

**DRAFT**

Macroinvertebrates and Environmental Characteristics of  
Owens Valley Springs, Inyo County, California

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## I. Introduction

The Great Basin landscape is characterized by a series of north-south oriented mountain ranges separated by valleys vegetated by zeric plant communities (Fierro 1986). It is the most arid region in North America, and its wetlands are relatively small and isolated (Houghton 1986). Streams and rivers originate in the mountains and flow onto valley floors where they end in terminal lakes or by percolating into alluvium. Unique biological characteristics of these wetlands was first appreciated when early surveyors identified a wide diversity of regionally endemic fishes and invertebrates (e.g., Brues 1928, 1932; Gilbert 1893, Snyder 1917, Call and Pilsbury 1886). Until recently, taxonomic, biogeographic, and ecological studies focused on streams, rivers, lakes, and large springs. Small springs were largely ignored until Hershler and Sada (1987) described a surprisingly diverse molluscan fauna from springs in southern Nevada. Subsequent surveys discovered many more new taxa, which has lead to knowledge that small springs are important habitats for a wide diversity of animals with limited distributions (e.g., Sada *et al.* 1995, Shepard 1993; Erman 1997, Hershler 1998, Baldinger *et al.* 2000). The large number of newly described taxa and the large number of unsurveyed habitats indicates that additional new species will be found in the region.

Some springs are also important resources for rare riparian and wetland plants (Skinner and Pavlik 1994, Sada *et al.* 1995), in addition to a wide diversity of terrestrial species (Thomas *et al.* 1979), and spring macroinvertebrates are believed be significant components of the aquatic biodiversity in semi-arid regions (Anderson and Anderson 1995).

Several studies have examined Owens Valley springs. Kratz *et al.* (1991) surveyed Fish Slough, and DeDecker (1992) documented impacts of ground water removal on spring discharge. Hershler (1989) and Hershler and Pratt (1990) described springsnails from Owens Basin springs. This report summarizes the first study examining macroinvertebrate communities in springs of the Eastern Sierra region. This study was designed to: 1— provide a list of macroinvertebrates occurring in Owens Valley seeps, springs, and springbrooks; 2—document the

location of rare species associated with springs and seeps; and 3—identify sites where monitoring programs can be implemented to determine impacts of future ground water and resource use on spring habitats.

## **II. Methods**

Aquatic macroinvertebrates were sampled from springs and seeps on City of Los Angeles, Department of Water and Power lands in the Owens Valley, Inyo County, California during the summers of 1999 and 2000. Springs were selected during interagency negotiations between the City of Los Angeles and Inyo County Water Department, and from recommendations made by Owens Valley citizens. Ecosystem Sciences, Inc., compiled a list of 101 springs to be surveyed, and they prepared aerial photographs and vegetation maps that we used to locate sample localities. Macroinvertebrate samples were collected at spring sources and springbrooks within areas delineated by vegetation surveys conducted during 1999 and 2000 by the Sweeney Granite Mountain Desert Research Center. The occurrence of mudflat or playa habitats, the absence of any discernable springs, and the presence of artesian wells and dredged ditches made it difficult to identify individual springs in a congregation of sites along the east side of Owens Dry Lake that were named U35 through U40. The homogeneity of aquatic habitat in this area indicates that macroinvertebrate communities are accurately described by two samples (99-72 & 99-73) consisting of an area near the water source and an area downstream.

A number of 'springs' identified on the Ecosystem Sciences list were spring provinces that included several to many springs. A minimum of two springs were sampled in each province, and several springs were sampled in larger provinces. In these areas, sample sites were selected to include the diversity of habitat types in a province.

### **Habitat Characteristics**

Abiotic characteristics of each macroinvertebrate collection site were recorded by measuring water temperature, pH, and conductivity. Habitat characteristics at larger springs were documented by measuring channel and instream features along five transects spaced every 50 cm; instream habitat features at three evenly spaced points along each transect (Table 1). All variables shown in Table 1 were estimated in small springs where aquatic habitat was too shallow or small for the current velocity meter to operate. Mean depth, water width, and substrate composition were estimated at these sites. Habitat condition was qualitatively assessed at each site by determining if the site was naturalized from past disturbance, undisturbed, slightly disturbed, moderately disturbed, or highly disturbed. Methods for this

Table 1. Habitat parameters measured or estimated at each site where macroinvertebrates were collected during the summers of 1999 and 2000 in the Owens Valley: a—at evenly spaced transects at each reach and b—at five evenly spaced points along each transect. Variables measured only at large springs, variables estimated at smaller springs.

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<p><b>a. Channel Morphology</b></p> <p>-----</p> <p>Wetted Perimeter Width</p> <p>Riparian Cover (Percent)</p> <p>Incised Banks (Presence)</p> <p>Banks Covered by Vegetation (Percent)</p>	<p><b>b. Parameters Measured Along Transects</b></p> <p>-----</p> <p>Water Depth</p> <p>Mean Water Column Velocity</p> <p>Substrate Composition</p> <p>Cover by Emergent Vegetation (Percent)</p> <p>Presence of Algae and CPOM</p>
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assessment are described in Appendix I. These methods have been used during surveys of approximately 2000 Great Basin springs (Sada field notes). Causes of disturbance were also recorded when possible. Many sites had recovered from past disturbance and were comparatively ‘undisturbed’. These sites were classified as naturalized, which indicates they have recovered from past disturbance. The ubiquity of historical livestock grazing in the Owens basin and the presence of old

pipe and diversion structures at many springs suggest that all sites have been historically impacted by some human activity. Therefore, it is doubtful that any Owens Valley spring can be considered pristine.

Conductivity and pH were measured using a YSI Model 33 meter and an Oakton pH Testr 2 handheld meter, respectively. Current velocity was measured with a Marsh-McBirney Model 2000 current meter that is calibrated annually. The location of most sites visited during 2000 were recorded using a Trimble GeoExplorer II GPS unit. Sites visited during 1999 were also mapped using GPS, but all files collected for this year were corrupted by complications encountered while compensating for Y2K upgrades. All 2000 data were differentially corrected. Poor GPS reception prevented mapping of some sites.

## **Spring Biota**

All springs identified by Ecosystem Sciences were visited, and macroinvertebrates were sampled from all sites with aquatic habitat. Springs longer than 50 m were sampled at the source and in the channel at 50 m downstream; smaller springs were sampled only at the source. In small springs with diverse aquatic habitat, composite macroinvertebrate samples were taken in source and channel habitats. Samples were collected using a 250 micron-mesh aquatic dip net, D-frame net, and an aerial sweep net. Dip and D-frame nets were used by roiling and rubbing substratum surfaces, and by sweeping through sediments, and submerged and emergent vegetation. Adults were collected by sweeping an aerial net through riparian vegetation. Samples were preserved in 90 percent ethyl alcohol and returned to the laboratory for processing, identification, and enumeration. Mollusks, aquatic insects, and mites were identified to genus or species when possible (identification of aquatic insects to the species level is usually limited to adults because aquatic habitats are typically occupied by larval and pupal stages that cannot be identified beyond genus). Ostracods, copepods, and oligochaetes were not identified any further.

Sampling did not include attempts to capture aquatic vertebrates. However, vertebrates were recorded when they were seen.

### **III. Results**

A total of 147 sites (including 105 springs) were surveyed during the summers of 1999 and 2000. This included nineteen dry sites, four wells, four stream sites, 64 spring sources, 12 composite source/channel sites, and 52 channels. A summary of habitat characteristics and macroinvertebrate communities is presented below, and habitat characteristics and macroinvertebrates of each site are shown in Appendices II and III, respectively.

#### **Habitat Characteristics**

A wide diversity of aquatic habitats was sampled. Water depth ranged from 0.5 cm to 150 cm, wetted perimeter width ranged from 10 cm to 70 m, mean water column velocity ranged from 0 cm/sec to 156.1 cm/sec, water temperature ranged from 8.5° C to 45° C, and conductivity ranged from 10 mhos to 28,000 mhos. Substrate composition of most springs was dominated by muck, but many springs also had gravel and cobble. Boulders were rare. The banks of most springbrooks were in good condition and well covered by riparian grasses and/or woody vegetation. Emergent vegetation occurred at most sites, and algae and CPOM were in many aquatic habitats.

Approximately 60 percent of the springs were rheocrenes and the remainder helocrenes. No limnocrenes are known from the Owens Valley. Spring type could not be determined at five sites because dredging or impoundment had substantially modified their natural character. Approximately 17 percent of sites were highly disturbed, 13 percent were moderately disturbed, and approximately 70 percent were either undisturbed (28 percent), slightly disturbed (25 percent), or naturalized from past disturbances (9 percent). These conditions are superior to observations by Sada *et al.* (1992) who found that approximately 75 percent of 505 springs surveyed in northern Nevada were either highly or moderately disturbed. Similar to observations by Sada *et al.* (1992), diversion and livestock grazing were the most common activities affecting spring condition in the Owens Valley.

Although there are many exceptions, a number of springs may be categorized by their location and similarities in their macroinvertebrate communities and habitats. Fault springs on the valley floor are generally small, and most of them appear to dry during periodic droughts. Their macroinvertebrate communities are generally depauperate and dominated by Chironomid larvae. High conductivity and community dominance by Dipteran larvae characterizes many of the springs along the south and east sides of Owens Dry Lake, and low conductivity, and diverse communities (that include many caddisfly and mayfly larvae) characterize many higher elevation springs along the Sierra Nevada foothills.

## **Spring Biota**

A total of 331 taxonomic groups of macroinvertebrates (including 58,648 individuals) were tallied from 92 sites that have been processed. Taxonomic groups and their abundance at each collection site are shown in Appendix III. All groups listed in Appendix III are not distinct because larval forms can often be identified only to genus, and adult and larval forms were frequently collected in a spring. In these instances, larvae and adults were individually counted but adults were identified to species and larvae to genus. Macroinvertebrate grab sample sizes ranged from 0 to 2654 animals at all sites, and richness at the sites ranged from 0 to 46 taxonomic groups (Appendix III). The only site without macroinvertebrates was Keough Hot Springs, which was probably too hot (45°C) to support macroinvertebrates. *Pyrgulopsis wongi* (a springsnail) was the most abundant species collected (17,899 individuals), followed by *Hyallela azteca* (an amphipod, 5,556 individuals), ostracods (5,528 individuals), *Pisidium* sp. (a bivalve mollusk, 2,687 individuals), *Paratendipes* sp. (a chironomid dipteran, 1,644 individuals), *Lepidostoma* sp. (a caddisfly, 1,644), then *Culicoides* sp. (a ceratopogonid dipteran, 1,040).

No Federal or State of California listed macroinvertebrate species were found. Several regionally rare species, and two State of California Species of Special Concern and Federal candidate species were found in a number of sites,

however (Table 2). Rare species included an undescribed species of cave amphipod (genus *Stagobromus*) that may be endemic to the Owens Basin. This collection was

Table 2. Sites where rare species and species known to occupy geologically persistent spring habitats were collected from Owens basin springs during surveys in 1999 and 2000. Future taxonomic studies may determine that some populations of these taxa are undescribed species. \*denotes Federal candidate species and State of California Species of Special Concern.

<b>Taxa</b>	<b>Site Names and Collection Nos.</b>
<i>Pyrgulopsis owensensis</i>	DWP28, 99-1—99-5 <sup>4</sup>
<i>Pyrgulopsis wongi</i>	DG82, 99-15; DG31 <sup>1</sup> , 99-20 & 21; U60 <sup>6</sup> , 99-74; DWP35, 00-5 & 6; DWP13 <sup>1</sup> , 00-7; U1, 00-19; DWP4 <sup>1</sup> , 00-25 & 26; DWP30 <sup>1</sup> , 00-30; LPT11 <sup>5</sup> , 00-36; DG176 <sup>1</sup> , 00-39; U10, 00-42; DWP8 <sup>1</sup> , 00-43; DWP5 <sup>3</sup> , 00-46; DWP12 <sup>1</sup> , 00-48—53; DWP6, 00-55; DWP7, 00-56 & 57; DG185 <sup>1</sup> , 00-61; DG72 <sup>1</sup> , 00-63—65; DWP32 <sup>1</sup> , 00-71 & 72
<i>Lepidostoma</i> sp.	DG76, 99-7—10; DG83 <sup>2</sup> , 99-14; DG81, 99-17; DWP27, 99-19; DG31 <sup>1</sup> , 99-21; DWP26, 99-23 & 24; U60 <sup>1</sup> , 99-74 & 75; DWP36, 00-3 & 4; DWP13 <sup>1</sup> , 00-7; DWP4 <sup>1</sup> , 00-26 & 27; DWP30 <sup>1</sup> , 00-29 & 30, DWP31, 00-33; DG176 <sup>1</sup> , 00-39; DWP8 <sup>1</sup> , 00-43; DWP12 <sup>1</sup> , 00-48 & 49; DG185 <sup>1</sup> , 00-60 & 61; DG72 <sup>1</sup> , 00-64 & 65; DWP32 <sup>1</sup> , 00-72
<i>Ambrysus</i> nr. <i>funnebris</i>	DWP5, 00-46 <sup>3</sup>
<i>Microcylloepus similis</i>	DWP28, 99-1—99-5 <sup>4</sup>
<i>Stictotarsus coelamboides</i>	U44, 00-67

<sup>1</sup>Sites occupied by *P. wongi* and *Lepidostoma* sp.

<sup>2</sup>Sites occupied by *Lepidostoma* sp. and *Stygobromus* sp.

<sup>3</sup>Sites occupied by *P. wongi* and *Ambrysus* nr. *funnebris*

<sup>4</sup>Sites occupied by *P. owensensis* and *Microcylloepus similis*

<sup>5</sup>Sites occupied by *P. wongi* and *Stictotarsus coelamboides*

<sup>6</sup>Sites occupied by *P. wongi* and *Dicosmoecus pallicorinis*

provided to Dr. J.R. Holsinger, Old Dominion University, for verification.

Several new populations of *P. wongi* were found, but no new populations of *P.*

*owensensis*. Several other rare species were found. *Stictotarsus coelamboides* had not been previously collected in the eastern Sierra and *Dicosmoecus pallicornis* is a regional endemic.

Collections from previously undiscovered springsnail populations were relaxed in menthol, preserved in 4 % formalin, and sent to Dr. Robert Hershler for verification. These collections will be deposited in the U.S. Museum of Natural History, Smithsonian Institution.

Vertebrates were scarce, and very few springs are known to be historical habitat. Absence of historical information precludes comparison of contemporary and historical occurrence of vertebrates in springs. Vertebrates observed during our surveys, and historical occurrence of native fishes in Fish Slough and springs at Cabin Bar Ranch, indicate, however, that vertebrates may have occupied a number of springs. Although native fish continue to occupy Fish Slough and Cabin Bar Ranch, fish assemblages in both of these areas are now dominated by introduced species. Warm Springs (DWP28) supports an introduced population of Owens pupfish (*Cyprinodon radiosus*), which is listed as endangered by State and Federal statute. We observed amphibians in smaller springs, which suggests that amphibians historically occupied more habitats than the fishes that require deeper, larger habitats. Table 3 lists springs where vertebrates were observed. This is believed to be an incomplete list of occupied habitats because we did not use effective capture techniques that are necessary to determine vertebrate presence and absence.

## **V. Discussion**

Each spring is a unique assemblage of interacting biotic and abiotic factors. Plant and animal communities associated with spring-fed wetlands are a function of physical and chemical characteristics of water and soils, proximity to other aquatic habitats, and prehistorical connections with regional drainage systems (Hubbs and

Table 3. Owens Valley springs and sample sites occupied by aquatic vertebrates during the summers of 1999 and 2000.

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<b>Taxa</b>	<b>Site Names and Collection Nos.</b>
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<i>Cyprinodon radiosus</i>	DWP28, 99-1—99-5, DG123, 99-49
<i>Pseudacris regilla</i>	DWP8, 00-43; DWP7, 00-56
<i>Bufo americanus</i>	DWP21, 99-52; U31, 00-12; U33, 00-11;
<i>Gambusia affinis</i>	DWP1, 99-34; DWP2, 00-21 & 23;
<i>Rana caetsebiana</i>	DWP2, 00-21
Unknown tadpoles	DWP12, 00-50

Miller, 1948, van der Kamp 1995, McCabe 1998). Primary abiotic factors that influence biotic characteristics of unmodified springs include habitat persistence, geographical and geological settings, and aquifer dynamics (Ferrington 1995, van der Kamp 1995).

Springs are distinctive aquatic habitats; when compared to streams their flow and temperature are more constant over an annual cycle and they have a more integral connection with groundwater. Though their biotic communities are usually less diverse than stream ecosystems, springs are often habitat for endemic species because they are predictable, benign habitats that have served as refugia during periods of climatic aridity. Geological and hydrogeological settings are also important factors that regulate the structure of aquatic communities in springs. Springs that flow over long time periods support different fauna than springs that periodically dry (Erman and Erman 1995, Sada and Nachlinger 1996) and cavern-forming karst and limestone formations may be particularly distinctive in providing subterranean habitat for the development of troglobitic life forms such as blind amphipods (Holsinger 1974).

Even though springs are comparatively small habitats in the Owens Valley, we found that they support a surprisingly high macroinvertebrate diversity. This diversity is similar to studies in other Great Basin springs. Herbst (1996) recorded

more than 200 macroinvertebrate taxa from Sheldon NWR springs, and Sada *et al.* (2000) identified 197 macroinvertebrate taxa and 155 plant species from Ruby Lake NWR springs.

Several recent studies have examined relationships between biotic and abiotic characteristics of Great Basin springs. Sada *et al.* (2000) found that substrate composition, water depth, springbrook width, current velocity, conductivity, and vegetation were the most influential environmental factors affecting macroinvertebrate communities in Ruby Lake NWR springs. Sada and Herbst (1999) found water temperature, current velocity, bank morphology, and the presence of gravel substrate and coarse particulate organic matter (CPOM) were most influential to structuring macroinvertebrate communities in thermal springs of southern Nevada. Sada and Herbst (2001) found that distance from the source, current velocity, substrate composition, CPOM, and cover were significant factors affecting macroinvertebrate communities in thermal springs of Death Valley.

Biological effects of comparatively subtle environmental changes have been examined by few studies. Sada and Nachlinger (1996, 1998) recognized this deficiency and assessed riparian and aquatic macroinvertebrate communities and abiotic characteristics of 65 springs in southern Nevada. They concluded that habitat condition (as impacted by livestock use, diversion, impoundment, and non-native species) strongly influenced biotic characteristics. Highly disturbed habitats had lower biodiversity and more upland and non-native plants in their riparian communities than springs in better condition. While biodiversity of larger springs also exceeded that of smaller springs, and biological characteristics of aquatic communities were influenced by pH and elevation, they concluded that the degraded condition of most springs often masked the influences of natural events and chemical characteristics of water on riparian and aquatic macroinvertebrate community structure.

A number of authors have summarized the influence of cultural uses (e.g., diversion, livestock grazing, impoundment, etc.) on individual taxa in springs. For species with available information (a total of 135 animals) Sada and Vinyard (in press), found that 54 percent of aquatic species endemic to Great Basin springs have suffered population losses and 62 percent have suffered major decreases in

historical distribution because of cultural uses. They also found that habitat alteration for diversion (ergo channelization, impoundment, removing water through pipes, etc.) and the introduction of non-native species were the most significant factors causing these changes. Diversion has also been identified as a detrimental factor influencing other wetlands in the southwestern U.S. (Minckley and Deacon 1968, Hendrickson and Minckley 1984, Williams *et al.* 1985, Rinne and Minckley 1991). Removing water through diversion reduces habitat for vegetation and aquatic biota by decreasing springbrook length, water width and depth, and the quantity of water available for riparian vegetation (Smith *et al.* 1991, Stromberg and Patten 1990, 1992). Decreased discharge may also affect aquatic communities by altering thermal characteristics of aquatic habitats and decreasing habitat heterogeneity. Ground water pumping and surface diversion have decreased and dried many springs and springbrooks in the western U.S., causing loss of many populations and several extinctions (e.g., Brune 1975, Dudley and Larson 1976, Johnson and Hubbs 1989, Miller *et al.* 1989). Habitat manipulation caused by impoundment or dredging may also influence functional characteristics of macroinvertebrate communities. Sada *et al.* (2000) observed that macroinvertebrate communities in dredged springs on Ruby Lakes NWR included more lotic species than communities in undredged rheocrenes.

The absence of historical surveys documenting characteristics of Owens basin springs prevents comparisons of current and past conditions. The presence of pipes, old diversion structures, and comparatively intense livestock grazing at many sites indicates, however, that all springs have been disturbed. The occurrence of rare taxa and taxa that occupy high quality habitats suggests that disturbance may not have caused large-scale functional changes of many spring habitats. The large number of naturalized habitats also suggests that current uses impact many springs less than those that occurred during historical use.

## **V. Monitoring Recommendations**

The response of springs to different levels and types of resource use may be assessed during long-term monitoring of riparian and aquatic macroinvertebrate communities. Monitoring programs should be designed to quantitatively describe

biotic communities and aquatic and riparian habitats. They should be initiated by first determining baseline conditions that identify spatial and temporal variability in biotic and abiotic features of target habitats. After this information is accumulated, future changes in biotic and abiotic characteristics of a spring can be assessed as being either within or outside the range of natural variation. Changes outside natural ranges can be determined as excessive, while those within the natural range are likely to be acceptable.

There are four basic phases to conducting meaningful long term monitoring programs. Selecting sites for monitoring is the first challenge. Suitable springs should have persistent aquatic habitat, be in good condition, and be minimally affected by short-term changes in climate. In the Owens Valley, many springs have naturalized from past disturbance and a number of sites contain taxa that indicate the persistent aquatic habitat. Habitats in the Owens Valley that are in comparatively good condition and occupied by these species are listed in Table 2. These habitats would be good candidates for long term monitoring.

The second phase of a monitoring program should quantify baseline conditions by describing long-term changes in vegetation and macroinvertebrate demography and assemblage structure, and characteristics of riparian and aquatic habitats. These factors can be determined by sampling for sufficient time to encounter a broad range of environmental conditions and fluctuations in demography and assemblage structure. The length of time necessary to determine characteristics of these parameters varies. For long-lived species (e.g., longevity of 30 years), protracted, comparatively infrequent sampling may be sufficient. For species with shorter life spans, adequate information may be accumulated more quickly, but duration of baseline sampling should also extend for sufficient time to encounter environmental variability. For these species, baseline conditions may be determined over several years of seasonal sampling.

The third phase of monitoring should verify baseline information by continuing to sample at a reduced level. During this phase, sampling may be reduced to seasons where maximum and minimum abundance is believed to occur (as indicated by information provided by baseline sampling) or to periods when environmental harshness is greatest and most benign. The third phase should also

be continued for several years, or until observations made during baseline studies can be validated.

The fourth phase of monitoring should determine if the range of future habitat and demography variability are within boundaries established by baseline and phase two monitoring. Sampling during this phase may be greatly reduced from phase three, and may consist of yearly, or even less frequent sampling. Sampling may become more frequent in the event of anticipated disturbance or when riparian vegetation or macroinvertebrate assemblage structure differs from predictions compiled during baseline monitoring.

## **VI. General Management Recommendations**

Ecosystem Sciences has prioritized wetland habitats in their land management planning efforts. Specific grazing prescriptions have been developed to maintain wetland habitats in good condition on a site-specific basis. The following is a series of general management recommendations for springs, which will be complimented by information that will be available later this year in a U.S. Bureau of Land Management technical reference (Sada et al. 2001).

No two springs are alike because each one has a unique suite of biotic, chemical, and physical characteristics. Biological functions of springs are also vulnerable to physical and biological changes that may accompany human use. Therefore, each spring may require individual management to maintain biological integrity and maximize potential biodiversity. There are several general management actions that can be implemented to protect spring ecosystems.

- ◆ Springs and their riparian vegetation should be managed as wetlands, and they can generally be protected by guidelines to manage similar wetland systems, such as riparian zones. Good standards and guidelines for use of these biological systems in the northern Great Basin are provided in documents such as the Toiyabe National Forest Land and Resource Management Plan (USDA 1986).

- ◆ Macroinvertebrate and vegetation surveys should be conducted prior to implementing management actions that may adversely affect spring biota. These studies will also provide an environmental baseline that can be used to judge the impacts of management changes.
- ◆ Springs and a portion of their spring brooks should always be protected from activities that either decrease biodiversity or cause functional changes in aquatic and vegetation communities. Modifications (ergo diversion, recreation, and ungulate use) should not impact the natural character of spring sources and at least 50 m of their uppermost springbrook. Greater lengths of large spring brooks should be protected, possibly extending downstream for several hundred meters. For these springs, the length of springbrook needing protection should be determined by surveys that identify areas with highest biodiversity and determine the area necessary to protect highest quality communities along the continuum from spring to spring brook terminus.

If diversion is necessary, all structures should be placed at least 50 m downstream from the spring. Environmental damage by springbox construction and operation can be minimized by collecting water from a dry well placed in the springbrook bed (at least 50 m downstream from the source). Diversions should also be limited to only the amount of water needed for the intended use. Unnecessary diversion should not occur, for instance, diversions should be limited to periods only when water is needed at a specified destination. They should not continue throughout the year when diversion is unnecessary. All water should remain in a springbrook when not being used for other purposes.

Spring sources should not be dredged or impounded. These alterations functionally change biological processes and they are not compatible with goals to utilize springs while maintaining their integrity. Downstream reaches of springbrook may be dredged or impounded with comparatively little effect on biotic communities, however.

- ◆ Management of ungulates and recreation within spring fed riparian zones should follow standards and guidelines for these uses that have been developed

by several land management agencies (e.g., Toiyabe National Forest Land and Resource Management Plan USDA 1986, USDI 1995). If disturbance cannot be managed without excluding use, exclosures should then be constructed and maintained to protect the spring, at least 50 m of springbrook, and an area extending at least 20 m beyond the outermost limits of all riparian vegetation.

- ◆ Vegetation and aquatic macroinvertebrate communities should be monitored to determine if existing uses are excessive and adversely impacting springs. This monitoring should follow USFWS, USFS, and BLM guidelines developed to determine livestock and recreation utilization that is compatible with maintaining healthy aquatic habitats and riparian zones.

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## Appendix I.

### Definition of Terms

Current Velocity--The average velocity of water measured on an imaginary vertical line at any point in a stream. A measurement of 60% of depth, measured from the surface, closely approximates the average for the water column.

Disturbance—Undisturbed sites were unimpacted by recent disturbances, or past disturbances had ceased and sites had regained much of their historical condition. Slightly disturbed sites were affected by activities causing minor changes from natural conditions. Moderately disturbed sites had minor diversions (or none) and riparian vegetation covered more than 50 percent of springbrook banks. Highly disturbed sites held little resemblance to natural springs and springbrooks. Either more than 50 percent of their discharge had been diverted and/or their riparian vegetation was sparse or absent. Naturalized sites had recovered from past disturbance and were in comparatively good condition.

Helocrene—A type of limnocrene that is shallow with extensive emergent marsh vegetation within and surrounding the source (Hynes 1970).

Limnocrene—A spring that discharges into a pond or basin which then overflows into a channel (Hynes 1970).

Rheocrene—A spring whose sources discharges directly into a flowing channel (Hynes 1970).

Substrate Composition--A particle-size analysis which describes the substrate by the proportional composition of materials. Distribution is described using a Wentworth particle scale, where materials are classified as: Fines (<1 mm), Sand (1 mm - 5 mm), Gravel (>5 mm - 80 mm), or Cobble (>80 mm - 300 mm). Size is defined as the minimum particle size of substrate as measured on a two-dimensional axis, as would pass through a substrate sieve.

Water Depth--The vertical distance from substrate to water surface.

Water Width--The length of wetted contact between a stream of flowing water and the stream bottom in a vertical plane at right angles to the direction of flow.

## **Appendix II.**

Characteristics of Owens Valley spring habitats where macroinvertebrates were sampled during 1999 and 2000. Habitat parameters are described in Appendix I. Source samples collected in spring sources, channel samples collected approximately 50 m downstream. \*denotes samples where spring morphology was measured along transects spanning the wetted perimeter. Characteristics of morphology were estimated at all other habitats. Characteristics of dry sites were not evaluated. Sites that were sampled within a spring province are identified with a capital A, B, or C following the site name provided by the Ecosystem Sciences list.

### **Appendix III.**

Aquatic macroinvertebrates and their abundance in samples collected by grab samples from Owens Valley springs during 1999 and 2000. Each site is identified by its name as was provided by Ecosystem Sciences, the collection number, and names shown on USGS topographic maps. Collection Type refers to source (S) and downstream (C, for channel) collections. A number was given to each taxon (Spp ID) to allow easy taxonomic reference on each page. This spreadsheet is large and can be most easily read down, then across. S = samples from a spring source, C = downstream samples from a channel or springbrook, COMP = source and channel composite samples, Playa = mudflat habitats (all of these are at Owens Dry Lake), Splits = number of times a macroinvertebrate sample was split. Sites that were sampled within a spring province are identified with a capital A, B, or C following the site name provided by the Ecosystem Sciences list. Blank cells represent that a taxon was not captured at a site.