butterfield pyrg is a small springsnail with 3.75 to 4.25 whorls. The shell is light-brown and measures 1.6 to 2.1 mm (0.6 to 1.8 in) in height and 1.2 to 1.6 mm in (0.5 to 0.6 in) width. The Butterfield pyrg was described by Hershler (1998) based on specimens collected by Hershler and Hovingh in 1992 from Butterfield Springs on private land in White River Valley, Nye County, Nevada, which is the only location this species is known to occur (Figure 5.6). The Hardy pyrg also occurs at Butterfield Springs.

All survey records for the Butterfield pyrg found spring temperatures ranged between 16.3 and 16.9 ºC (61.3 and 62.4 ºF), DO between 6.6 and 7.2 mg/L (ppm), pH between 7.8 and 8.2, conductivity between 310 and 384 µS/cm, discharge measurements between 70 and 600 L/min (0.041 and 0.353 cfs), and velocity measurements were between 18.3 and 28.6 cm/sec (7.2 and 11.26 in/sec).

Surveys for the Butterfield pyrg have been intermittent (Table 5.93) Surveys were conducted at three of the four springs Butterfield C, D, and E) in 2016. Two springs (Butterfield Springs A and B), where springsnails were reported in 2008 could not be located in 2016. Butterfield Spring E was discovered in 2016 and is the largest spring in the province, supporting an abundant population of springsnails. We determined that a single population of springsnails occurs in the Butterfield Springs Province due to connected water sources. In 2016, Butterfield and Hardy pyrgs were recorded in 440 m (1,443 ft) of springbrook (464.8 m^2 (5,003 ft^2) of habitat). Sada (2016) collected 165 springsnails from Butterfield Spring E and found that the Butterfield pyrg comprised 94 percent of the assemblage with the remaining 6 percent was Hardy pyrgs.

Table 5.93. Relative abundance and springbrook data of Butterfield pyrg.

Spring	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance	Source
Butterfield A and B	7/23/2008	500	70	abundant*	Sada 2016
Butterfield C	6/28/1992	-	-	abundant	Sada 2016
	7/23/2008	20	12	common*	Sada 2016
Butterfield D	7/23/2008	30	30	common *	Sada 2016
Butterfield Springs C and D	7/22/2008	60	-	abundant *	Sada 2016
	6/7/2016	40	40	scarce	Sada 2017
Butterfield Spring E	6/6/2016	2000	400	abundant	Sada 2017

*Surveys in 2008 documented springsnails in four springs within the Butterfield Spring province, however, no collections or attempts were made to determine relative abundance or whether or not both species were present in each spring.

Table 5.94. Current conditions of Butterfield pyrg.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Butterfield Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate

In 2016, the Butterfield pyrg was found in 3 of 4 springs (Butterfield Spring C, D, and E) (Table 5.93). We assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. We ranked substrate and vegetation as moderate or high for those springs with abundant or common determinations of springsnail abundance. We considered spring diversions, impoundments, and barriers to spring flow to rank free-flowing water.

Butterfield Springs were ranked moderate overall due to size of springs, spring discharge, abundance (common or abundant), extent of habitat occupied by springsnails in these springs, and stressors affecting the species (Table 5.94). We are not able to consider abundance in 2016 for the Butterfield pyrg due to the potential occurrence of other pyrgs (Hardy pyrgs) and lack of identification of those pyrgs sampled.

We determined the overall current condition of the Butterfield pyrg is moderate (Table 5.94). The spring province is surrounded by extensive development and disturbance. Butterfield Springs A and B could not be found in 2016 and may no longer persist. All springs occupied by the Butterfield pyrg have been dredges and water is periodically pumped and removed from Butterfield Springs C and D, where pyrgs were scarce in 2016. The discovery of a Butterfield pyrgs at a new location, where they are abundant in a large spring, supports a moderate ranking for this species in consideration of the stressors present and potential loss of pyrgs at Butterfield Springs A and B.

5.6.3 Hardy Pyrg

The Hardy pyrg occurs in White River Valley, Nye County, Nevada. The current distribution of this species includes Butterfield Springs, Emigrant Springs, Arnoldson Spring, Hardy Springs, Silver Spring, Ruppes Boghole Spring, and Parker Station Spring (Figure 5.6). Springsnails at Indian Springs may be Hardy pyrgs, but samples have not been collected and identified to confirm the species of pyrg present.

The Hardy pyrg was originally described by Hershler (1998, pp. 47-50) based on specimens collected by Landye in 1973 at Hardy Springs province. It is a small to medium springsnail with 3.5 to 4.75 whorls. The shell is tan and measures 1.6 to 3.9 mm (0.6 to 1.5 in) in height and 1.2 to 3.0 mm (0.5 to 1.2 in) in width.

All survey records for the Hardy pyrg found spring temperatures ranged between 12.6 and 24.6 ºC (54.7 and 76.3 ºF), DO between 2.6 and 8.5 mg/L (ppm), pH between 7.5 and 8.2, conductivity between 297 and 550 µS/cm, discharge measurements between 1 and 600 L/min (>0 and 0.353 cfs), and velocity measurements were between 0 and 36 cm/sec (14.2 in/sec).

The Hardy pyrg was found in 11 springs (Table 5.95) and 5 populations during 2016 surveys. The populations include Butterfield, Emigrant, Hardy Springs A-E, Hardy Spring F, and Parker Station. Landowners did not provide permission in 2016 to survey Silver Springs (with two locations documented in 2008) and Ruppes Bog Hole (two historical locations). Surveys performed in 2009 and 2012 found that Hardy pyrgs may be extirpated from the two Ruppes Boghole springs due to spring drying. It may occur in Ruppes Boghole but could not be confirmed in 2016. Hardy pyrgs were captured and released from approximately 940 m (3,084 ft) of springbrook and occupied approximately 1,290 m^2 (13,885 ft^2) of habitat. All springs were degraded by cattle, horses, diversion, or impoundment, or dredging. Restoration activities were not observed any spring.

Surveys were conducted at three of the four springs of the Butterfield Springs Province in 2016. Two springs (Butterfield Springs A and B) where springsnails were reported in 2008 could not be located in 2016. Hardy pyrg was found at a new location (Butterfield Spring E) in 2016. In 2016, Butterfield and Hardy pyrgs were recorded in 440 m (1,444 ft) of springbrook (464.8 m^2 of habitat). Sada (2017) collected 165 springsnails from Butterfield Spring E and found that Butterfield pyrg comprised 94 percent of the assemblage with the remaining 6 percent Hardy pyrg.

Sada (2017, p. XX) observed springsnails only at Emigrant Spring I in the Emigrant Springs Province and not in the other five springs in the province, where they were common or abundant in 2008 and 2010. Sada (2017, p. XX) determined that Hardy pyrg and Emigrant pyrg (*Pyrgulopsis gracilis*) comprised 19 percent and 81 percent of the assemblage, respectively at Emigrant Spring I.

The private landowner did not give permission to sample Arnoldson Spring in 2016, but observation of Arnoldson Spring from the highway indicated that its discharge was reduced from years past, and the spring was highly disturbed, which suggests springsnails may be extirpated from this site. Hershler sampled this spring in 1992 and found White River Valley pyrgs to be common (Sada 2016, entire). Observation of Arnoldson Spring from the highway in 2016 indicated that discharge had been reduced from years past, and the spring was highly disturbed.

The Hardy pyrg was found in six springs in the Hardy Springs Province during 2016 surveys. Hardy Spring L, where they were reported to be scarce in 2008, could not be found in 2016. Hardy Springs A-E are close to one another and flowed westward into a single springbrook that was impounded approximately 70 m (230 ft) downstream from the eastern-most spring source. Springsnails occurred in this springbrook until the impoundment, and not further downstream. A number of additional springs occur in this province, but they are located distantly west of springsnail habitats, and their habitat is not suitable for springsnails. Hardy pyrgs occur as two populations in the Hardy Springs Province, Hardy Springs A-E and Hardy Spring F. If extant, Hardy Springs G and L may provide additional populations of the Hardy pyrg due to their isolation from other springs in the province.

Parker Station is relatively large, valley floor spring was wide, deep, and characterized by deep, fine sediments that prevented surveyor access to the channel in 2016. Hardy pyrg could only be sampled along the banks where they occurred only in patches of watercress, which suggests that springsnails also occupied this vegetation in the channel. They did not occupy grasses, rushes, and spikerush growing along at least 75 cm (30 in) along each side of the springbrook. Springsnails occupied 150 m (492 ft) of springbrook and an estimated 525 m^2 (1,722 ft^2) of watercress habitat, which excludes springbrook margins with grasses, rushes, and spikerush.

Table 5.95. Relative abundance and springbrook data of Hardy pyrg.

Spring	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance	Source
Butterfield A and B	7/23/2008	500	70	abundant*	Sada 2016
Butterfield C	6/28/1992	-	-	abundant	Sada 2016
	7/23/2008	20	12	common*	Sada 2016
Butterfield D	7/23/2008	30	30	common *	Sada 2016
Butterfield Springs C and D	7/22/2008	60	-	abundant *	Sada 2016
	6/7/2016	40	40	scarce	Sada 2017
Butterfield Spring E	6/6/2016	2000	400	abundant	Sada 2017
Emigrant Spring A	7/23/2008	75	75	abundant **	Sada 2016
	6/15/2010	30	30	common	Sada 2016
	6/7/2016	70	0	none	Sada 2017
Emigrant Spring B	7/23/2008	40	0	none	Sada 2016
	6/7/2016	120	0	none	Sada 2017
Emigrant Spring D	6/7/2016	150	0	none	Sada 2017
Emigrant Spring E	6/7/2016	150	0	none	Sada 2017
Emigrant Spring F	6/7/2016	75	0	none	Sada 2017
Emigrant Spring H	7/23/2008	35	35	abundant	Sada 2016
	6/7/2016	35	0	none	Sada 2017
Emigrant Spring I	6/7/2016	300	85	common	Sada 2017
Emigrant Spring J	6/7/2016	70	0	none	Sada 2017
Arnoldson	6/29/1992	-	-	common	Sada 2016
	9/12/2006	121	-	common	Sada 2016
	7/2/2016	50	0	none	Sada 2017
Hardy Spring A	7/22/2008	1000	72	common	Sada 2016
	6/14/2012	1000	50	scarce	Sada 2016
	6/8/2016	72	72	abundant	Sada 2017
Hardy Spring B	7/22/2008	30	30	common	Sada 2016
	6/8/2016	45	45	abundant	Sada 2017
Hardy Spring C	7/22/2008	0	0	none	Sada 2016
	6/8/2016	11	10	scarce	Sada 2017
Hardy Spring D	7/22/2008	18	18	common	Sada 2016
	6/8/2016	21	21	abundant	Sada 2017
Hardy Spring E	7/22/2008	12	0	none	Sada 2016
	6/8/2016	12	12	common	Sada 2017
Hardy Spring F	7/22/2008	35	35	common	Sada 2016
	6/8/2016	60	55	abundant	Sada 2017
Hardy Spring G	7/22/2008	200	80	common	Sada 2016
Hardy Spring L	7/22/2008	100	50	scarce	Sada 2016
Silver Spring Province	6/28/1992	-	-	common	Sada 2016
Silver Spring A	7/22/2008	110	-	none	Sada 2016

Silver Spring B	7/22/2008	45	3	scarce	Sada 2016
Silver Spring C	7/22/2008	45	3	scarce	Sada 2016
Ruppes Boghole Province	6/15/2010	40	0	none	Sada 2016
Ruppes Boghole A	6/29/1992	-	-	common	Sada 2016
	6/14/2012	-	-	none	Sada 2016
Ruppes Boghole B	7/9/2009	-	-	none	Sada 2016
	6/14/2012	-	-	none	Sada 2016
Parker Station Spring	6/29/1992	-	-	abundant	Sada 2016
	7/2/2016	400	150	abundant	Sada 2017

*Surveys in 2008 documented springsnails in four springs within the Butterfield Spring province, however, no collections or attempts were made to determine relative abundance or whether or not both species were present in each spring.

** Surveys in 2008 documented springsnails as common or abundant in spring five springs within this province. No collections were made during these surveys, and no attempts were made to determine whether or not the two species were present in each spring.

Table 5.96. Current conditions of Hardy pyrg.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Butterfield Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate
Emigrant Springs Province	Adequate	Moderate	Moderate/High	Adequate	Moderate
Hardy Springs A-E	Adequate	Moderate	High	Adequate	Moderate
Hardy Spring F	Adequate	Moderate	High	Adequate	Moderate
Parker Station Spring	Adequate	Moderate	High	Adequate	High/Moderate
Silver Spring Province	Inadequate	Moderate	Low	Inadequate	Low
Ruppes Boghole Province	Inadequate	Low	Low	Inadequate	Low

In 2016, the Hardy pyrg was found in seven springs (Table 5.95). We assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. We ranked substrate and vegetation as moderate or high for those springs with abundant or common determinations of springsnail abundance. We considered spring diversions, impoundments, and barriers to spring flow to rank free-flowing water.

We ranked Butterfield Springs as moderate overall due to size of springs, spring discharge, abundance (common or abundant), extent of habitat occupied by springsnails in these springs, and stressors affecting the species (Table 5.96). We are not able to consider abundance in 2016 for the Hardy pyrg due to the potential occurrence of other pyrgs (Butterfield pyrgs) and lack of identification of those pyrgs sampled. We determined the overall current condition of the Butterfield pyrg is moderate (see discussion above for Butterfield pyrg).

We ranked Emigrant and Hardy Springs provinces as moderate due to size of springs, number of springs occupied by Hardy pyrgs, spring discharge, abundance (common or abundant), extent of habitat occupied by springsnails, and stressors affecting the species. We ranked Parker Station Spring as high/moderate based on the size of the spring, extent of area occupied by springsnails, and stressors (disturbance).

Silver Springs and Ruppes Boghole Springs were not surveyed in 2016. Our low ranking for these springs is based on data collected in 2008 and prior. The springbrook length and extent occupied by springsnails were low as observed during surveys. Persistence or abundance of Hardy pyrgs at Silver Springs and Ruppes Boghole Spring could not be determined in 2016.

5.6.4 Flag Pyrg

Flag pyrg occurs in White River Valley, Nye County, Nevada in two populations, Meloy Spring and Flag Springs (Figures 5.6 and 5.8). It co-occurs with White River Valley pyrg at Flag Springs. The Flag pyrg was described by Hershler (1998, pp. 39-41) based on specimens collected by Landye in 1973 at Flag Springs. The Flag pyrg is a small springsnail with 2.75 to 3.75 whorls. The shell is light brown and measures 1.2 to 2.2 mm (0.05 to 0.09 in) in height and 1.0 to 2.0 mm (0.04 to 0.08 in) in width.

All survey records for the Flag pyrg found spring temperatures ranged between 16.4 and 22.4 ºC (61.5 and 72.3 ºF), DO 5.3 mg/L (ppm), pH between 7.5 and 8.4, conductivity between 300 and 482 µS/cm, discharge measurements between 1,400 and 2,500 L/min (0.82 and 1.47 cfs), and velocity measurements were between 48 and 54 cm/sec (18.8 and 21.2 in/sec).

Flag Springs Province supports a large Flag pyrg population. Sada (2017, pp. XX) found Flag pyrg in all of its known locations, where they occupied a total of 265 m (869 ft) of springbrook and 566.1 m^2 (6,093.4 ft^2) of habitat. Springsnails have been recorded in Flag Spring A and Flag Spring B but Sada (2017, p. XX) did not find them at Flag Spring C where they were recorded as scarce during surveys in 2009. Sada (2017) collected a sample of 210 springsnails at Flag Spring A and determined that 36 percent were White River Valley pyrgs and 64 percent were Flag pyrgs. Although springsnails were not collected from Flag Spring B, the quality of this habitat suggests that this spring also supports both of these species, but the relative abundance of each species may differ.

Meloy Spring also supports a large Flag pyrg populations. The Flag pyrg occupies 35 m (115 ft) of springbrook (33.0 m^2 (3,552 ft^2) of habitat) at Meloy Spring. Stressor impacts on Meloy Spring are low and the overall species' needs are provided by the spring.

Comment [CSE71]: Need to double check this information.

Table 5.97. Relative abundance and springbrook data of Flag pyrg.

Spring or Spring Province	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance	Source
Meloy Spring	6/25/1992	-	-	abundant	Sada 2016
	7/2/2016	35	35	abundant	Sada 2017
Flag Spring A	3/2/2005	603	170	abundant	Sada 2016
	7/9/2009	500	90	common	Sada 2016
	6/6/2016	2000	170	abundant	Sada 2017
Flag Spring B	3/2/2005	88	-	common	Sada 2005
	7/9/2009	500	80	common	Sada 2016
	6/6/2016	600	60	common	Sada 2017
Flag Spring C	3/2/2005	105	-	common	Sada 2016
	7/9/2009	65	1	scarce	Sada 2016
	6/6/2016	-	-	none	Sada 2017

Table 5.98. Current conditions of Flag pyrg.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Flag Spring Province	Adequate	High	High	Adequate	High/Moderate
Meloy Spring	Adequate	High	High	Adequate	High/Moderate

We expect all springs listed in the above table contain populations of the Flag pyrg, except possibly Flag Spring C (Table 5.97). We assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. Substrate and vegetation was ranked moderate or high for those springs with abundant or common determinations of springsnail abundance (Table 5.98).

Flag Spring A and B was ranked high/moderate due to their large spring size, common or abundant occurrence at two of three springs, high spring discharge, and reference condition of Flag Springs A and B and extent of habitat occupied by springsnails in these springs; however, springsnails were not detected at Flag Spring C in 2016. Meloy Spring was ranked high/moderate due to no observed changes in condition since the 1990s, moderate length and area of springsnail habitat, and stressors present.

We determined the overall current condition of the Flag pyrg at all sites is high to moderate (Table 5.98). Although the pyrg may be present in low numbers or absent at Flag Spring C, all remaining population appear to be thriving.

5.6.5 Lake Valley Pyrg

Lake Valley pyrg is known only from Wambolt Springs, Lake Valley, Lincoln County, Nevada (Figure 5.9). This species was described by Hershler (1998, pp. 56-57) based on specimens collected by Hershler and Hovingh in 1992 from Wambolt Springs. Lake Valley pyrg is a medium springsnail with 4.5 to 5.0 whorls. The shell is tan and measures 2.2 to 2.7 mm (0.9 in to 1.1 in) in height and 1.4 to 2.0mm (0.6 to 0.8 in) in width.

All survey records for the Lake Valley pyrg found spring temperatures ranged between 13.6 and 19.3 ºC (56.5 and 66.7 ºF), DO 4.2 mg/L (ppm), pH between 7.05 and 8.3, conductivity between 297 and 326 µS/cm, discharge measurements between 8 and 100 L/min (0.005 and 0.059 cfs), and velocity measurements were between 0 and 5.3 cm/sec (2.09 in/sec).

The Wambolt Springs Province consists of five springs. Surveys in 2009 found Lake Valley pyrg in three of four springs surveyed (Wambolt springs A, C, and D), which closely align in a meadow. Sada (2017) considered Lake Valley pyrg abundant in 123 m (649 ft) of springbrook and 271.9 m^2 (2,926.7 ft^2) of habitat in this province (Table 5.99).

Table 5.99. Relative abundance and springbrook data of Lake Valley pyrg.

Spring or Spring Province	Survey Date	Springbrook Length (m)	Occupied Length of Springbrook (m)	Relative Abundance (N, S, C, A)	Source
Wambolt Spring A	7/8/2009	7	4	scarce	Sada 2016
Wambolt Spring B	9/18/2004	-	-	scarce	Sada 2016
	7/8/2009	0	0	none	Sada 2016
	7/2/2016	200	70	abundant	Sada 2017
Wambolt Spring C	9/18/2004	268	-	common	Sada 2016
	7/8/2009	300	25	common	Sada 2016
	7/2/2016	300	33	abundant	Sada 2017
Wambolt Spring D	9/18/2004	268	-	scarce	Sada 2016
	7/8/2009	400	40	common	Sada 2016
	7/2/2016	200	20	common	Sada 2017
Wambolt Spring E	9/18/2004	-	-	scarce	Sada 2016

Table 5.100. Current conditions of Lake Valley pyrg.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Wambolt Springs Province	Adequate	High	Moderate	Adequate	Moderate

The Lake Valley pyrg occurs in Wambolt Springs 3 of 4 springs (Wambolt B, C, and D) surveyed in 2016 (Table 5.99). We assume that if the species is present within a spring or spring province, the water quality and discharge are adequate. Substrate and vegetation was ranked moderate or high for those springs with abundant or common determinations of springsnail abundance (Table 5.100). Free-flowing water was moderate due to the small amount of flow and small spring size; historical diversions remain but are not in use.

Wambolt Springs were ranked moderate due to the small size of the three springs, amount of spring discharge, abundance (common or abundant) of springsnails, extent of habitat occupied by springsnails in these springs; however, Wambolt Springs A and E were not found or surveyed in 2016.

We determined the overall current condition of the Lake Valley pyrg is moderate (Table 5.100). Wambolt Springs B and C support abundant populations of Lake Valley pyrgs and the pyrg is common at Wambolt C Spring. Spring developments have modified the springs and cattle disturb habitat but we determined that the overall effect of the stressors on the Lake Valley pyrg is low.

5.7 Spring Valley HA (184) and Snake Valley HA (195), Nevada, and House, Canyon, and Pahvant Mountain Ranges HAs (285, 286, and 287), Utah – Springs and Spring Provinces and Current Habitat Conditions

The springsnail species present in the Spring and Snake valleys in Nevada and in the House, Canyon, and Pahvant Mountain Ranges in Utah is the bifid duct pyrg (Figures5.9-5.11).

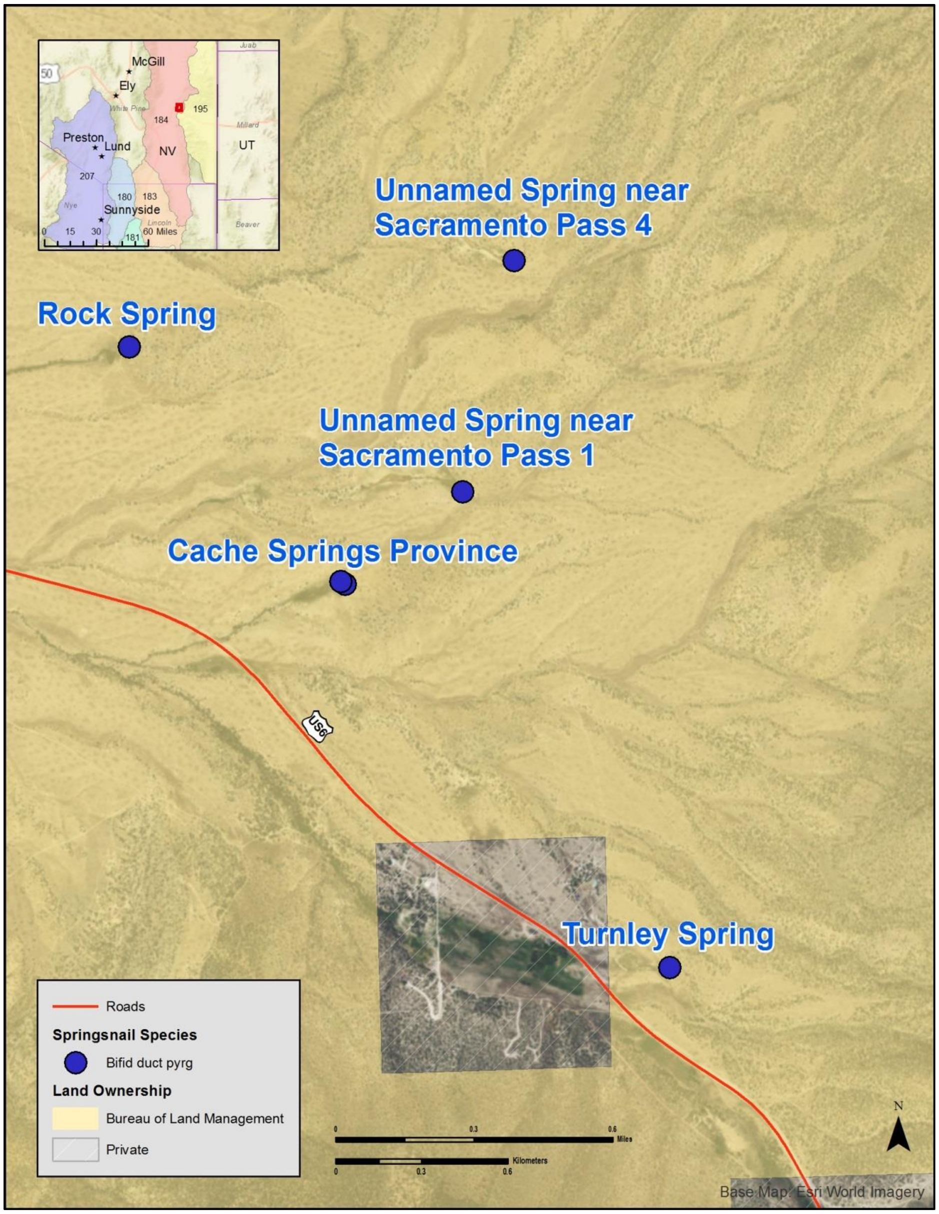


Figure 5.9. Map of land ownership and location of springs occupied by the bifid duct pyrg in the Spring Valley HA (184), White Pine County, Nevada.

5.7.1 Turnley Spring

Turnley Spring is located in the Sacramento Pass that divides the northern and southern sections of the Snake Range in eastern White Pine County, Nevada (Figure 5.9). This spring is located on BLM land at an elevation of 2,042 m (6,700 ft), and spring flow is fed from a mountain block aquifer.

We compiled information on water quality and quantity at springs from several sources (Table 5.101). Sada (2017, p. 104) recorded mean WW, WD, and CV as 300 cm (118 in), 50 cm (19.7 in), and 0.0 cm/sec, respectively. Surveys conducted in 2016 estimated emergent cover at 10 percent and bank cover at 60 percent (Sada 2017, entire). Substrate consisted of 20 percent sand and 80 percent gravel. Pond snails (*Lymnaea* sp.) were the only gastropod found in the spring, and watercress was the only vegetation noted during 2016 surveys.

Comment [PME72]: First time these acronyms have been used?

Table 5.101. Attribute measurements for Turnley Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Turnley Spring	11.82–14.44 (53.3–58)	7.0–7.35	390–436	2.50–7.27	0–60.0 (0–0.04)	0

Golden *et al.* 2007, p. 109; Sada 2016, entire; Sada 2017, entire.

Sada (2017, p. 106) reported water diversion, impoundment, and channel modification as the primary stressors affecting Turnley Spring (Table 5.102). Spring flow is completely captured in a spring box that diverts and pipes all of the water to nearby pastures on private land. Surface water is now restricted to a 300-cm (118-in) wide, deep circular pool, which has eliminated the springbrook and precludes the ability to estimate discharge. Surveys conducted by Hershler in 1991 and Sada in 1998 reported the bifid duct pyrg as extant, but scarce, and both surveys noted the spring was highly disturbed by diversion. Schwaneflugel (Sada 2016, entire) reported the species as common in 2009, but surveys conducted by BIOWEST in 2006 (Golden *et al.* 2007, p. 123) and Sada in 2016 (Sada 2017, p. 104) reported the species as absent. Sada (2017, p. 104) considers springsnails extirpated at this spring. We expect that future conditions associated with these stressors will likely remain similar to current conditions as we have no information that would indicate otherwise.

Table 5.102. Current stressors for Turnley Spring.

Stressor (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Spring Modifications from the following Sources						
Surface Water Diversion	Current	High	High	Significant Mortality	NC	M
Impoundment	Current	High	High	Significant Mortality	NC	M
Channel Modification	Current	High	High	Significant Mortality	NC	M

[1] D = Decreasing; I = Increasing; NC = No Change
[2] L = Low; M = Moderate; H = High
See methodology section for explanation of column headings

Turnley Spring occurs on BLM land managed for multiple uses. Management of multiple use land in this area is under the direction of the BLM's Ely District RMP (see Appendix A); however, we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.7.2 Cache Springs Province

Cache Springs (also known as Unnamed Springs near Sacramento Pass 2A and 2B) is a province of two spring sources located in the Sacramento Pass that divides the northern and southern sections of the Snake Range in eastern White Pine County, Nevada. This spring province is located on BLM land at an elevation of 1,958 m (6,424 ft), and spring flow is fed from the local mountain block aquifer.

We compiled information on water quality and quantity at springs from several sources (Table 5.103). Sada (2017, p. 100) recorded mean wetted width, wetted depth, and current velocity for Cache Spring A as 214.4 cm (84.4 in), 2.4 cm (0.9 in), and 0.2 cm/sec (0.08 in/sec), and for Cache Spring B as 80.0 cm (31.5 in), 2.7 cm (1.1 in), and 0.0 cm/sec, respectively. At Cache Spring A, surveys conducted in 2016 estimated emergent cover at 81.1 percent and bank cover at 93.3 percent (Sada 2017, entire). Substrate consisted of 60 percent fines, 20 percent sand, and 20 percent gravel. Amphipods were present, and the dominant vegetation consisted of rushes, reeds, and watercress. At Cache Spring B, estimated emergent cover was 86.7 percent and bank cover was 91.7 percent. Substrate consisted of 100 percent fines. Amphipods were present, and the dominant vegetation consisted of rushes and sedges.

Table 5.103. Attribute measurements for Cache Springs Province.

Spring or Spring Province	**Temperature °C (°F)**	**pH**	**Cond (µS/cm)**	**DO mg/L (ppm)**	**Flow L/min (cfs)**	**Velocity cm/sec (in/sec)**
Cache Spring A	11.96–12.3 (53.5–54.1)	7.52	411–442	-	20–25 (0.01)	0.2 (0.08)
Cache Spring B	12.51–13.6 (54.5–56.5)	7.43	425–510	-	3–5 (>0)	0

Sada 2016, entire; Sada 2017, entire.

Sada (2017, p. 106) reported water diversion, impoundment, channel modification, and livestock use as the primary stressors affecting these springs (Table 5.104). Vegetation and substrate at both springs are moderately disturbed by livestock. The channel of Cache Spring A, the larger of the two springs, has been dredged in the past and there is evidence of old berms that impounded water. These obstructions no longer pool water in the springbrook and do not appear to be currently affecting springsnail habitat. We expect that future conditions associated with these stressors will likely remain similar to current conditions as we have no information that would indicate otherwise.

Table 5.104. Current stressors for Cache Springs Province.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]

Vegetation and Soil Disturbance (Grazing and Browsing)	Current	Moderate	Moderate	Basic Need	NC	M
Spring Modifications from the following Sources						
Surface Water Diversion	Current	Moderate	Moderate	Basic Need	NC	M
Impoundment	Current	Moderate	Moderate	Basic Need	NC	M
Channel Modification	Current	Moderate	Moderate	Basic Need	NC	M

[1] D = Decreasing; I = Increasing; NC = No Change
[2]L = Low; M = Moderate; H = High
See methodology section for explanation of column headings

Cache Springs occurs on BLM land managed for multiple uses. Management of multiple use land in this area is under the direction of the BLM's Ely District RMP (see Appendix A); however, we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.7.3 Rock Spring

Rock Spring (also known as Unnamed Spring near Sacramento Pass 3) is located in the Sacramento Pass that divides the northern and southern sections of the Snake Range in eastern White Pine County, Nevada. This spring is located on BLM land at an elevation of 1,942 m (6,371 ft), and spring flow is fed from a mountain block aquifer that discharges from the base of limestone bedrock.

We compiled information on water quality and quantity at springs from several sources (Table 5.105). Sada (2017, p. 99) recorded mean WW, WD, and CV as (79.7 in), 2.3 cm (0.9 in), and 2.4 cm/sec (0.9 in/sec), respectively. Surveys conducted in 2016 estimated emergent cover at 87.5 percent and bank cover at 78.1 percent (Sada 2017, entire). Substrate consisted of 10 percent sand and 90 percent gravel. Amphipods were detected in the spring, and vegetation consisted of spikerush, salt grass, and watercress.

Table 5.105. Attribute measurements for Rock Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Rock Spring	11.99–13.03 (53.6–55.5)	7.3–7.98	445–671	8.34	30–50 (0.02–0.03)	2.4 (0.9)

Albrecht *et al.* 2009, p. 17; Sada 2017, entire.

The primary stressors affecting Rock Spring are water diversion, impoundment, channel modification, and minor to moderate disturbance to vegetation and substrate from livestock use and a road that crosses the springbrook about 30 m downstream from the source (Sada 2017, pp. 100 and 106; Table 5.106). The springbrook is impounded about 80 m below the source and downstream from springsnail habitat. A gage measuring discharge is located several meters

Comment [PME73]: Both "gage" and "gauge" have been used in this document – probably should pick one and stick with it.

below the road. We expect that future conditions associated with these stressors will likely remain similar to current conditions as we have no information that would indicate otherwise.

Table 5.106. Current stressors for Rock Spring.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance from the following Sources						
Grazing and Browsing	Current	Moderate	Moderate	Basic Need	NC	M
Roads	Current	Low	Small	Basic Need	NC	M
Spring Modifications from the following Sources						
Surface Water Diversion	Current	Moderate	Moderate	Basic Need	NC	M
Impoundment	Current	Moderate	Moderate	Basic Need	NC	M
Channel Modification	Current	Moderate	Moderate	Basic Need	NC	M

[1] D = Decreasing; I = Increasing; NC = No Change
[2] L = Low; M = Moderate; H = High
See methodology section for explanation of column headings

Rock Spring occurs on BLM land managed for multiple uses. Management of multiple use land in this area is under the direction of the BLM's Ely District RMP (see Appendix A); however, we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.7.4 Unnamed Spring Near Sacramento Pass #1

Unnamed Spring near Sacramento Pass # 1 is located near Cache Springs in the Sacramento Pass that divides the northern and southern sections of the Snake Range in eastern White Pine County, Nevada. This spring is located on BLM land at an elevation of 1,976 m (6,483 ft), and spring flow is fed from the local mountain block aquifer.

We compiled information on water quality and quantity at springs from several sources (Table 5.107). Sada (2017, p. 100) recorded mean WW, WD, and CV as 239.2 cm (94.2 in), 2.4 cm (0.9 in), and 1.1 cm/sec (0.43 in/sec), respectively. Surveys conducted in 2016 estimated emergent cover at 82.5 percent and bank cover at 84.6 percent (Sada 2017, entire). Substrate consisted of 60 percent fines, 30 percent sand, and 10 percent gravel. Clams and amphipods were present, and the dominant vegetation consisted of rushes, spikerush, and watercress.

Table 5.107. Attribute measurements for Unnamed Spring Near Sacramento Pass #1.

Spring or Spring Province	**Temperature °C (°F)**	**pH**	**Cond (µS/cm)**	**DO mg/L (ppm)**	**Flow L/min (cfs)**	**Velocity cm/sec (in/sec)**
Unnamed Spg near Sac Pass # 1	12.48–13.5 (54.5–56.3)	7.64	415–466	-	40–110 (0.02–0.06)	1.1 (0.43)

Sada 2016, entire; Sada 2017, entire.

Sada (2017, p. 106) reported water diversion, impoundment, channel modification, and moderate disturbance to vegetation and substrate from livestock use as the primary stressors affecting this spring (Table 5.108). The channel had been previously dredged, channelized, and impounded, but has naturalized from these significant disturbances over time; currently, these disturbances appear to be a minor impact on the habitat. We expect that future conditions associated with these stressors will likely remain similar to current conditions as we have no information that would indicate otherwise.

Table 5.108. Current and historic stressors for Unnamed Spring near Sacramento Pass #1.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Grazing and Browsing)	Current	Moderate	Moderate	Basic Need	NC	M
Spring Modifications from the following Sources						
Surface Water Diversion	Historic	Low	Moderate	Basic Need	NC	M
Impoundment	Historic	Low	Moderate	Basic Need	NC	M
Channel Modification	Historic	Low	Moderate	Basic Need	NC	M

[1] D = Decreasing; I = Increasing; NC = No Change
[2] L = Low; M = Moderate; H = High
See methodology section for explanation of column headings

Unnamed Spring near Sacramento Pass # 1 occurs on BLM land managed for multiple uses. Management of multiple use land in this area is under the direction of the BLM's Ely District RMP (see Appendix X); however, we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.7.5 Unnamed Spring Near Sacramento Pass # 4

Unnamed Spring Near Sacramento Pass # 4 is located upslope from Unnamed Spring Near Sacramento Pass # 1 in White Pine County, Nevada. This spring is located on BLM land at an elevation of 2,025 m (6,645 ft). Since this spring was not surveyed in 2016, information on the source of the spring flow was not submitted. However, based on the location of this spring in relation to the other springs in this area, we assume the source of flow is the same as for the other springs, which is the local mountain block aquifer.

Sada did not survey this spring in 2016; however, it was surveyed in 2009, and the following water quality measurements provided in Table 5.109 were collected (Sada 2016, entire). Additional information on WW, WD, CV, vegetation, substrate, and occupation by other fauna was not provided.

Table 5.109. Attribute measurements for Unnamed Spring Near Sacramento Pass #4.

Spring or Spring Province	**Temperature °C (°F)**	**pH**	**Cond (µS/cm)**	**DO mg/L (ppm)**	**Flow L/min (cfs)**	**Velocity cm/sec (in/sec)**

Unnamed Spg near Sac Pass # 4	12.49 (54.5)	7.32	437	-	5.0 (>0)	-

Sada 2016, entire.

We have no information on the types of stressors that may be affecting this spring. Sada did not survey this spring in 2016, and information on disturbance at the spring during the survey conducted in 2009 was not available.

Unnamed Spring Near Sacramento Pass # 4 occurs on BLM land managed for multiple uses. Management of multiple use land in this area is under the direction of the BLM's Ely District RMP (see Appendix X); however, we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

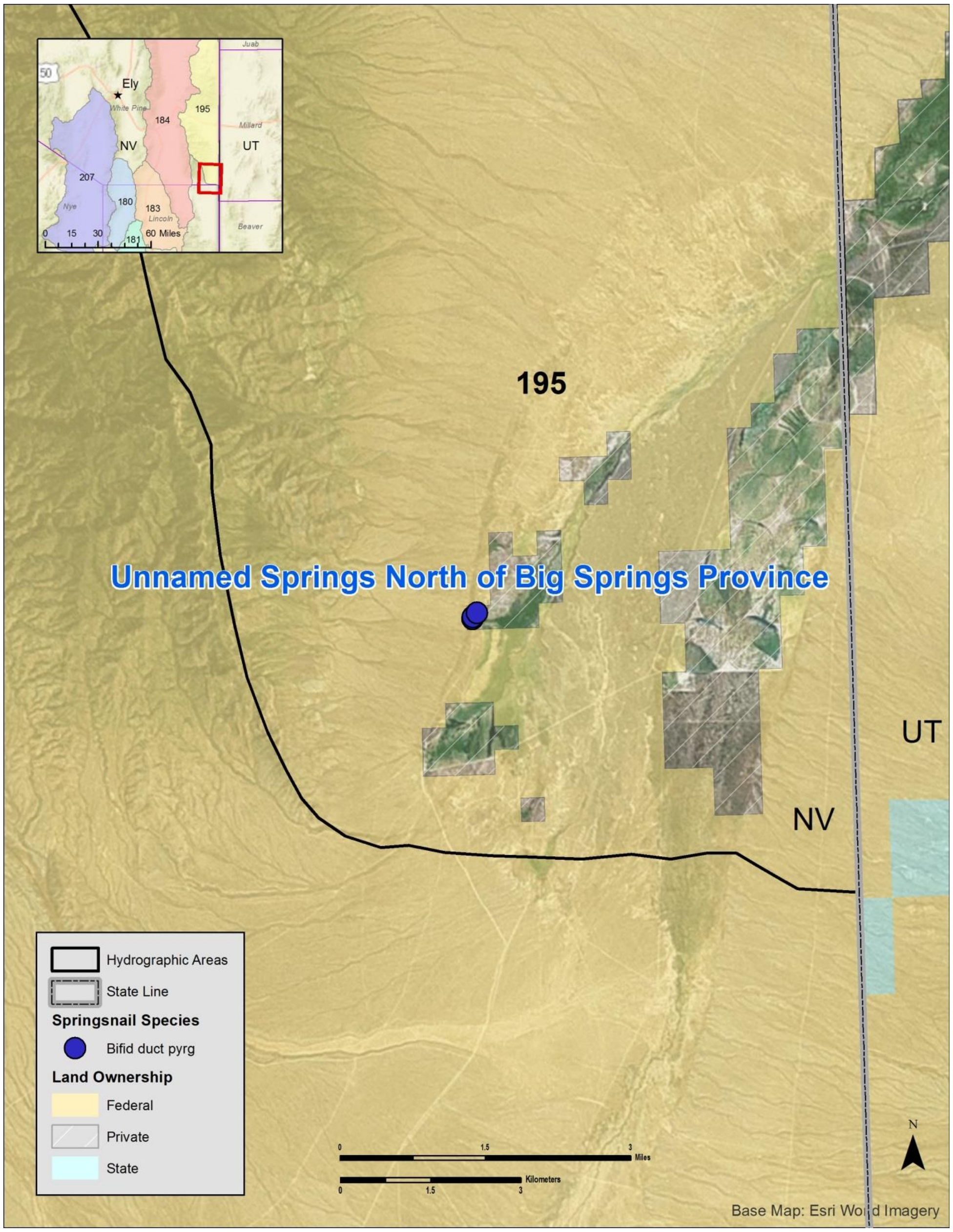


Figure 5.10. Map of land ownership and location of springs occupied by the bifid duct pyrg in the Snake Valley HA (195), White Pine County, Nevada.

5.7.6 Unnamed Springs North of Big Springs Province

Unnamed Springs North of Big Springs is a province of at least three spring sources located at the southeastern base of the Snake Range in Snake Valley, White Pine County, Nevada. This spring province is located on private land at an average elevation of 1,698 m (5,570 ft). The source of spring flow was not included in the information available to us, but may be from a mountain block aquifer based on the location of the spring at the base of the Snake Range.

We compiled information on water quality and quantity at springs from several sources (Table 5.110). Sada (2016, entire) recorded mean WW and WD in 2009 as 80 cm (31.5 in) and 5 cm (2.0 in), respectively, and CV measurements were not provided. However, SNWA (2011, p. 3-15) recorded CV at Unnamed 1A as 6.09 cm/sec (2.4 in/sec) in the spring of 2010 and at Unnamed 1B as 1.22 cm/sec (0.48 in/sec) in the spring of 2010 and 3.05 cm/sec (1.2 in/sec) in the fall of 2010. Sada (2009 field notes) estimated emergent cover at 40 percent and bank cover at 80 percent. Substrate consisted of 70 percent sand and 30 percent gravel. Amphipods were present and the dominant vegetation consisted of rushes, spikerush, and watercress.

Table 5.110. Attribute measurements for Unnamed Springs North of Big Springs Province.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Unnamed N of Big A	12.6–14.8 (54.7–58.6)	7.17–7.8	335–464	4.61-7.6	15.0 (0.01)	-
Unnamed N of Big 1A	13.3–18.3 (55.9–64.9)	7.59–7.84	408–455	-	-	6.09 (2.4)
Unnamed N of Big 1B	14.4–16.7 (57.9–62.1)	7.66–7.87	430–492	-	-	1.22–3.05 (0.48–1.2)

Golden *et al.* 2007, p. 61; SNWA 2011, pp. 3-9 through 3-15; Sada 2016, entire.

Sada did not obtain landowner permission to survey this spring province in 2016; therefore, no recent information is available on the stressors that may be affecting this spring. Sada, however, noted in 2009 that this site had moderate disturbance from livestock use, which would affect vegetation and substrate.

This spring province occurs on private land. We are unaware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

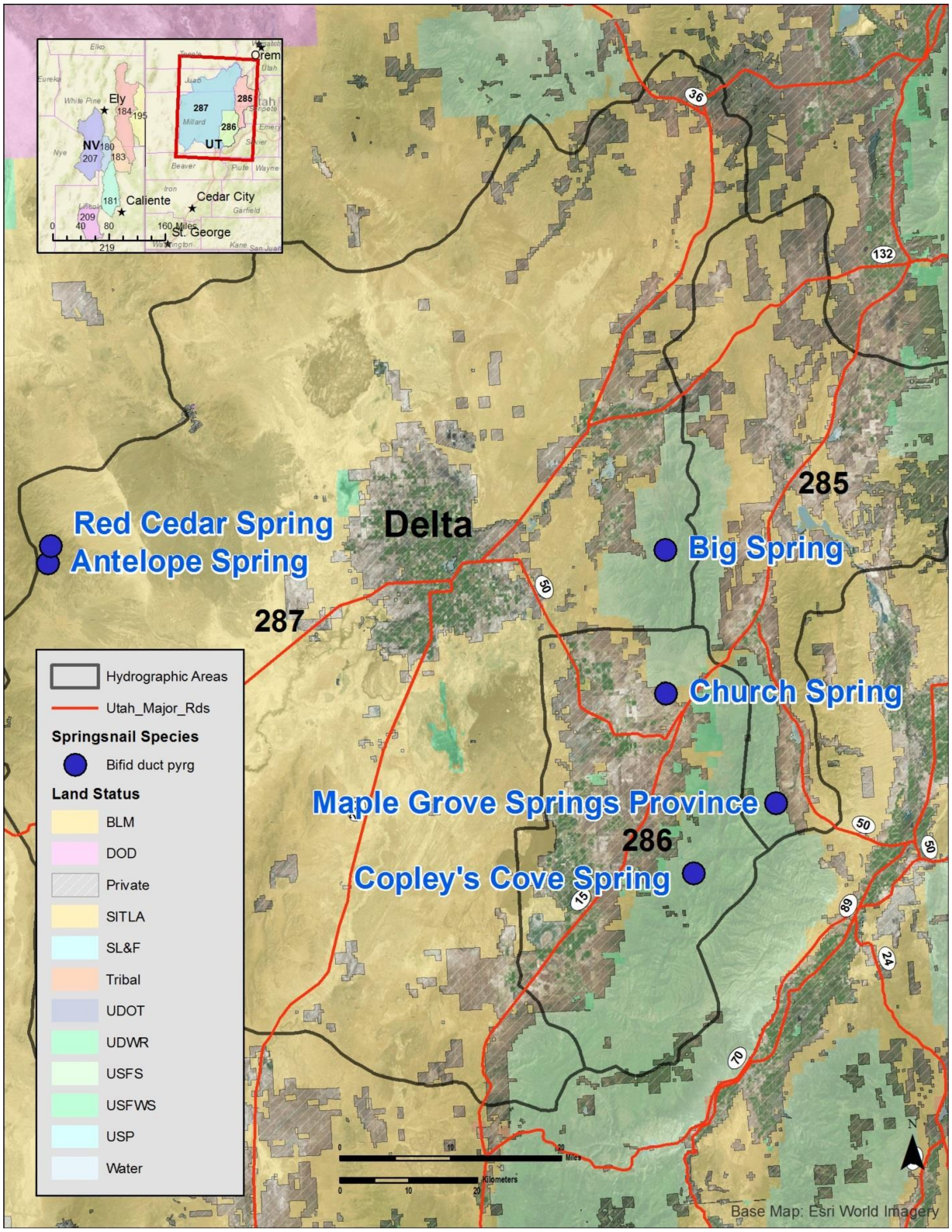


Figure 5.11. Map of land ownership and location of springs occupied by the bifid duct pyrg in the House, Canyon, and Pahvant Mountain Ranges HAs (285, 286, and 287), Millard County, Utah.

5.7.7 Antelope Spring

Antelope Spring is located in the House Range, north of Highway 6 and 64.4 km (40 mi) west of Delta in Millard County, Utah on the western edge of the Sevier Desert Water Policy Area 68. This spring is located on BLM land at an elevation of 2,282 m (7,487 ft), and spring flow is fed from a mountain block aquifer.

Historically, this was a complex of several springs that may have supported a large springsnail population (Sada 2017, p. 101). The remaining flowing spring head is fenced, and all of the flow is captured in a metal box that diverts water into a 5.08-cm (2-in) pipe. Springsnails were present only in a very small seep that discharges approximately 15 m (49 ft) southwest of the spring box. The spring flows down a steep hillside in a pinon pine forest.

We compiled information on water quality and quantity at springs from several sources (Table 5.111). Sada (2017, p. 101) recorded mean WW, WD, and CV at the small seep as 15 cm (5.9 in), 0.5 cm (0.20 in), and 0.0 cm/sec, respectively (depth and velocity were estimated because there was too little water to measure using instruments). Surveys conducted in 2016 estimated emergent cover at 100 percent and bank cover at 100 percent (Sada 2017, entire). Substrate consisted of 10 percent fines and 80 percent gravel. Unknown species of Pupillidae, Lymnaeidae, and Gyralus were present, and the dominant vegetation consisted of rushes and spikerush.

Table 5.111. Attribute measurements for Antelope Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Antelope Spring	11.5-14.5 (52.7–58.1)	7.50	418–622	6.50	2.0 (>0)	-

Oliver 2011, entire; Matthews and Wheeler 2015, entire; Sada 2017, entire.

The primary stressor affecting Antelope Spring is water diversion (Sada 2017, entire; Table 5.112). All flow from the main spring head has been boxed and piped, resulting in complete drying of any habitat that may have existed in the past (Sada 2017, p. 101). Despite the loss of this habitat, the small flow from the adjacent seep maintains about 75 m (246 ft) of occupied habitat, and Sada (2017, p. 101) considers this small spring to be in near reference condition. We expect that future conditions associated with these stressors will likely remain similar to current conditions (i.e., the existing diversion would most likely remain in place) and additional impacts would not occur since this spring is located in a Wilderness Study Area (WSA) (see additional information below) and should be managed by the BLM to achieve the non-impairment standard.

Burden *et al.* (2016, p. 3) identified an area of significant groundwater development in the basin fill deposits in the valley floor to the east of the House Range (area 24). Safe yield estimates for this area were not provided in the groundwater management plan for the Sevier River Basin; however, the estimated recharge for this area is 41,000 afy (Heilweil and Brooks (eds.) 2011, p. 170). The amount of appropriated groundwater rights are not readily available, but well withdrawal estimates for this area generally show an increasing trend, varying between 10,000 and 50,000 afy since the 1960's (Heilweil and Brooks 2011, Auxiliary 4), and reaching 55,000 afy in 2015 (Burden *et al.* 2016, p. 5).

Table 5.112. Current stressors for Antelope Spring.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend[1]**	**Confidence of Trend[2]**
Spring Modifications (Surface Water Diversion)	Current	High	Very High	Basic Need	NC	H

[1] D = Decreasing; I = Increasing; NC = No Change
[2]L = Low; M = Moderate; H = High
See methodology section for explanation of column headings

Antelope Spring occurs on BLM land within the Howell Peak WSA (BLM 1991, pp. 75–84). Management within WSAs is guided by BLM Manual 6330 – Management of BLM Wilderness Study Areas (BLM 2012d, entire; Appendix X). The objectives of this policy are to: (1) manage and protect WSAs, consistent with relevant law, to preserve wilderness characteristics so as not to impair the suitability of such areas for designation by Congress as wilderness; and (2) provide policy guidance for prolonged stewardship of WSAs until Congress makes a final determination on the management of WSAs (BLM 2012d, p. 1-2). The non-impairment standard is defined as uses and/or facilities that are both temporary and do not create surface disturbance (BLM 2012d, p. 1-10). This policy provides guidance on evaluating proposals for new uses within WSAs, but also allows certain preexisting uses to continue (such as grazing, mining, and mineral leasing uses and facilities that were allowed on the date of approval of FLPMA [October 21, 1976]). This area also falls under the purview of the BLM's Richfield District House Range Resource Area RMP (BLM 1987, entire; Appendix A). Other than managing this area in accordance with the House Range Resource Area RMP and BLM Manual 6330 to achieve the non-impairment standard, we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.7.8 Red Cedar Spring

Red Cedar Spring (also known as Spring above Swasey Spring) is located about 2.5 km (4 mi) north of Antelope Spring in the House Range, Millard County, Utah on the western edge of the Sevier Desert Water Policy Area 68. This spring is located on BLM land at an elevation of 2,164 m (7,100 ft), and spring flow is fed from a mountain block aquifer.

The spring head emerges from the root base of a large juniper. Sada (2017, p. 101) considers this spring to be in near reference condition. There was evidence of wild horse use along downstream reaches of the springbrook, but it did not appear to affect springsnail abundance or ecological health of the spring.

We compiled information on water quality and quantity at springs from several sources (Table 5.113). Sada (2017, p. 101) recorded mean WW, WD, and CV as 42.5 cm (16.7 in), 1.8 cm (0.71 in), and 6.2 cm/sec (2.4 in/sec), respectively. Surveys conducted in 2016 estimated emergent cover at 50 percent and bank cover at 37.8 percent (Sada 2017, entire). Substrate consisted of 30 percent sand, 50 percent gravel, and 20 percent cobble. Sada (2017, entire) did not note any other species occurring at this site, but Matthews and Wheeler (2015, entire) observed a peaclam shell (Family Sphaeriidae). Wild rose was the dominant vegetation.

Table 5.113. Attribute measurements for Red Cedar Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Red Cedar Spring	10.4 (50.7)	7.80	389	7.60	40.0 (0.02)	6.2 (2.4)

Matthews and Wheeler 2015, entire; Sada 2017, entire.

The only evidence of disturbance at this site was wild horse use downstream from the spring head, which Sada (2017, p. 101) considered to have a negligible effect on the springbrook (Table 5.104). We expect that future conditions associated with wild horse use will likely remain similar to current conditions and additional impacts would not occur since this spring is located in a WSA (see additional information above) and should be managed by the BLM to achieve the non-impairment standard.

Burden *et al.* (2016, p. 3) identified an area of significant groundwater development in the basin fill deposits in the valley floor to the east of the House Range (area 24). Safe yield estimates for this area were not provided in the groundwater management plan for the Sevier River Basin; however, the estimated recharge for this area is 41,000 afy (Heilweil and Brooks (eds.) 2011, p. 170). The amount of appropriated groundwater rights are not readily available, but well withdrawal estimates for this area generally show an increasing trend, varying between 10,000 and 50,000 afy since the 1960's (Heilweil and Brooks, 2011, Auxiliary 4), and reaching 55,000 afy in 2015 (Burden *et al.* 2016, p. 5).

Table 5.114. Current stressors for Red Cedar Spring.

Stressor (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Vegetation and Soil Disturbance (Grazing and Browsing)	Current	Negligible	Insignificant	Basic Need	NC	H

[1] D = Decreasing; I = Increasing; NC = No Change

[2] L = Low; M = Moderate; H = High

See methodology section for explanation of column headings

Red Cedar Spring occurs on BLM land within the Swasey Mountain WSA (BLM 1991, pp. 63–74). Management within WSAs is guided by BLM Manual 6330 – Management of BLM Wilderness Study Areas (BLM 2012d, entire; Appendix X). Management objectives for WSAs and the definition of the non-impairment standard are discussed above under the Antelope Spring section. This area also falls under the purview of the BLM's Richfield District House Range Resource Area RMP (BLM 1987, entire; Appendix A). Other than managing this area in accordance with the House Range Resource Area RMP and BLM Manual 6330 to achieve the non-impairment standard, we are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.7.9 Big Spring

Big Spring is located on the western slope of the Canyon Mountains on the eastern edge of the Sevier Desert Water Policy Area 68, about 8 km (5 mi) east of Oak City and about 1.6 km (1 mi) east of the Oak Creek Recreational Site Campground in Millard County, Utah. This spring is located on USFS land at an elevation of 1,884 m (6,181 ft), and spring flow is fed from a mountain block aquifer.

This is a relatively cold, large, deep spring that is tributary to Oak Creek. The spring discharges from a large, horizontal culvert, and the springbrook flows through an incised channel. The spring is near a campground, but isolated from public use by a newly constructed barbed wire fence. A gravel road bridge crosses the springbrook below springsnail-occupied habitat and above the spring's confluence with Oak Creek.

We compiled information on water quality and quantity at springs from several sources (Table 5.115). Sada (2017, p. 101) recorded mean WW, WD, and CV as 253.8 cm (99.9 in), 51.0 cm (20.1 in), and 12.5 cm/sec (4.9 in/sec), respectively. Surveys conducted in 2016 estimated emergent cover at 78.6 percent and bank cover at 45.6 percent (Sada 2017, entire). Substrate consisted of 60 percent gravel, 30 percent cobble, and 10 percent boulder. No other species were observed at this site. The dominant vegetation consisted of watercress and willow.

Table 5.115. Attribute measurements for Big Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Big Spring	9.3–9.6 (48.7–49.3)	8.6	352–458	9.3	400–8500 (0.24–5.0)	12.5 (4.9)

Oliver 2011, entire; Sada 2017, entire.

Sada (2017, entire) noted water diversion and recreation as stressors currently affecting the site, although the effect of these disturbances appeared to be minor (Table 5.115). Recreational access to the spring that may cause disturbance to vegetation and substrate is being controlled by a newly-constructed fence, and the system has naturalized to any disturbance that may be caused from the culvert occurring at the spring head (Sada 2017, p. 102). We expect that future conditions associated with these stressors will likely remain similar to current conditions as we have no information that would indicate otherwise.

Burden *et al.* (2016, p. 3) identified an area of significant groundwater development in the basin fill deposits in the valley floor to the west of the Canyon Mountains (area 24). Safe yield estimates for this area were not provided in the groundwater management plan for the Sevier River Basin; however, the estimated recharge for this area is 41,000 afy (Heilweil and Brooks (eds.) 2011, p. 170). The amount of appropriated groundwater rights are not readily available, but well withdrawal estimates for this area generally show an increasing trend, varying between 10,000 and 50,000 afy since the 1960's (Heilweil and Brooks 2011, Auxiliary 4), and reaching 55,000 afy in 2015 (Burden *et al.* 2016, p. 5).

Table 5.115. Current stressors for Big Spring.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance (Recreation)	Current	Low	Insignificant	Unknown	NC	M
Spring Modifications (Surface Water Diversion)	Current	Low	Insignificant	Basic Need	NC	M

[1] D = Decreasing; I = Increasing; NC = No Change
[2] L = Low; M = Moderate; H = High
See methodology section for explanation of column headings

Big Spring occurs within the Fishlake National Forest and management is under the direction of the Fishlake National Forest Land and Resource Management Plan (USFS 1986, entire; Appendix A). Big Spring falls within Management Area # 4, where the management emphasis is focused on fish habitat improvement and habitat needs of one or more indicator species (USFS 1986, pp. IV-51, IV-85, and IV-95). The goals of management are to maintain or improve aquatic habitat condition for fish at or above a good habitat condition rating, maintain stable stream channels, meet water quality standards for cold water fisheries, provide healthy, self-perpetuating riparian plant communities and provide habitats for viable populations of wildlife. We are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site, although springsnails may indirectly benefit from the implementation of some management prescriptions for fish habitat improvement consistent with the USFS's forest management plan.

5.7.10 Church Spring

Church Spring is located northwest of the Pavant Range at the southern base of the Canyon Mountains, about 14.5 km (9 mi) north of Holden in Millard County, Utah. It occurs in the northeastern part of the Pahvant Valley Water Policy Area 67. This spring is located on private land at an elevation of 1,607 m (5,272 ft), and spring flow is fed from the local aquifer. Church Spring is the lowest elevation spring currently known that supports a population of bifid duct pyrg.

We compiled information on water quality and quantity at springs from several sources (Table 5.116). Sada (2017, p. 102) recorded mean WW, WD, and CV as 137.5 cm (54.3 in), 17.4 cm (6.85 in), and 38.1 cm/sec (15 in/sec), respectively. Surveys conducted in 2016 estimated emergent cover at 55 percent and bank cover at 63.4 percent (Sada 2017, entire). Substrate consisted of 100 percent gravel. Amphipods were present, and watercress was the dominant vegetation.

Table 5.116. Attribute measurements for Church Spring.

Spring or Spring Province	**Temperature °C (°F)**	**pH**	**Cond (µS/cm)**	**DO mg/L (ppm)**	**Flow L/min (cfs)**	**Velocity cm/sec (in/sec)**
Church	14.2	-	303	-	150–250	38.1

Spring	(57.6)				(0.09–0.15)	(15)

Oliver 2011, entire; Sada 2017, entire.

Water diversion and channel modification were the primary stressors affecting Church Spring (Table 5.117). The springbrook has been channelized to facilitate delivering water to downstream pastures and cropland. A new channel is being constructed to deliver water to a new area, but it had not been connected to the existing springbrook when Sada visited the site in July 2016 (Sada 2017, p. 102). Disturbance from roads and livestock use was also noted, but the effect to the habitat appeared to be minimal (Sada 2017, entire). A road fords the springbrook twice, once approximately 50 m (164 ft) from the source and the other approximately 700 m (2297 ft) from the source. Watercress covers large portions of the springbrook, and has been removed in some areas to facilitate water flow. Springsnail abundances appeared to be reduced in those areas where watercress had been removed, but overall, springsnail densities were high throughout the springbrook despite this disturbance (Sada 2017, p. 102). Based on observations of a newly constructed diversion ditch, we expect that water diversion and channel modification activities are likely to increase in the future at this spring. We expect that future conditions associated with disturbance to vegetation and substrate from livestock use and roads will likely remain similar to current conditions as we have no information that would indicate otherwise.

Burden *et al.* (2016, p. 3) identified an area of significant groundwater development in the basin fill deposits in the Pavant Valley (area 23). The Pahvant Valley Groundwater Management Plan estimates the safe yield at 60,000 afy (UDWRi 1994, p. 2). The amount of appropriated groundwater rights are not readily available, but well withdrawal estimates for this area have generally increased and frequently exceeded 60,000 afy since the 1960s (Heilweil and Brooks 2011, Auxiliary 4), and reached 128,000 af in 2015 (Burden *et al.* 2016, p. 5).

Table 5.117. Current stressors for Church Spring.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend**[1]	**Confidence of Trend**[2]
Vegetation and Soil Disturbance from the following Sources						
Grazing and Browsing	Current	Low	Small	Unknown	NC	L
Roads	Current	Low	Small	Basic Need	NC	L
Spring Modifications from the following Sources						
Surface Water Diversion	Current	Moderate	Moderate	Basic Need	I	M
Channel Modification	Current	Moderate	Moderate	Basic Need	I	M

[1] D = Decreasing; I = Increasing; NC = No Change
[2] L = Low; M = Moderate; H = High
See methodology section for explanation of column headings

This spring occurs on private land. We are unaware of any management actions specific to spring or springsnail conservation that are being implemented at this site.

5.7.11 Maple Grove Springs Province

Maple Grove Springs is a province of five springs located approximately 30 km (19 mi) south of Scipio in Millard County, Utah on the eastern slope of the Pahvant Range and within the southern part of the Lower Sevier River Water Policy Area 66. This spring province is located on USFS within the Fishlake National Forest land at an average elevation of 2,000 m (6,560 ft), and spring flow is fed from a mountain block aquifer at the base of the mountains.

This spring province occurs within the Maple Grove Campground. The largest spring and its springbrook (Maple Grove Spring A) are adjacent to campsites. The other four springs are tributary to Spring A, and flow through meadows within a deciduous forest. Maple Grove Springs is the type locality for the bifid duct pyrg (Hershler 1998, p. 110), and the springs are in near reference condition (Sada 2017, p. 102).

Maple Grove Spring A

We compiled information on water quality and quantity at springs from several sources (Table 5.118). Maple Grove Spring A is the largest of the five springs, and runs swift, deep, and cold. Sada (2017, p. 102) recorded mean WW, WD, and CV as 251.8 cm (99.1 in), 12.9 cm (5.08 in), and 62.8 cm/sec (24.7 in/sec), respectively. Surveys conducted in 2016 estimated emergent cover at 5.5 percent and bank cover at 90 percent (Sada 2017, entire). Substrate consisted of 10 percent sand, 60 percent gravel, and 30 percent cobble. Rainbow trout occurred in a pooled area of the springbrook. The dominant vegetation consisted of willow, spikerush, and watercress.

Table 5.118. Attribute measurements for Maple Grove Spring A.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Maple Grove Spring A	10.5 (50.9)	-	280	-	500–3,000 (0.29–1.77)	62.8 (24.7)

Oliver 2011, entire; Sada 2017, entire.

The primary stressors affecting Maple Grove Spring A are disturbance to vegetation and substrate from roads and recreational activities, and potential predation and competition from invasive aquatic species (Sada 2017, entire; Table 5.119). This spring is readily accessible from campsites, resulting in a network of small trails that have formed along the springbrook. Sada (2017, p. 103) noted that the trails appear to have little effect on springsnail habitat or the ecological health of the spring system. Rainbow trout occur within the springbrook, but appear to prefer pooled areas and are not widely distributed through the spring system. The spring discharges from large pipes that are set into the base of the mountains, and Sada (2017, p. 102) noted no evidence of the natural characteristics of its source. We expect that future conditions associated with these stressors will likely remain similar to current conditions as we have no information that would indicate otherwise.

Table 5.119. Current stressors for Maple Grove Spring A.

Stressor (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]

Predation and Competition (Invasive Aquatics)	Current	Negligible	Insignificant	Unknown	NC	M
Vegetation and Soil Disturbance from the following Sources						
Roads	Current	Moderate	Moderate	Unknown	NC	M
Recreation	Current	Moderate	Moderate	Unknown	NC	M

[1] D = Decreasing; I = Increasing; NC = No Change
[2] L = Low; M = Moderate; H = High
See methodology section for explanation of column headings

Maple Grove Springs B, C, D, E

Comment [PME74]: Would be nice to see maps for all of the lettered "sub" springs presented in this document.

We compiled information on water quality and quantity at springs from several sources (Table 5.120). Maple Grove Spring B is a relatively large spring that runs deep, swift, and cold. Mean WW, WD, and CV were 140 cm (55.1 in), 10.2 cm (4.02 in), and 65.0 cm/sec (25.6 in/sec), respectively (Sada 2017, p. 103). It flowed approximately 255 m (837 ft) before its confluence with Spring A. A hiking trail crossed the spring brook approximately 150 m (492 ft) from its source. Surveys conducted in 2016 estimated emergent cover at 38.9 percent and bank cover at 100 percent (Sada 2017, entire). Substrate consisted of 10 percent sand, 30 percent gravel, and 60 percent cobble. Oreohelix shells were detected at this spring, and the dominant vegetation consisted of willow, rushes, spikerush, and watercress.

Maple Grove Spring C is a relatively small, cool spring that flowed approximately 135 m (443 ft) before its confluence with Spring A. Mean WW, WD, and CV were 30.0 cm (11.8 in), 3.8 cm (1.50 in), and 13.8 cm/sec (5.4 in/sec), respectively, and a hiking trail crossed the spring brook (Sada 2017, p. 103). Surveys conducted in 2016 identified no emergent cover at this spring, but estimated bank cover at 100 percent (Sada 2017, entire). Substrate consisted of 50 percent sand and 50 percent gravel. Amphipods were detected in this spring, and the dominant vegetation consisted of willow, rushes, and watercress.

Maple Grove Spring D is a small spring that flowed approximately 84 m (275 ft) before its confluence with Spring C. Mean WW, WD, and CV were 45.0 cm (17.7 in), 2.5 cm (0.98 in), and 13.8 cm/sec (5.4 in/sec), respectively, and a hiking trail crossed the spring brook (Sada 2017, p. 103). Surveys conducted in 2016 estimated emergent cover at 2.5 percent and bank cover at 100 percent (Sada 2017, entire). Substrate consisted of 80 percent sand and 20 percent gravel. Amphipods were detected in this spring, and the dominant vegetation consisted of willow, rushes, spikerush, and watercress.

Maple Grove Spring E is a small spring that flowed approximately 175 m (574 ft) before its confluence with Spring A. Mean WW, WD, and CV were 123.8 cm (48.7 in), 5.4 cm (2.12 in), and 12.4 cm/sec (4.9 in/sec), respectively, and a hiking trail crossed its spring brook (Sada 2017, p. 103). Surveys conducted in 2016 estimated emergent cover at 53.8 percent and bank cover at 100 percent (Sada 2017, entire). Substrate consisted of 80 percent sand, 10 percent gravel, and 10 percent boulder. Amphipods were detected in the spring, and the dominant vegetation consisted of willow and cattails.

Table 5.120. Attribute measurements for Maple Grove Springs B, C, D, and E.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Maple Grove B	9.9–11.1 (49.8–52)	8.40	270–438	7.80	300 (0.18)	65 (25.6)
Maple Grove C	10.8 (51.4)	-	272	-	40.0 (0.02)	13.8 (5.4)
Maple Grove D	13.1 (55.6)	-	314	-	5.0 (>0)	13.8 (5.4)
Maple Grove E	15.5 (59.9)	-	344	-	30.0 (0.02)	12.4 (4.9)

Sada 2016, entire; Sada 2017, entire.

The only stressor noted at these four springs was disturbance to vegetation and substrate from hiking trails crossing the springbrooks (Table 5.121). Sada (2017, p. 103) considered the affect from this disturbance to be minor. We expect that future conditions associated with disturbance from recreational activities will likely remain similar to current conditions as we have no information that would indicate otherwise.

Burden *et al.* (2016, p. 3) did not identify any areas of significant groundwater development in the general vicinity of Maple Grove Springs. Safe yield estimates for this area were not provided in the groundwater management plan for the Sevier River Basin; however, the estimated recharge for this area is 36,000 afy (Heilweil and Brooks (eds.) 2011, p. 170). The amount of appropriated groundwater rights are not readily available, but well withdrawal estimates for this area varied without an obvious pattern between 2,000 and 10,000 afy during the period 1940 – 2015 (Heilweil and Brooks (eds.) 2011, Auxiliary 4; Burden *et al.* 2016, p. 5).

Table 5.121. Current stressors for Maple Grove Springs B, C, D, and E.

Stressor (Source)	Immediacy	Intensity	Exposure	Response	Expected Future Trend[1]	Confidence of Trend[2]
Vegetation and Soil Disturbance (Recreation)	Current	Negligible	Insignificant	Behavioral	NC	M

[1] D = Decreasing; I = Increasing; NC = No Change
[2]L = Low; M = Moderate; H = High
See methodology section for explanation of column headings

Maple Grove Springs occurs within the Fishlake National Forest and management is under the direction of the Fishlake National Forest Land and Resource Management Plan (USFS 1986, entire; Appendix A). Maple Grove Springs falls within Management Area # 4, where the management emphasis is focused on fish habitat improvement and habitat needs of one or more indicator species (USFS 1986, pp. IV-51, IV-85, and IV-95). The goals of management are to maintain or improve aquatic habitat condition for fish at or above a good habitat condition rating, maintain stable stream channels, meet water quality standards for cold water fisheries, provide healthy, self-perpetuating riparian plant communities and provide habitats for viable populations of wildlife. We are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site, although springsnails may indirectly benefit from the implementation of some management prescriptions for fish habitat improvement consistent with the USFS's forest management plan. Although rainbow trout were observed in a naturally pooled area of the springbrook, signs were seen at the campground prohibiting building of dams to pond water (Krueger 2016, p. 2).

5.7.12 Copley's Cove Spring

Copley's Cove Spring (also known as Unnamed Spring South of Chokecherry and South Fork Chalk Creek) is located on the western slope of the Pavant Mountain Range, approximately 12 km (7.5 mi) east of Fillmore on the New Chalk Creek Canyon Road in Millard County, Utah. This spring occurs in the eastern part of the Pahvant Valley Water Policy Area 67. This spring is located on USFS land in the Fishlake National Forest at an elevation of 1,989 m (6,525 ft), and spring flow is fed from a mountain block aquifer.

We compiled information on water quality and quantity at springs from several sources (Table 5.122). Sada (2017, p. 104) recorded mean WW, WD, and CV as 175.0 cm (68.9 in), 5.4 cm (2.12 in), and 12.4 cm/sec (4.9 in/sec), respectively. Surveys conducted in 2016 estimated emergent cover at 35.0 percent and bank cover at 2.5 percent (Sada 2017, entire). Substrate consisted of 20 percent gravel, 60 percent gravel, and 20 percent boulder. No other fauna were detected in the spring, and the dominant vegetation was watercress.

Table 5.122. Attribute measurements for Copley's Cove Spring.

Spring or Spring Province	Temperature °C (°F)	pH	Cond (µS/cm)	DO mg/L (ppm)	Flow L/min (cfs)	Velocity cm/sec (in/sec)
Copley's Cove Spring	10.0–10.2 (50–50.4)	8.40	178–317	8.90	150–900 (0.09-0.53)	19.7 (7.8)

Oliver 2011, entire; Sada 2017, entire.

The primary stressors affecting Copley's Cove Spring are water diversion and disturbance to vegetation and substrate from recreational activities (Sada 2017, entire; Table 5.123). The spring discharges from a spring box and pipes. No evidence of a natural spring source was observed, but the aquatic habitat had naturalized from this historical disturbance (Sada 2017, p. 104). Water flowed from the source area onto a relatively wide level ponded area that was densely covered by watercress before plunging down a steep slope, and through a culvert under a gravel road before entering the creek. The spring source and ponded area at the spring source were fenced, and a hiking trail runs parallel to and about 5 m (16 ft) above the springbrook. Sada (2017, entire) considered the effects of these stressors on the habitat and ecological health of the spring to be minor. We expect that future conditions associated with these stressors will likely remain similar to current conditions as we have no information that would indicate otherwise.

Burden *et al.* (2016, p. 3) identified an area of significant groundwater development in the basin fill deposits in the Pavant Valley (area 23). The Pahvant Valley Groundwater Management Plan estimates the safe yield at 60,000 afy (UDWRi 1994, p. 2). The amount of appropriated groundwater rights are not readily available, but well withdrawal estimates for this area have generally increased and frequently exceeded 60,000 afy since the 1960s (Heilweil and Brooks (eds.) 2011, Auxiliary 4), and reached 128,000 af in 2015 (Burden *et al.* 2016, p. 5).

Table 5.123. Current stressors for Copley's Cove Spring.

Stressor (Source)	**Immediacy**	**Intensity**	**Exposure**	**Response**	**Expected Future Trend[1]**	**Confidence of Trend[2]**
Vegetation and Soil Disturbance (Recreation)	Current	Low	Insignificant	Unknown	NC	M
Spring Modifications (Surface Water Diversion)	Current	Low	Insignificant	Basic Need	NC	M

[1] D = Decreasing; I = Increasing; NC = No Change
[2] L = Low; M = Moderate; H = High
See methodology section for explanation of column headings

Copley's Cove Spring occurs within the Fishlake National Forest and management is under the direction of the Fishlake National Forest Land and Resource Management Plan (USFS 1986, entire; see Appendix A). Copley's Cove Spring falls within Management Area # 4, where the management emphasis is focused on fish habitat improvement and habitat needs of one or more indicator species (USFS 1986, pp. IV-51, IV-85, and IV-95). The goals of management are to maintain or improve aquatic habitat condition for fish at or above a good habitat condition rating, maintain stable stream channels, meet water quality standards for cold water fisheries, provide healthy, self-perpetuating riparian plant communities and provide habitats for viable populations of wildlife. We are not aware of any management actions specific to spring or springsnail conservation that are being implemented at this site, although springsnails may indirectly benefit from the implementation of some management prescriptions for habitat improvement consistent with the USFS's forest management plan.

5.8 Spring and Snake Valleys, Nevada, and House, Canyon, and Pahvant Mountain Ranges, Utah – Springsnail Species and Current Population Conditions

5.8.1 Bifid Duct Pyrg

The bifid duct pyrg was first described in Hershler (1998, pp. 108-110) as a medium-sized springsnail measuring 1.7 to 3.0 mm (0.07 to 0.12 in) in height and 1.3 to 2.1 mm (0.05 to 0.08 in) in width. The shell is ovate with 3.5 to 5 whorls with an ovate aperture that is slightly disjunct from the whorl. The species name, *peculiaris*, refers to the unique configuration of the female bursal duct in this species.

The bifid duct pyrg occurs in White Pine County, Nevada and Millard County, Utah. The species was first collected by Hershler (1998, p. 110) from the following areas:

- Snake Valley in Nevada: One location described as Big Springs Creek in Snake Valley (also identified as Unnamed Springs North of Big Springs (Hershler no date circa 1995, station 193) and Springs to the North of Big Spring (National Museum of Natural History 2016, entire)),

- Spring Valley in Nevada: Turnley Spring,
- Round Valley in Utah: Maple Grove Spring (type locality),
- Oak Creek, Pahvant Valley in Utah: (1) Church Spring, and (2) South Fork Chalk Creek (also known as Copley's Cove Spring or Unnamed Spring South Fork Chokecherry Creek (Sada 2016, entire)),
- Sevier River Drainage in Utah: Big Spring,
- Whirlwind Valley in Utah: Spring Above Swasey Spring (also known as Red Cedar Spring (Sada 2016, entire)),
- House Range, Sevier Desert Drainage in Utah: Antelope Spring

Surveys conducted since 1995 have documented the species in four additional sites:

- Spring Valley in Nevada: (1) Rock Spring, also known as Unnamed Spring near Sacramento Pass # 3; (2) Cache Springs Province, also known as Unnamed Springs near Sacramento Pass # 2A and # 2B; (3) Unnamed Spring near Sacramento Pass # 1; and (4) Unnamed Spring near Sacramento Pass # 4)

Additionally, surveys since 1995 have discovered additional occupied springs at the Maple Grove site, which is now considered/called Maple Grove Springs Province. Considering all 12 locations, 2 of the springs or spring provinces are on private land, 3 are on Forest Service land, and 7 are on BLM land.

The bifid duct pyrg has also been reported occupying Big Springs or Big Springs Creek (not to be confused with Big Springs Creek described in Hershler 1998, p. 110), which is located in Snake Valley, White Pine County, Nevada (Golden *et al.* 2007, pp. 86-87; SNWA 2011, p. 3-28). The SNWA (2011, p. 3-28) stated previous surveys conducted by Golden *et al.* (2007, entire) identified the bifid duct pyrg at Big Springs, and Golden *et al.* (2007, pp. 86–87) noted bifid duct pyrg as absent through visual observation at Big Springs and present through visual observation at Big Springs Creek. The species observed in Big Springs Creek was identified as bifid duct pyrg through a personal communication with Sada (Golden *et al.* 2007, p. 87); however, we are not aware of any records either in Sada's springsnail database (Sada 2016, entire) or in Hershler's museum database (National Museum of Natural History 2016, entire) verifying bifid duct pyrg as the springsnail species that occurs in Big Springs Creek or Big Springs. Hershler (National Museum of Natural History 2016, entire) and Sada (2016, entire) identify the springsnail species occurring at Big Springs as the longitudinal gland pyrg (*Pyrgulopsis anguina*).

At Turnley Spring in 1991 and again in 1998, the bifid duct pyrg was noted as scarce (Sada 2016, entire). In 2006, survey efforts resulted in no springsnails (Golden *et al.* 2007, p. 229), but in 2009 the species was common in a small area (Sada 2016, entire). Most recently in 2016, the species was absent (Sada 2017, p. 104). This spring, which is located on BLM land, has been heavily modified with the springhead capped and the springbrook impounded, forming a deep circular pool (Sada 2017, p. 104).

At Rock Spring (also known as Unnamed Spring near Sacramento Pass # 3) in 2008, the species was first discovered and found to be abundant (Albrecht *et al.* 2009, pp. 24, 31, and 32), whereas a year later it was recorded to be common (Sada 2016, entire). Most recently in 2016, the species was recorded as abundant (Sada 2017, entire). The species occupies 65 m (213 ft) of springbrook (131.6 m^2 [1,417 ft^2] of habitat), and mean catch per unit effort was 26.6 with a range from 5 to 78 (Sada 2017, p. 100). Rock Spring is located on BLM land.

Cache Springs Province includes two tributary springs—Cache Spring A and B (also known as Unnamed Springs # 2A and # 2B near Sacramento Pass) on BLM land. The bifid duct pyrg was first discovered here in 2009 (Sada 2016, entire) and was recorded as common at both spring sources. In 2016, the species was noted as abundant at the larger spring (Cache Spring A; mean catch per unit effort = 47.2 with a range of 17 to 175), and common at the smaller spring (Cache Spring B; mean catch per unit effort = 17.3 with a range of 7 to 32) (Sada 2017, p. 100). The species occupies 95 m (311.7 ft) of springbrook (203.7 m^2 [2192.6 ft^2] of habitat) at Cache Spring A, and 7 m (23.0 ft) of springbrook (5.6 m^2 [60.3 ft^2] of habitat) at Cache Spring B (Sada 2017, p. 100).

In 2009, the bifid duct pyrg was documented to occur at two unnamed springs on BLM land in Spring Valley: Unnamed Spring near Sacramento Pass #1 and Unnamed Spring near Sacramento Pass # 4 (Sada 2016, entire); the species was recorded as common at both springs. In 2016, bifid duct pyrgs were found to be abundant at spring #1 (mean catch per unit effort = 35.5 with a range of 1 to 81), occupying 135 m (443 ft) of springbrook (322.9 m^2 [3475.7 ft^2] of habitat) (Sada 2017, p. 101). Unnamed Spring near Sacramento Pass # 4 has not been surveyed since 2009.

Unnamed Springs North of Big Springs Province includes three spring sources that converge and flow towards Big Springs Creek. This spring province occurs on private land. Within this province bifid duct pyrg was first documented in one of the springs in 1992 (National Museum of Natural History 2016, entire). The species is known to be common or abundant within the springs during surveys conducted a few years between 1998 and 2010 (Sada 2016, entire; SNWA 2011, pp. 3–31 and 3–37); the species was only documented as “present” in 2004 (Golden *et al.* 2007, p. 87). Surveyors did not obtain landowner permission to determine abundance and spring conditions in 2016. BIOWEST (Golden *et al.* 2007, p. 87) identified the species occurring at Unnamed Spring North of Big Spring #1 as the longitudinal gland pyrg (*Pyrgulopsis anguina*); however, Hershler (National Museum of Natural History 2016, entire) has not confirmed the occurrence of the longitudinal gland pyrg at this spring, and we assume the species detected at this spring by BIOWEST in 2004 is the bifid duct pyrg.

Antelope Spring and Red Cedar Spring occur in the House Mountain Range on BLM land within the Howell Peak and Swasey Mountain Wilderness Study Areas (WSAs). Bifid duct pyrg was first collected at these two springs in 1993; it was scarce at Antelope Spring and common at Red Cedar Spring (Sada 2016, entire). At Antelope Spring, subsequent surveys between 2011 and 2016 all noted species abundance remains scarce (Oliver 2011b, p. 11; Matthews and Wheeler 2015, pp. 2–3; Sada 2017, p. 101). The main spring source at Antelope Spring has been capped and piped, but a seep occurs adjacent to the original spring source, which supports a small springsnail population (Sada 2017, p. 101). Bifid duct pyrg at Antelope Spring occupies 75 m (246 ft) of springbrook (11.3 m^2 [121.6 ft^2] of habitat) and has a mean catch per unit effort of 0.7 (range 0 to 1) (Sada 2017, p. 101). At Red Cedar Spring[3], subsequent surveys in 2015 and 2016

[3] Hershler (1998, p. 110) identified Red Cedar Spring as Spring above Swasey Spring.

noted the species to be abundant (Matthews and Wheeler 2015, p. 4; Sada 2017, p. 101). In 2016, bifid duct pyrg was found to occupy 510 m (1673.2 ft) of springbrook (21.8 m^2 [234.7ft^2] of habitat), and mean catch per unit effort was 26.8 with a range of 0 to 79 (Sada 2017, p. 101).

Big Spring is located on the west slope of the Canyon Mountains on USFS land in the Fishlake National Forest, Millard County, Utah. Bifid duct pyrg was first collected at this spring in 1993 and noted as scarce (Sada 2016, entire). Subsequent surveys in 2011 found the species to be uncommon to common (Oliver 2011b, p. 9) and in 2016 to be common (Sada 2017, p. 102). In 2016, the species occupied 82 m (269 ft) of springbrook (208.1 m^2 [2240 ft^2] of habitat), and mean catch per unit effort was 6.8 with a range of 0 to 38 (Sada 2017, p. 102).

Church Spring is located at the southern base of the Canyon Mountains, which occur at the northern edge of Pavant Valley in Millard County, Utah. It is the only spring occupied by bifid duct pyrg in Utah that is located on private land. The species was first collected at Church Spring in 1996 (National Museum of Natural History 2016, entire) and reported in Hershler (1998, p. 110). Subsequent surveys found the species to be common in 2011 (Oliver 2011b, p. 7) and abundant in 2016 (Sada 2017, p. 102). The spring is relatively large and deep, with a swift flow. The springbrook has been channelized to facilitate delivery of water to downstream pastures and cropland (Sada 2017, p. 102). In 2016, springsnails occupied 785 m (2575 ft) of springbrook (1,079.4 m^2 [11,619 ft^2] of habitat), and mean catch per unit effort was 45 with a range from 4 to 175 (Sada 2017, p. 102).

Maple Grove Springs is a spring province with at least five known spring sources (Maple Grove Spring A, B, C, D, and E) located on the eastern slope of the Pahvant Mountain Range in Millard County, Utah. This spring province occurs within a recreational campground on USFS land in the Fishlake National Forest. Hershler collected bifid duct pyrg at Maple Grove Springs in 1993 (National Museum of Natural History 2016, entire), which is the type locality for the species (Hershler 1998, p. 110). The species was reported as common (Sada 2016, entire). , which is the type locality for the species (Hershler 1998). Hershler reported the species as common (Sada 2016). Subsequent surveys in 2011 of the largest springbrook (Maple Grove Spring A) found a total of nine springsnails; thus abundance was recorded as scarce (Oliver 2011b, pp. 1–2). His notes reflect that he knew of four spring sources in the area, but it was not clear whether or not he surveyed the other springs. In 2016, Sada (2017, pp. 102-103) surveyed five springs in the area and determined species abundance to range from common to abundant, with the highest species abundance in Maple Grove Springs B and E. Occupied habitat ranged from 37.8 m^2 [406.9 ft^2] at Maple Grove Springs D to 1,543.5 m^2 [16,614 ft^2] at Maple Grove Springs A. Mean catch per unit effort in 2016 ranged from 46 at Maple Grove Springs D to 378 at Maple Grove Springs B (Sada 2017, pp. 102–103).

Copley's Cove Spring is located on the western slope of the Pahvant Mountain Range on USFS land at Fishlake National Forest, Millard County, Utah. Bifid duct pyrg was first collected at this spring in 1993 (also identified as South Fork Chalk Creek (Hershler 1998, p. 110) and Chokecherry Creek (National Museum of Natural History 2016, entire)); abundance information was not recorded. Subsequent surveys in 2011 and 2016 found the species to be abundant (Oliver 2011b, p. 5; Sada 2017, p. 104). This springbrook runs adjacent to and about 5 m (16.4 ft) below a recreational trail in the forest. In 2016, springsnails occupied 110 m (360.9 ft) of springbrook

(192.5 m^2 [2072.1 ft^2] of habitat) and mean catch per unit effort was 42.5 with a range of 7 to 143 (Sada 2017, p. 104).

The following information summarizes available water quality measurements taken during all surveys conducted at springs occupied by the bifid duct pyrg (Golden *et al.* 2007, entire; Albrecht *et al.* 2009, entire; Oliver 2011, entire; SNWA 2011, entire; Matthews and Wheeler 2015, entire; Sada 2016, entire; Sada 2017, entire). Water temperatures ranged from 9.30 to 18.33 °C (48.74 to 64.99 °F); pH ranged from 7.00 to 8.60; conductivity ranged from 178 to 671 µS/cm; DO ranged from 2.5 to 9.3 mg/L (ppm); spring discharge ranged from 2.0 to 8500.0 L/min (>0 to 5.0 cfs); and velocity ranged from 0 to 65.0 cm/sec (0 to 25.6 in/sec).

Table 5.124 summarizes all known surveys conducted for bifid duct pyrg, including estimates of total springbrook length, occupied springbrook length, and relative abundance.

Table 5.124. Relative abundance and springbrook data for bifid duct pyrg.

Spring or Spring Province		Survey Date	Springbrook Length (m)	Occupied Springbrook Length (m)	Relative Abundance	Source
		08/06/91	0.0	0.0	scarce	Sada 2016
		06/20/98	0.0	0.0	scarce	Sada 2016
		08/23/06	171.0 ?	-	none observed	Golden *et al.* 2007
		07/07/09	9.0	2.5	common	Sada 2016
Turnley Spring		07/01/16	0.0	0.0	none observed	Sada 2017
		05/21/08	-	52.8	abundant	Albrecht *et al.* 2009
		07/08/09	600.0	80.0	common	Sada 2016
Rock Spring		06/28/16	150.0	65.0	abundant	Sada 2017
		07/08/09	1,000.0	210.0	common	Sada 2016
Cache Springs A		06/28/16	1,500.0	95.0	abundant	Sada 2017
		07/08/09	10.0	10.0	common	Sada 2016
Cache Springs B		06/28/16	7.0	7.0	abundant	Sada 2017
Unnamed Spring near Sacramento Pass #1		07/08/09	400.0	120.0	common	Sada 2016
		06/28/16	250.0	135.0	abundant	Sada 2017
Unnamed Spring near Sacramento Pass #4		07/08/09	300.0	60.0	common	Sada 2016
	A	06/23/92	-	-	-	Sada 2016
	A	06/19/98	-	-	common	Sada 2016
	A	06/19/98	-	-	-	Sada 2016
	A	09/17/04	-	-	-	Golden *et al.* 2007
	A	07/30/09	60.0	40.0	common	Sada 2016
	1A	05/07/09	-	59.0	common	SNWA 2011
	1B	05/07/09	-	52.0	abundant	SNWA 2011
	1A	09/21/09	-	57.0	abundant	SNWA 2011
	1B	09/22/09	-	48.0	abundant	SNWA 2011
	1A	05/18/10	-	67.0	common	SNWA 2011
	1B	05/19/10	-	52.0	abundant	SNWA 2011
Unnamed Springs North of Big Springs	1A	09/21/10	-	60.0	abundant	SNWA 2011

Comment [PME75]: If the length is uncertain, suggest only showing sig figs to the nearest meter instead of adding decimal places.

Spring or Spring Province		Survey Date	Springbrook Length (m)	Occupied Springbrook Length (m)	Relative Abundance	Source
	1B	09/21/10	-	52.0	abundant	SNWA 2011
Antelope Spring		05/13/93	-	-	scarce	Sada 2016
		10/28/11	-	30.0	scarce	Oliver 2011
		05/20/15	-	36.8	scarce	Matthews and Wheeler 2015
		06/29/16	200.0	75.0	scarce	Sada 2017
Red Cedar Spring		05/13/93	-	-	common	Sada 2016
		05/20/15	-	325.0	abundant	Matthews and Wheeler 2015
		06/29/16	700.0	510.0	abundant	Sada 2017
Big Spring		07/13/93	-	-	scarce	Sada 2016
		10/27/11	-	-	common	Oliver 2011
		06/30/16	150.0	82.0	common	Sada 2017
Church Spring		09/28/96	-	-	-	Sada 2016
		10/27/11	-	-	common	Oliver 2011
		06/30/16	1,000.0	785.0	abundant	Sada 2017
Maple Grove Springs	B	07/12/93	-	-	common	Sada 2016
	A?	10/27/11	90.0	30.0	scarce	Oliver 2011
	A	06/30/16	1,000.0	613.0	common	Sada 2017
	B	06/30/16	255.0	255.0	abundant	Sada 2017
	C	06/30/16	135.0	135.0	common	Sada 2017
	D	06/30/16	84.0	84.0	common	Sada 2017
	E	06/30/16	175.0	175.0	abundant	Sada 2017
Copley's Cove Spring		07/13/93	-	-	-	Sada 2016
		10/27/11	-	-	abundant	Oliver 2011
		06/30/16	170.0	110.0	abundant	Sada 2017

Comment [PME76]: The length numbers seem different enough that the spring labeled "A?" might not actually be the same as the one labeled "A." A lot can change in 5 years though!

Unless otherwise noted, current condition information (Table 5.125) for these 12 springs or spring provinces are primarily from 2016 surveys, as documented in Sada (2017, pp. 99-106). For the four factors affecting current condition of springs, we assume that if the species is present within a spring or spring province, the water quality and discharge is adequate.

Table 5.125. Current conditions of bifid duct pyrg.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Turnley Spring	Adequate	Low	Low	Inadequate	Low[a]
Rock Spring	Adequate	High	Moderate	Adequate	Moderate/High[b]
Cache Springs	Adequate	High	High	Adequate	High[c]
Unnamed Spg near Sac Pass # 1	Adequate	High	High	Adequate	High[c]
Unnamed Spg near Sac Pass # 4[d]	Adequate	High	High	Adequate	High
Unnamed Spgs N of Big Springs[e]	Adequate	High	High	Adequate	High
Antelope Spring	Adequate	Moderate	Moderate	Adequate	Moderate[f]

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Red Cedar Spring	Adequate	High	High	Adequate	High
Big Spring	Adequate	High	High	Adequate	High
Church Spring	Adequate	High	High	Adequate	High[g]
Maple Grove Springs	Adequate	High	High	Adequate	High
Copley's Cove Spring	Adequate	High	High	Adequate	High

[a] Springhead capped, flow impounded, no flowing springbrook, springsnails absent.
[b] Road crosses occupied habitat – interrupts free water flow and disturbs springbrook.
[c] Evidence of historical dredging and impoundment, but no longer pools water or obstructs flow.
[d] Current conditions estimated from information provided in Sada 2016, entire.
[e] Current conditions estimated from information provided in SNWA 2011, Chapter 3 and Sada 2016, entire.
[f] Main springhead capped, flow piped, no flow in old springbrook, but adjacent seep supports a small springsnail population.
[g] Unknown effects of a new ditch constructed that would divert spring flow to agricultural fields.

At Turnley Spring, spring discharge was assumed to be inadequate and free-flowing water was ranked low due to the capped springhead and impounded flow, resulting in the flowing springbrook being converted into a ponded aquatic environment that does not provide optimal habitat for bifid duct pyrg. Substrate and vegetation was ranked low due to the altered aquatic environment and the absence of springsnails noted during the most recent survey conducted in 2016. Water quality was considered adequate at Turnley Spring since we do not have data that indicates water quality (i.e., temperature, pH, conductance, and DO) is not sufficient to support springsnails, and springsnails were observed during a survey at Turnley Spring in 2009.

Free-flowing water at Rock Spring was ranked moderate because a road crosses the springbrook within the occupied range of bifid duct pyrg, disturbing habitat and most likely affecting downstream flow below the road. However, the springsnail population is considered common to abundant at this spring, resulting in an overall ranking of moderate to high condition.

Both Cache Springs Province and Unnamed Spring near Sacramento Pass # 1 were given an overall ranking of high, even though evidence of historical dredging and channelization of the springbrook was observed during surveys conducted in 2016. Sada (2017, pp. 100-101) noted that these vegetation and substrate disturbances appear to have normalized over time and are not affecting the ability of these springs to support common to abundant populations of bifid duct pyrg.

Substrate and vegetation and free-flowing water at Antelope Spring were given a moderate ranking because the main springhead is capped, flow is piped, the original springbrook is dry, and the adjacent seep has a low discharge rate, dense vegetation consisting of rushes and spikerush, and a small but stable springsnail population. Current overall condition of Church Spring was given a high ranking based on an abundant springsnail population, dominance of watercress, extent of habitat, and high spring discharge rate; however, the current springbrook has been converted into a diversion ditch leading to adjacent agricultural fields and pastureland downstream from the springhead, watercress has been removed from parts of the diversion to facilitate water flow, and new ditch construction is underway by the private landowner that may result in diverting spring flow to additional agricultural fields. Given the unknown status of new ditch construction on this property, there is some uncertainty associated with our current overall condition ranking of high for Church Spring.

6 POTENTIAL FUTURE CONDITIONS – SPECIES VIABILITY

The viability of the 14 species of springsnails depends on maintaining resilient populations over time. There are uncertainties regarding the future condition of the numerous springs that support springsnails populations. The future use of springs on private land is an important uncertainty, which pertains to many springs in this assessment. An existing or future landowner may take some action that reduces or eliminates spring flow, springsnail habitat, or populations at a spring. Other uncertainties include the introduction of nonnative species such as mosquitofish, red-rimmed melania, crayfish, and various species of aquatic plants. Potential climate changes that may be manifested could exacerbate, for example, drought conditions, or potential groundwater withdrawals; both of these conditions could reduce spring discharge, but there is uncertainty concerning the species' response to these stressors. If a reduction of spring discharge or free-flowing water occurs, there may be uncertainty to the cause if multiple stressors are affecting the springs and springsnail populations. In consideration of the uncertainties, we developed three future scenarios that may affect the resiliency, redundancy, and representation over the next 50 years. The scenarios are:

1) Springs maintain adequate spring flow or discharge
2) Springs experience reduction in spring flow or discharge
3) Springs experience extreme reduction in spring flow or discharge or it is completely eliminated; flow and discharge are inadequate

6.1 Resiliency

Resiliency is the ability of populations to withstand stochastic events. Based upon survey data as early as the 1960s and most recently from 2016 within the analysis area, we can conclude that springsnail populations can recover or stabilize from anthropogenic disturbances such as impoundment, channel modification, and surface water diversion, which have the potential to result in initial population-level impacts. Martinez and Sorensen (2007, p. 31) concluded that isolated populations of endemic aquatic invertebrates may be resilient to short-term temporal population declines. The springsnail populations cannot, however, be resilient if their needs, which include water quality, substrate and vegetation, free-flowing water, and adequate spring discharge, are not being met.

Determining what may occur to springs on private land is not possible. If drought conditions persist in the west, water availability may not be able to meet human demand. Springs on private land may be modified in multiple ways in order to meet water demands for other uses, such as irrigation or livestock watering. Impacts to springs could include vegetation and soil disturbance, water pollution, groundwater pumping, and spring modifications (i.e., surface water diversion, channel modification, or impoundment). Assessing which stressors may occur in the future cannot be predicted. Uncertainties also exist at springs on state and federal lands, as stochastic events are random and cannot be predicted.

Groundwater pumping and altered precipitation and temperature could result in a reduction of adequate spring discharge and free-flowing water for springsnail populations. Since we cannot predict the extent or location of such water reductions or if groundwater pumping, altered precipitation and temperature, or both would occur, population resiliency is discussed under each of the three potential spring flow scenarios:

6.1.1 Scenario 1: Springs maintain adequate spring flow or discharge.

If adequate spring flow and discharge at springs does not change over the next 50 years, we anticipate springsnails to maintain their current levels of resiliency (as in the Current Conditions Tables in Chapter 5). It is also possible that springs may undergo future restoration activities, thereby improving their overall condition.

If unforeseen stochastic events occur, such as flooding or wildfire, that severely impact populations, management actions on Federal and state lands to restore habitat may occur. Restoration or reintroduction efforts would likely help populations rebound at these sites. Private lands could see populations being extirpated if stochastic events are severe enough and restoration activities do not or cannot occur, even with adequate spring discharge.

We would expect population resiliency to remain the same for stochastic events under Scenario 1, since spring flow and discharge will remain adequate.

6.1.2 Scenario 2: Springs experience reduction in spring flow or discharge.

If spring flow and discharge are reduced over the next 50 years due to groundwater pumping, altered precipitation and temperature, or both, populations would likely experience reduced resiliency than current conditions. While a reduction in water quantity alters pH and DO concentration (Sada *et al.* 2015, p. 45), water quality is likely to remain adequate. A reduction in spring discharge results in a decrease in habitat size, including springbrook length and wetted width (Sada *et al.* 2015, p. 45). For example, Morrison *et al.* (2013, p. 12) found substantial decreases in habitat (water depth and habitat size) with only small discharge reductions; the rate of change was greatest with only a 10 percent reduction in spring flow. Thus, a decrease in habitat and water quality is dependent upon the quantity of flow reduction. Overall, these types of changes are likely to reduce population abundance due to reduction in habitat size.

Future conditions at each spring, with the reduction of discharge, would likely be lower compared to current conditions. Discharge would diminish and the amount of available habitat could decrease. Depending upon the amount of discharge reduction, free-flowing water may be modified. If the quantity of water is reduced in a spring that currently has low water levels, the modified future levels may be so low that portions of the springbrook are no longer under water. The areas no longer under water would no longer have free-flowing water. For future conditions tables presented later in this chapter, there may be two habitat needs with reductions in ranking (i.e., aquatic vegetation and substrate, and free-flowing water) and then adequate discharge could become inadequate. Springs could then see a full decline in their overall condition (high to moderate, moderate to low, etc.). See below for future condition spring rankings and summaries of resiliency for each species under scenario 2. Springs would likely be more affected by stochastic events under scenario 2, thereby potentially causing more significant population- or rangewide-level impacts to populations than under scenario 1.

6.1.3 Scenario 3: Springs experience extreme reduction in spring flow or discharge or it is completely eliminated. Flow and discharge are inadequate.

Flows and discharges that are inadequate over the next 50 years would likely result in the extirpation of all affected springsnail populations, since two of their basic needs would be eliminated. There would be no resiliency for any species.

6.2 Redundancy

Redundancy is having a sufficient number of populations for a species to withstand catastrophic events. Compared to resiliency, redundancy is about spreading the risk, as measured through the duplication and distribution of populations across the range of the species. These risks could be exacerbated by events such as (but not limited to) widespread wildfires, intense drought, and more variable amounts of precipitation and snowpack melt. Some species' populations evaluated in this report are so small that it is not possible for them to exhibit redundancy.

We evaluated redundancy under the same potential spring flow scenarios:

6.2.1 Scenario 1: Springs maintain adequate spring flow or discharge.

Spring flow and discharge would remain adequate over the next 50 years in response to groundwater pumping and altered precipitation and temperature. We would expect most species' populations to persist with high levels of redundancy. Those species with one to few populations may not be able to withstand a large catastrophic event, possibly becoming extirpated if impacts are significant, even if flows and discharges remain adequate. This may also hold true for populations on those private lands where conservation plans/measures are not in place. Those species with numerous populations would likely withstand such events. Many uncertainties exist under this scenario depending upon the type and extent of catastrophic event (wildfire, earthquake, etc.).

6.2.2 Scenario 2: Springs experience reduction in spring flow or discharge.

Under this scenario, we would expect most species' populations to see a decline in redundancy. Populations would likely already be under decreased resiliency due to decreased habitat and decreases in free-flowing water. Those species with multiple populations, however, would have greater redundancy with catastrophic events resulting in reduced flows and discharge than those with fewer populations. Also, those springs on lands with management or conservation plans may undergo management actions to offset resiliency loss, thereby increasing redundancy and persistence. See below for summaries of redundancy for each species under scenario 2.

6.2.3 Scenario 3: Springs experience extreme reduction in spring flow or discharge or it is completely eliminated. Flow and discharge are inadequate.

Populations with inadequate flow and discharge would experience no redundancy, as populations are likely extirpated. It is not possible to estimate if any populations may be able to survive under such dire conditions, but we assume that extirpation is likely because two of their four basic needs would not be met.

6.3 Representation

Representation is the ability of a species to adapt to changing environmental conditions. It can be measured through ecological diversity (environmental variation) and genetic diversity within and among populations. Many species of springsnails have likely existed within their current spring distribution since the Pleistocene Epoch (approximately 10,000 years ago) and earlier to the late Tertiary era (approximately 2.6 million years ago) (Hershler and Liu 2008, p. 100). The genetic diversity of springsnail populations, as it relates to their ability to adapt over time to long-term changes in the environment, has not been studied much for the species reviewed in this report. Given the long period of time springsnail populations have persisted in their respective spring systems, we assume they can withstand and adapt to some perturbations in their environmental conditions; however, that adaptive ability may be species and spring system specific. Within the springbrooks inhabited by a given species, the areas of springbrook occupied could have a range of specific combinations of physiochemical characteristics tolerable by that species (Sada 2017, p. 13). The long-term isolation and small area within some spring systems, though, may make springsnails weakly adapted to survive introduced predation and competition, subsequently elevating the risk of extirpations in some populations of springsnail species (Sada 2017, p. 11).

6.3.1 Scenario 1: Springs maintain adequate spring flow or discharge.

Maintaining adequate spring flow and discharge over the next 50 years should result in genetic diversity in all springsnail populations similar to current conditions, as long as habitat changes or other disturbances do not occur at the population or rangewide levels. Thus, representation would be maintained at current levels.

6.3.2 Scenario 2: Springs experience reduction in spring flow or discharge.

We would expect a drop in resiliency in most populations over the next 50 years. If populations with low resiliency were to be extirpated, those species would see a loss of representation. Extirpation of a species that resides in only a single population would result in the loss of that species. See below for summaries of representation for each species under scenario 2.

6.3.3 Scenario 3: Springs experience extreme reduction in spring flow or discharge or it is completely eliminated. Flow and discharge are inadequate.

Under this scenario, we would expect all springsnail populations to be extirpated over the next 50 years as water quantities would not be adequate for survival. Species would lose all representation upon widespread extirpation.

6.4 Species Summaries for 3Rs

We use the best available information to project the likely future conditions of the 14 species of springsnails. Our goal is to describe the viability of the species in a manner that will address the needs of the species in terms of resiliency, redundancy, and representation. The following sections summarize the conditions presented under future condition scenario 2, as described above, given that the best available information indicates this to be the most likely scenario into the future (50 years). Overall, these summaries take into account a combination of the species needs, current condition, and projected future condition under scenario 2.

6.4.1 Spring Mountains pyrg

Resiliency

We expect that a decrease in spring discharge would result in reduced Spring Mountains pyrg population resiliency. All populations would have a decrease in substrate and aquatic vegetation Table 6.1). We project a high to moderate level future condition for six springs, while one spring—Willow Spring—is projected to have moderate to low conditions due to its current condition experiencing residual impacts from historical activities. We expect that the populations with high or moderate rankings will persist and Willow Spring, with moderate to low conditions may be at a higher risk of extirpation from stochastic events in the future. As such, we expect in 50 years, under Scenario 2, Spring Mountains pyrg future condition may be reduced from 7 to 6 populations where it would persist.

Table 6.1. Spring Mountains pyrg future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Red Spring	Adequate	Moderate	High	Adequate	High/Moderate
Willow Spring	Adequate	Low	Moderate	Adequate	Moderate/Low
Kiup Spring	Adequate	Moderate	High	Adequate	High/Moderate
Horse Spring A	Adequate	Moderate	High	Adequate	High/Moderate
Horse Spring B	Adequate	Moderate	High	Adequate	High/Moderate
Horse Spring C	Adequate	Moderate	High	Adequate	High/Moderate
Crystal Spring	Adequate	Moderate	High	Adequate	High/Moderate

*See Chapter 5 to compare this information against current conditions.

Accurate historical and current estimates of abundance are not available for the Spring Mountains pyrg. The best available data indicate that 2 to 20 surveys or collections at each of the 7 springs have been the basis for abundance estimates (1973–2016). This information is based on varying survey or collection efforts, as described in detail (with references) in all current condition discussions in Chapter 5. At this time, the best available information does not indicate that the species' abundance is significantly impacted by human activities. Additionally, the best available information does not indicate either increasing or declining numbers of springsnails for this species.

For small populations, demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact the population. Based on our evaluation of the best available information, there is no information on population sizes for the Spring Mountains pyrg, nor is there any information to indicate what a viable (or minimal) Spring Mountains pyrg population size should be. Regardless, surveys conducted in 2016 (Sada 2017, entire) continue to document its presence at six of the seven historical locations; surveyors were unable to access one spring in 2016. The likelihood for this species to persist with an appropriate population size and growth rate at seven springs is supported by our current overall finding of no change in the expected future trend for the species under future condition Scenarios 1 and 2. Therefore, the total abundance across the Spring Mountains pyrg's range is not likely to be at or near a level that would significantly affect the species' demographic stochasticity.

Redundancy

Seven populations of Spring Mountains pyrg are currently known to exist and all would see a decline in resiliency under Scenario 2. We expect that at least six of the seven populations would persist at a high to moderate future expected condition in two hydrographic areas. We expect that the redundancy of the Spring Mountains pyrg will likely be adequate to persist from catastrophic events because the seven populations are distributed across two hydrographic areas at five general locations separated from each other by distances ranging from 7 to 59 km (4 to 37 mi).

As indicated above, population size, growth rate, and current population trends are unknown for the Spring Mountains pyrg due to the lack of abundance information. Its current range consists of spring brooks from seven spring sources where the area occupied can fluctuate broadly between seasons and years. Its range occurs within a 162 mi^2 (419 km^2) area. Within this range based mostly on 2016 survey data of accessible sites, we identified approximately 584 m (1,916 ft) of springbrook habitat occupied by Spring Mountains pyrgs. Based on our assessment of potential stressors, it is unlikely that future changes in species condition would result in a significant loss of redundancy under future condition Scenario 1 or 2.

Representation

The genetic diversity of the Spring Mountains pyrg is fairly high with unique haplotypes of the cytochrome c oxidase1 (COI-1) region of mitochondrial DNA (mtDNA) that tend to be unique at springs (McKelvey et al. 2017, entire). We assume that maintaining populations at the extent of the species' range would preserve the existing potential ecological diversity. Under Scenario 2, we would expect all populations to exhibit a decrease in resiliency. Only one population, Willow Spring, has a potential future condition score of moderate/low. If this population were to be extirpated due to a catastrophic event, representation would be reduced slightly because it is reported to be a reintroduced population and it is one of the smaller populations compared to the others. The potential loss of the Willow Springs population in the future would not eliminate the Spring Mountains pyrg from a substantial portion of its range.

Currently, we are unaware of any documented specific risks for the Spring Mountains pyrg related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics. This species is widely distributed (up to seven known spring locations in two hydrographic basins with a maximum distance of 59 km (37 mi) between locations). Rates of dispersal or gene flow are not known to have changed. Additionally, the best available information does not indicate that the current abundance of the species is at level that is causing inbreeding depression or loss of genetic variation. Nor is there any information to indicate that this species could not adapt to changing conditions. Representation would, therefore, be maintained in the future for Spring Mountains pyrg.

6.4.2 Corn Creek pyrg

Resiliency

We expect that a decrease in spring discharge would result in reduced Corn Creek pyrg population resiliency. Both the water quality and discharge at Southeast of Corn Creek Spring would likely become inadequate (Table 6.2) because they are both currently nearly inadequate (see Chapter 5). All populations would see a decrease in substrate and aquatic vegetation due to a decrease in spring discharge. Additionally, a decrease in spring discharge in the future would likely lead to the extirpation of the population at Southeast of Corn Creek Spring.

Table 6.2. Corn Creek pyrg future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Corn Creek Springs (A, B, C)	Adequate	Moderate/Low	High	Adequate	Moderate
Unnamed Spring Near Corn Creek Springs	Adequate	Moderate/Low	Moderate	Adequate	Moderate
Southweast of Corn Creek Spring	Indequate	Low	Low	Indequate	Low

*See Chapter 5 to compare this information against current conditions.

Accurate historical and current estimates of abundance are not available for the Corn Creek pyrg. The best available data indicate that 18 collections or surveys are the basis for abundance estimates (1975–2016). This information is based on varying survey or collection efforts, as described in detail (with references) in all current condition discussions in Chapter 5. At this time, the best available information does not indicate that the species' abundance is significantly impacted by human activities. Additionally, the best available information does not indicate either increasing or declining numbers of springsnails for this species.

For small populations, demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact the population. Based on our evaluation of the best available information, there is no information on population sizes for the Corn Creek pyrg, nor is there any information to indicate what a viable (or minimal) Corn Creek pyrg population size should be. Regardless, surveys conducted in 2016 (Sada 2017, entire) documented its occurrence in two historical locations (one of which is represented by three separate springs with short springbooks that are tributary to a single springbrook) and one new location, Southeast of Corn Creek Spring. The high likelihood for this species to persist under Scenarios 1 and 2 with an appropriate population size and growth rate at these three locations is supported by our current overall finding of no change in the expected future trend for the species. Therefore, the total abundance across the Corn Creek pyrg's range is not likely to be at or near a level that would significantly affect the species' demographic stochasticity.

Redundancy
There are three populations of the Corn Creek pyrg and all would see a decline in resiliency under Scenario 2, with future conditions expected as moderate for two populations and low for one population. All three populations are on Federal land (Desert NWR), which is being managed with a beneficial conservation efforts expected to continue, making these locations have a low overall low risk from an anthropogenic caused catastrophy. All three populations have apparently persisted for hundreds to thousands of years or more without catastrophic extirpation. Under the worst-case Scenario 3, we predict that two populations of Corn Creek pyrg would remain.

As indicated above, population size, growth rate, and current population trends are unknown for the Corn Creek pyrg due to the lack of abundance information. Its current range consists of five spring sources with three populations in the Corn Creek area with pyrgs occupying approximately 21 m (69 ft) of springbrook and 15 m^2 (49 ft^2) of habitat. Based on our assessment, it is likely that future changes in species condition would result in the possible loss of one of three of the populations and thus, reduced redundancy to the species.

Representation
Genetic diversity in the Corn Creek pyrg is unknown and we assume that maintaining populations at the extent of the species' range would preserve the existing potential of ecological diversity. Under Scenario 2, we expect all populations to exhibit a drop in resiliency. The Southeast of Corn Creek Spring population has a future condition score of low. If this population were to be extirpated due to catastrophic event, representation would be reduced in the densest population of the Corn Creek pyrg. The loss of the Southeast of Corn Creek Spring population would eliminate the Corn Creek pyrg from one of three parts of its geographic range.

Currently, we are unaware of any documented specific risks for the Corn Creek pyrg related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics. Rates of dispersal or gene flow are not known to have changed. Additionally, the best available information does not indicate that the current abundance of the species is at level that is causing inbreeding depression or loss of genetic variation. Nor is there any information to indicate that this species could not adapt to changing conditions. Because this species occurs within only five springs at three locations/populations that are up to approximately 619 m (2,031 ft) apart, the Corn Creek pyrg is not well represented currently as well as in the future under Scenario 2 and 3. However, this representation appears to not have been well represented historically, as it is only known to occur in the Corn Creek Spring area.

6.4.3 Moapa pebblesnail

Resiliency
We expect that a decrease in spring discharge would result in reduced Moapa pebblesnail population resiliency, as well as overall lowered future conditions (compared to current conditions) in all six populations (Table 6.3). All populations but Cardy Lamb Spring would likely see a decrease in substrate and vegetation due to a decrease in spring discharge. Since Cardy Lamb Spring has a low current condition ranking for vegetation and substrate due its

small habitat size, a decrease in discharge should not change this low ranking. Spring discharge decreases may also result in decreases in free-flowing water. If the quantity of water is reduced in a spring that currently has low water levels or is a high-elevation spring, the modified future levels may be so low that portions of the springbrook are no longer under water. The areas no longer under water would be considered barriers to free-flowing water. Springs that do not have high discharge rates and water depths would be more susceptible to having reduced free-flowing water under Scenario 2. The populations most likely to see the most adverse effects from the reduction in free-flowing water are Apcar Springs Province, Cardy Lamb Spring, Pederson Springs Province, and Plummer Springs Province.

Table 6.3. Moapa pebblesnail future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Apcar Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate
Baldwin Spring	Adequate	Moderate	Moderate	Adequate	Moderate
Cardy Lamb Spring	Adequate	Low	Low	Adequate	Low
Muddy Spring	Adequate	Moderate	High	Adequate	High/Moderate
Pederson Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate
Plummer Springs Province	Adequate	Moderate	High	Adequate	High/Moderate

*See Chapter 5 to compare this information against current conditions.

Under Scenario 2, all six Moapa pebblesnail populations should see an expected future condition ranking lower than their current condition (see Chapter 5). Two populations would have high/moderate resiliency and three populations would have moderate resiliency; these five populations (Apcar Springs Province, Baldwin Spring, Muddy Spring, Pederson Springs Province, and Plummer Springs Province) all harbor an abundance value of "common" (i.e., catch per unit effort between 6 and 20 individuals) as opposed to scarce or abundant. Based on the current abundance, we can assume that in the future these populations would be able to withstand stochastic events, regardless of the lowered resiliency. The Cardy Lamb population, would have low resiliency because its habitat is currently small and would remain small in the future, and its abundance is currently scarce. This population would be at the greatest risk of surviving stochastic events. A decrease in discharge under Scenario 2, however, should not result in extirpation of any of the six Moapa pebblesnail populations.

There have been limited surveys for Moapa pebblesnail for each of the six populations (see the current condition discussion (with references) in Chapter 5). The relative abundance data we have (2000–2016) show at least common for five of six springs, and scarce at the the Cardy Lamb Spring. Three of these springs have a population that is spread throughout the province (Apcar Springs Province, Pederson Springs Province, and Plummer Springs Province). At this time, the best available data do not indicate whether abundance is increasing or decreasing at these springs. Demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact populations. All of the springs with Moapa pebblesnail populations have undergone various disturbance and stressor effects in the past. Many of these conditions have since stabilized and all six Moapa pebblesnail populations have persisted. The populations also appear to persist with effects from the current stressors.

There are also potential effects from future stressors that should be considered, such as groundwater pumping. Tetra Tech (2012, entire) evaluated modeling simulations of groundwater systems in southeastern Nevada under seven scenarios in 12 hydrographic areas. Moapa pebblesnail populations occur within hydrographic area 219, Muddy River Springs Area, which is included in this study. Modeling simulation 1 is based on existing groundwater rights that are currently pumped. After 50 years of pumping under the current pumping simulation 1, aquifer drawdown is 0.6 to 1.5 m (2 to 5 ft), and simulated spring discharges are reduced but still adequate (Tetra Tech 2012, p. 13; Figure 3.1-2a). Modeling simulation 2 is based on all existing groundwater rights, both pumped and unpumped, if they were to be pumped. After 50 years of pumping under the pumping simulation 2, aquifer drawdown would be 3 to 6.1 m (10 to 20 ft) and simulated spring discharges reduced, with Pederson Springs Province going dry (Tetra Tech 2012, p. 52; Figure 3.2-2a). Additionally, Plummer Springs Province is also predicted to go dry after 60 years under modeling simulation 2. There are additional scenarios that include the pumping of all pumped and unpumped groundwater rights as well as pending applications. Since we do not know if any pending applications will be permitted, those scenarios cannot be predicted to occur. Under the Tetra Tech (2012, entire) modeling, simulation predictions most closely match our Scenario 2, which results in reduced flow but adequate discharge (for most springs).

The pumping simulations performed by Tetra Tech (2012, entire) show that pumping at the rates imposed during the test can be expected to result in substantial declines in groundwater levels and spring flows. An additional simulation of the second year data (Service *et al.* 2013, pp. 4-5) suggest that the Tetra Tech model simulations (Tetra Tech 2012, entire) underestimate the amount of drawdown created by pumping, underestimate the impacts to spring discharges, and overestimate the timeframes in which the projected impacts will occur (Service *et al.* 2013, pp.4–5). The effectiveness of pumping reductions was simulated with the modeling, but the impacts were not directly evaluated during the test. If higher elevation springs stop flowing completely, it is not known how the system will respond to adjustments in pumping and whether biological resources (i.e., species needs) may be adversely affected in the process (Service *et al.* 2013, pp.4–5).

In a recent pumping test (Executive Order 1169) that overlapped with the six springs and spring provinces that support Moapa pebblesnail (see Chapter 4 for more details), groundwater levels decreased 0.7 to 1.1 m (2.5 to 3.5 ft). Discharge at Pederson Springs Province, the highest elevation springs for this species, declined 63 percent during the test and was predicted to run dry after only 1.5 years if the current rate of pumping were to continue. Other springs in the Muddy River Springs hydrographic area also saw a decline in discharge, though not at rates that would result in drying of these springs. The results of this pumping test also most closely match the reduced flow and adequate discharge of our future conditions Scenario 2.

There is also a Memorandum of Agreement for Coyote Spring Valley and California Wash Hydrographic Basins (SNWA *et al.* 2006, entire), between SNWA, the Service, CSI, Moapa

Band of Paiute Indians, and MVWD. This is an agreement regarding certain planned groundwater pumping in the Coyote Spring and California Wash hydrographic basins with measures to mitigate potential impacts of such pumping on the endangered Moapa dace (SNWA *et al.* 2006, entire). The Parties agreed upon the necessity to maintain specified minimum in-stream flows in the Warm Springs area and Parties agreed to work together and with others to implement research and restoration projects (SNWA *et al.* 2006, entire). This agreement could ensure adequate discharge in hydrographic area 219 for Moapa pebblesnail into the future.

The likelihood for the six populations of Moapa pebblesnail to continue to persist with an appropriate population size and growth rate at these six springs appears high based on the future expected condition of the six springs and spring provinces within the species range. Therefore, the Moapa pebblesnail's demographic stochasticity is not likely to be significantly affected.

Redundancy

There are six populations of Moapa pebblesnail, and with future conditions expected as moderate to high/moderate for five of six springs, redundancy should be adequate. However, other factors need to be evaluated when determining redundancy. All Moapa pebblesnail populations occur within the Muddy River Springs Area hydrographic basin (219) within springs that occur in an area within 2.1 km (1.3 mi) of each other. If one large catastrophic event were to occur in the Muddy River Springs Area, there is potential for redundancy to be low due to the close proximity of springs, but this seems unlikely. The most likely catastrophic event to occur in the Muddy River Springs Area is wildfire; however, even if all of the surface vegetation were burned, the best available information indicates that Moapa pebblesnail populations should endure. Based on what we know about the current abundance, range, and effects of stressors, it is unlikely that there would be a great loss in redundancy, which should remain adequate for the Moapa pebblesnail into the future.

Representation

Genetic diversity in Moapa pebblesnail is currently unknown, but we would assume that maintaining populations at the extent of the species' range would preserve the existing potential ecological diversity. Under Scenario 2, we would expect all populations to exhibit a drop in resiliency but maintain adequate redundancy. Only one population, Cardy Lamb Spring, has a future condition score of low. If this population were to be extirpated due to a catastrophic event, representation would likely be reduced but only slightly, since the Cardy Lamb Spring population is the smallest of all Moapa pebblesnail populations due to its restricted habitat (see Chapter 5). This loss of this one population would not eliminate Moapa pebblesnail from a substantial portion of its geographic range.

Currently, we are unaware of any risks to the Moapa pebblesnail related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics (including rates of dispersal or gene flow). Additionally, the best available information does not indicate that the current abundance of the species is at a level that is causing inbreeding depression or loss of genetic variation. We assume that the current level of genetic diversity has contributed to its persistence throughout its range, and the species should continue to express the same level of genetic diversity necessary to adapt to changing environmental conditions. Representation would, therefore, be maintained for Moapa pebblesnail into the future.

6.4.4 Moapa Valley pyrg

Resiliency

We expect that a decrease in spring discharge would result in reduced Moapa Valley pyrg population resiliencyas well as overall lowered future conditions (compared to current conditions) in all six populations (Table 6.4). All populations but Cardy Lamb Spring would likely see a decrease in substrate and vegetation due to a decrease in spring discharge. Since Cardy Lamb Spring currently has a low current condition ranking for vegetation and substrate due its small habitat size, a decrease in discharge should not change this low ranking. Spring discharge decreases may also result in decreases in free-flowing water. If the quantity of water is reduced in a spring that currently has low water levels or is a high-elevation spring, future levels may be so low that portions of the springbrook are no longer under water. Those portions no longer under water would be considered barriers to free-flowing water. The remaining six springs/spring provinces that do not have current high discharge rates and water depths would be more susceptible to having reduced free-flowing water under Scenario 2. The populations of Moapa Valley pyrg predicted to see the most adverse effects from the reduction in free-flowing water under Scenario 2 are Apcar Springs Province, Cardy Lamb Spring, Pederson Springs Province, and Plummer Springs Province.

Table 6.4. Moapa Valley pyrg future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Apcar Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate
Baldwin Spring	Adequate	Moderate	Moderate	Adequate	Moderate
Cardy Lamb Spring	Adequate	Low	Low	Adequate	Low
Muddy Spring	Adequate	Moderate	High	Adequate	High/Moderate
Pederson Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate
Plummer Springs Province	Adequate	Moderate	High	Adequate	High/Moderate

*See Chapter 5 to compare this information against current conditions.

Under Scenario 2, all Moapa Valley pyrg populations should see an expected future condition ranking lower than their current condition. Two populations (Muddy Spring and Plummer Springs Province) would have high/moderate resiliency and three populations (Apcar Springs Province, Baldwin Spring, and Pederson Springs Province) would have moderate resiliency. Four of the populations (Apcar Springs Province, Muddy Spring, Pederson Springs Province, and Plummer Springs Province) have all had common relative abundance for Moapa Valley pyrg during survey efforts available from 2000 to 2016 (see Chapter 5), while abundance at Baldwin was scarce. Based on the future expected condition of the springs or provinces, we can assume that these populations would be able to withstand stochastic events, regardless of the lowered resiliency. The Cardy Lamb Spring population, with low resiliency, would be at the lowest ranking, since habitat is (and would be) very small and the abundance is currently scarce. This population would be at the greatest risk of surviving stochastic events. A decrease in spring discharge under Scenario 2, however, should not result in extirpation of any of the six Moapa Valley pyrg populations.

There have been limited surveys for Moapa Valley pyrg for each of the six populations (see the current condition discussion (with references) in Chapter 5). The relative abundance data we have (2000–2016) show at least common for four of six springs (and scarce at the other two). Three of these springs have a population that is spread throughout the province (Apcar Springs, Pederson Springs, and Plummer Springs Provinces). The best available information does not indicate whether abundance is increasing or decreasing at these springs. Demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact populations. All of the springs with Moapa Valley pyrg populations have experienced historical disturbances; many of these conditions have since stabilized and all six Moapa Valley pyrg populations have persisted.

There are also potential effects from future stressors that should be considered, such as groundwater pumping. For example, Tetra Tech (2012, entire) evaluated modeling simulations of groundwater systems in southeastern Nevada under seven scenarios in 12 hydrographic areas, including hydrographic area 219, Muddy River Springs Area, which encompasses the entire range of Moapa Valley pyrg. Modeling simulation 1 is based on existing groundwater rights that are currently pumped. After 50 years of pumping under the current pumping simulation 1, aquifer drawdown is 0.6 to 1.5 m (2 to 5 ft), and simulated spring discharges are reduced but still adequate (Tetra Tech 2012, p. 13; Figure 3.1-2a). Modeling simulation 2 is based on all existing groundwater rights, both pumped and unpumped, if they were to be pumped. After 50 years of pumping under the pumping simulation 2, aquifer drawdown would be 3 to 6.1 m (10 to 20 ft) and simulated spring discharges reduced, with Pederson Springs and Plummer Springs Provinces going dry after 50 and 60 years, respectively (Tetra Tech 2012, p. 52; Figure 3.2-2a). There are additional simulations that include the pumping of all pumped and unpumped groundwater rights as well as pending applications; however, we do not know if any pending applications will be permitted within the Moapa Valley pyrg's range. Under the Tetra Tech (2012, entire) modeling, simulation predictions most closely match our Scenario 2, which results in reduced flow but adequate discharge (for most springs).

The pumping simulations performed by Tetra Tech (2012, entire) show that pumping at the rates imposed during the test can be expected to result in substantial declines in groundwater levels and spring flows. An additional simulation of the second year data (Service *et al.* 2013, p. 4–5) suggests that the Tetra Tech model underestimates the amount of drawdown created by pumping and the impacts to spring discharges, and overestimates the timeframes in which the projected impacts will occur (Service *et al.* 2013, pp.4–5). The effectiveness of pumping reductions was simulated with the modeling, but the impacts were not directly evaluated during the test. If higher elevation springs stop flowing completely, it is not known how the system will respond to adjustments in pumping and whether biological resources may be adversely affected in the process (Service *et al.* 2013, pp.4–5).

In a recent pumping test (Executive Order 1169) that overlapped with the six springs and spring provinces that support Moapa pebblesnail (see sections Chapter 4), groundwater levels decreased

0.7 to 1.1 m (2.5 to 3.5 ft). Discharge at Pederson Springs Province, the highest elevation spring for this species, declined 63 percent during the test and was predicted to run dry after only 1.5 years if the current rate of pumping were to continue. Other springs in the Muddy River Springs hydrographic area also saw a decline in discharge, though not at rates that would result in drying of these springs. The results of this pumping test also most closely match the reduced flow and adequate discharge of our future conditions Scenario 2.

There is also a Memorandum of Agreement between SNWA, the Service, CSI, Moapa Band of Paiute Indians, and MVWD for planned groundwater pumping at Coyote Spring Valley and California Wash Hydrographic Basins (SNWA *et al.* 2006, entire). See further discussion of this agreement above in section 6.4.3. This agreement could ensure adequate discharge in hydrographic area 219 for Moapa Valley pyrg.

The likelihood for the six populations of Moapa Valley pyrg to continue to persist with an appropriate population size and growth rate at these six springs appears high based on the future expected condition of the springs. Therefore, the Moapa Valley pyrg's demographic stochasticity is not likely to be significantly affected.

Redundancy

There are six populations of Moapa Valley pyrg, and with future conditions expected as moderate to high/moderate for five of six springs, redundancy should be adequate. However, other factors need to be evaluated when determining redundancy. All Moapa Valley pyrg populations occur within the Muddy River Springs Area hydrographic basin (219) within a total span of 2.1 km (1.3 mi). If one large catastrophic event were to occur in the Muddy River Springs Area, there is potential for reduced redundancy due to the close proximity of springs. However, this seems unlikely because the most likely catastrophic event to occur in the Muddy River Springs Area is wildfire, and even if all of the surface vegetation were burned, it is likely that Moapa Valley pyrg populations should endure. Based on what we know about the current abundance, range, and effects of stressors, it is unlikely that there would be a significant reduction in redundancy for the Moapa Valley pyrg.

Representation

Genetic diversity in Moapa Valley pyrg is currently unknown, but we would assume that maintaining populations at the extent of the species' range would preserve the existing potential ecological diversity. Under Scenario 2, we expect all populations to exhibit a drop in resiliency but maintain adequate (albeit reduced from current conditions) redundancy. Only one population, Cardy Lamb Spring, has a future condition score of low. If this population were to be extirpated due to a catastrophic event, representation would likely be reduced but only slightly, since the Cardy Lamb Spring population is the smallest of all Moapa Valley pyrg populations due to its restricted habitat. This loss would not eliminate Moapa Valley pyrg from a significant portion of its geographic range.

There are currently no known risks to the Moapa Valley pyrg related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics (including rates of dispersal or gene flow). Additionally, the best available indicates that the current abundance of the species is not at a level that would cause inbreeding depression or loss of genetic variation. We assume that the current level of genetic diversity has contributed to its persistence throughout its range, and the species should continue to express the same level of genetic diversity necessary to adapt to changing environmental conditions. Representation would, therefore, be maintained for Moapa Valley pyrg.

6.4.5 Grated tryonia

Resiliency

Grated tryonia co-exists with Moapa pebblesnail and Moapa Valley pyrg (see above sections 6.4.3 and 6.4.4), Hubbs pyrg, and Pahranagat pebblesnail (see sections 6.4.7 and 6.4.8). Therefore, we assume similar future conditions to those species (i.e., decreases in population resiliency and future conditions at all springs) (Table 6.3). Under Scenario 2, lower discharge would reduce the habitat available for grated tryonia, thereby decreasing the rankings for substrate and vegetation.

Spring discharge decreases may also result in decreases in free-flowing water. As similarly described above, if the quantity of water is reduced in a spring that currently has low water levels or is a high-elevation spring, the modified future levels may be so low that portions of the springbrook are no longer under water. The areas no longer under water would be considered barriers to free-flowing water. Springs that do not have high discharge rates and water depths would be more susceptible to having reduced free-flowing water. The grated tryonia populations most likely to see the most adverse effects from the reduction in free-flowing water are Apcar Springs Province, Cardy Lamb Spring, Pederson Springs Province, and Plummer Springs Province.

Table 6.5. Grated pyrg future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Apcar Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate
Ash Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate
Baldwin Spring	Adequate	Moderate	Moderate	Adequate	Moderate
Cardy Lamb Spring	Adequate	Low	Low	Adequate	Low
Crystal Springs Province	Adequate	Low	Moderate	Adequate	Moderate/Low
Hot Creek Springs Province	Adequate	Moderate	High	Adequate	High/Moderate
Moon River Spring	Adequate	Moderate	High	Adequate	High/Moderate
Moorman Spring	Adequate	Moderate	High	Adequate	High/Moderate
Muddy Spring	Adequate	Moderate	High	Adequate	High/Moderate
Pederson Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate
Plummer Springs Province	Adequate	Moderate	High	Adequate	High/Moderate

*See Chapter 5 to compare this information against current conditions.

Under Scenario 2, five populations would have high/moderate resiliency, four populations would have moderate resiliency, one population would have moderate/low, and one population would have low resiliency. Apcar, Pederson, and Plummer Springs Provinces, and Crystal, Moon River, and Moorman Springs all have scarce abundance of grated tryonia (see Chapter 5). The populations at Moon River and Moorman Springs would be more likely to be at risk of withstanding a catastrophic event due to their scarce abundance and because each one is a single spring and not a province of springs. A decrease in discharge under Scenario 2, however, should not result in extirpation of any grated tryonia populations.

There have been limited surveys for grated tryonia for each of the 11 populations. The relative abundance data that we do have (1992–2016) show at least common abundance for five springs and scarce abundance for six springs. At this time, the best available information does not indicate whether abundance is increasing or decreasing at these springs. Demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact populations. All of the springs with grated tryonia populations have experienced historical disturbances; many of these conditions have since stabilized and all 11 grated tryonia populations have persisted. The populations also appear to persist with individual-level effects from the current stressors.

There are also potential effects from future stressors that should be considered, such as groundwater pumping. For example, as similarly described above under sections 6.4.3 and 6.4.4, Tetra Tech (2012, entire) evaluated modeling simulations of groundwater systems in southeastern Nevada under seven scenarios in 12 hydrographic areas, including hydrographic area 219, Muddy River Springs Area, which encompasses the entire range of grated tryonia. After 50 years of pumping under the current pumping simulation 1, aquifer drawdown is 0.6 to 1.5 m (2 to 5 ft), and simulated spring discharges are reduced but still adequate (Tetra Tech 2012, p. 13; Figure 3.1-2a). Or, after 50 years of pumping under the pumping simulation 2, aquifer drawdown would be 3 to 6.1 m (10 to 20 ft) and simulated spring discharges reduced, with Pederson Springs and Plummer Springs Provinces going dry after 50 and 60 years, respectively (Tetra Tech 2012, p. 52; Figure 3.2-2a). There are additional simulations that include the pumping of all pumped and unpumped groundwater rights as well as pending applications; however, we do not know if any pending applications will be permitted within the grated tryonia's range. Under the Tetra Tech (2012, entire) modeling, simulation predictions most closely match our Scenario 2, which results in reduced flow but adequate discharge (for most springs).

The pumping simulations performed by Tetra Tech (2012, entire) show that pumping at the rates imposed during the test can be expected to result in significant declines in groundwater levels and spring flows. An additional simulation of the second year data (Service *et al.* 2013, p. 4–5) suggest that the Tetra Tech (2012, entire) model underestimates the amount of drawdown created by pumping and the impacts to spring discharges, and overestimates the timeframes in which the projected impacts will occur (Service *et al.* 2013, pp.4–5). The effectiveness of pumping reductions was simulated with the modeling, but the impacts were not directly evaluated during the test. If higher elevation springs stop flowing completely, it is not known how the system will respond to adjustments in pumping and whether biological resources may be adversely affected in the process (Service *et al.* 2013, pp.4–5).

As described under sections 6.4.3 and 6.4.4, the SNWA and CSI hold water rights applications in Coyote Spring Valley totaling 135,000 afy, and Executive Order 1169 required multiple entities in five hydrographic basins (including basin 219 where grated tryonia populations exist) to conduct a pump test of all existing water rights. Test results indicate groundwater levels decreased 0.8 to 1.1 m (2.5 to 3.5 ft). Discharge at Pederson Springs Province, the highest elevation spring, declined 63 percent during the test and was predicted to run dry after only 1.5 years if the current rate of pumping were to continue. Other springs in the Muddy River Springs hydrographic area also saw a decline in discharge, though not at rates that would result in drying of these springs. The results of this pumping test most closely match the reduced flow and adequate discharge of our future conditions Scenario 2.

As described under sections 6.4.3 and 6.4.4, there is also a Memorandum of Agreement between between SNWA, the Service, CSI, Moapa Band of Paiute Indians, and MVWD for Coyote Spring Valley and California Wash Hydrographic Basins (SNWA *et al.* 2006, entire). See further discussion of this agreement above in section 6.4.3. This agreement could ensure adequate discharge in hydrographic area 219 for grated tryonia.

Grated tryonia also occurs within a hydrographic basin (White River Valley) identified to be impacted by the SNWA GWD Project. BLM identified a one percent decrease in spring flow at Hot Creek Springs Province and Moorman Spring as a result of the proposed alternative for the project 75 years after full build out (BLM 2012, Chapter 3, Section 3.3 Water Resources, p. 183). This project, should it be built, would impact the springs similarly to our future conditionsScenario 2.

The likelihood for the 11 populations of grated tryonia to continue to persist with an appropriate population size and growth rate at these 11 springs appears high based on the future expected condition of the springs. Therefore, the grated tryonia's demographic stochasticity is not likely to be greatly affected.

Redundancy

There are currently 11 populations of grated tryonia, and with future conditions expected as high/moderate resiliency for five, moderate resiliency for four, moderate/low for one, and low resiliency for one, redundancy should be adequate. However, other factors need to be evaluated when determining redundancy. Grated tryonia populations occur within three hydrographic basins (Muddy River Springs Area [219], Pahranagat Valley [209], and White River Valley [207]. All of the springs span a distance of 214 km (133 mi). If catastrophic events were to occur, grated tryonia populations are spread out enough geographically so that redundancy would likely remain high. If extirpation were to occur at Cardy Lamb Spring due to events causing inadequate discharge and free-flowing water, 10 populations of grated tryonia would likely still exist, and redundancy should remain high. Based on what we know about the current abundance, range, and effects of stressors, as described in detail (with references) in Chapter 5), it is unlikely that there would be a great loss in redundancy, which should remain adequate to high for the grated tryonia.

Representation

Genetic diversity in grated tryonia is currently unknown, but we would assume that maintaining populations at the extent of the species' range would preserve any potential ecological diversity. Under Scenario 2, we would expect all populations to exhibit a drop in resiliency but maintain adequate to high redundancy. Only one population, Cardy Lamb Spring, has a future condition score of low. If this population were to be extirpated due to catastrophic event, representation would be reduced but only slightly, since the Cardy Lamb Spring population is the smallest of all grated tryonia populations (due to its restricted habitat). This potential loss would be insignificant across its geographic range.

There are currently no known risks to the grated tryonia related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics (including rates of dispersal or gene flow). Additionally, the best available information does not indicate that the current abundance of the species is at a level causing inbreeding depression or loss of genetic variation. We assume that the current level of genetic diversity has contributed to its persistence throughout its range, and the species should continue to express the same level of genetic diversity necessary to adapt to changing environmental conditions. Representation would, therefore, be maintained for grated tryonia.

6.4.6 Blue Point pyrg

Resiliency

Blue Point pyrg exists only in Blue Point Spring within the Lake Mead Recreation Area as a single population (Table 6.6). We expect that a decrease in spring discharge would result in a loss of Blue Point pyrg population resiliency. If the spring discharge greatly decreases, the substrate and vegetation would likely decrease. Blue Point Spring currently has a high condition ranking for vegetation and substrate, thus a decrease in discharge may change this ranking to moderate.

Table 6.6. Blue Point pyrg future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Apcar Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate

*See Chapter 5 to compare this information against current conditions.

A decrease in spring discharge may also reduce free-flowing water. Springs that do not have high discharge rates and water depths will be more susceptible to having reduced free-flowing water under Scenario 2. Although Blue Point Spring may be affected from a reduction in free-flowing water under Scenario 2, we assume that the ranking would remain moderate for the entire spring, essentially one half lower ranking than its current condition. Thus, this population would have moderate resiliency into the future under Scenario 2.

Accurate historical and current estimates of abundance are not available for the Blue Point pyrg at the present time; however, its relative abundance is consistently scarce. Available data indicate that 12 collections or surveys are the basis for abundance estimates (1988–2016), as described in detail (with references) in Chapter 5. This information is based on varying survey or collection efforts. At this time, the best available information indicates that the species' abundance is scarce and significantly impacted by invasive fish species by causing mortality. The best available information indicates that a population decline for this species could result in extinction.

For small populations, demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact the population. Based on our evaluation of the best available information, there is no information on population sizes for the Blue Point pyrg, nor is there any information to indicate what a viable (or minimal) Blue Point pyrg population size should be. Regardless, surveys conducted in 2016 (Sada 2017, entire) failed to detect its presence at Blue Point Spring.

Surveyors had access to Blue Point Spring in 2016, visiting the spring at different times of the year and documented its abundance as consistently scarce (see also Chapter 5). Given future conditions under Scenario 2, there is potential for this species to not persist at a (currently undetermined) appropriate population size and growth rate. Therefore, the total abundance across the Blue Point pyrg's range is likely to be at or near a level that would significantly affect the species' demographic stochasticity.

Redundancy
Because Blue Point pyrg exists as a single population located at one location, it has limited ability to withstand a catastrophic event under Scenario 2. With future conditions expected as moderate, redundancy may not be adequate for Blue Point pyrg. The one population is on Federal land managed by the National Park Service, so this spring is likely to exhibit adequate redundancy as a result of policies and management actions that are intended to preserve and protect the area (NPS 1986, entire). Under the worst-case scenario of extirpation at Blue Point Spring due to events causing inadequate discharge and free-flowing water, there would be no other remaining known populations of Blue Point pyrg.

As indicated above, little is known about the population size, growth rate, and current population trends of the Blue Point pyrg due to minimal population data. Its range and area of occupied habitat is uncertain at this time, but likely occurs within an area less than 5 m^2 (54 ft^2). Based on our assessment of stressors (see Chapter 5), it is likely that future changes in species condition would result in a significant loss of redundancy to the species.

Representation
Genetic diversity in Blue Point pyrg is currently unknown, but given the species occurs as a single population, we assume that genetic diversity is low. Under Scenario 2, the population of Blue Point pyrg should persist with moderate future condition, moderate resiliency, and adequate redundancy. The loss of this population in Blue Point Spring due to a catastrophic event would likely result in extinction of the species. Because this species occurs at only one spring, we determined that Blue Point pyrg is not well represented currently or under future condition Scenario 2.

Currently, we are unaware of documented risks for the Blue Point pyrg related to a specific change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics; however, we are aware that invasive fish species may be a risk. Blue Point pyrg is narrowly distributed at a single location. Thus, there are no rates of dispersal or gene flow. Additionally, there is no currently available information to indicate that the current abundance of the species is at a level that is causing inbreeding depression or loss of genetic variation. Nor is there any information to indicate that this species would need to adapt to changing conditions. Representation would, therefore, be maintained for Blue Point pyrg.

6.4.7 Hubbs pyrg

Comment [HC77]: Who owns and manages the land? If not being managing, then risk of extinction could be higher.

Do we know why the species went extinct at Hiko Spring?

Resiliency

The Hubbs pyrg currently exists only on private land at Crystal Springs Province (Table 6.7) and is considered extirpated from Hiko Spring (likely from impoundment, diversion, and invasive species) which has been impounded and diverted. Both spring areas are on private land. Under Scenario 2, the future condition for the Hubbs pyrg may be reduced. We expect that a decrease in spring discharge would result in a loss of Hubbs pyrg resiliency. The substrate and vegetation would likely decrease slightly from moderate to low; such a decrease may lower the future condition from moderate to moderate/low. We do not anticipate that a potential future reduction in spring discharge would be sufficient in itself to cause the extinction of the Hubbs pyrg.

Table 6.2. Hubbs pyrg future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Crystal Springs Province	Adequate	Low	Moderate	Adequate	Moderate/Low

*See Chapter 5 to compare this information against current conditions.

Under Scenario 2, the future condition for Hubbs pyrg at Crystal Springs Province should see an expected ranking one half lower than its current condition. The population would have moderate/low resiliency and should not result in extirpation under Scenario 2.

Accurate historical and current estimates of abundance are not available for the Hubbs pyrg at the present time; however, the best available information indicates it is extirpated from Hiko Spring and only persists at Crystal Springs Province. Available data indicate that 20 collections or surveys are the basis for abundance estimates (1969–2016), as described in detail (with references) in Chapter 5. This information is based on varying survey or collection efforts. The best available information indicates that the population of Hubbs pyrg may fluctuate broadly at Crystal Springs Province where the species' relative abundance has fluctuated as broadly as abundant to scarce and vice versa.

For small populations, demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact the population. We found no information on population sizes for the Hubbs pyrg, nor is there any information to indicate what a viable (or minimal) Hubbs pyrg population size should be. The likelihood for this species to persist with an appropriate population size and growth rate at this location is uncertain. Therefore, it is unclear if the total abundance across the Hubbs pyrg's range is likely to be at or near a level that would significantly affect the species' demographic stochasticity.

Redundancy

Because Hubbs pyrg exists as a single population located in one location, it has limited ability to withstand a catastrophic event under Scenario 2. With future conditions expected to become moderate/low, redundancy should be adequate for Hubbs pyrg. As indicated above, population size, growth rate, and current population trends at Crystal Springs Province are unknown for the Hubbs pyrg due to the lack of abundance information; however, the best available information indicates it is extirpated from Hiko Spring. Its current range consists of one population in Crystal Springs Province with pyrgs occupying an area of approximately 30 m^2 (323 ft^2). If Hubbs pyrg at Crystal Springs Province became extirpated due to catastrophic lower flow and discharge or other event, we expect the Hubbs pyrg could become extinct.

Representation

Genetic diversity in Hubbs pyrg is currently unknown, but given the species occurs as a single population, we assume that genetic diversity is low. Under Scenario 2, we expect the population of Hubbs pyrg may persist with moderate/low future condition and moderate resiliency. The loss of this population in Crystal Springs Province would likely result in extinction of the species. Because this species occurs at only one spring province, we determined that Hubbs pyrg is not well represented currently or under future condition Scenario 2.

Currently, we are unaware of any documented specific risks for the remaining population of Hubbs pyrg related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics. There are no known dispersal or gene flow between populations given there is onlya singlepopulation, and thus no known changes to dispersal. Additionally, the best available information does not indicate that the current abundance of the species is at level that is causing inbreeding depression or loss of genetic variation. Nor is there any information to indicate that this species could not adapt to changing conditions. Because this species occurs at one spring province with one population, we determined that Hubbs pyrg is not well represented currently or under Scenario 2, and may not have been well represented historically as it is only known to have occurred in Hiko Spring and Crystal Springs Province.

6.4.8 Pahranagat pebblesnail

Resiliency

Under Scenario 2, we expect to see a decrease in population resiliency and future condition for all four populations of Pahranagat pebblesnail (Table 6.8). Vegetation and substrate would be reduced to moderate for all springs and there would be no decrease in condition from the reduction in free-flowing water due to the current size, depth, and discharge rates of these springs (as described indetail (with references) in Chapter 5). Three populations would have high/moderate resiliency and one population would have moderate resiliency. Moon River Spring and Moorman Spring would be more at risk of withstanding a catastrophic event than Ash Springs Province and Hot Creek Springs Province due to their scarce Pahranagat pebblesnail abundance and because they are each one spring instead of a province of springs. A decrease in spring discharge under Scenario 2, however, should not result in extirpation of any Pahranagat pebblesnail populations.

Table 6.8. Pahranagat pebblesnail future conditions*.

Spring or Spring	Water	Substrate	Free-	Adequate	Future

Province/Population	Quality	and Vegetation	Flowing Water	Discharge	Expected Condition
Ash Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate
Hot Creek Springs Province	Adequate	Moderate	High	Adequate	High/Moderate
Moon River Spring	Adequate	Moderate	High	Adequate	High/Moderate
Moorman Spring	Adequate	Moderate	High	Adequate	High/Moderate

*See Chapter 5 to compare this information against current conditions.

There have been limited surveys for Pahranagat pebblesnail for each of the four populations (see Chapter 5). Hot Creek Springs Province, Moon River Spring, and Moorman Spring only have abundance data from 2016, while Ash Springs Province has data from 1992, 2014, 2015, and 2016. The relative abundance data available show at least common abundance for two of four springs (and scarce abundance for the other two). The best available data does not indicate whether abundance is increasing or decreasing at these springs. Demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact populations. All of the springs with Pahranagat pebblesnail populations have experienced historical disturbances; many of these conditions have since stabilized and all four Pahranagat pebblesnail populations have persisted.

There are also potential effects from future stressors that should be considered, such as groundwater pumping. This species occurs within a hydrographic basin (White River Valley) identified to be impacted by the SNWA GWD Project. BLM identified a one percent decrease in spring flow at Hot Creek Springs Province and Moorman Spring as a result of the proposed alternative for the project 75 years after full build out (BLM 2012, Chapter 3, Section 3.3 Water Resources, p. 183). This project, should it be built, would impact the springs similarly to our future condition Scenario 2.

The likelihood for the four populations of Pahranagat pebblesnail to continue to persist with an appropriate population size and growth rate at these four springs appears high based on the future expected condition of the springs. Therefore, the Pahranagat pebblesnail's demographic stochasticity is not likely to be greatly affected.

Redundancy

There are four populations of Pahranagat pebblesnail; redundancy should adequate given future expected conditions are high/moderate for Hot Creek Springs Province, Moon River Spring, and Moorman Spring and moderate condition for Ash Springs Province. However, other factors need to be evaluated when determining redundancy. All four Pahranagat pebblesnail populations occur within the Pahranagat Valley and the White River Valley hydrographic basins within a total span of 125 km (78 mi). If catastrophic events were to occur, Pahranagat pebblesnail populations are spread out geographically so that redundancy should be high. Given the best available information on the current abundance, range, and effects of stressors, it is unlikely that there would be a great loss in redundancy, which should remain adequate to high for the Moapa pebblesnail.

Representation

Genetic diversity in Pahranagat pebblesnail is currently unknown, but we assume that maintaining populations at the extent of the species' range would preserve any potential ecological diversity. Under Scenario 2, we expect all populations to exhibit a drop in resiliency but maintain adequate to high redundancy.

There are currently no known risks to the Pahranagat pebblesnail related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics (including rates of dispersal or gene flow). Additionally, the best available information does not indicate that the current abundance of the species is at level to cause inbreeding depression or loss of genetic variation. We assume that the current level of genetic diversity has contributed to its persistence throughout its range, and the species should continue to express the same level of genetic diversity necessary to adapt to changing environmental conditions. Representation would, therefore, be maintained for Pahranagat pebblesnail.

6.4.9 White River Valley pyrg

Resiliency

White River Valley pyrg occurs in seven springs or spring provinces, each providing a single population. Spring modifications (i.e., surface water diversion, impoundments, channel modification), competition/predation (nonnative fish), and vegetation and soil disturbance (as a result of recreation, grazing and browsing, invasive aquatic plants, and roads) are the stressors across the species range. There are no important stressors affecting the species at Flag Springs Province, Camp Spring, Lund Spring, or Preston Big Spring. Water diversion is an important stressor at Cold and Nicholas springs but access was not provided to determine effects of other stressors at this these springs. The effects of stressors on the White River Valley pyrg at Arnoldson are unknown due to no access to the spring. Groundwater withdrawal is an additional stressor that may potentially affect the future condition of the species particularly at Flag Springs Province. Based on climate change projections, we do not expect a significant decrease in precipitation in White River Valley over the next 50 years.

Table 6.8. White River Valley pyrg future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Flag Springs Province	Adequate	High	High	Adequate	High/Moderate
Camp Spring	Adequate	High	High	Adequate	Moderate
Lund Spring	Adequate	High	High	Adequate	Moderate
Preston Big Spring	Adequate	Moderate	High	Adequate	Moderate
Arnoldson Spring	Unknown	Low	Low	Inadequate	Low
Cold Spring	Adequate	Insuff. data	Low	Adequate	Low
Nicholas Spring	Adequate	Insuff. data	Low	Unknown	Low

*See Chapter 5 to compare this information against current conditions.

One of the seven springs is or has experienced decreased spring discharge. In November 2012, we determined that spring discharge may be reduced at Flag Spring Province (which occurs on BLM lands) as a result of SNWA's full, proposed rate of groundwater pumping from the GWD project (Service 2012, p. 164). Thus, BLM determined that a reduced rate of pumping would instead only result in a 6 percent decrease in spring flow at Flag Springs Province. Currently, the project is on hold, and we are uncertain if it will be implemented as originally proposed (see Chapter 4—*Southern Nevada Water Authority Groundwater Development Project* for more details).

Based on climate change projections, we do not expect a large decrease in precipitation in White River Valley over the next 50 years. Stressor impacts are expected to result in low to moderate/high future condition across the range of the species, with an overall moderate condition under Scenario 1 or 2. We expect that a major decrease in discharge under Scenario 3 would reduce White River Valley pyrg population resiliency, resulting in less free-flowing water and aquatic habitat for the species. Since Arnoldson Spring, Cold Spring, and Nicholas Spring have an overall low current condition ranking for vegetation, substrate, and free-flowing water, a major decrease in discharge (Scenario 3) may result in loss of springsnails at these springs due to loss of habitat (drying of springs); the other four springs would likely change to moderate/low future conditions, thus the possibility of persistence into the future. Scenario 3, though the most unlikely scenario, may cause extirpation of pyrgs from one to three springs, but not likely the remaining four springs and spring province.

Accurate historical and current estimates of abundance are not available for the White River Valley pyrg at the present time. The best available data indicate that two to three surveys at each of the six springs and one spring province (totaling nine springs) have been the basis for abundance estimates (1992–2016), as described indetail (with references) in Chapter 5. This information is based on limited survey efforts and in some cases limited access. Although human activities are causing the most significant impacts from the various stressors, the best available information does not indicate that the species' abundance is significantly impacted. Additionally, the best available information does not indicate either increasing or declining numbers of springsnails for this species.

For small populations, demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact the population. At this time, there is no information on population sizes for the White River Valley pyrg, nor is there any information to indicate what a viable (or minimal) White River Valley pyrg population size should be. Regardless, surveys conducted in 2016 (Sada 2017, entire) continue to document its presence at five of the nine historical springs at ## locations; only two springs surveyed in 2016 (i.e., xxx and yyy) did not have White River Valley pyrgs present. The likelihood for this species to persist with an appropriate population size and growth rate at five or more springs is supported by our current overall finding of no change in the expected future conditions for the species under Scenarios 1 and 2. Therefore, the total abundance across the White River Valley pyrg's range is not likely to be at or near a level that would significantly affect the species' demographic stochasticity.

Redundancy

There are currently five known and possibly seven populations of White River Valley pyrg. Under Scenario 2, we would expect that at least four populations of White River Valley pyrg would persist and redundancy would be adequate for White River Valley pyrg. It is possible that Cold Spring, Nicholas Spring, and Arnoldson Spring may become extirpated under Scenario 2.

Comment [HC78]: Why possibly seven? This is notclear

As indicated above, population size, growth rate, and current population trends are unknown for the White River Valley pyrg due to minimal abundance information. Its range occurs along 66 km (41 mi) of the White River. Within this range, based mostly on 2016 survey data, we identified approximately 700 m (2,297 ft) of springbrook and 1,042 m^2 (11,216 ft^2) of habitat occupied by White River Valley pyrgs. Based on our assessment of stressors, it is unlikely that future changes in species condition would result in a significant loss of redundancy to the species under Scenario 1 or 2.

<u>Representation</u>

Genetic diversity in White River Valley pyrg is currently unknown, but we assume that maintaining populations at the extent of the species' range would preserve any potential ecological diversity. Under Scenario 2, we expect that at least four of the existing seven populations (Flag Spring Province, Camp Spring, Lund Spring, and Preston Big Spring) would persist and exhibit moderate future conditions. Because Arnoldson, Preston Big Spring, Cold, and Nicholson Springs are clustered in the same area, the loss of one or more springs would not eliminate White River Valley pyrg from a substantial portion of its geographic range provided one or more populations persist in the area.

Currently, we are unaware of any documented specific risks for the White River Valley pyrg related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics. Rates of dispersal or gene flow are not known to have changed. Additionally, the best available information does not indicate that the current abundance of the species is at level that is causing inbreeding depression or loss of genetic variation. Nor is there any information to indicate that this species could not adapt to changing conditions. Representation would, therefore, be maintained for White River Valley pyrg.

6.4.10 Flag pyrg

<u>Resiliency</u>

Flag pyrg exists as two populations, co-existing with White River Valley pyrg in Flag Springs Province (comprised of three springs) and as the only pyrg known to occur at Meloy Spring (Table 6.9). No important stressors are known at springs occupied by the species. Spring modifications (i.e., surface water diversion and impoundments) and vegetation and soil disturbance as a result of roads are the stressors across the range of the species (as described in detail (with references) in Chapter 5). These stressors are not causing loss or degradation of habitat or loss of individuals. Based on climate change projections, we do not expect a large decrease in precipitation in White River Valley over the next 50 years. Additionally groundwater withdrawal is a stressor that may affect the future condition of the species but we expect all populations of the pyrg (i.e., Flag Springs Province or Meloy Spring) will persist in the future.

Table 6.9. Flag pyrg future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Flag Springs Province	Adequate	High	High	Adequate	High
Meloy Spring	Adequate	Moderate	High	Adequate	High

*See Chapter 5 to compare this information against current conditions.

We have no information that the Flag Springs Province (which occurs on BLM land) has experienced decreased spring discharge. In November 2012, we determined that spring discharge may be reduced at Flag Spring Province (which occurs on BLM lands) as a result of SNWA's full, proposed rate of groundwater pumping (Service 2012, p. 164). If this project goes forward as currently proposed, BLM determined that spring flow at Flag Springs Province would be reduced 6 percent at Flag Springs Province. Because the spring flow is high at this province (i.e., 1400 to 5329 L/min (cfs), this reduction would result in an insignificant effect on the species. Based on climate change projections, we do not expect a large decrease in precipitation in White River Valley over the next 50 years. Stressors are not expected to change the high future condition for the species at either location under Scenario 1 or 2. We expect that a major decrease in discharge under Scenario 3 would reduce Flag pyrg population resiliency, resulting in less free-flowing water and aquatic habitat for the species. Since Flag Spring Province and Meloy Spring have an overall moderate or high current condition ranking for vegetation, substrate, and free-flowing water, a major decrease in discharge (Scenario 3) may change this ranking to moderate or low.

Accurate historical and current estimates of abundance are not available for the Flag pyrg at the present time (see Chapter 5). Available data based on limited survey efforts indicate that two to three surveys at each of the four springs have been the basis for abundance estimates (1992–2016). At this time, the best available information does not indicate that the species' abundance is significantly impacted by human activities. Additionally, the best available information does not indicate either increasing or declining numbers of springsnails for this species.
For small populations, demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact the population. At this time, there is no information on population sizes for the Flag pyrg, nor is there any information to indicate what a viable (or minimal) Flag pyrg population size should be. Regardless, surveys conducted in 2016 (Sada 2017, entire) continue to document its presence at three of the four historical locations; only one spring surveyed in 2016 (Flag Springs Province C) did not have Flag pyrgs present. The likelihood for this species to persist with an appropriate population size and growth rate at these locations is supported by our current overall finding of no change in the expected future trend under Scenarios 1 and 2. Therefore, the total abundance across the Flag pyrg's range is not likely to be at or near a level that would significantly affect the species' demographic stochasticity.

Redundancy

As indicated above, population size, growth rate, and current population trends are unknown for the Flag pyrg due to limited abundance information. Its range consists of four springs at two locations approximately 67 km (42 mi) apart. Within this range based mostly on 2016 survey data, we identified approximately 265 m (869 ft) of springbrook and 566 m^2 (6,092 ft^2) of habitat occupied by Flag pyrgs. Based on our assessment of the most significant stressors (i.e., water diversions and impoundments) currently affecting the species, it is unlikely that future changes in species condition would result in a significant loss of redundancy to the species under Scenarios 1 or 2.

Representation
Genetic diversity in Flag pyrg is currently unknown, but we assume that maintaining populations at the extent of the species' range would preserve any potential ecological diversity. Under Scenario 1 or 2, we expect that both Flag Springs Province and Meloy Spring populations would persist and exhibit high future conditions.

Currently, we are unaware of any documented specific risks for the Flag pyrg related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics. This species is represented at two isolated locations. Rates of dispersal or gene flow are not known to have changed. Additionally, the best available information indicates that the current abundance of the species is not at level that is causing inbreeding depression or loss of genetic variation. Nor is there any information to indicate that this species could not adapt to changing conditions. Representation would, therefore, be maintained for Flag pyrg.

6.4.11 Lake Valley pyrg

Lake Valley pyrg is known only from Wambolt Springs Province, where it exists as two populations at five springs: Wambolt Springs A-D and Wambolt Spring E (Table 6.10). Vegetation and soil disturbance from grazing and browsing and spring modifications as a result of surface water diversion are the stressors at these springs (as described in detail (with references in Chapter 5), and are expected to result in moderate future condition for the Lake Valley pyrg. We expect that a decrease in spring discharge under Scenarios 2 and 3 would reduce Lake Valley pyrg population resiliency. A reduced discharge from the springs would likely result in less free-flowing water and aquatic habitat for the species. Wambolt Spring E would be more susceptible to having reduced free-flowing water because this spring does not currently have high discharge rates and water depth. Since Wambolt Springs A–D currently have a moderate current condition ranking for vegetation and substrate, a substantial decrease in discharge (Scenario 2) may change this ranking to low.

Table 6.10. Lake Valley pyrg future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Wambolt Springs A-D	Adequate	Moderate	Moderate	Adequate	Moderate
Wambolt Spring E	Unknown	Unknown	Unknown	Unknown	Unknown

*See Chapter 5 to compare this information against current conditions.

Accurate historical and current estimates of abundance are not available for the Lake Valley pyrg at the present time. Limited survey efforts have resulted in one to three surveys at each of the springs in the province to serve as the basis for abundance estimates (2004–2016). At this time, the best available information does not indicate that the species' abundance is significantly impacted by the current stressors. Additionally, the best available information does not indicate either increasing or declining numbers of springsnails for this species.

For small populations, demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact the populations. Currently, there is no information on population sizes for the Lake Valley pyrg, nor is there any information to indicate what a viable (or minimal) Lake Valley pyrg population size should be. Regardless, surveys conducted in 2016 (Sada 2017, entire) documented its occurrence at three of the five historical springs; two springs, Wambolt Springs A and E, could not be found. The high likelihood for this species to persist under Scenarios 1 and 2 with an appropriate population size and growth rate at Wambolt Springs B, C, and D is supported by our current overall finding of no change in the expected future conditions for the species. Therefore, the total abundance across the Lake Valley pyrg's range is not likely to be at or near a level that would significantly affect the species' demographic stochasticity.

Redundancy

Because Lake Valley pyrg exists at a single geographic locality, it has limited ability to withstand a catastrophic event under Scenarios 2 or 3. Lake Valley pyrg could become extirpated at one or more springs due to catastrophic lower flow and discharge. While redundancy would be low, the risk of total extirpation may not be likely given that there are multiple springs in this province. We would expect Lake Valley pyrg to remain at a minimum of one to two of the springs in this province.

As indicated above, population size, growth rate, and current population trends are unknown for the Lake Valley pyrg due to limited abundance information. Its current range consists of three to five springs and two populations (although the population at Wambolt Spring E was not found during 2016) with pyrgs occupying 123 m (649 ft) of springbrook and 271.9 m^2 (2,926.7 ft^2) of habitat. Based on our assessment of stressors under current conditions, it is unlikely that future changes in species condition would result in a significant loss of redundancy to the species.

Representation

Genetic diversity in Lake Valley pyrg is currently unknown, but given the species occurs as within one geographic location, we assume that genetic diversity is low. Under Scenario 2, we expect the populations of Lake Valley pyrg to persist with moderate future conditions, moderate resiliency, and adequate redundancy.

Currently, we are unaware of any documented specific risks for the Lake Valley pyrg related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics. Rates of dispersal or gene flow are not known to have changed. Additionally, the best available information does not indicate that the current abundance of the species is at level that is causing inbreeding depression or loss of genetic variation. Nor is there any information to indicate that this species could not adapt to changing conditions. Because this species occurs at only one spring province with two populations approximately 416 m (1,365 ft) apart, we determined that Lake Valley pyrg is not well represented currently or under Scenario 2 or 3, and may not have been well represented historically as it is only known to occur in the Wambolt Springs province.

6.4.12 Butterfield pyrg

Resiliency

Butterfield pyrg is known from three springs that comprise Butterfield Spring Province, where it exists as a single population and co-exists with Hardy pyrg (Table 6.11). Because the two species are similarly distributed with the same species needs, we expect to see the same decreases in future condition rankings and resiliency for all populations of both species. Spring modification as a result of surface water diversion, as well as vegetation and soil disturbance from grazing and browsing, and invasive plants are the only stressors in the province, and are expected to result in moderate effect on the Butterfield pyrg in the future. Based on climate change projections, we do not expect a large decrease in precipitation in White River Valley over the next 50 years. Additionally, groundwater withdrawal is a stressor that may affect the future condition of the species.

Table 6.11. Lake Valley pyrg future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Butterfield Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate

*See Chapter 5 to compare this information against current conditions.

We have no information that the Butterfield Springs Province (which occurs on BLM land) has experienced decreased spring discharge. In November 2012, we determined that spring discharge may be reduced at Butterfield Spring Province (which occurs on BLM lands) as a result of SNWA's full, proposed rate of groundwater pumping (Service 2012, p. 164). If this project goes forward as currently proposed, BLM determined that spring flow at Flag Springs Province would be reduced 6 percent at Butterfield Springs Province. Spring flow at this province has been measured from 70 to 600 L/min (cfs). This reduction may result in a significant effect one or more springs in this province.

We expect that a major decrease in spring discharge under Scenario 3 would reduce Butterfield pyrg population resiliency. A reduced discharge from the springs would likely result in less free-flowing water and aquatic habitat for the species. Butterfield Springs C and D, which are springs that do not have high discharge rates and water depth, would be more susceptible to having reduced free-flowing water. Butterfield Spring E is a large spring with a moderate discharge rate (150 L/min (0.09 cfs)) and moderate depth, which should retain moderate future condition for the spring and population. Because Butterfield Springs A and B could not be found during the 2016 survey, we have no current information for these springs. Since Butterfield Springs Province currently has a moderate current condition ranking for vegetation and substrate, a substantial decrease in discharge (Scenario 2) may change this ranking to low, but would not result in extirpation of Butterfield pyrgs from any currently occupied springs.

Accurate historical and current estimates of abundance are not available for the Butterfield pyrg at the present time. Available data from limited survey efforts indicate that one to two surveys at each of the springs in the province have been the basis for abundance estimates (1992–2016), as described in detail (with references) in Chapter 5. At this time, the best available information does not indicate that the species' abundance is significantly impacted by the stressors. Additionally, the best available information does not indicate either increasing or declining numbers of springsnails for this species.

For small populations, demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact the population. There is no information on population sizes for the Butterfield pyrg, nor is there any information to indicate what a viable (or minimal) Butterfield pyrg population size should be. Regardless, surveys conducted in 2016 (Sada 2017, entire) located a new occupied spring in the province (Butterfield Spring E) and documented its occurrence in two other springs (Butterfield Springs C and D); two springs, Butterfield Springs A and B, could not be found. The likelihood for this species to persist with an appropriate population size and growth rate at these three springs is supported by our current overall finding of no change in the expected future conditions for the species under Scenario 1 or 2. Therefore, the total abundance across the Butterfield pyrg's range is not likely to be at or near a level that would significantly affect the species' demographic stochasticity.

Redundancy

Because Butterfield pyrg currently exists at three of five springs as a single population, it has limited ability to withstand a catastrophic event under Scenarios 2 or 3. Butterfield pyrg at Butterfield Springs C and D could become extirpated due to catastrophic lower flow and spring discharge (Scenario 3). While redundancy would be low, the risk of total extirpation may not be likely given that there are multiple springs in this province. We would expect Butterfield pyrgs to remain at Butterfield Spring E under Scenario 2 due to its large size and abundant pyrg population.

As indicated above, population size, growth rate, and current population trends are unknown for the Butterfield pyrg due to the minimal abundance information. Its current range consists of three springs with pyrgs occupying 440 m (1,443 ft) of springbrook (464.8 m^2 [5,003 ft^2] of habitat. Based on our assessment of stressors and the current conditions, it is unlikely that future changes in species condition would result in a significant loss of redundancy to the species under Scenario 1 or 2.

Representation

Genetic diversity in Butterfield pyrg is currently unknown, but given the species occurs as a single population (albeit currently at three springs), we assume that genetic diversity is low. Under Scenario 2, we expect the population of Butterfield pyrg to persist with moderate future conditions, moderate resiliency, and adequate redundancy.

Currently, we are unaware of any documented specific risks for the Butterfield pyrg related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics. Rates of dispersal or gene flow are not known to have changed. Additionally, the best available information does not indicate that the current abundance of the species is at level that is causing inbreeding depression or loss of genetic variation. Nor is there any information to indicate that this species could not adapt to changing conditions. Because this species occurs at three springs at one spring province, we determined that Butterfield pyrg is not well represented currently or under Scenario 2, and may not have been well represented historically as it is only known to occur in the Butterfield Springs Province.

6.4.13 Hardy pyrg

Resiliency

The Hardy pyrg exists in 5 to 6 populations in 11 to 12 springs (Table 6.12). At Butterfield Springs Province, Hardy pyrg co-exists with Butterfield pyrg. Stressors that the species experiences at one or more springs include vegetation and soil disturbance (as a result of grazing and browsing, invasive aquatic plants, and roads), spring modifications (i.e., channel modification and impoundments), and water pollution from herbicides, all of which are discussed in detail (with references) in Chapter 5. The most significant stressors within the species range are spring channel modification, water diversions and impoundments, water pollution (herbicides at Silver Springs Province), vegetation and soil disturbance (as a result of grazing and browsing, invasive plants), at Butterfield Springs Province, Emigrant Springs Province, Ruppes Boghole, Hardy Springs Province, and Preston Big Spring. Based on climate change projections, we do not expect a large decrease in precipitation in White River Valley over the next 50 years. Although not currently an important stressor, groundwater withdrawal may affect the future condition of the species, particularly at Butterfield Springs Province.

Table 6.12. Lake Valley pyrg future conditions*.

Spring or Spring Province/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Future Expected Condition
Butterfield Springs Province	Adequate	Moderate	Moderate	Adequate	Moderate
Emigrant Springs Province	Adequate	Moderate	High/Moderate	Adequate	Moderate/Low
Hardy Springs Province	Adequate	Moderate	High	Adequate	Moderate
Parker Station Spring	Adequate	Moderate	High	Adequate	High/Moderate
Silver Spring Province	Inadequate	Moderate	Low	Inadequate	Low
Ruppes Boghole Springs Province	Inadequate	Low	Low	Inadequate	Low

*See Chapter 5 to compare this information against current conditions.

We have no information that the Butterfield Springs Province (which occurs on BLM land) has experienced decreased spring discharge. In November 2012, we determined that spring discharge may be reduced at Butterfield Spring Province (which occurs on BLM lands) as a result of SNWA's full, proposed rate of groundwater pumping (Service 2012, p. 164). If this project goes forward as currently proposed, BLM determined that spring flow at Flag Springs Province would be reduced 6 percent at Butterfield Springs Province. Spring flow at this province has been measured from 70 to 600 L/min (cfs). This reduction may result in a significant effect one or more springs in this province.

Based on climate change projections, we do not expect a large decrease in precipitation in White River Valley, which encompasses all six locations for Hardy pyrg, over the next 50 years. The stressors are expected to result in low to moderate/high future condition across the range of the species, with an overall moderate condition under Scenario 1 or 2. A major decrease in spring discharge under Scenario 3 would reduce Hardy pyrg population resiliency, resulting in less free-flowing water and aquatic habitat for the species. We expect that a major decrease in spring discharge under Scenario 3 would reduce Butterfield pyrg population resiliency. A reduced discharge from the springs would likely result in less free-flowing water and aquatic habitat for the species. Butterfield Springs C and D, which are springs that do not have high discharge rates and water depth, would be more susceptible to having reduced free-flowing water. Butterfield Spring E is a large spring with a moderate discharge rate (150 L/min (0.09 cfs)) and moderate depth, which should retain moderate future condition for the spring and population. Because Butterfield Springs A and B could not be found during the 2016 survey, we have no current information for these springs. Since Butterfield Springs Province currently has a moderate current condition ranking for vegetation and substrate, a substantial decrease in discharge (Scenario 2) may change this ranking to low, but would not result in extirpation of Butterfield pyrgs from any currently occupied springs. Hardy pyrgs in Silver Springs Province and Ruppes Boghole Springs Province would likely become extirpated due to reduced habitat or drying of the springs. Since the other locations, which in total comprise XX springs at four locations, are occupied by Hardy pyrgs and currently have an overall moderate current condition ranking for vegetation, substrate, and free-flowing water, a major decrease in spring discharge under Scenario 3 may change this ranking to low.

Accurate historical and current estimates of abundance are not available for the Hardy pyrg at the present time. Available data from limited survey efforts (and in some cases limited access) have resulted in 1 to 3 surveys at each of the 28 springs across the species range, which are the basis for abundance estimates (1992–2016) (see Chapter 5). At this time, the best available information does not indicate that the species' abundance is significantly impacted by the stressors. Additionally, the best available information does not indicate either increasing or declining numbers of springsnails for this species.

For small populations, demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact the population. There is no information on population sizes for the Hardy pyrg, nor is there any information to indicate what a viable (or minimal) Hardy pyrg population size should be. Regardless, surveys conducted in 2016 (Sada 2017, entire) continue to document its presence at 11 of the 28 historical locations. In 2016, six springs could not be accessed, four springs could not be located, and seven springs were surveyed but did not have Hardy pyrgs present. The likelihood for this species to persist with an appropriate population size and growth rate at a minimum of 11 springs is supported by our current overall finding of no change in the expected future conditions for the species under Scenarios 1 and 2. Therefore, the total abundance across the Hardy pyrg's range is not likely to be at or near a level that would significantly affect the species' demographic stochasticity.

Redundancy

There are currently six populations of Hardy pyrg. Under Scenario 2, we would expect that at least four populations would persist in moderate future condition and redundancy should be adequate for Hardy pyrg.

As indicated above, population size, growth rate, and current population trends are unknown for the Hardy pyrg due to the minimal abundance information. Its range occurs within a 84-mi^2

(218-km^2) area. Within this range, based mostly on 2016 survey data of accessible sites, we identified approximately 894 m (2,933 ft) of springbrook and 1,220 m^2 (13,132 ft^2) of habitat occupied by Hardy pyrgs. Based on our assessment of the current stressors, it is unlikely that future changes in species condition would result in a significant loss of redundancy under Scenario 1 or 2.

Representation

Genetic diversity in Hardy pyrg is currently unknown, but we expect that maintaining populations across the species' range would preserve any potential ecological diversity. Under Scenario 2, we expect all populations to exhibit reduced resiliency, while at least four of the existing six populations would likely persist.

Currently, we are unaware of any documented specific risks for the Hardy pyrg related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics. This species is widely distributed (up to 28 known spring locations over 84 mi^2 (218 km^2) at six locations. Rates of dispersal or gene flow are not known to have changed. Additionally, the best available information does not indicate that the current abundance of the species is at level that is causing inbreeding depression or loss of genetic variation. Nor is there any information to indicate that this species could not adapt to changing conditions. Representation would, therefore, be maintained for Hardy pyrg.

6.4.14 Bifid Duct pyrg

Resiliency

The bifid duct pyrg occurs or historically occurred within 19 springs from 12 locations (three of which are spring provinces) in Nevada and Utah. The stressor most likely to be the causal factor in the future (Scenario 2) across the species range is altered precipitation and temperature from climate change, and for 2 populations (Unnamed Springs North of Big Springs Province and Church Spring), spring modification resulting from potential spring development on private land. Although altered precipitation and temperature may result in potential impacts in the future according to climate change projections, we do not expect a significant decrease in precipitation within the range of the bifid duct pyrg over the next 50 years. Additionally, groundwater withdrawal is a stressor that may affect the future condition of the species (see further discussion below). In most cases, impacts to bifid duct pyrg populations from current stressors (as described in detail (with references) in Chapter 5) are not expected to increase in the future.

Table 6.13. Bifid duct pyrg future conditions*.

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Turnley Spring	Adequate	Low	Low	Inadequate	Low
Rock Spring	Adequate	Moderate	Moderate	Adequate	Moderate
Cache Springs Province	Adequate	Moderate	Moderate	Adequate	High/Moderate
Unnamed Spg near Sac Pass # 1	Adequate	Moderate	Moderate	Adequate	High/Moderate
Unnamed Spg near Sac Pass # 4	Adequate	Moderate/Low	Moderate/Low	Adequate	Moderate
Unnamed Spgs N of	Adequate	Moderate	Moderate	Adequate	Moderate

Spring/Population	Water Quality	Substrate and Vegetation	Free-Flowing Water	Adequate Discharge	Current Overall Condition
Big Springs					
Antelope Spring	Adequate	Low	Low	Inadequate	Low
Red Cedar Spring	Adequate	Moderate	High	Adequate	High/Moderate
Big Spring	Adequate	Moderate	High/Moderate	Adequate	High/Moderate
Church Spring	Adequate	Moderate	Moderate	Adequate	Moderate
Maple Grove Springs	Adequate	High/Moderate	High/Moderate	Adequate	High/Moderate
Copley's Cove Spring	Adequate	High/Moderate	High/Moderate	Adequate	High/Moderate

*See Chapter 5 to compare this information against current conditions.

The SNWA filed water rights applications in 1989 to develop groundwater resources in Spring and Snake Valleys. According to the results of the hydrologic model used by BLM for their FEIS on the SNWA GWD Project (BLM 2012), groundwater development in Spring Valley is not expected to impact water resources at the springs occupied by bifid duct pyrg in Spring Valley. However, a great deal of uncertainty is associated with potential impacts to the Unnamed Springs north of Big Springs in Snake Valley (Service 2012, pp. 194–201; Prudic *et al.* 2015, p. 135). Development of additional groundwater resources is not expected to affect the springs occurring in Utah because the associated hydrographic basins are currently fully appropriated and managed under the State of Utah's Water Rights Policy for the Sevier River Basin (UDWRi 1997, entire), and most groundwater production wells are located on the valley floor (Burden *et al.* 2016, pp. 46, 47, and 58) and separated from the higher elevation mountain block aquifers that supply the source of water for most of the springs in Utah.

Our climate analysis results (Service 2016, unpublished data) show that average annual temperatures in areas where the 12 springs occur could increase 4 to 6 °F (2 to 3 °C), accompanied by reduced snowpack and runoff and a slight reduction in precipitation (USGCRP 2014, pp. 465-466). Although we are uncertain as to the degree or extent of effect this may have on spring flow, we expect that these projected changes may influence the amount of recharge to the mountain block aquifers that provide the source of flow to these springs, with more profound effects to smaller springs with lower discharge rates.

We expect a reduction in discharge under Scenario 2 would result in a reduction in resiliency for all populations of bifid duct pyrg. The degree to which reduction in discharge would affect resiliency would vary among populations, based on the current size of the population, the amount of flow at each spring site, the extent of habitat, and uncertainties associated with management on private land [and proposed groundwater development projects]. Smaller populations (e.g., Turnley Spring and Antelope Spring) would be less resilient to random events than larger populations. A reduction in discharge would likely result in a greater reduction in wetted substrate and vegetation and free-flowing water for smaller springs with lower discharge rates (e.g., Unnamed Spring near Sac Pass # 4 and Antelope Spring).

Under Scenario 2, bifid duct pyrg populations would likely see expected future conditions decrease from one-half to one full ranking from their current condition, with the exception of Turnley Spring (unchanged from current condition). Six populations would have moderate to high resiliency, four populations would have moderate resiliency, and two populations would have low resiliency (Table 6.13). Resiliency at Turnley Spring is expected to continue to remain in its low condition due to a capped springhead and loss of a flowing springbrook. We expect that any reduction in discharge at Antelope Spring could potentially result in loss of flow and subsequent extirpation of the population because the primary springhead is capped and piped, current flow at the adjacent seep is very low, and current relative abundance of bifid duct pyrg in the seep is estimated as scarce. Rock Spring, Cache Springs Province, Unnamed Spring Near Sacramento Pass # 1, Red Cedar Spring, Big Spring, Maple Grove Springs Province, and Copley's Cove Spring may experience a slight decrease in resiliency due to the potential for reduced spring discharge resulting from effects of climate change; however, these effects should be moderated due to current habitat extent, population size, and moderate to high discharge rates. Resiliency at Unnamed Spring Near Sacramento Pass # 4 may be more affected by a decrease in spring flow because the current discharge rate is relatively low. A greater level of uncertainty is associated with the resiliency of the springsnail population at Unnamed Springs North of Big Springs and Church Spring because of the potential for combined effects of reduced spring flow from climate change and unknown status of management and conservation activities on the private land.

Accurate historical, and in some cases current, estimates of abundances are not available for the bifid duct pyrg at the present time. Available data indicate that 1 to 8 surveys have been conducted at each of the 12 springs or spring provinces, with an average of 3.3 surveys over the period of 1991 to 2016. As a result, population trends for this species are not well established, and the information currently available to us does not indicate that the species' abundance across its range is significantly impacted by human activities, other than the population at Turnley Spring. Additionally, the best available information does not indicate either increasing or declining numbers of springsnails for this species.

For small populations, demographic stochasticity (the variability of annual population change that results from random birth and death events at the individual level) can impact the population. Based on our evaluation of the best available information, accurate population size and trend for the bifid duct pyrg are not known, nor is there any information to indicate what a viable (or minimal) bifid duct pyrg population size should be. Regardless, surveys conducted in 2016 (Sada 2017, entire) at 10 of the 12 known spring sites documented the species at all but one location, and surveys conducted in 2009 and 2010 at the other 2 sites documented the species as common to abundant (SNWA 2011, P. 3-31; Sada 2016, entire). Overall, under Scenario 2, we expect 10 of the 12 populations to persist into the future, which should not result in significantly affecting the resiliency of populations across the range of the species.

Redundancy

There are 12 populations of bifid duct pyrg with the majority seeing a decline in resiliency under Scenario 2. Of the 12 current populations, 2 may potentially become extirpated due to future expected conditions under Scenario 2. One population at Turnley Spring was recorded as absent during 2016 surveys, and the springhead was capped, forming a pond that has eliminated the flowing springbrook. Unless the springhead and springbrook are restored to provide suitable springsnail habitat, we do not expect conditions to improve in the future. The other population that may become extirpated in the future according to Scenario 2 occurs at Antelope Spring, where the main springhead is capped and piped and the springbrook below is dry, the spring discharge rate at the adjacent seep is low, and current springsnail relative abundance is estimated as scarce. Any reduction in spring discharge assumed under Scenario 2 is expected to result in a loss of flow at this spring, and potential extirpation of the population.

The other 10 populations would likely experience a reduction in resiliency, but not to the extent that the populations would be lost. With future conditions expected to be moderate to high for six populations and moderate for four populations, the species should maintain an adequate level of redundancy to withstand most catastrophic events under Scenario 2. In addition, these 10 populations are broadly distributed among several hydrographic basins, valleys, and mountain ranges spanning 2 states, reducing the risk of any one catastrophic event affecting a majority of the populations.

Representation
No research has been conducted to address the genetic diversity represented by bifid duct pyrg. We are unaware of any documented specific risks for the bifid duct pyrg related to a substantial change or loss of diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics. Rates of dispersal or gene flow are not known to have changed. Additionally, the best available information does not indicate that the current abundance of the species is at a level that is causing inbreeding depression or loss of genetic variation, nor is there any information to indicate that this species could not adapt to changing conditions. We assume that the current level of genetic diversity expressed by this species has over time contributed to its persistence throughout its range. Therefore, based on the number of extant populations expected to remain under Scenario 2 (10 out of 12) and the relatively broad distribution of bifid duct pyrg, the species should continue to express the same level of genetic diversity necessary to adapt to changing environmental conditions as it has in the past.

6.5 Status Assessment Summary

We used the best available information to project the likely future conditions of the 14 species of springsnails. Our results described a range of possible and probable conditions in terms of how many and where springsnail populations are likely to persist into the future. We reason that springs that provide for the needs of the springsnails have a high likelihood of supporting a springsnail population that will have persistence into the future with reasonable certainty.

It is likely that stressors discussed in this SSA are already occurring or may occur in the future. In consideration of altered precipitation and temperature, it is reasonable that spring flow will change, but we are uncertain of the magnitude of risk and if the factor could be managed. This is further discussed in the climate change section 4.4. If populations lose resiliency due to a decline in spring flow, their persistence may depend on habitat enhancements and/or reintroductions of refugia populations. Adequate spring discharge and free-flowing water are the largest factors affecting the future persistence of these springsnails.

APPENDIX A: CURRENT MANAGEMENT AND CONSERVATION MEASURES

Comment [CSE79]: NOTE TO REVIEWERS. We do not necessarily have all of the information on how each of these documents is ameliorating impacts to spring habitat or springsnails. Please provide any additional, specific information you may have on how these are functioning, reducing impacts to spring habitat, or providing benefit to springsnails. If we missed a plan your agency is responsible for that is providing benefit to springsnails and their habitat, please let us know. We will then incorporate additional information into Chapters 5 and 6, as appropriate.

The springsnails described in this assessment occur on private, state, and Federal lands. Various laws, regulations, policies, and management plans may provide conservation or protections for springsnails. Particularly relevant ones include the following:

1 FEDERAL LAWS, REGULATIONS, POLICIES, AND MANAGEMENT PLANS

1.1 National Environmental Policy Act of 1969

All Federal agencies are required to adhere to the National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. 4321 et seq.) for projects they fund, authorize, or carry out. Prior to implementation of such projects with a Federal nexus, NEPA requires the agency to analyze the project for potential impacts to the human environment, including natural resources. The Council on Environmental Quality's regulations for implementing NEPA state that agencies shall include a discussion on the environmental impacts of the various project alternatives (including the proposed action), any adverse environmental effects that cannot be avoided, and any irreversible or irretrievable commitments of resources involved (40 CFR part 1502). The public notice provisions of NEPA provide an opportunity for the Service and other interested parties to review proposed actions and provide recommendations to the implementing agency. NEPA does not impose substantive environmental obligations on Federal agencies—it merely prohibits an uninformed agency action. However, if an Environmental Impact Statement is prepared for an agency action, the agency must take a "hard look" at the consequences of this action and must consider all potentially significant environmental impacts.

Although NEPA requires full evaluation and disclosure of information regarding the effects of contemplated Federal actions on sensitive species and their habitats, it does not by itself regulate activities that might affect the 14 springsnails evaluated herein; that is, effects to the species and their habitat would receive the same scrutiny as other plant and wildlife resources during the NEPA process and associated analyses of a project's potential impacts to the human environment. We receive notification letters for Draft and Final Environmental Impact Reports prepared pursuant to NEPA including Land Management Plans, as discussed below. The Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) follow the NEPA process and analysis for projects planned and implemented on their lands.

1.2 Bureau of Land Management

Land management by the BLM is directed by the following laws, policies, manuals, and management plans. These directives provide conservation assurance to springsnails as stated in the following:

1.2.1 Federal Land Policy and Management Act of 1976

The Federal Land Policy and Management Act of 1976 (FLPMA; 43 U.S.C. 1701 *et seq.*) is the primary Federal law governing most land uses on BLM lands, and directs development and implementation of Resource Management Plans (RMPs) that direct management at a local level. The bifid duct pyrg (*Pyrgulopsis peculiaris*), Spring Mountains pyrg (*Pyrgulopsis deaconi*), and grated tryonia (*Tryonia clathrata*) had been designated as BLM sensitive species in Nevada prior to 2011. The Moapa pebblesnail (*Pyrgulopsis avernalis*), Pahranagat pebblesnail (*Pyrgulopsis merriami*), and Moapa Valley pyrg (*Pyrgulopsis carinifera*) were designated as sensitive species in 2011 on BLM lands in Nevada (BLM IM-NV-2011-059-1). Further, BLM policies direct management to consider candidate species on public lands under their jurisdiction. The management guidance afforded species of concern and candidate species under BLM Manual 6840 – Special Status Species Management (BLM 2008) states that “Bureau sensitive species will be managed consistent with species and habitat management objectives in land use and implementation plans to promote their conservation and to minimize the likelihood and need for listing under the Endangered Species Act” (BLM 2008, p. .05V). BLM Manual 6840 further requires that RMPs should address sensitive species, and that implementation “should consider all site-specific methods and procedures needed to bring species and their habitats to the condition under which management under the Bureau sensitive species policies would no longer be necessary” (BLM 2008, p. 2A1). As designated sensitive species in Nevada under BLM Manual 6840, Moapa pebblesnail, Pahranagat pebblesnail, Moapa Valley pyrg, bifid duct pyrg, Spring Mountains pyrg, and grated tryonia conservation must be addressed in the development and implementation of RMPs on BLM lands.

The Utah BLM does not currently include springsnail species on their official sensitive species list; however, an Instruction Memorandum (IM) was issued in 2007 adopting the existing UDWR Utah Sensitive Species List and stated that the BLM would use the official UDWR list that is in place at the time of a given action that occurs on BLM-administered land. The Utah BLM is currently working on updating their sensitive species list to be consistent with the UDWR list where springsnails occur on BLM-administered land (C. Mellon, BLM Utah, pers. comm. February 28, 2017).

RMPs are the basis for all actions and authorizations involving BLM-administered lands and resources. They authorize and establish allowable resource uses, resource condition goals and objectives to be attained, program constraints, general management practices needed to attain the goals and objectives, general implementation sequences, intervals and standards for monitoring and evaluating RMPs to determine effectiveness, and the need for amendment or revision (43 CFR 1601.0-5(k)). The RMPs also provide a framework and programmatic direction for implementation plans, which are site-specific plans written to regulate decisions made in a RMP. Examples include fluid mineral development, travel management, and wildlife habitat management. Implementation plan decisions normally require additional planning and NEPA analysis, as described above.

Three RMPs in the analysis area for this report include springsnail habitat management objectives, each of which contain specific measures or direction pertinent to management of springsnails or their habitat. These measures and their direction vary, with some measures directed at a particular land resource (e.g., riparian areas), and others relevant to specific best management practices (e.g., limited water extraction). If an RMP contains specific direction regarding springsnail habitat, conservation, or management, it represents a regulatory mechanism that has the potential to ensure that the species and its habitats are protected during permitting and other decision-making on BLM lands. This section describes our understanding of how RMPs are currently implemented in relation to springsnail conservation.

1.2.2 Bureau of Land Management, Las Vegas Resource Management Plan, 1998

The Las Vegas RMP provides management guidance for approximately 3.3 million acres of public land administered by the BLM. It identifies and analyzes alternatives for long-term management of public lands and resources administered by BLM in the Las Vegas District. The RMP is a comprehensive document that addresses all resources and programs administered by BLM, including management of water resources, riparian areas, wild horses and burros, fire, wildlife, livestock grazing, soil, air, vegetation, and withdrawal review.

The Moapa pebblesnail is listed as a special status invertebrate in the Muddy River system. The objectives and management directions that may apply to springsnails and their habitat include:

1. Riparian Management Objective RP-1: Provide widest variety of vegetation and habitat for wildlife, fish, and watershed protection; ensure that all riparian areas are in proper functioning condition by achieving an advanced ecological status, except where resource management objectives require an earlier successional stage.

    a. Management Direction RP-1-a. Complete assessments on all riparian areas, including development of actions necessary to achieve Proper Functioning Condition on all areas that are functioning at risk.
    b. Management Direction RP-1-b. Improve riparian areas, giving priority to areas Functioning at Risk with a downward trend. Implement measures to protect riparian areas, such as fencing and/or alternate water sources away from the riparian area.
    c. Management Direction RP-1-c. Ensure that the minimum requirement of Proper Functioning Condition on all riparian areas is maintained or achieved.
    d. Management Direction RP-1-d. Do not allow competitive off-road vehicle events within 0.25 mile of natural water sources and associated riparian areas.

2. Special Status Species Objective SS-2: Manage habitat to further sustain the populations of Federally listed species so they would no longer need protection of the Endangered Species Act. Manage habitats for non-listed special status species to support viable populations so that future listing would not be necessary.

    a. Management Direction SS-2-a: Enter into conservation agreements with the U.S. Fish and Wildlife Service and the State of Nevada that, if implemented, could reduce the necessity of future listings of the species in question.

3. Water Resource Management Objective WT-1: Maintain the quality of waters presently in compliance with State and/or Federal water quality standards. Improve the quality of waters found to be in noncompliance.

4. Water Resource Management Objective WT-3: Ensure availability of adequate water to meet management objectives including the recovery and/or re-establishment of Special Status Species.

    a. Management Direction WT-3a: Determine water needs to meet management objectives. File for appropriative water rights on public and acquired lands in accordance with the State of Nevada water laws for water sources that are not federally reserved.

1.2.3 Bureau of Land Management, Ely Resource Management Plan, 2007

The purpose of the approved RMP is to provide direction for management of renewable and nonrenewable resources found on 11.5 million acres of public lands within the Ely planning area and to guide decision-making for future site-specific actions. The RMP directs the Ely District Office in resource management activities including leasing minerals such as oil and gas; construction of electrical transmission lines, gas pipelines, and roads; grazing management; recreation; preserving and restoring wildlife habitat; selling or exchanging lands for the benefit of local communities; military use of the planning area; and conducting other activities that require land-use planning decisions.

Eleven springsnail species (including the Spring Mountains pyrg, bifid duct pyrg, and grated tryonia, which are evaluated in this SSA) are present in the planning area and are BLM Sensitive Species.
Several of the RMP's stipulations and best management practices will provide conservation to springsnails and their habitat. These include the following:

Objective – Special Status Species: To manage suitable habitat for special status species in a manner that will benefit these species directly or indirectly and minimize loss of individuals or habitat from permitted activities.

A. Management Actions and Parameters – Special Status Species Habitat:

- SS-9: Springsnail surveys are required prior to spring source development

Resource Best Management Practices

- 1.7.7: For streams currently occupied by any special status species, do not allow extraction of water from ponds or pools if stream inflow is minimal (i.e., during drought situations) and extraction of water would lower the existing pond or pool level.

1.2.4 Bureau of Land Management, Red Rock Canyon NCA General Management Plan, 2004

The following items are listed in the final resource management plan under the biodiversity preservation (1A) and riparian restoration (1E) resource sections:

- 1A.1 - Conduct an ongoing program of population monitoring for Special Status Species (springsnail monitoring is ongoing by BLM)
- 1A.2 - Re-introduce springsnails (Spring Mountains pyrg and Southeast Nevada pyrg (*P. turbatrix*) into restored Willow Spring riparian habitat (completed in 2012)
- 1E.2 – Adopt a policy of discouraging recreation use in riparian habitats
- 1E.4 - As a minimum, ensure proper functioning condition of riparian areas. Restore surface flow for riparian vegetation where it has been decreased or eliminated by diversion or impoundment
- 1E.5 - Restore spring brook flows and riparian areas in Red Spring and Willow Spring to ensure adequate habitat for springsnails (Spring Mountains pyrg). Maintain protective fencing around key habitat areas as needed (completed in 2012).

1.2.5 Bureau of Land Management House Range Resource Area Resource Management Plan, 1987

The House Range Resource Area (HRRA) RMP is the management plan currently in effect for the BLM’s Richfield District in Utah. This area encompasses the House Range, where Antelope Spring and Red Cedar Spring are located (these springs are occupied by the bifid duct pyrg). The Range Management section of the RMP identifies Red Cedar Creek and Antelope Spring as riparian habitat in the resource area that would be evaluated and monitored for resource condition. Where resource conditions show a need for protection from livestock grazing, management options of seasonal deferment, off-site water development, and /or enclosure fencing with water gaps would be applied as necessary. No range improvement projects would be authorized in riparian areas, unless these would maintain or improve riparian habitat (BLM 1987, pages 29-30). The RMP does not include management actions specific to springsnail conservation; however, management that maintains or improves riparian habitat should also provide conservation benefits for springsnails.

Antelope Spring and Red Cedar Spring also occur within the Howell Peak and Swasey Mountain Wilderness Study Areas (WSAs) (see section 1.2.6 below). The RMP did not make any decisions or recommendations regarding wilderness designation of any of the four WSAs occurring within the HRRA, and stated that until Congress decides on designation or non-designation of the WSAs in the resource area, these areas would be managed in conformance with the BLM’s Interim Management Policy. Designation of any of the four WSAs would constitute an amendment to the RMP, and if designated, would be managed in accordance with the BLM’s Wilderness Management Policy and provisions of the implementing legislation (BLM 1987, page 2).

1.2.6 Bureau of Land Management Manual 6330 – Management of BLM Wilderness Study Areas

This policy was established in 2012, superseding the Interim Management Policy for Lands Under Wilderness Review issued in 1979. The objectives of this policy are to (1) manage and protect WSAs, consistent with relevant law, to preserve wilderness characteristics so as not to impair the suitability of such areas for designation by Congress as wilderness; and (2) provide policy guidance for prolonged stewardship of WSAs until Congress makes a final determination on the management of WSAs (BLM 2012, page 1-2). The non-impairment standard is defined as uses and/or facilities that are both temporary and do not create surface disturbance (BLM 2012, page 1-10). This policy provides guidance on evaluating proposals for new uses within WSAs, but also allows certain preexisting uses to continue (such as grazing, mining, and mineral leasing uses and facilities that were allowed on the date of approval of FLPMA (October 21, 1976)). Antelope Spring and Red Cedar Spring in Utah are located within the Howell Peak and Swasey Mountain WSAs managed by the BLM Richfield District.

1.3 National Park Service

1.3.1 Organic Act

Comment [CSE80]: A description of this still needs to be completed.
A description of the Lake Mead GMP, Management Plan, Land Protection Plan, and Foundation Document may also need to be provided still.

The National Park Service (NPS) Directives System provides instructions and guidance for required and/or recommended actions that has 3 levels of documents (https://www.nps.gov/policy/DOrders/thingstoknow.htm, Accessed February 1, 2017). The first level is the Management Policies book that provides a framework to guide management decisions (NPS 2006). Level 2 is the Director's Orders, which has more detailed interpretations. Level 3 includes reference manuals, handbooks, and other documents having further detailed information. All policies and direction are "guided by and consistent with the Constitution, public laws, Executive proclamations and orders, and regulations and directives from higher authorities".

The management policies (Level 1) are mandatory for NPS unless specifically waived by the Secretary, Assistant Secretary, or Director (NPS 2006, p. 3). Much of the management policy applicable to springsnails and the springs they depend on are found within the Natural Resource Management Section (NPS 2006, pp. 35–57). There are many policies that may benefit springsnails directly or indirectly but the following from pages 42–44 are particularly relevant to springsnail conservation, and may provide benefits to the Blue Point pyrg (*Pyrgulopsis coloradensis*) that occupies Blue Point spring at Lake Mead National Recreation Area:

- "preserving and restoring the natural abundances, diversities, dynamics, distributions, habitats, and behaviors of native plant and animal populations and the communities and ecosystems in which they occur;
- restoring native plant and animal populations in parks when they have been extirpated by past human-caused actions;
- minimizing human impacts on native plants, animals, populations, communities, and ecosystems, and the processes that sustain them; and
- prevent the introduction of exotic species into units of the national park system, and remove, when possible, or otherwise contain individuals or populations of these species that have already become established in parks."

In addition the NPS generally relies upon natural processes to maintain animal species and their natural fluctuations; however management may be permitted in unnatural conditions where it won't cause other unacceptable impacts (NPS 2006, p. 44)

The Director's Order 77 and Natural Resources Management Reference Manual #77 are currently being developed and are likely to have guidance or direction that benefit springsnail conservation (https://home.nps.gov/applications/npspolicy/DOrders.cfm, Accessed February 1, 2017). The Freshwater Resources Management section of the reference manual provides policy and program objectives "...to maintain, rehabilitate, and perpetuate the inherent integrity of water resources and aquatic ecosystems" (https://www.nature.nps.gov/rm77/freshwater.cfm, Accessed February 1, 2017) that are applicable to spring and springsnail conservation.

1.4 U.S. Forest Service

Land management by the U.S. Forest Service (USFS) is directed by the following laws, policies, manuals, and management plans. These directives provide conservation assurance to springsnails as stated in the following:

1.4.1 National Forest Management Act (NFMA) 1976

The National Forest Management Act (NFMA) (16 U.S.C. § 1600 *et seq*.) requires the USFS to develop a planning rule under the principles of the Multiple–Use, Sustained–Yield Act (MUSY) of 1960 (16 U.S.C. § 528–531), which broadened the management of USFS lands to include outdoor recreation, range, watershed, and wildlife and fish purposes. The NFMA outlines the process for the development and revision of the land management plans and their guidelines and standards (16 U.S.C. § 1604(g)).

A new National Forest System (NFS) land management planning rule (planning rule) was adopted by the USFS in 2012 (77 FR 21162; April 9, 2012). The new planning rule guides the development, amendment, and revision of land management plans for all units of the NFS to maintain and restore NFS land and water ecosystems while providing for ecosystem services and multiple uses. Land management plans (also called Forest Plans) are designed to: (1) Provide for the sustainability of ecosystems and resources; (2) meet the need for forest restoration and conservation, watershed protection, and species diversity and conservation; and (3) assist the Forest Service in providing a sustainable flow of benefits, services, and uses of NFS lands that provide jobs and contribute to the economic and social sustainability of communities (77 FR 21261, April 9, 2012). A land management plan does not authorize projects or activities, but projects and activities must be consistent with the plan (77 FR 21261; April 9, 2012). The plan must provide for the diversity of plant and animal communities including species-specific plan components in which a determination is made as to whether the plan provides the "ecological conditions necessary to…contribute to the recovery of federally listed threatened and endangered species…" (77 FR 21265; April 9, 2012).

The Record of Decision for the final planning rule was based on the analyses presented in the *Final Programmatic Environmental Impact Statement, National Forest System Land Management Planning* (77 FR 21162–21276; April 9, 2012), which was prepared in accordance with the requirements of the NEPA (discussed above). In addition, the NFMA requires land management plans to be developed in accordance with the procedural requirements of NEPA, with a similar effect as zoning requirements or regulations as these plans control activities on the national forests and are judicially enforceable until properly revised (Coggins *et al.* 2001, p. 720).

1.4.2 U.S. Forest Service, Spring Mountains National Recreation Area Act, 1993

In 1993, the Spring Mountains National Recreation Area (SMNRA) was established to include 316,000 acres of Federal lands managed by the Forest Service in Clark and Nye Counties, Nevada for the following purposes: 1) To preserve the scenic, scientific, historic, cultural, natural, wilderness, watershed, riparian, wildlife, threatened and endangered species, and other values contributing to public enjoyment and biological diversity in the Spring Mountains of Nevada; 2) To ensure appropriate conservation and management of natural and recreation resources in the Spring Mountains; and 3) To provide for the development of public recreation opportunities in the Spring Mountains for the enjoyment of present and future generations.

Resource management and conservation actions for the Spring Mountains pyrg are found within the Conservation Agreement for the SMNRA (Section 3.1.4 below).

1.4.3 U.S. Forest Service, Fishlake National Forest Land and Resource Management Plan, 1986

The Fishlake National Forest is located in central Utah surrounding the town of Richfield, which is about 140 miles south of Salt Lake City. The Forest encompasses 1.5 million acres, including the Canyon and Pahvant Ranges, where Big Spring, Maple Grove Springs, and Copley's Cove Spring occur (these springs are occupied by the bifid duct pyrg). The Forest Plan (USFS 1986) is composed of two major parts: Forest Direction and Management Area Direction. Forest Direction consists of goals, objectives, and management requirements, while the Management Area Direction consists of management area prescriptions applicable to specific management areas shown on the Forest Plan map.

Management requirements that include management direction broadly benefitting riparian habitat conservation include: wildlife and fish cooperation with other agencies (including coordination with U.S. Fish and Wildlife Service on all matters dealing with diversion or modification of Waters of the United States); range resource management; riparian area management; water uses management; and water resource improvement and maintenance. Under Management Area Direction, the three springs that occur on the Forest are associated with Management Area 4, which has a management emphasis associated with Fish Habitat Improvement and Habitat for Management of Indicator Species, including macroinvertebrates. The Forest Plan does not include management actions specific to springsnail conservation; however, management that maintains or improves riparian habitat should also provide conservation benefits for springsnails.

1.5 U.S. Fish and Wildlife Service

Land management by the U.S. Fish and Wildlife Service (Service) is directed by the following laws, policies, manuals, and management plans. These directives provide conservation assurance to springsnails as stated in the following:

1.5.1 U.S. Fish and Wildlife Service, National Wildlife Refuge System Administration Act of l966 and the National Wildlife Refuge Improvement Act, 1997

The National Wildlife Refuge System Administration Act of 1966 authorized the Secretary of the Interior to permit the use of refuges whenever it is determined that such a use is compatible with the purposes for which the area was established (Service 2012b, no pagination). The National Wildlife Refuge Improvement Act of 1997 amended the 1966 Act to specifically state that the mission of the National Wildlife Refuge System is wildlife conservation. It identified a number of wildlife-dependent recreational uses that will be given priority consideration, mandated a long-term refuge planning process, and clarified the process for determining the compatibility of refuge uses (Service 2012c, no pagination). It also mandated that all Service refuges have a Comprehensive Conservation Plan by 2012 (Service 2009, p. 1). The National Wildlife Refuge System is managed by the Service primarily for the benefit of fish, wildlife, and plant resources and their habitats (Service 2009, p. 2).

1.5.2 U.S. Fish and Wildlife Service, Desert Refuge Complex Comprehensive Conservation Plan (Ash Meadows, Desert, Moapa Valley, and Pahranagat National Wildlife Refuges), 2009

The Service manages the Desert National Wildlife Refuge Complex in accordance with the approved Comprehensive Conservation Plan (CCP). The CCP provides long-range guidance on refuge management through its vision, goals, objectives, and strategies. The CCP also provides a basis for a long-term adaptive management process that includes monitoring the progress of management actions, evaluating and adjusting management actions based on new information or techniques, and revising management and monitoring plans accordingly. The Corn Creek pyrg (*P. fausta*) occurs on the Desert National Wildlife Refuge.

Goal 1 for Ash Meadows National Wildlife Refuge species management is to restore and maintain viable populations of all endemic, endangered, and threatened species within the refuge's Mojave Desert oasis ecosystem. Strategies to meet this goal include: 1) Investigate feasibility and funding for captive populations of all sensitive species (e.g., aquatic snails, etc.).

Goal 1 for Moapa Valley National Wildlife Refuge endemic and special status species is to protect and restore, when possible, healthy populations of endemic and special status species. This includes restoration of historic hydrology and native plant communities. Such restoration should not only favor Moapa dace and other native species (including the Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia) but should also discourage non-native species. Strategies to meet this goal include: 1) Consider habitat needs of other special status fish and invertebrates when designing and implementing restoration projects (including the Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia) and 2) Monitor streams before and after rehabilitation, to determine benefits or detriments to invertebrate populations.

2 STATE PLANS

2.1 STATE OF NEVADA

2.1.1 Nevada Department of Wildlife, Nevada State Wildlife Action Plan, 2012

All 14 springsnail species are designated as Species of Conservation Priority (but not state protected). There are no legal protections provided under Nevada Revised Statute (NRS) 501, and they are not listed in the Nevada Administrative Code (NAC) Chapter 503.

The Nevada Department of Wildlife (NDOW) developed its State Wildlife Action Plan as a requirement to apply for State Wildlife Grant funds through the U.S. Fish and Wildlife Service. These funds are used by NDOW for the conservation of Nevada's wildlife. One of the State Wildlife Action Plan's goals is to establish "springs and springbrook habitats functioning naturally within the natural fluctuation inherent to the spring type". Objectives that would need to be met to achieve this goal include the following: (1) a measurable increase in the number of springs and springbrooks functioning naturally and supporting the natural ecological community expected for each spring by 2022; and (2) No net loss of spring/springbrook-dependent Species of Conservation Priority.

2.1.2 The Wetland Conservation Plan for Wildlife Management Areas, 1998

The Wetland Conservation Plan (WCP) for NDOW's Wildlife Management Areas was completed in July 1998 (Huffman et al. 1998). The overall goal of the WCP is no net loss of wetlands on Wildlife Management Areas (WMAs) and to increase wetland quantity and quality within WMAs with emphasis on sensitive species and control of tamarisk (*Tamarix* spp.). Specific WCP Recommendations on Kirch WMA (which support populations of Pahranagat pebblesnail, grated tryonia, White River Valley pyrg, and Flag pyrg are: (1) develop infrastructure to promote a watchable wildlife experience; (2) prioritize management for populations of endemic fish; and (3) land acquisition/acquire additional water rights (NDOW 2000, p. 3). Although management specific to springsnail conservation is not provided by the WCP, it is expected that management actions that benefit the endemic fish at Flag and Hot Creek Springs Provinces will also provide conservation benefits for the springsnails.

2.1.3 Kirch Wildlife Management Area Conceptual Management Plan

NDOW developed the Kirch Wildlife Management Area Conceptual Management Plan (NDOW 2000, entire) to guide the management of species, habitats and programs on the W.E. Kirch WMA. Four endemic fish species occur on the Kirch WMA. They are the White River spinedace (*Lepidomeda albivalis*), the Moorman White River springfish (*Crenicthys baileyi thermophilus*), the White River speckled dace (*Rhinichthys osculus velifer*), and the White River desert sucker (*Catostomus clarki intermedius*). They inhabit Flag and Hot Creek Springs Provinces, which are also occupied by the Pahranagat pebblesnail, grated tryonia, White River Valley pyrg (*P. sathos*), and Flag pyrg (*P. breviloba*). Wildlife population and habitat goals for Kirch WMA include maintaining and enhancing native fish and their habitat. Waters of Flag Springs Province, Hot Creek Springs Province, and the first three miles of Sunnyside Creek and surrounding habitat associated with these waters have been dedicated to the recovery of the native fish species (NDOW 2000, p. 52). Although management specific to springsnail conservation is not provided in the Kirch WMA Conceptual Management Plan, objectives and strategies identified in the plan for native fish management at Flag and Hot Creek Springs Provinces, such as securing appropriated continued flow of water, maintaining stability of undercut banks and riparian vegetation through control of livestock grazing, recovering the Flag Springs Province to historic conditions and flow regime, encouragement of the recruitment of gravels and seasonal flows, avoiding disturbance activities in stream channels and adjacent riparian and upland habitats, controlling invasive weeds, and acquiring important wildlife habitat and water rights from willing sellers (NDOW 2000, pp. 66, 72, and 74), may also provide conservation benefits for the springsnails.

2.2 STATE OF UTAH

2.2.1 Utah Division of Wildlife Resources, Utah State Wildlife Action Plan, 2015-2025

The bifid duct pyrg is designated as a species of greatest conservation need that is critically imperiled (S1). It is also designated by the Utah Division of Wildlife Resources (UDWR) as a Species of Concern, because there is credible scientific evidence to substantiate a threat to continued population viability and its limited distribution makes it susceptible to habitat loss and degradation in an area experiencing continuing impacts to the aquatic habitat (Utah Division of Wildlife Administrative Rule R657-48; UDWR 2015, p. 94).

All springsnails in the State of Utah are controlled for collection, importation, and possession. Recent surveys of the six known Utah populations documented relative abundance as scarce at two springs, abundant at three springs, and common to abundant at one spring province (Sada 2017).

3 OTHER AGREEMENTS AND PLANS WITHIN THE ANALYSIS AREA

3.1 U.S. Fish and Wildlife Service Recovery Plans

3.1.1 White River Spinedace Recovery Plan, 1994

The endangered White River spinedace is extant in only one of several historically occupied habitats in northern White River Valley of Nye and White Pine Counties, Nevada. The species persists in Flag Springs Province, which also provides habitat for the White River Valley pyrg and Flag pyrg. The entire Flag Springs province and appurtenant water rights are owned by the State of Nevada, thereby providing some protection for springsnails from development and potential water withdrawals, since adequate habitat conditions must be maintained for the spinedace. The recovery plan calls for the development of a habitat management plan for Flag Springs and its implementation.

3.1.2 Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem, 1995

The Service prepared a recovery plan for the Moapa dace (*Moapa coriacea*) in 1983, which specified research-related tasks to guide recovery. This document is a revision of the 1983 recovery plan and incorporates recent research data and addresses the species current status, threats, and recovery needs. It also addresses the current status, threats, and recovery needs of the seven other rare aquatic species (including the Moapa pebblesnail and grated tryonia) which occur with Moapa dace in the Muddy River ecosystem and are species of special concern. Conservation measures include protecting the following springs through conservation agreements, easements, or management plans: Apcar Springs Province, Baldwin Spring, Cardy Lamb Spring, Muddy Spring, Moapa Valley NWR, and Upper Muddy River. Implementation of tasks in this recovery plan should reduce threats to the special status species mentioned (2 springsnails) and may improve their status such that listing is not necessary to provide for their long-term protection.

3.1.3 Recovery Plan for the Aquatic and Riparian Species of Pahranagat Valley, 1998

The objective of this Recovery Plan is to recover and maintain the aquatic and riparian habitats of the Pahranagat Valley so that the three endangered fish species may be removed from the Federal list of endangered and threatened species. This Recovery Plan also addresses the research and habitat needs of several unlisted species of concern to the Service. Because this Plan addresses an ecosystem, actions taken to improve the status of the native fishes should also improve the status and condition of other endemic species (including the Pahranagat pebblesnail and grated tryonia). Recovery actions include: 1) maintain and enhance aquatic and riparian habitats in Pahranagat Valley (which includes Ash Springs Province, Hiko Spring, and Crystal Springs Province) and 2) develop and implement monitoring plan for the native aquatic invertebrates.

3.2 Voluntary and Stipulated Agreements

3.2.1 Conservation Agreement for the Spring Mountains National Recreation Area, 1998

This Conservation Agreement has been developed to facilitate voluntary cooperation between the USFS, the Service, and State of Nevada Department of Conservation and Natural Resources (DCNR), in providing long-term protection for the rare and sensitive flora and fauna of the SMNRA. Baseline information included completing a Spring Vulnerability Assessment. This assessment: 1) characterized spring and seep aquatic and riparian communities, 2) determined habitat conditions at representative springs throughout the range, 3) documented the distribution of rare aquatic and riparian species associated with these representative springs, 4) determined the vulnerability of these habitats to loss of native species from current use, and 5) provided a prioritized list of springs where management is required to improve habitats and reestablish biodiversity to natural conditions. Approximately 25 percent of the known springs in the mountain range were sampled and occurrence records of two species of springsnails (one which is the Spring Mountains pyrg) were documented during this study.

Conservation Actions / Monitoring include: 1) develop and implement a plan to monitor springsnail populations and habitats at Kiup Spring, Willow Creek, and Cold Creek (includes habitat for the Spring Mountains pyrg) and 2) develop a plan to monitor riparian function and habitat condition. The plan will focus primarily on Deer Creek, Cold Creek, Willow Creek, and Carpenter Canyon, but may include others areas as appropriate. Monitoring protocol will be specific to each area, emphasizing evaluation of habitat requirements of the species particularly dependent on these areas. Periodic monitoring of riparian areas will be conducted, using methods described in the riparian monitoring plan.

Standards and Guidelines include: When developing water sources, pipe water from a point downstream of the source if snails or other sensitive species are present, or if the spring source has not been previously developed.

1.1.1 Warm Springs Natural Area Stewardship Plan, 2011

The Warm Springs Natural Area is owned by the Southern Nevada Water Authority (SNWA). The purpose of the Stewardship Plan is to establish a long-term management direction for the Warm Springs Natural Area that will foster relations between SNWA and the property neighbors, while preserving the important ecological integrity of the property. The purpose of the property is to protect Moapa dace and its habitat, which will also provide protections for Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia through the protection of free-flowing water and adequate discharge. The mission statement for the Warm Springs Natural Area is “To manage the property as a natural area for the benefit of native species and for the recovery of the endangered Moapa dace – consistent with SNWA’s commitments to the Southern Nevada Public Land Management Act funding of the property.

3.2.2 Coyote Spring Valley Stipulation and Monitoring, Management, and Mitigation Plan for Existing and Future Permitted Groundwater Development in Coyote Spring, 2001

This Stipulation was made and entered into between the Las Vegas Valley Water District and SNWA and the BLM, NPS, and Service. The plan consists of four main components:

1. Monitoring Requirements, related to production wells, monitoring wells, elevation control, streamflow and springflow, water quality, quality of data, and reporting
2. Management Requirements include the goal to manage the development of the carbonate aquifer as a water resource without resulting in unreasonable adverse impacts to the state and federal water rights and water resources of the Federal Bureaus, the creation of a Technical Review Panel, a public symposium, and the details of the decision making process
3. Mitigation Requirements
4. Modification of the Plan

Stipulations should provide springsnail habitat protections for the Moapa pebblesnail, Moapa Valley pyrg, grated tryonia, and Blue Point pyrg from water withdrawals in the Muddy Springs, Pederson Spring, Warm Springs, Apcar Spring, Baldwin Spring, Plummer Spring, Rogers Spring, and Blue Point Spring.

3.2.3 Memorandum of Agreement for Coyote Spring Valley and California Wash Hydrographic Basins, 2006

This agreement is between the Moapa Band of Paiute Indians (Tribe), SNWA, Coyote Springs Investment LLC (CSI), Moapa Valley Water District (MVWD), and the Service. This is an agreement regarding certain planned groundwater pumping in the Coyote Spring and California Wash hydrographic basins with measures to mitigate potential impacts of such pumping on the endangered Moapa dace. The Parties agreed upon the necessity to maintain specified minimum in-stream flows in the Warm Springs area and Parties agreed to work together and with others to implement research and restoration projects. Such measures should also provide protections for the Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia adjacent to the Muddy River by preventing drawdown of the springs that provide habitat to these springsnails.

3.2.4 Water Settlement Agreement for Coyote Spring Valley and California Wash Hydrographic Basins, 2006

This agreement is between the Tribe, Las Vegas Valley Water District, SNWA, MVWD, Muddy Valley Irrigation Company (MVIC), and the State of Nevada (State). This is an agreement regarding surface water rights in and to the Muddy River, and groundwater rights in and to the California Wash hydrographic basin. Following the terms and conditions set forth in the agreement should provide protections for the Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia adjacent to the Muddy River from water depletion that may threaten the existence of these springsnails.

3.2.5 Kane Springs Amended Stipulation, 2006

The purpose of this plan is to describe the agreements of Lincoln County Water District and Vidler Water Company, Inc. (LCWD&VWC) and the Service regarding the monitoring, management, and mitigation of potential impacts due to development of groundwater resources in the Kane Springs Valley area. This plan consists of four principle components, as follows:

1. Monitoring Requirements, related to production wells, monitoring wells, elevation control, streamflow and springflow, water quality, quality of data, and reporting
2. Management Requirements, related to the creation and role of a Technical Review Team, the development and use of a numerical groundwater flow model, the establishment of action criteria, and the details of the decision making process;
3. Mitigation Requirements
4. Modification of the Plan

Stipulations should provide for the maintenance of habitat for the Moapa pebblesnail, Moapa Valley pyrg, and grated tryonia within the Muddy River/Warm Springs/Moapa Valley National Wildlife Refuge areas in the adjacent hydrographic basin.

3.2.6 Hydrologic and Biological Monitoring, Management, and Mitigation Plan for Development of Groundwater in the Delamar, Dry Lake, and Cave Valley Hydrographic Basins, 2008

This plan is a component of a Stipulation between the SNWA and the U.S. Department of the Interior bureaus, including the Bureau of Indian Affairs, the BLM, the Service, and the NPS. The Plan consists of three principal components:

1. Monitoring Requirements - including, but not limited to, existing wells, new monitoring wells, water chemistry analyses, spring discharge measurements, quality control procedures, and reporting requirements
2. Management Requirements – including, but not limited to, creation of a Biologic Resources Team to review biological information collected pursuant to this Plan and advise the Executive Committee; the expansion of the duties of the Technical Review Panel to review information collected under this Plan and advise the Executive Committee; the use of an agreed upon transient groundwater flow system numerical model to help predict effects of groundwater withdrawals by SNWA in the Hydrographic Basins; and the use of the consensus-based decision making process established in the Spring Valley Stipulation
3. Mitigation Requirements – including, but not limited to the: (1) modification, relocation or reduction in points of diversion and/or rates and quantities of groundwater withdrawals, the augmentation of Federal Water Rights, Federal Resources, and/or Water Dependent Ecosystems; (2) acquisition of real property and/or water rights dedicated to the protection of Special Status Species; and (3) measures designed and calculated to rehabilitate, repair, or replace any and all Federal Water Rights, Federal Resources, and Water Dependent Ecosystems if necessary to achieve the Common Goals

Spring discharge measurements will be monitored at Flag Springs Province, Hot Creek Springs Province, Moorman Spring, Ash Springs Province, and Crystal Springs Province. Spring discharge sites to be evaluated for monitoring include Hiko Spring, Maynard Spring, and Hardy Springs Province. Stipulations should provide springsnail habitat protections from water withdrawals in these areas for the White River Valley pyrg, Flag pyrg, grated tryonia, Pahranagat pebblesnail, Hubbs pyrg (*P. hubbsi*), and Hardy pyrg (*P. marcida*).

3.2.7 Lake Valley Stipulation and Hydrologic Monitoring, Management, and Mitigation Plan for Development and Export of Groundwater in the Lake Valley Hydrographic Basin, 2008

The stipulation and plan are between Tuffy Ranch Properties, LLC (TRP) and the BLM. The plan describes the obligations regarding the development, monitoring, management, and mitigation related to the stipulation applications for the interbasin transfer from Lake Valley Hydrographic Basin. The plan consists of four principle components, as follows:

1. Monitoring Requirements, related to production wells, monitoring wells, elevation control, springflow, quality of data, and reporting

2. Management Requirements, related to the details of decision making processes, the revision and use of a numerical groundwater flow model, the establishment of specific actions
    - TRP agrees to limit its interbasin transfer of groundwater from the Atlanta Farms area of Basin 183 to Coyote Springs Valley to the greater of an amount equal to 12,000 acre feet, the existing perennial yield for Basin 183 as may be modified by the State Engineer, or such other amount as may be agreed to by the BLM and TRP. Notwithstanding the foregoing, such Interbasin Transfer may not exceed the amount authorized and approved by the State Engineer.
    - To the extent the State Engineer in subsequent hearings approves the new applications by TRP (not to exceed 24,000 acre feet) for appropriation of groundwater, fifty percent of the water may be exported and fifty percent of such water shall remain in Basin 183 unless the BLM otherwise agrees.
3. Mitigation Requirements
4. Modification of the Plan

Stipulations should provide habitat protections for the Lake Valley pyrg (*Pyrgulopsis sublata*) from water withdrawals in the Lake Valley hydrographic basin.

3.2.8 Biological Monitoring Plan for the Spring Valley Stipulation, 2009

The Spring Valley Biological Monitoring Plan (Plan) is a component of a stipulated agreement between the SNWA and four U.S. Department of the Interior Bureaus: BIA, BLM, Service, and NPS. The purpose of the Plan is to establish a monitoring program that will further the understanding of groundwater-influenced ecosystem dynamics and track biotic community responses to SNWA's groundwater withdrawal from the Spring Valley Hydrographic Basin (Spring Valley HB) in east-central Nevada. This document focuses on monitoring baseline conditions prior to SNWA groundwater withdrawal (the Pre-Withdrawal Phase) from Spring Valley.

Because springsnails require persistent water of suitable quality, they are excellent indicators of the health of spring systems and are well-suited for long-term monitoring. For these reasons, as well as those outlined by Sada (2000) and listed below, the Biological Work Group chose to specifically monitor springsnails (which includes the bifid duct pyrg) as part of this Plan):

- Springsnail demography in unaltered habitats indicates that population variation may be predictable
- Springsnails occur in small habitats that can be easily sampled
- Springsnail populations are susceptible to comparatively rapid changes in abundance and distribution in response to changes in habitat conditions (e.g. both surface water diversions and excessive groundwater withdrawal)

Key ecological attributes and indicators to be monitored include bifid duct pyrg abundance and distribution. Stipulations should provide habitat protections for the bifid duct pyrg from water withdrawals in the Spring Valley hydrographic basin.

3.2.9 Utah – Nevada Draft Agreement for Management of the Snake Valley Groundwater System, 2009

In 1989, the SNWA submitted water rights applications in five hydrographic basins (Snake, Spring, Delamar, Dry Lake, and Cave valleys) as part of a proposed project to develop a water conveyance system through Clark, Lincoln, and White Pine counties. The purpose of the project is to convey up to 155,000 acre feet per year of groundwater from Lincoln and White Pine counties to help meet Southern Nevada's water needs. One of the hydrographic basins, Snake Valley, occurs in both Nevada and Utah. In 2004 the Lincoln County Conservation, Recreation, and Development Act (LCCRDA; P.L. 108-424) was signed into law. A portion of the Act requires the states of Nevada and Utah to reach an agreement regarding the division of water resources for any groundwater basins located within both states prior to any transbasin diversion. In response to this requirement, the two states negotiated a Draft Agreement, which was released for public review on August 13, 2009 (BLM 2013 Utah Nevada Draft Snake Valley Agreement website). The Agreement would have included establishment of monitoring plans, early warning indicators, and provisions for avoiding, minimizing, and mitigating any effects from groundwater development identified by monitoring.

The Draft Agreement stated that the Nevada State Engineer would not schedule a hearing for SNWA's Snake Valley applications until after September 1, 2019 (10 years after the State Engineer originally scheduled the Snake Valley water applications hearing in September-October 2009). This 10-year period was to be used to conduct additional studies and collect data on the Snake Valley aquifer and groundwater availability.

In April 2013, the State of Utah rejected the Draft Agreement, and the current status of this Agreement is unknown. However, LCCRDA directs that an agreement must be in place before any groundwater resources in White Pine or Lincoln counties can be developed in basins that adjoin with Utah. In the interim, the Service is serving as a member of the Biological Working Group for the implementation of the SNWA-DOI Stipulation Agreement for Spring Valley, which also includes some monitoring in southern Snake Valley at springs occupied by the bifid duct pyrg.

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A review of: "**The Species Status Assessment for 14 springsnails in the Great Basin and Mojave Desert**"

By: David L. Rogowski
Date: 5 May 2017

Thank you for the opportunity to review the Species Status Assessment for the 14 springsnails in the Great Basin and Mojave Desert. I wish I was familiar with each spring and springsnail, but I am not, in those cases I relied on the literature and what was presented in the SSA. I spent a fair amount of time reviewing Section 6 – Potential Future Conditions – Species Viability. In many cases I did not agree with the authors, I thought they were overly optimistic or completely ignored their own data and current conditions presented in the SSA. Many of the statements in section 6.4 Species Summaries I found to be misleading and incorrect (detailed below). The major general comments are detailed below; within the SSA I have more specific comments and edits.

If you have any questions or concerns, please feel free to contact me.

Listing Potential Future Conditions with a number (1-3) gives the impression that this is the order of likelihood for each scenario. I do not believe this is correct. 2 and 3 are the most likely scenarios. Either state, they are in no particular order, or do away with the current numbering and order of scenarios (use bullets). Ideally, I would like to see a probability for each scenario.

Provide evidence for each scenario. This can be accomplished at a minimum of just looking at past data on springs in the area of concern. How many have dried up? How many are under threat from over-allocation (21 of 74 springs from Table 4.1). How many have suffered reduced flow/volume? Based on this information you should be able to rank and assign a probability to each future condition. There are a variety of springs that have dried up and a number of subpopulations that have been extirpated from springs in the recent past (White Valley pyrg, Flag pyrg, and Lake Valley pyrg), thus current conditions are not adequate for the continued viability of many of these 14 springsnails. Additionally, that calls into question the realistic probability of future Scenario 1. I find Scenario 1 highly unlikely. Provide some evidence that it is a likely future scenario. Can you document any spring(s) maintaining its flow (quantity) unchanged over the past 50, 25, or even the last 10 years. If you do find this evidence, what percent have been able to maintain the same flow over those time periods? Have any springs actually increased discharge?

As adequate water is probably the greatest threat to these species. I would like to see more attention and more quantitative data and analyses conducted in regards to water availability past, present, and future. For example *Table 4.1 Hydrographic regions and areas currently or historically occupied by the 14 springsnail species*, there should be a summary of the data presented in that table. Twenty one of the 74 (28%) of springs presented are in areas where groundwater allocation exceeds the estimated perennial or safe yield. This is a conservative number, as you have listed a spring (Manse Spring) that no longer has water – thus it is no longer a spring and does not contain any springsnails.

"Since we cannot predict where new domestic wells would be drilled or the amount of water new and existing wells would pump, we recognize that this is a potential future stressor, but do not analyze it in the spring descriptions (page 48)*"* This is very shortsighted. This potentially poses the greatest threat to the continuance of these springsnails and it is totally discounted. This is not acceptable. This should and can be addressed. All potential future water withdrawals can and most likely will result in a decrease in spring flow - and this will occur in every area that is not protected against development (housing, industry, agriculture, oil-gas-mineral, etc…). The southwest in general is replete with examples of dropping groundwater levels, springs drying, as well as reduced spring and stream flows.

When there is no information - meaning there are no studies that investigated a particular topic, the authors should be careful about how they phrase it. Currently the authors state that there is no known impacts of X, when it is better and more accurate to state there aren't any known studies that have investigated the effect of X on the springsnails. This is a big difference and should be corrected throughout the document. For example this phrase:

> "*At this time, the best available information does not indicate that the species' abundance is significantly impacted by the stressors. Additionally, the best available information does not indicate either increasing or declining numbers of springsnails for this species*."

is used quite frequently and is very misleading. It more appropriate and correct to state:

> *"We do not have enough information or data to determine whether the population is being significantly impacted by stressors or not. Nor do we have enough information or data to determine whether the population is increasing, decreasing, or remaining the same."*

There are other similar examples of this misleading wording used throughout the document. Another example that is used throughout the SSA is below:

> *"No research has been conducted to address the genetic diversity represented by bifid duct pyrg. We are unaware of any documented specific risks for the bifid duct pyrg related to diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics. Rates of dispersal or gene flow are not known to have changed. Additionally the best available information does not indicate that the current abundance of the species is at a level that is causing inbreeding depression or loss of genetic variation, nor is there any information to indicate that this species could not adapt to changing conditions."*

The above statement is very misleading, and not really accurate. It is more correct and accurate to state:

We are unaware of any studies on the bifid duct pyrg related to diversity in life history traits, population demographics, morphology, behavior, or genetic characteristics. Rates of dispersal or gene flow are not known. There is not enough information to determine the current abundance of the species, thus we do not know if inbreeding depression or loss of genetic variation is a concern, nor is there any information on the genetic diversity of this species and whether it is adequate to adapt to changing conditions.

Also – stating that the species needs are met because they are present is not accurate. eg: "Since the species are present within the spring, we determined that the species needs are met within the parameters of the data collected." This is very circular and there is no evidence that this assumption is correct. For most species and subpopulations there is not enough information to determine if the population is increasing, decreasing or remaining stable. Thus, the population could be in decline due to a variety of reasons (stressors) and we wouldn't know it. Conditions may be adequate for a short period of time that allows the species to hang on, but for most of the time it could just be barely hanging on.

In each Table (eg 5.2) of "Stressors for …" there is subsection "Spring Modifications from the following sources?" What about groundwater impacts? Why is this not covered? In all likelihood groundwater levels are decreasing and one would expect that to impact many of these springs, if not now, they will in the future ("Expected Future Trend")

I would like to see a more quantitative assessment of the springsnails. For example, for resiliency and "future conditions", the ratings/scoring needs to be defined. What does each of these terms mean: inadequate, adequate, low, moderate and high? These terms need to be quantified and defined. How does "adequate" differ from "low"?

Springsnails that only occur in one location (eg Blue Point pyyrg, and Hubbs pyrg) by definition should have a redundancy score or ranking of inadequate. I believe for each of these species (listed above) the SSA concludes that redundancy is adequate – that is incorrect.

What about addressing Scenario 3 – I believe this is a much more likely scenario than number one. I do not think it is adequately addressed for each species.

I am dismayed to see that the authors think that a loss of subpopulations is acceptable and they rank future conditions to likely remain adequate for resiliency, redundancy, and representation. The White Valley pyrg, Flag pyrg, and Lake Valley pyrg, have lost subpopulations in recent history. To me this is indicative that they are not doing well. When you lose a subpopulation, resiliency, redundancy, and representation are all reduced, and if this occurred over recent history and there is no expected change or improvement in water flow (quantity) one should expect that other springs and springsnail subpopulations will suffer the same fate. The loss of subpopulations would be expected to increase under Scenario 2 of decreasing water quantity and with the same stressors that were present originally that resulted in the loss of these numerous subpopulations.