THE PROBABLE EFFECTS OF GROUND WATER USE PROPOSED BY THE LAS VEGAS VALLEY WATER DISTRICT ON SPRING-DWELLING ANIMALS IN SOUTHERN NEVADA AND SOUTHEASTERN CALIFORNIA

Donald W. Sada and James E. Deacon
Environmental Studies Program
University of Nevada, Las Vegas

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INTRODUCTION

The Las Vegas Valley Water District proposes to increase water diversions for municipal and industrial use in southern Nevada. These projects may affect fluvial and spring fed aquatic habitats in the region. Effects of increased diversion on fluvial habitats in the Virgin River were examined by Deacon and Sada (1994). Impacts to spring habitats anticipated by the annual pumping of between 200,000 acre feet and 800,000 acre feet of ground water in southern Nevada are examined in this report. Springs that may be affected are small and isolated, and scattered throughout southern Nevada and southeastern California as islands within an expansive desert (Hubbs and Miller 1948a, La Rivers 1962, Garside and Schilling 1979). These habitats support the highest diversity of rare aquatic animals in the region, as demonstrated by many studies documenting the unique biota that distinguishes the invertebrate and vertebrate spring assemblages (Hubbs and Miller 1948a, La Rivers 1949 a,b, 1950, Hershler 1994, Schmude 1990, Polhemus and Polhemus 1994). Knowledge of this unique fauna is increasing, as shown by recent studies describing a number of new species in these habitats, and it is very likely that additional new species will be found in the future (Hershler and Sada 1987 Hershler 1989, Shephard 1990, 1992; Schmude 1992, Polhemus and Polhemus 1994).

All aquatic habitats in the region have been impacted by human activities. The Colorado River and most of its tributaries have been impounded and diverted, and many non-native species introduced for sport, bait, and management (Miller 1961, Holden 1991, Minckley et al. 1991, Gregory and Deacon 1994). Springs have been altered by the same activities, as well as by impacts of livestock grazing and ground water depletion (Williams et al. 1985, Miller 1961, Minckley and Deacon 1968, Sada et al. 1991). These disturbances have caused decline of many populations and extinction of several species (Miller et al. 1989). Recent discoveries of new species in springs throughout the region suggest that other, undescribed species also became extinct from these activities (see Hershler and Sada 1987). Declines in extant populations have necessitated the listing of many aquatic species as either threatened, endangered, or of special concern by Federal and State governments, and the American Fisheries Society (Rinne 1984, U.S. Fish and Wildlife Service 1991, Williams et al. 1985, Williams and Sada 1985a).

This report analyzes anticipated impacts to spring biota of ground water use proposed by the Las Vegas Valley Water District by: 1--summarizing impacts of ground water depletion on spring biota throughout western North America, and 2--examining impacts to spring biota of southern Nevada and southeastern California that may be anticipated by the proposed project. Current vagaries of the project proposal make it impossible to quantify impacts to specific spring resources. Therefore, this report broadly analyzes impacts by considering how lower spring discharge may affect the biota of 10 showcase springs that represent the wide diversity of spring habitats and aquatic organisms occupying the impacted area.

EFFECTS OF GROUND WATER USE ON SPRING BIOTA

The unique biota of springs in western North America were documented by early studies (Gilbert 1893; Brues 1928, 1932; Hubbs 1929). Expansion of agriculture and municipalities into the region during the post World War II period began an intensive use of ground water, that caused a decline in spring discharge. By the mid-1970s, Brune (1975) reported 68 of 281 major springs in Texas had dried from effects of ground water pumping. Fisheries surveys in the early 1950's revealed that ground water pumping also impacted fish populations. Hubbs and Springer (1957) and Johnson Hubbs (1989) note disappearance of Big Bend gambusia (<u>Gambusia gaigei</u>) and Commanche Springs pupfish (<u>Cyprinodon elegans</u>)from springs in southern Texas. In southern Nevada, ground water depletion led to the extinction of Las Vegas dace (<u>Rhinichthys deaconi</u>)(Miller 1984), the Pahrump Ranch poolfish (Empethrichys latos pahrump), the Raycraft Ranch poolfish (E. l. concavus) (Miller 1961, Miller et al. 1989), and several springsnail populations (Landye 1973, Hershler and Sada). Other ground water depletions in southern Nevada eliminated Ash Meadows Amargosa pupfish (Cyprinodon nevadensis mionectes) and Ash Meadows speckled dace (Rhinichthys osculus nevadensis) populations (Soltz and Naiman 1978, Williams and Sada 1985b), and extinction of several fish species in Mexico (Miller et al. 1989). Landye (1981) cited ground water use near Roswell, New Mexico as the reason for extinction of the Roswell tryonia springsnail (Tryonia sp.) in South Spring.

Many authors have stated their concern for spring biota throughout western North America because of decreased spring discharge caused by ground water depletion (Minckley and Deacon 1968, Soltz and Naiman 1978, Landye 1981, McMahon and Miller 1982, Williams et al. 1985, Miller and Fuiman 1987, Schoenherr 1988). Reasons for concern are also suggested by studies indicating that aquatic animal communities are impacted by incremental decreases in spring discharge. Incremental decreases in the level of Devils Hole were correlated with lower Devils Hole pupfish (Cyprinodon diabolis) populations (Dudley and Larson 1976, Deacon 1979, Deacon and Deacon 1979), and decreased stream and spring brook flows caused by diversions are known to adversely impact wetland, riparian, and aquatic environments (Brothers 1984, Hendrickson and Minckley 1985, Stromberg and Patten 1990, Stromberg et al. 1992). Instream flow analytical methods also describe relationships between fish populations and characteristics of aquatic habitats in fluvial environments, and show that fish population size and habitat size are correlated (Bovee and Milhous 1978). Relationship of habitat size to fish species diversity and body size was examined for desert fishes by Smith (1981). He found that larger habitats support larger fish and a higher species diversity than small habitats. Results from all of these studies differ little from conclusions of other work, showing that species diversity and animal size are greatest in large habitats, and that extinction rates are highest in small habitats. Many of these relationships are founded on the theory of island biogeography (MacArthur and Wilson 1967, MacArthur 1972), and they are accepted as the basic tenets of preserve design in the practice of conservation biology for desert fishes (Moyle and Sato 1991, Moyle and Yoshiyama 1994).

ANALYSIS OF SHOWCASE SPRINGS

It is difficult to analyze impacts of ground water withdrawal proposed by the Las Vegas Valley Water District on aquatic biota of southern Nevada and southeastern California using existing information. A more through analysis will be possible when location of wells and their pump rates are determined, and ecological studies have been conducted to quantify habitat requirements of spring biota and determine their response to decreased spring discharge. With this paucity of information, anticipated impacts of ground water removal are best examined by selecting springs throughout the impacted area, considering ecological aspects of their aquatic communities, then postulating how these communities may be impacted by decreased spring discharge.

Ten springs are discussed as showcase examples of how the proposed project may affect the spring biota of southern Nevada and southeastern California (Figure 1). The showcase springs provide habitat for a small portion of the rare biota occupying southern Nevada and southeastern California springs, and they are believed to represent less than five percent of springs inhabited by rare aquatic animals in the region (Sada field notes, Hershler field notes). Although several ecological studies have been conducted in some of these springs, studies in others have been

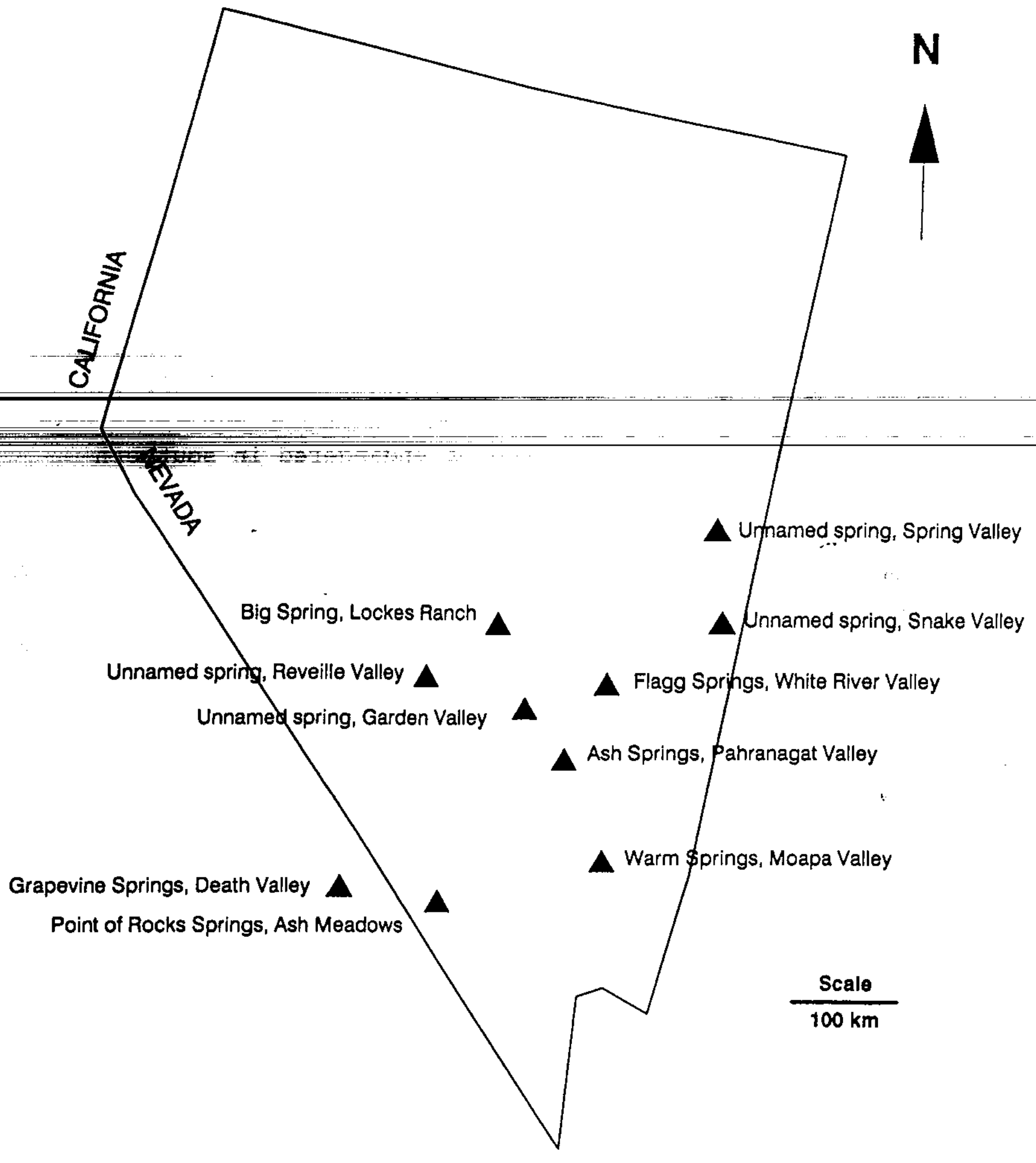

Figure 1. The approximate location of showcase springs in southern Nevada and southeastern California.

superficial. Additional research is needed to understand the ecology and distribution of species occupying springs throughout the region. Sada and Deacon (1994a) summarized studies describing the distribution and ecology of species in these springs.

Analysis of the proposed project is additionally complicated by the altered condition of spring habitats and their native biotic communities. Most spring habitats in the region have been degraded by diversion, ground water pumping, and livestock grazing (see Dudley and Larson 1976, Courtenay et al. 1985, Sada et al. 1991). Impact of these activities on native biota is indicated by the large number of animals in these habitats that are currently listed as threatened or endangered in southern Nevada (Williams et al. 1985, U.S. Fish and Wildlife Service 1991). Since the status of many populations is already degraded from historical conditions, future activities that adversely impact these habitats are likely to act in a cumulative manner and additionally deteriorate the quality of these habitats for their native biota. Habitats may be degraded in several ways. Ground water pumping may dry springs, reduce habitat size and heterogeneity, and/or create habitat that is more suited to non-native species than to native species. Recent studies have shown that native species are better able to persist in the presence of non-native species where habitats have not been disturbed by anthropogenic activities (Baltz and Moyle 1993).

SHOWCASE SPRINGS

1. **Turnley Spring**--Spring Valley, White Pine County, Nevada. This small spring lies at 2040 meters elevation on the west side of the Spring Range on public domain land. During a summer 1992 visit Hershler (field notes) estimated the average depth and width of the spring at 8 cm and 30 cm, respectively. The spring had been modified by diversion that captures much of its discharge in a pipe for delivery to a trough. Biological

studies in this spring have been limited to springsnail surveys, which found that it supports a population of an undescribed species of Pyrgulopsis restricted to Spring Valley (R. Hershler pers. comm., Smithsonian Institution, Washington, D.C., August 25, 1994). Springsnails were scarce in this spring (Hershler field notes). Distribution of springsnails in Spring Valley has not been determined; however, surveys of other springs in the area suggest that there are only a few populations.

Table 1. Rare aquatic species occupying Turnley Spring, Spring Valley, White Pine County, Nevada..

Common Name	Scientific Name
Spring Valley springsnail	*Pyrgulopsis* sp.

Knowledge of springsnail ecology is mostly provided by observations made during taxonomic studies. Their habitat is restricted to spring sources, and a limited distance of spring brook (usually less than 200 meters), where the water quality is good. Members of the genus Pyrgulopsis generally prefer sand and gravel substrates or aquatic vegetation where water current velocities are moderate (approx. 10 cm/sec) (Sada unpublished data). Their habitats may be thermal (up to 32°C) or cold (down to 8°C). Springsnails are small (frequently less than 3 mm tall), feed on algae, and are not believed to live much longer than one year. Reproduction probably occurs in spring when eggs are laid.

The small size of this spring and scarcity of springsnails suggest that this population could easily be extirpated by decreases in spring discharge.

2. **Unnamed spring tributary to Snake Creek--**Snake Valley, Great Basin National Park, White Pine County, Nevada. This small spring lies on the east side of the Snake Range on U.S. National Park Service land. During a summer 1992 visit Hershler (field notes) estimated its depth to be 2-3 cm and its width 2 m. This aquatic habitat appeared to be in comparatively natural condition, and only slightly disturbed by recreationists. Biological studies have been limited to surveys for springsnails, which found that it supports a population of an undescribed *Pyrgulopsis* species restricted to Snake Valley (R. Hershler pers. comm., Smithsonian Institution, Washington, D.C., August 25, 1994). Springsnails were recorded as common in this spring (Hershler field notes). Distribution of springsnails in Snake Valley has not been determined; however, surveys of other springs in the area suggest very few springsnail populations occur in the area.

Table 2. Rare aquatic species occupying an unnamed spring tributary to Snake Creek, Snake Valley, White Pine County, Nevada.

Common Name	Scientific Name
Snake Valley pebble snail	*Pyrgulopsis* sp.

The ecology of this species is believed to be similar to that described above for the springsnail in Turnley Spring, Spring Valley.

The small size of this spring suggests that its aquatic habitat and springsnail population are vulnerable to adverse impacts of decreased spring discharge.

3. **Big Spring, Lockes Ranch**--Railroad Valley, Nye County, Nevada. This large privately owned limnocrene is located on the valley floor and is habitat for three rare species (Table 3). The aquatic habitat and biota in this spring were studied by Deacon et al. (1980) during the summer of 1980, and several authors have examined Railroad Valley springfish ecology (Hubbs 1932, Williams and Williams 1982, Williams 1986). Polhemus and Polhemus (1994) summarized its hemipteran fauna. No non-native species are known from Big Spring. Mifflin (1968) reported its discharge decreased to 1970 lpm from an historical high of 5700 lpm because of nearby ground water pumping. Big Spring is Critical Habitat for the Railroad Valley springfish (U.S. Fish and Wildlife Service 1986).

Table 3. Rare aquatic species occupying Big Spring at Lockes Ranch, Railroad Valley, Nye County, Nevada. [1]denotes species endemic to Railroad Valley, [2]denotes species listed as threatened or endangered by the U.S. Fish and Wildlife Service, [3]denotes taxa in Big Springs that additional taxonomic analysis may determine to be distinctive.

Common Name	Scientific Name
Railroad Valley springfish[1,2]	Crenichthys nevadae
Railroad Valley turban snail[1]	Pyrgulopsis sp.
Railroad Valley belostoman bug[3]	Belostoma bakeri

The spring pool is up to 1.5 m deep. The spring brook is broad (approximately 2 m wide), comparatively deep (up to 0.4 m), and bordered by sedges, grasses, and other low-lying perennials (Deacon et al. 1980). Woody riparian vegetation is sparse, and the habitat has been periodically disturbed for diversion to irrigate pastureland and during road construction. It appears that these disturbances have been infrequent and the aquatic habitat has recovered and become naturalized. Water temperatures at the source range between 37°C and 38°C (Garside and Schilling 1979), which is near the thermal maximum tolerated by Railroad Valley springfish (Williams 1986).

Rare species utilize all of the area wetted by spring discharge. Springfish occupy the entire water column where they feed on invertebrates (Williams and Williams 1982), and springsnails occupy soft substrates (Deacon et al. 1980). Population samples during the summer of 1980 found that springfish and turban snails were abundant (Deacon et al. 1980). Snail densities exceeded 10,000/m^2, and springfish near the spring source always numbered near 12,000.

No studies have examined ecology of the belostoman bug. In other parts of its range, this species occupies quiet water with abundant aquatic vegetation or debris where it preys on a variety of vertebrates (e.g. small fish) and invertebrates (Usinger 1956).

There is no information that allows a full assessment of how past reductions in spring discharge have impacted the aquatic biota of Big Spring. It is reasonable to assume, however, that water depth and wetted area have both decreased from historic conditions. This has decreased both the amount of aquatic habitat and its diversity by reducing current velocities and water depth. Additional decreases in spring discharge will have a similar affect on aquatic habitat, possibly reducing vertebrate and invertebrate abundance and diversity in the spring.

4. Flagg Springs--Wayne E. Kirsh Wildlife Management Area, White River Valley, Nye County, Nevada. This spring province includes several springs that converge into a spring brook flowing into a large marsh on the White River Valley floor. It is Critical Habitat for White River spinedace (U.S. Fish and Wildlife Service 1985), and six rare aquatic species are known from the site (Table 4). Recovery programs are being conducted to eliminate largemouth bass (Micropterus salmoides) from the spring province (G. Scoppettone, U.S. National Biological Survey, Reno, Nevada, pers. comm., August 22, 1994).

Table 4. Rare aquatic species occupying Flagg Springs, White River Valley, Nye County, Nevada. [1]denotes species endemic to White River Valley, [2]denotes species listed as endangered by the U.S. Fish and Wildlife Service, [3]denotes taxa in Flagg Springs that additional taxonomic analysis may determine to be distinctive.

Common Name	Scientific Name
White River spinedace[1,2]	Lepidomeda albivallis
White River desert sucker	Catostomus clarki intermedius
White River speckled dace[1]	Rhinichthys osculus ssp.
White River Valley springsnail[1]	Pyrgulopsis sp.
White River Valley turban snail[1]	Pyrgulopsis sp.
White River creeping water bug[3]	Ambrysus woodburyi

Little is known about the ecology of rare species in Flagg Springs. More information will be available when studies by the U.S. National Biological Survey have been completed. It is possible to anticipate impacts of decreased spring discharge on rare species in this spring province by considering knowledge about ecology of closely related vertebrates and invertebrates in other areas.

Spinedace live in pools where there is flowing water. They feed mostly on insects and other invertebrates taken from the substrate and drift (Rinne 1971, Runck and Blinn 1993). Desert suckers occupy gravel and cobble substrates in flowing water where they feed on algae and insects gleaned from rocks (Minckley 1973). These suckers spawn over gravel during the late winter and early spring. Larval and juvenile fish prefer shallow water along the stream bank, and move into deeper water as they grow. Speckled dace are also insectivorous, taking prey from the substrate, drift, and water surface. They occupy a variety of habitats that include pools and flowing water in riffles (Baltz and Moyle 1982, Moyle and Vondracek 1985).

The two springsnails occupy different habitats. One is found only near springs and the other only in spring brooks. Their ecology is believed to be similar to other *Pyrgulopsis* species occupying flowing habitats. *Ambrysus* is a predatory aquatic bug that lives in gravel substrate where the current is swift (Usinger 1946).

Decreased spring discharge would affect habitats occupied by all rare species. Spinedace would be most affected by decreases in pool size and depth, speckled dace and suckers by decreases in current velocity, and depth and the aerial extent of riffle habitats. Sucker reproductive success could be decreased by reduction of larval and juvenile habitat near spring brook banks. Decreased discharge would also result in slower current velocity, possibly allowing siltation of gravel substrates and invasion of spring brooks by emergent vegetation. This would reduce springsnail and *Ambrysus* habitat.

5. Unnamed spring in Reveille Valley--Nye County, Nevada. This small heliocrene lies at 1900 meters elevation along the west side of Reveille Valley on public domain land. During a summer 1993 visit, Sada (field notes) estimated that the spring was 2-3 cm deep, 50 m wide, and moderately disturbed by livestock trampling. Biological studies of this spring have been limited to surveys for springsnails, which revealed that it supports a population of an undescribed Pyrgulopsis species restricted to Reveille Valley (R. Hershler pers. comm., Smithsonian Institution, Washington, D.C., August 25, 1994). This is the only rare species known from this site (Table 5). The springsnail population was small and occupied less than 2 m^2 of habitat (Sada field notes). The distribution of springsnails in Reveille Valley has not been determined; however, they are believed to occupy only a few habitats.

Heliocrenes are marshy wetlands maintained by small springs. In the Great Basin they frequently produce so little water that there is no outflow, making it difficult to measure their discharge. They usually support a limited amount of springsnail habitat, restricted to an immediate area surrounding the source where water quality is high (usually less than 5 m^2)(Sada field notes). Low discharge and small size of these aquatic habitats indicates that springsnail populations in heliocrenes are highly susceptible to activities that reduce habitat quality.

Table 5. Rare aquatic species occupying an unnamed spring in Reveille Valley, Nye County, Nevada. This springsnail is endemic to Reveille Valley.

Common Name	Scientific Name
Reveille Valley springsnail	Pyrgulopsis sp.

Ecology of this springsnail is believed to be similar to that of other springsnails discussed above. Characteristics of this habitat and the limited amount of area occupied by springsnails indicate, however, that this species requires habitats with lower current velocities than habitat preferred by other springsnails. Small discharge from this heliocrene and the limited amount of area occupied by springsnails suggest this population is extremely vulnerable to adverse impacts of decreased spring discharge.

6. Unnamed spring south of Cherry Creek--Garden Valley, Nye County, Nevada. This small heliocrene lies on the west side of Garden Valley on public domain land. During a summer 1992 visit, Hershler (field notes) estimated its depth to be less than 1 cm, and the aquatic habitat was moderately disturbed by livestock trampling and residential use. Biological studies of this spring have been limited to springsnails surveys, which found that it supports an undescribed species of Pyrgulopsis restricted to Garden Valley (R. Hershler pers. comm., Smithsonian Institution, Washington, D.C., August 25, 1994). This is the only rare species known from this site (Table 6). Springsnails were common (Hershler field notes). The distribution of springsnails in Garden Valley has not been determined; however, surveys of other springs in the area suggest that its distribution is limited to a small number of sites.

Table 6. Rare aquatic species occupying an unnamed spring south of Cherry Creek, Garden Valley, Nye County, Nevada.

Common Name	Scientific Name
Garden Valley springsnail	Pyrgulopsis sp.

Ecology of this springsnail is believed to be similar to other Pyrgulopsis species, as described above. Characteristics of heliocrene aquatic habitat indicate, however, that this species requires habitats with slower current than other species. The small amount of water and the restricted amount of springsnail habitat make viability of this population highly vulnerable to reductions in discharge.

7. **ASH SPRINGS**, Pahranagat Valley, Lincoln County, Nevada. This spring complex lies on U.S. Bureau of Land Management and private lands on the valley floor. It is the warmest spring in the area (Garside and Schilling 1979), and it is believed to have the highest diversity of rare aquatic animals in Pahranagat Valley (Gilbert 1893, La Rivers 1949a, Miller and Hubbs 1960, Landye 1973, Williams and Wilde 1981, Tuttle et al. 1990, Schmude 1992, Polhemus and Polhemus 1994) (Table 7).

Rare species occupy(ied) a wide variety of aquatic habitats in this spring and spring brook. Generally, rare invertebrates occur near the spring source, and fishes are distributed throughout the wetted area.

The Pahranagat roundtail chub and White River springfish are listed as endangered by the U.S. Fish and Wildlife Service and State of Nevada (U.S. Fish and Wildlife Service 1991, Rinne 1984). Ash Spring is designated Critical Habitat for the springfish (U.S. Fish and Wildlife Service 1985b). It is also habitat for a number of non-native fish and invertebrate species (Tuttle et al. 1990). Ash Springs has been modified by impoundment for diversion, and use as a recreation site (Courtenay et al. 1985).

The diversity of rare species in Pahranagat Valley has diminished from impacts of competition and predation from non-native species and modification of aquatic habitat for agriculture. The Pahranagat spinedace and desert sucker were extinct by 1959, probably from introduction of non-native fish species (Miller and Hubbs 1960), habitat modification, and introduction of disease and parasites (Deacon 1979). Habitat requirements of these species were never determined. However, both species were always captured in the spring brook, and never near the spring source (Miller and Hubbs 1960).

Table 7. Rare aquatic species occupying Ash Springs and its outflow, Lincoln County, Nevada. [1]denotes taxa endemic to Ash Springs, [2]denotes taxa endemic to the Pahranagat Valley, [3]denotes species listed as threatened or endangered by the U.S. Fish and Wildlife Service, [4]denotes extinct taxa, and [5]denotes taxa that additional taxonomic analysis may determine to be distinctive.

Common Name	Scientific Name
Pahranagat roundtail chub[2,3]	Gila robusta jordani
White River springfish[1,2,3]	Crenichthys baileyi baileyi
Pahranagat speckled dace[2]	Rhinichthys osculus velifer
Pahranagat spinedace[2,4]	Lepidomeda altivelis
White River desert sucker	Catostomus clarki intermedius
White River tryonia	Tryonia clathrata
Pahranagat Valley turban snail[2]	Pyrgulopsis merriami
Ash Springs riffle beetle	Stenelmis lariversi
Mormon naucorid bug[5]	Ambrysus mormon
Pahranagat Valley belostoman bug[5]	Belostoma bakeri
Pahranagat Valley naucorid	Pelocoris shoshone shoshone
Pahranagat Valley riffle beetle[2]	Microcylloepus moapus fraxinus

Native fishes are currently distributed throughout spring and spring brook (Tuttle et al. 1990, Hardy 1982). The springfish is endemic to Ash Spring (Williams and Wilde 1981), and most abundant near the spring source where current velocity is low. Adults appear to be most common near the substrate in deep habitats, whereas juveniles are more dispersed and occupy shallower water.

Roundtail chubs historically occupied all major springs and their outflows in Pahranagat Valley, but they are now restricted to habitats in Ash Spring and its outflow. Tuttle et al. (1990) found chubs most abundant in the outflow from Ash Spring, where adults hold close to the substrate in current velocities ranging from 0.00 m/sec to 0.80 m/sec. Spawning occurs in January and February over gravel substrates in pools where mean water column velocity ranges from 0.08 m/sec to 0.54 m/sec. Water temperature during spawning ranged from 17.0°C to 24.5°C, and dissolved oxygen concentrations from 6.3 mg/l to 8.3 mg/l. Larval roundtail chubs (< 25 mm) occupy calm, shallow habitats along the stream bank.

Speckled dace are the most abundant native fish in the Pahranagat Valley and occupy a wider variety of habitats than other native fish. They do not occupy the source of Ash Spring, but are widely distributed throughout the spring brook where they prefer habitat near the substrate. Mean focal current velocity of adults is 0.12 m/sec, and less for juveniles. Juveniles are near the surface in slower currents, and larval speckled dace inhabit much of the water column where current velocity is low (Tuttle et al. 1990).

Springsnails, riffle beetles, and Pelocoris shoshone are restricted to the spring source. Pyrgulopsis merriami occupies only clean gravel and cobble substrate in flowing water. Both riffle beetles are on clean sand substrates near spring heads, and Tryonia and Pelocoris shoshone are known only from springpool margins. Tryonia is scarce and limited to sand and silt substrates; it is believed to occupy less than 2 m^2 of habitat in Ash Spring. Pelocoris shoshone inhabits emergent vegetation along calm lagoons. Ambrysus mormon is the only rare invertebrate in Ash Springs that occupies the spring brook, it is not found in the spring pool. Other Ambrysus mormon populations are found in spring brooks where there is gravel substrate (Usinger 1946). In other habitats this species occupies areas adjacent to stream margins, from which they may venture into the center of the stream to forage on insects and other invertebrates found among the rocks (Usinger 1946). Habitat use by the belastoman bug is unknown. In other portions of its range, it occupies calm habitats where there is debris or vegetation that it can use as cover while hunting for vertebrate and invertebrate prey (Usinger 1956).

Decreased spring discharge may affect habitats in several ways. Shallower pools would adversely affect roundtail chub and springfish habitats. Decreased flow would also lower current velocities and decrease availability of aquatic insects that are food for roundtail chubs. Sedimentation could also increase with lower current velocity. This sediment would cover gravel and cobble substrates and reduce habitat for several aquatic invertebrates and roundtail chub spawning. Lower current velocities may also stimulate submerged vegetation and decrease availability of clean gravel and sand substrates. Lower flow may also modify thermal dynamics of the spring system by decreasing extent of thermal habitats and limiting them to upstream areas near springs. Effects of this impact would be most apparent during cooler periods of the year and when space that is currently partitioned by native and non-native species becomes more limited. It may also decrease thermal habitats required by many rare species.

8. Grapevine Springs--Death Valley National Monument, Inyo County, California. This spring province is located on the west side of the Grapevine Mountains in northern Death Valley. It includes a number of small, thermal springs that discharge from a hill and flow less than 100 m before percolating into the alluvium. All rare species in Grapevine Springs are invertebrates (Table 8); the aquatic habitat is believed to be too small for vertebrates. Although rare species occupy all springs in the province, some springs support a full complement, while others are inhabited by only a few. These differences may be attributed to spring size and aquatic habitat characteristics.

The Oasis Valley springsnail occupies a wide variety of habitats, which may be one reason it is the most widely distributed springsnail in southern Nevada and southeastern California (Hershler 1989). In Ash Meadows it occupies habitats with low and high current velocities and gravel and mud substrates, and on several types of aquatic vegetation (Hershler and Sada 1987). It is known to occupy four springs in the Grapevine Springs complex (Hershler 1989). _Tryonia margae_ and _Tryonia rowlandsi_ are believed to be endemic to Grapevine Springs. Both species are known from only two springs in the province, and syntopic in only one of them. _Tryonia margae_ occupies both thermal and cool springs, while _T. rowlandsi_ occupies only thermal habitats. Both species appear to be limited to shallow habitat near the spring source where water flows over travertine (Hershler 1989).

Table 8. Rare aquatic species occupying Grapevine Springs, Death Valley National Monument, Inyo County, California. [1]denotes species endemic to Death Valley, none on these species are known outside of the Amargosa River drainage, southwestern Nevada and southeastern California.

Common Name	Scientific Name
Grapevine Springs elongate tryonia[1]	_Tryonia margae_
Grapevine Springs squat tryonia[1]	_Tryonia rowlandsi_
Oasis Valley springsnail	_Pyrgulopsis micrococcus_
Amargosa Pelocoris bug	_Pelocoris shoshone shoshone_
Amargosa riffle beetle	_Microcylleopus similis_

Habitats occupied by the riffle beetle and Pelocoris bug at Grapevine Springs are less understood because dense riparian vegetation hampers sampling. Polhemus and Polhemus (1994) reported the Pelocoris bug from small pools, and Shepard (1992) merely records collecting the species for taxonomic analysis.

The small size of these springs and limited amount of habitat occupied by rare species indicates that viability of these populations could be easily jeopardized by decreasing spring discharge. Their sensitivity may be indicated by the disappearance of the Death Valley Pelocoris bug from Grapevine Canyon, located several kilometers south of Grapevine Spring. Polhemus and Polhemus (1994) attribute absence of aquatic bugs from this site to diversion and perturbations of springs during construction and occupation of Scottys Castle.

9. Point of Rocks Springs--Ash Meadows, Nye County, Nevada. Ash Meadows is a unique spring province inhabited by at least 32 endemic plants and animals (U.S. Fish and Wildlife Service 1990). Much of the area was purchased by The Nature Conservancy in 1984, and later that year sold to the U.S. Fish and Wildlife Service to establish the Ash Meadows National Wildlife Refuge for protection of its endemic flora and fauna. Point of Rocks Springs is a complex of seven thermal springs in the east central portion of Ash Meadows. Six of these springs flow from a hillside before they converge and flow across the valley floor (Hershler and Sada 1987). The seventh spring, Kings Pool, is located on the valley floor and is the largest spring of the complex. The Point of Rocks Springs fauna is distinctive, including three endemic species and several other rare species (Table 9). Three species occupying the complex are listed as threatened or endangered by the U.S. Fish and Wildlife Service. Point of Rocks Springs is Critical Habitat for the Ash Meadows Amargosa pupfish and Ash Meadows naucorid (U.S. Fish and Wildlife Service 1990). These springs have been altered for recreation, and agricultural and municipal development (Soltz and Naiman 1978), and its aquatic fauna includes several non-native species (Miller 1948, Williams and Sada 1985b, Hershler and Sada 1987). The Ash Meadows poolfish was extinct by the early 1950s, due probably as a consequence of impacts from non-native fishes (Miller et al. 1989).

The U.S. National Biological Survey is conducting ecological investigations in Ash Meadows to determine habitat use and requirements of many aquatic species (G. Scoppettone, pers. comm., U.S. National Biological Survey, Reno, Nevada, August 30,

Table 9. Rare aquatic taxa occupying Point of Rocks Springs and its outflow, Ash Meadows, Nye County, Nevada. [1]denotes species endemic to Point of Rocks Springs, [2]denotes species listed as threatened or endangered by the U.S. Fish and Wildlife Service, [3]denotes species extinct from Point of Rocks Springs, and [4]denotes taxa in Point of Rocks Springs that additional taxonomic analysis may determine to be distinctive.

Common Name	Scientific Name
Ash Meadows Amargosa pupfish [2]	Cyprinodon nevadensis mionectes
Ash Meadows speckled dace[2]	Rhinichthys osculus nevadensis
Ash Meadows poolfish[3]	Empetrichthys merriami
Ash Meadows naucorid bug[1,2]	Ambrysus amargosus
Ash Meadows pebble snail[1]	Pyrgulopsis erythropoma
Point of Rocks tryonia snail[1]	Tryonia elata
Amargosa tryonia	Tryonia variegata
Amargosa riffle beetle	Stenelmis calida
Amargosa Pelocoris	Pelocoris shoshone amargosus
Ash Meadows skater[4]	Rhagovelia distincta
Ash Meadows assiminea[4]	Assiminea sp.

1994). Until they have been completed, the best ecological information for these species is provided by observations made during taxonomic studies and studies conducted on closely related species in other areas.

Rare species occupy all aquatic habitats in the complex. All rare invertebrates are most common in thermal habitats near springs and in relatively short lengths of the spring brooks. The Ash Meadows naucorid, Amargosa Pelocoris, and all springsnails are restricted to small springs and the spring source in Kings Pool (La Rivers 1948, Chandler 1949, La Rivers 1953, Hershler and Sada 1987, Polhemus and Polhemus 1994). The Ash Meadows naucorid, Amargosa riffle beetle, and Ash Meadows pebble snail occupy gravel substrates in flowing water. Both Tryonia species are limited to sand and silt substrates and aquatic vegetation, and occupy less than 2 m^2 of habitat in each spring. The Ash Meadows assiminea is a semi-aquatic snail that occupies grasses and sedges along stream banks. It rarely lives more than 5 cm from an aquatic habitat. Throughout their range, riffle beetles occupy a wide variety of permanent aquatic habitats, but it is unusual to find them in low gradient, turbid, sandy streams where dissolved oxygen concentration is low (Usinger 1956). In southern Nevada, Chandler (1949) and La Rivers (1949a,b) reported riffle beetles common in densely vegetated marshes, and in gravel substrates associated with riffle habitats. Riffle beetles feed on aquatic vegetation (Usinger 1956).

The Ash Meadows naucorid bug, Amargosa Pelocoris, and Ash Meadows skater are predatory aquatic insects that occupy both ponded and flowing habitats. As with other naucorids, the Ash Meadows naucorid bug occupies gravel substrates in swiftly flowing water (La Rivers 1953, Usinger 1956). It has been extirpated from Kings Pool, and is now limited to a few small springs in the complex. The distribution of Pelocoris shoshone and the Amargosa skater is poorly known in Point of Rocks Springs, but they are both believed to be most abundant in Kings Pool and its outflow. In other portions of their range, Pelocoris shoshone inhabits areas the near source of thermal springs, either near emergent vegetation or along banks with overhanging grasses (La Rivers 1948, 1950), and skaters live on the water surface in fast moving riffle habitats (Usinger 1956).

The Ash Meadows Amargosa pupfish inhabits Kings Pool, its outflow, and a series of artificial ponds on the valley floor. It is absent from all small springs in the complex. Pupfish are habitat generalists and utilize most wetted area in a habitat. Adults prefer deeper water, and juveniles prefer shallow habitats where primary productivity is high and there are few interactions with adults (Sada and Deacon 1994). They are opportunistic omnivores whose diet changes throughout the year, and usually consists of the most abundant invertebrates and plant material in the environment. Spawning occurs primarily during spring and summer, and eggs are laid on soft substrate and aquatic vegetation. Incubation is short and they grow to sexual maturity quickly. Pupfish generally do not live more than one year (Soltz and Naiman 1978).

The Ash Meadows speckled dace occupies only the outflow from Kings Pool. In other portions of their range, speckled dace prefer flowing water habitats where they feed on aquatic insects collected from the substrate, drifting in the water column, and from the surface. They spawn in spring and summer and live as long as four years (Moyle 1976).

The small size of most springs occupied by rare invertebrates at Point of Rocks Springs indicates that these species are most susceptible to decreases in spring discharge. Decreases in discharge could result in extinction of the three species endemic to this spring complex. Depth and wetted area of larger waters (e.g. Kings Pool) suggest that species occupying these habitats would persist through small decreases that might cause demise of invertebrates in smaller springs. Reduced discharge would affect fish and invertebrates in larger waters by decreasing water depth, the amount of aquatic habitat, and current velocity.

10. Warm Springs--Moapa Valley, Clark County, Nevada. This spring complex includes a number of headwater springs that maintain a relatively continuous discharge of 1.4 m^3/sec and create the Muddy River (Eakin 1964). A wide variety of aquatic habitats are found in Moapa Valley, including thermal spring habitats, small fluvial habitats in spring brooks, and comparatively large and deep riverine habitats in the Muddy River. Environments in springs and spring brooks are relatively constant, whereas river habitat is unpredictable and frequently scoured by large floods. Aquatic habitats at Warm Springs lie on private land and the Moapa National Wildlife Refuge, which includes a spring province that has been rehabilitated to aid recovery of Moapa dace (Scoppettone et al. 1992).

A number of rare species inhabit all spring and fluvial habitats at Warm Springs (Hubbs and Miller 1948b; La Rivers 1949 a & b, 1950; Cross 1976, Deacon and Bradley 1972; Pratt 1977; Williams 1978; Williams and Wilde 1981; Polhemus and Polhemus 1994) (Table 10). The Moapa dace is the only species at Warm Springs listed as endangered by the U.S. Fish and Wildlife Service and the State of Nevada (U.S. Fish and Wildlife Service 1991, Rinne 1984). As with other springs in the region, rare invertebrates generally inhabit springs and their spring brooks, and fishes occupy a broad variety of habitats from spring sources to larger habitats downstream.

The two undescribed species of *Pyrgulopsis* occupy only spring sources and a short distance of spring brook. One species is limited to gravel substrates where current velocity is moderate (e.g. approx. 10 cm/sec) and the other is found on woody debris and filamentous algae where current is slow. White River tyronia occupy only sand and silt substrates near spring sources in backwaters where current velocity is low.

Observations by La Rivers (1948, 1950) and Usinger (1946) provide the best information describing habitat for the three naucorids in the Warm Springs area. Distributions of *U. moapensis* and *Ambrysus mormon* overlap in upper Muddy River, but the two species occupy different habitats. *Usingerina moapensis*

Table 10. Rare aquatic taxa occupying Warm Springs and the upper Muddy River, Clark County, Nevada. [1]denotes species endemic to the Muddy River, [2]denotes species listed as threatened or endangered by the U.S. Fish and Wildlife Service, and [3]denotes taxa in the Muddy River springs that additional taxonomic analysis may determine to be distinctive.

Common Name	Scientific Name
Moapa dace[1]	_Moapa coriacea_
Virgin roundtail chub	_Gila robusta seminuda_
Moapa White River springfish[1]	_Crenichthys baileyi moapa_
Moapa speckled dace[1]	_Rhinichthys osculus moapae_
White River tryonia	_Tryonia clathrata_
Moapa turban snail[1]	_Pyrgulopsis merriami_
Moapa pebble snail[1]	_Pyrgulopsis carinifera_
Moapa Warm Spring riffle beetle[1]	_Stenelmis moapa_
Moapa naucorid[1]	_Usingerina moapensis_
Moapa skater[3]	_Rhagovelia becki_
Moapa riffle beetle[1]	_Microcylloepus moapus moapus_
Moapa pelocoris[3]	_Pelocoris shoshone shoshone_

inhabits gravel substrate in swiftly flowing water and _A. mormon_ occupies vegetation along stream banks. La Rivers (1950) found _Pelocoris shoshone_ occupied only calm waters of a vegetated marsh that were not inhabited by either of the other naucorids (La Rivers 1950).

Riffle beetles occupy a wide variety of habitats at Warm Springs. La Rivers (1949a) reported _S. calida_ as common on gravel substrate and aquatic vegetation in both swift and ponded thermal waters. Habitat use by _Microcylloepus moapus_ is unknown, but it appears to be similar to that of _S. calida_ (La Rivers 1949b). Both riffle beetles occupy marsh and swiftly flowing habitats in association with all of the naucorid species (La Rivers 1950).

The Muddy River fish assemblage depends upon an integrated, free-flowing complex of springs, spring brooks, and the Muddy River. Native fish diversity increases with habitat size; fewer species occupy spring areas than the river. Distributions of

Moapa dace and Moapa White River springfish overlap in springs and in upstream portions of the Muddy River, and roundtail chub and speckled dace mostly occupy large riverine habitats (Deacon and Bradley 1972).

Juvenile Moapa dace occupy spring habitats where they are near the water surface in slow current. The first several months of life are spent near springs before they migrate to the river and grow to adulthood. Moapa dace spend most of their adult life in the river, where Scoppettone et al. (1992) found the distribution of large fish correlated with habitat volume. Moapa dace livelihood depends upon successful migration from the river onto spawning habitats found only near springs. Spawning occurs throughout the year, but reproductive activity appears to be greatest in late winter and early spring. When in the river and large spring brooks, adults are close to the substrate where the current is swift and drifting insects can be efficiently taken. Moapa dace are insectivorous, feeding on aquatic and terrestrial insects taken from drift (Scoppettone et al. 1992).

Springfish occupy most of the water column in slow, thermal water where there is dense instream cover (Cross 1976). Deacon and Bradley (1972) found them most abundant near springs. Springfish are opportunistic omnivores that feed on a variety of foods (Deacon et al. 1980). They spawn mostly during spring and summer and probably live less than two years.

Distribution of roundtail chubs and speckled dace was studied by Cross (1976) and Deacon and Bradley (1972), but life history information and habitat use is known mostly from other roundtail chub populations. The ecology of _Gila robusta seminuda_ is not believed to differ greatly from the Pahranagat roundtail chub, which is omnivorous, spawns during the spring over gravel substrate, and occupies deep pools. Moapa speckled dace are scarce and found only in the river, downstream from most of the area occupied by Moapa dace. They occupy riffle habitats and areas with high turbidity (Cross 1976, Deacon and Bradley 1972).

Impacts of decreased spring discharge on aquatic animals in the Warm Springs area are similar to those discussed for other aquatic biota in southern Nevada and southeastern California. Lower flows will reduce volume, the aerial extent of aquatic habitats, and habitat heterogeneity. Several invertebrate species are believed to be more susceptible to these impacts than vertebrates because they occupy comparatively small and specific habitats. Reduced spring flow will decrease pool depth and adversely impact roundtail chub habitat, and reduce habitat volume which may adversely affect large Moapa dace. Correlations between Moapa dace size and fecundity indicate this may also reduce Moapa dace reproductive potential (Scoppettone et al. 1992). Lower current velocity would adversely affect Moapa dace and speckled dace habitats by decreasing food abundance in drift.

SUMMARY AND CONCLUSION

Development of ground water resources for agricultural and municipal use throughout the western U.S. has reduced spring discharge in many areas. Extinction of many populations of aquatic species has resulted, and consequences of these activities have frequently justified listing aquatic species as threatened or endangered.

Aquatic biota in springs of southern Nevada and southeastern California includes many endemic vertebrates and invertebrates. Several are listed as threatened or endangered by State and Federal governments. Utilization of ground water resources to the extent proposed by the Las Vegas Valley Water District is likely to reduce spring discharge and adversely affect many populations and species in spring habitats. Although the response of each species to reduced discharge cannot be quantified, information provided by studies in other aquatic ecosystems demonstrates that reduced spring flow will cause the extinction of some populations by eliminating and modifying habitats, and by creating new habitat that is more conducive to non-native than native species. Incremental reductions in spring discharge are likely to modify aquatic habitats and reduce population sizes of most rare species. Species occupying the most limited types of habitat are most vulnerable to extirpation by changes in habitat. More definitive estimates of probable impacts of ground water depletion on the aquatic biota of southern Nevada and southeastern California can be made as the magnitude of effects on the habitat become more precisely defined, and studies are conducted to quantify the response of most spring dwelling animals to habitat modifications caused by reduced spring discharge.

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