Assessment of biological and physical relationships of spring and seep ecosystems across a gradient of human impacts

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Northern Colorado Plateau Network Inventory and Monitoring Program

May 2010

Old Bates Wilson Camp Spring, Canyonlands National Park

Final Report

Funded by: Canyonlands Natural History Association and Rocky Mountain Cooperative Ecosystem Study Unit

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Abstract

The Northern Colorado Plateau Network (NCPN) has selected springs as a Vital Sign for monitoring and is currently investigating the use of aquatic macroinvertebrate species assemblages as an indicator of ecosystem health. The relationship between anthropogenic disturbance and aquatic macroinvertebrate community species composition at springs on the Colorado Plateau is unclear. NCPN staff and cooperators visited 45 springs and hanging gardens in six national park units and on surrounding public lands. Forty springs were divided into impact categories based on visible disturbances at the site and measures of soil and riparian area integrity. We were able to detect differences in vegetation, water temperature, turbidity, and E. coli presence at high impact sites versus low and moderate impact sites. Despite these differences, overall patterns indicate that aquatic macroinvertebrate assemblages and metrics do not differ between springs with different levels and types of anthropogenic impacts. Amphipod and non-insect richness were the only invertebrates that showed any differences, peaking at moderately disturbed sites and with lowest richness at highly disturbed sites, Based on our dataset, we recommend that aquatic macroinvertebrate sampling not be included in long-term monitoring as a surrogate method for determining anthropogenic impacts at springs and seeps on the Northern Colorado Plateau.

Background

In 2008, the Northern Colorado Plateau Network (NCPN) requested $14,178 from the Canyonlands Natural History Association (CNHA) to conduct a project entitled, "Assessment of biological and physical relationships of spring, seep and hanging garden ecosystems across a gradient of human impacts" at Arches National Park (ARCH), Canyonlands National Park (CANY), Hovenweep National Monument (HOVE), and Natural Bridges National Monument (NABR). NCPN received a partial award for $10,000 from CNHA. NCPN received an additional $5,000 from the Rocky Mountain Cooperative Ecosystems Studies Unit to expand the project to two parks in Colorado, Black Canyon of the Gunnison NP (BLCA) and Curecanti National Recreation Area (CURE). This is the final report of that project.

Introduction

In arid and semi-arid regions, springs and seeps occupy a small fraction of the total area, yet they support disproportionately high levels of productivity, endemism and biodiversity (Erman 2002; Hershler and Sada 2002; Sada et al. 2005). High numbers of endemic and obligate taxa are attributed to annual water availability, physical isolation and stable environmental conditions (Erman and Erman 1995; Hershler and Sada 2002). At broader spatial scales, springs and seeps play key roles in arid ecosystems by providing refugia for migratory birds, reptiles and amphibians, supporting high rates of primary and secondary production and providing the primary source of water for downstream streams.

As one of the primary sources of water in arid and semi-arid regions, human activities are often concentrated around springs and seeps, making them highly susceptible to human impacts. Specifically, surface and groundwater diversions, livestock grazing and recreation are disproportionately high in these areas and represent primary threats to spring and seep ecosystems. A study in northern Arizona classified more than 93% of springs on non-National Park Service (NPS) federal lands as ecologically impaired or functioning at risk (Grand Canyon Wildlands Council 2002). Overall the condition of springs and seeps on federal land is poorly known. Federal agencies such as the National Park Service and US Forest Service are currently developing protocols to monitor the status and trends of these ecosystems.

Aquatic macroinvertebrate assemblages and metrics have been widely used as indicators of water quality in wadeable stream and riverine ecosystems (Lenat and Barbour 1994). Aquatic macroinvertebrates occupy a critical position in the food web and are relatively easy to sample and identify. Their susceptibility to pollution retains a biological memory of events that other water quality sampling methods may not detect. However, current metrics have had limited testing in arid and semi-arid springs, especially in small systems that are naturally subject to high levels of disturbance such as fluctuations in temperature and water availability.

To effectively monitor, manage and protect spring and seep ecosystems we must first characterize their structure and function, as well as responses to natural and anthropogenic environmental gradients. Such preliminary studies may assist in the identification of key macroinvertebrate species or assemblages capable of discriminating between springs of different condition (i.e., good, fair, poor), as well as the physicochemical determinants of assemblage structure. To accomplish this goal, the NPS and the Bureau of Land Management (BLM)/Utah State University (USU) BugLab entered into a joint agreement in 2007 to conduct integrated assessments of the chemical, physical and biological condition of spring and seeps throughout the Northern Colorado Plateau Network. Specific questions to be addressed included:

1. How do macroinvertebrate communities vary along a gradient of increasing anthropogenic activities?
2. How does water quality vary along the gradient?
3. How do physical habitat characteristics (especially sediment) vary along the gradient?

Study Area

The Colorado Plateau is a semi-arid geographic province bounded by the Uinta and Wasatch Mountains of Utah to the north, the Rocky Mountains of Colorado to the east, the Mogollon Rim of Arizona to the south, and the Great Basin of Nevada to the west (Fig. 1). It is characterized by spectacular canyons that have eroded into primarily sedimentary rock. The region ranges between 1200 and 3350 m (4,000 to 11,000 ft) in elevation and receives 15 to 40 cm (6 to 16 inches) of rain annually.

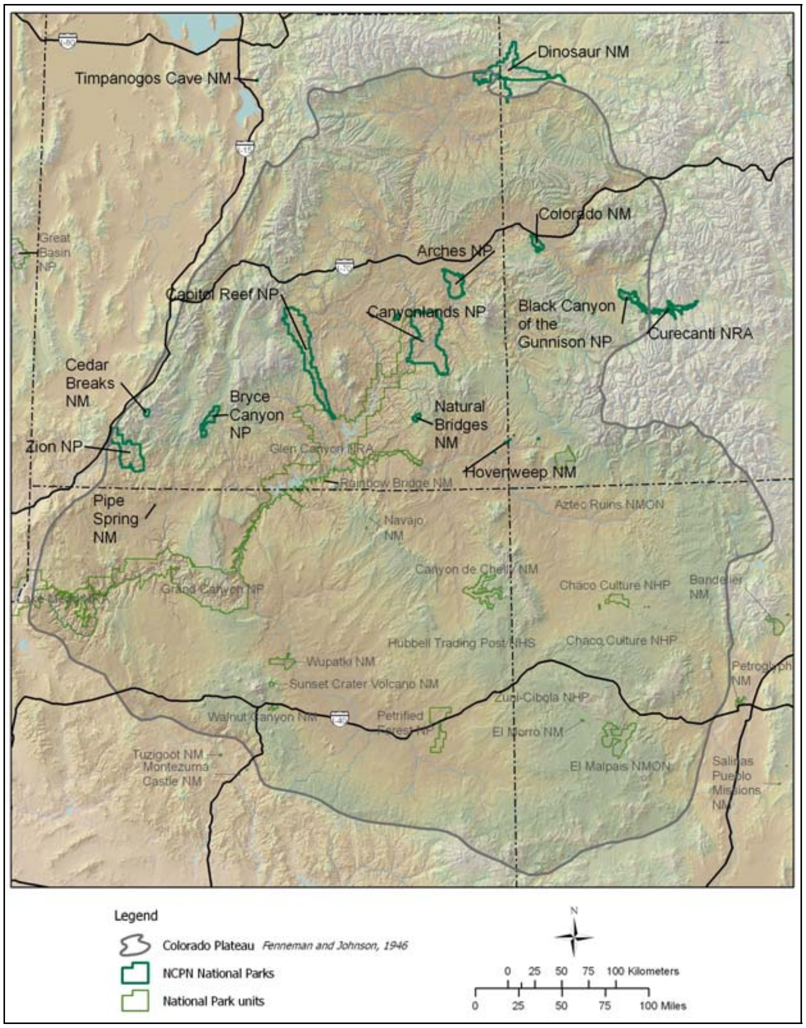

Fig. 1. General boundaries of the Colorado Plateau and NCPN parks.

The Northern Colorado Plateau Network of the National Park Service is comprised of 16 national park units. This study focuses more narrowly on the parks and public lands in Southeastern Utah, including Arches National Park (ARCH), Canyonlands National Park (CANY), Hovenweep National Monument (HOVE), Natural Bridges National Monument (NABR) and surrounding Bureau of Land Management (BLM) land (Fig. 2; Appendix A). Five additional springs were sampled at Black Canyon of the Gunnison National Park (BLCA) and Curecanti National Recreation Area (CURE) in Colorado (Fig. 3). Due to differences in geology and elevation, results for BLCA and CURE springs are summarized in the results section but are not included with the analyses of Southeastern Utah springs.

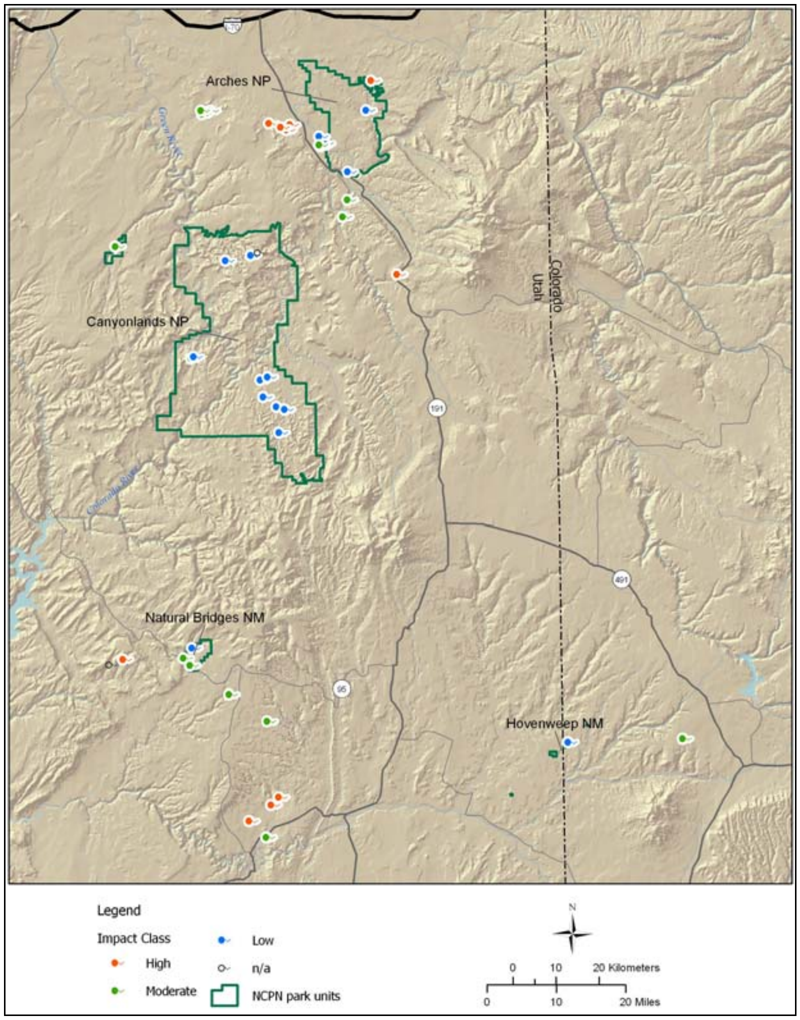

Fig. 2. Locations of Southeastern Utah springs sampled as part of the disturbance gradient project.

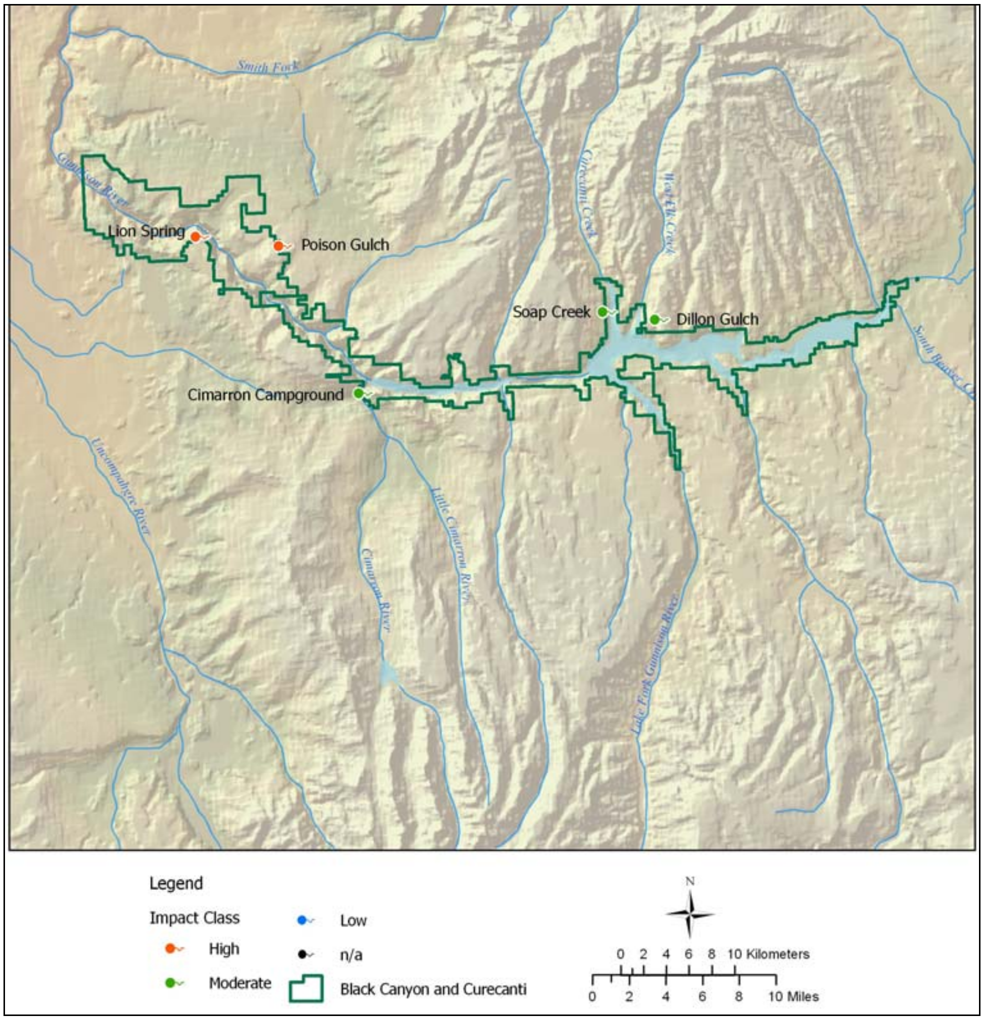

Fig. 3. Locations of Black Canyon of the Gunnison National Park and Curecanti National Recreation Area springs sampled.

Study sites were selected by National Park Service and Bureau of Land Management staff to represent a range of anthropogenic disturbances. For each spring, the land manager made an initial estimate of whether the spring was a reference site, moderately impacted, or heavily impacted. After the initial year of sampling, the population of interest was narrowed to springs emerging from sandstone aquifers between 1200 and 2000 m in elevation. Forty sites were visited between May 9 - September 22, 2008 and May 5 - 23, 2009.

Methods

Hydrology

We estimated discharge by funneling water through piping and collecting the water in a container of known volume for a specified length of time. Six readings were taken and averaged for the final discharge estimate. We collected core water quality measures of dissolved oxygen, pH, specific conductivity and water quality using a calibrated In-Situ TROLL 9500 multiparameter probe. A 500-mL sample bottle was filled using standard methods and tested for nitrates, nitrites and total phosphorous at a state certified water quality laboratory. We processed turbidity samples with a calibrated Hach 2100P turbidimeter. A 100-mL bacterial coliform sample was collected and immediately placed on ice. We processed samples within eight hours of the collection time using the Idexx Colilert system, incubating for 24 hours at 35°C before taking a final reading.

Aquatic Macroinvertebrates
The objective of the aquatic macroinvertebrate sampling was to collect as many different kinds of invertebrates living at a site as possible while minimizing research impacts to the site?. We sampled until 500 individuals were collected, or for 3 hours, or until all habitat had been sampled (for springs of small size), whichever was accomplished first. We collected samples with a rectangular kicknet and handnet with 500-micron mesh and by hand picking invertebrates from vegetation and substrate. All spring-associated habitats were sampled including standing water at the spring site, outflows, and small water pockets surrounding each spring. Samples collected at all microhabitats were composited to form a single sample for each site. Collected invertebrates were stored in 70% ethanol. The National Aquatic Monitoring Center in Logan, UT identified all macroinvertebrate samples. Ambiguous taxa were resolved by removing parents or by merging children with parents based on abundances at different taxonomic levels (Cuffney et al. 2007). Unresolved data are presented in Appendix C. Macroinvertebrate metrics were created using the Invertebrate Data Analysis System (IDAS v 3.0; Cuffney 2003).

Environmental and Disturbance Measures
We characterized sites by aspect, slope, spring type, geology, elevation, and microhabitat availability. Potential solar radiation was recorded using a Solar Pathfinder. We sampled substrate using a random walk within the main spring pool or area. Fifty pebbles were blindly selected and measured along the b-axis.

We recorded any disturbances visible at or surrounding the spring site, including natural and anthropogenic sources. Disturbances included recreation, grazing, trails, motor vehicles (roads and off-road vehicles), and flow modifications. We estimated vertical bank stability and overbank cover around the main spring pool, and riparian area soil integrity and plant community structure and cover in the associated riparian areas, using methods detailed by Stacey et al. (2005). We then created a spring impact score based on vertical bank stability and riparian soil integrity measurements. We tallied the number and type of disturbances noted at and around each spring. The disturbance tally and spring impact score were then combined to determine a total disturbance score, with possible scores from 1 to 6. Using the disturbance scores, springs were classified as reference springs (scores of 1 or 2), moderately disturbed (scores of 3 or 4), and heavily disturbed (scores of 5 or 6).

Multivariate Data Analysis
A series of data screening procedures, transformations and relativizations were performed prior to running multivariate analyses. We deleted rare species (i.e., taxa found at less than 5% of sites) because they increase the signal to noise ratio and obscure patterns in the data. Abundance data were log transformed ($\log_{10}(x+1)$) to reduce the influence of hyper abundant taxa and then relativized by row totals to obtain the relative abundance of

individual taxa within a site. Proportion data were arcsine square-root transformed. Outliers with a standard deviation greater than 2.5 were removed from the analysis due to their disproportionate effect on multivariate analyses.

Nonmetric multidimensional scaling (NMDS) ordination
NMDS is an indirect gradient analysis technique that uses rank community dissimilarities to iteratively search for the optimal arrangement of sample objects in as few dimensions as possible (McCune and Grace 2002). NMDS was run with Sørensen's distance in PC-ORD version 5. We assessed dimensionality by evaluating the relationship of final stress versus the number of dimensions; in addition, a Monte Carlo test with 250 runs of the randomized data quantified the probability of observing a stress as low as or lower than that observed through chance alone. Macroinvertebrate metrics and environmental data were overlain onto the ordination as joint plot overlays. A value of 0.30 was chosen as a cutoff for interpreting ecologically meaningful joint plot correlations.

We tested for differences in assemblage composition among impact categories and cluster analysis groupings using a multiple response permutation procedure (MRPP) with Sørensen's distance (Mielke and Berry 2001). MRPP is a nonparametric permutation procedure that tests for differences among two or more groups. A *p*-value assesses the probability of observed group differences under the null hypothesis, while an *A*-statistic quantifies effect size and within group homogeneity (McCune and Grace 2002). Indicator Species Analysis (Dufrene and Legendre 1997) was further used to determine taxa with high fidelity to the different groupings.

Univariate Data Analysis
Univariate data were investigated using the Shapiro-Wilk's test for normality and Levene's test for equality of variance (Sokal and Rohlf 1995). When appropriate, proportion data were arcsine square-root transformed to improve normality. Normal data with equal variance were analyzed using One-Way Analysis of Variance (ANOVA). Data that could not meet normality assumptions but had equal variance were analyzed using the non-parametric Kruskal-Wallis test. All univariate analyses were completed in R 2.10.0 (R Development Core Team 2009).

Results

BLCA/CURE Springs
Lion and Poison Gulch springs were sampled at Black Canyon of the Gunnison National Park (BLCA), and Cimarron Campground, Dillon Gulch and Soap Creek springs were sampled at Curecanti National Recreation Area (CURE). Both BLCA springs were classified as High Impact sites, while all three CURE springs were Moderate Impact springs. Common impacts included livestock grazing, the presence of trails, flow modifications, and visibility from a road (potentially increasing visitation).

No invertebrates were sampled at Lion Spring due to the small area of the site. For the other four sites in this region, similarly to results discussed below, amphipod percent total richness was low, with no amphipods collected at any of the sites. Non-insect percent total richness was zero at three of the sites. It was similar to the total sample average percent richness (n=45) at Dillon Gulch Spring due to the presence of flatworms (*Turbellaria*).

Elevated nutrient levels (nitrates, nitrites, and total phosphorous) were found at all of the springs, and elevated *E. coli* levels were present at Lion, Poison Gulch and Soap Creek springs. Turbidity was higher than the total sample average (n=45) at the BLCA springs.

Disturbance Study – Southeastern Utah Springs
Final sample sizes for the different disturbance categories were Low Impact (n = 16), Moderate Impact (n = 14) and High Impact (n = 10). Trails and recreational use were the primary disturbances associated with low impact springs. Moderate impact springs generally added one additional disturbance to the presence of trails such as a road, livestock use, or a flow modification. High impacts springs generally had both livestock use and road/OHV use present.

Do macroinvertebrate communities vary along a gradient of increasing anthropogenic activities?
After deletion of rare taxa and outliers, the final multivariate community dataset included 38 springs and 29 taxa. Two high impact springs, Lime Creek #1 and Tusher Canyon, were determined to be outliers due to their low species richness and low abundance of individuals. Including these outliers created instabilities in the ordinations that could not be resolved. All springs are included in the univariate analyses.

NMDS ordination recommended a three-dimensional solution (stress = 14.75, instability < 0.0001, iterations = 500). The three axes represent 83.5% of the variation in the dataset (Axis 1 = 30.8, Axis 2 = 38.3, Axis 3 = 14.4). For ease of visualization, Axis 1 and Axis 2 are presented here (Fig. 3). The axes do not have inherent meaning; rather the scatter of points in space indicates similarities between aquatic macroinvertebrate communities, with similar sites lying closer together.

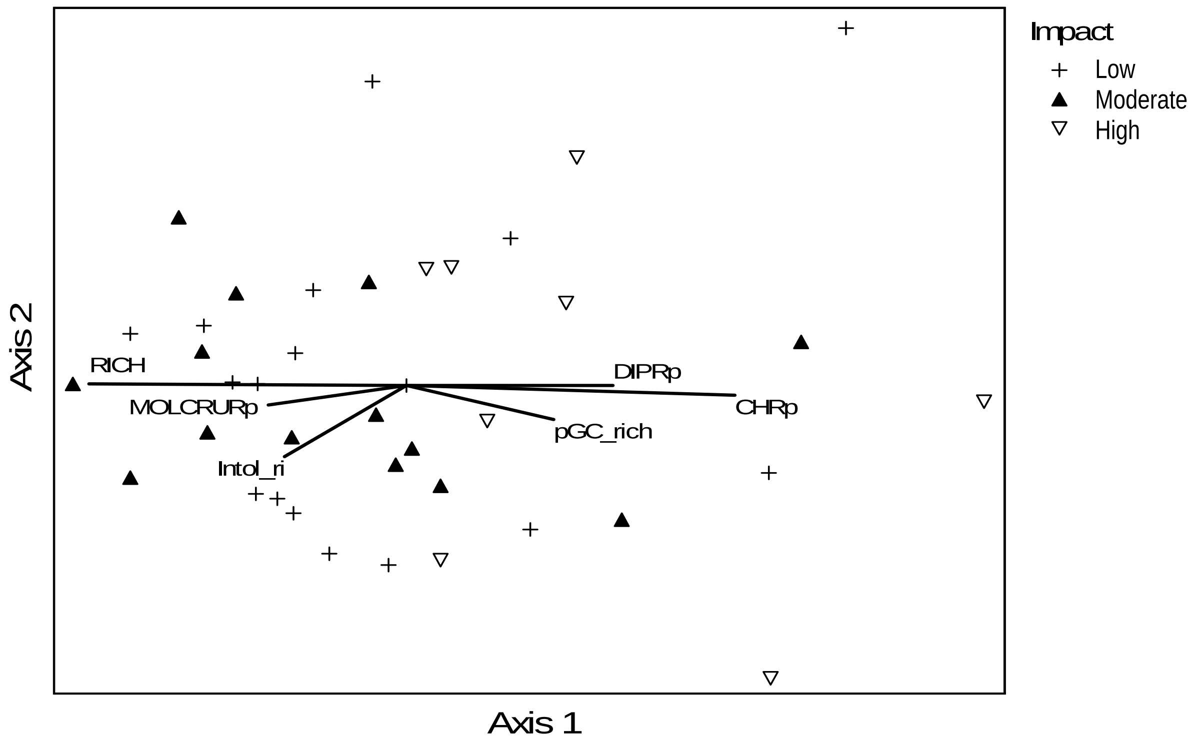

Fig. 3. NMDS ordination of aquatic macroinvertebrate assemblage data overlain with macroinvertebrate metrics.

No environmental data correlated with the structure of the ordination. Macroinvertebrate metrics such as total richness (RICH, $r^2 = 0.70$), richness composed of mollusks and crustaceans (MOLCRURp, $r^2 = 0.25$), richness of taxa intolerant of poor water quality (Intol_ri, $r^2 = 0.328$), richness of gatherer-collector functional group (pGC_rich, $r^2 = 0.380$), richness composed of midges (CHRp, $r^2 = 0.755$) and richness composed of true flies (DIPRp, $r^2 = 0.435$) correlated with the ordination.

Visual interpretation of the ordination and the correlated metrics does not show a clear pattern of clustering by the impact category (low, moderate or high). Springs of different impact categories are scattered throughout the ordination with only modest separation. MRPP analysis indicates that macroinvertebrate communities in the three impact categories differ statistically; however the effect level is so low that it is doubtful whether this difference translates into a true ecological difference ($A = 0.017$, $p = 0.052$).

Further exploration of the macroinvertebrate data weakens the hypothesis that assemblages differ along a gradient of anthropogenic disturbance. Indicator Species Analysis found no taxa with high fidelity to and abundance in low impact sites, two taxa indicative of moderate impact sites (dragonflies known as darners - Aeshnidae, Indicator Value = 51.7, p = 0.006; and whirligig beetles – *Gyrinus* sp., Indicator Value = 35.7, p = 0.048), and only one indicator species for high impact sites (horseflies – *Tabanus* sp., Indicator Value = 29.1, p = 0.031).

There were no differences shown by univariate analyses in functional groups (predators, shredders, scrapers, etc.) or tolerance levels between impact categories. Very few differences were noted in taxa groupings (2 out of 21 possible groupings). Richness composed of amphipods differed between groups (Fig. 4; $\chi^2 = 10.4281$, df = 2, p = 0.005). The richness of non-insect taxa (worms, spiders, amphipods, crustaceans, amphibians, mollusks and flatworms) also differed between groups (Fig. 5; $\chi^2 = 6.1437$, df = 2, p = 0.046). Both of these taxa categories show a pattern of increasing richness from low to moderate disturbance, with decreasing richness at high impact sites.

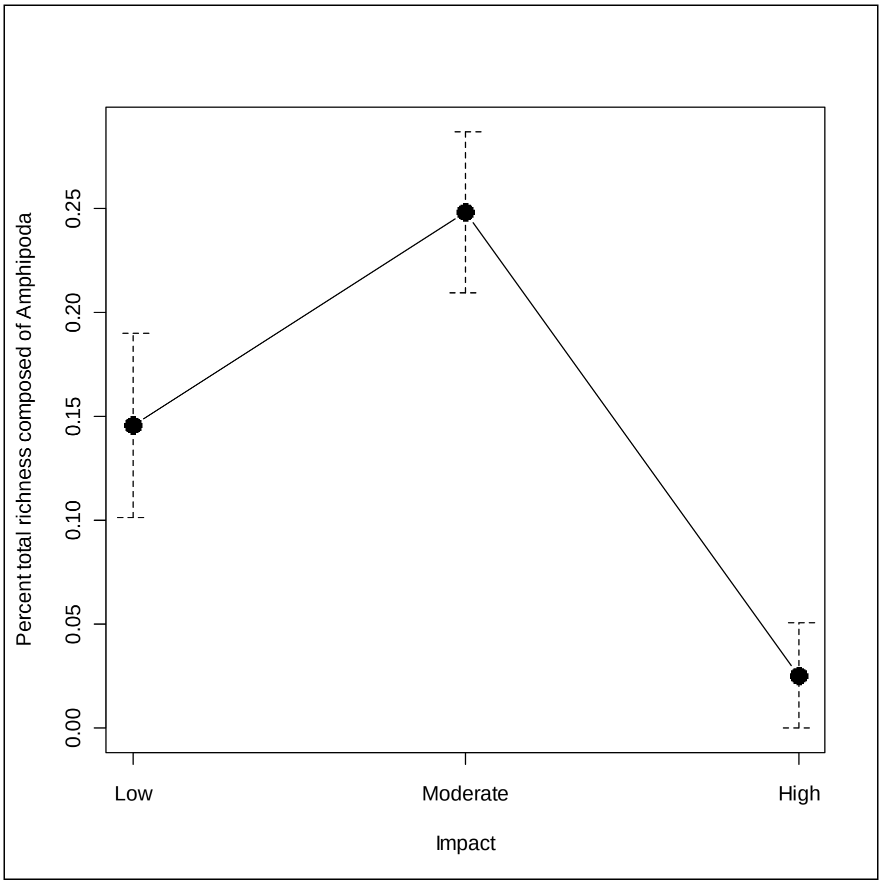

Fig. 4. Mean (+/- standard error) amphipod percent total richness by impact category.

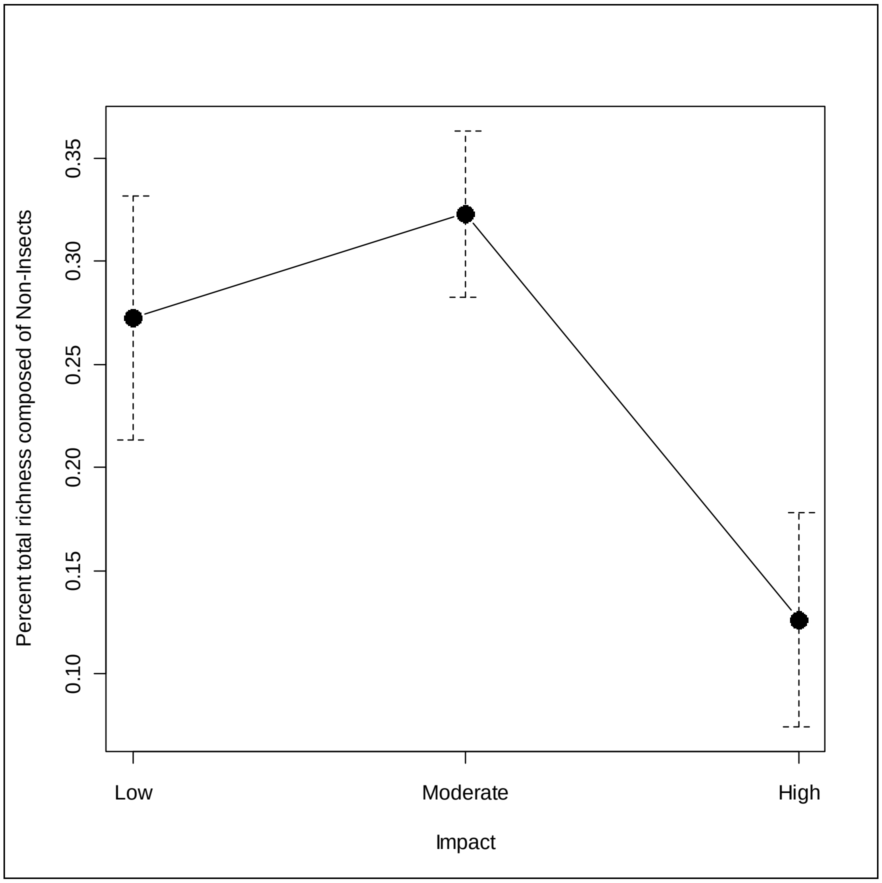

Fig. 5. Mean (+/- standard error) non-insect percent total richness by impact category.

Does water quality vary along the gradient?

Several, but not all, water quality parameters differed between impact categories. Water temperature showed a pattern of increasing as disturbance increased (Fig. 6; $F = 4.385$, $df = 2,37$, $p = 0.020$). Turbidity (Fig. 7; $\chi^2 = 13.09$, $df = 2$, $p = 0.001$) and *Escherichia coli* abundance (a bacterial indicator of fecal contamination; Fig. 8; $\chi^2 = 13.76$, $df = 2$, $p = 0.001$) were very low at low and moderate impact springs but showed wide variation including high values at high impact springs. Other water quality indicators such as specific conductivity, pH, dissolved oxygen, and nutrients (nitrate/nitrites and total phosphorous) did not differ along the disturbance gradient.

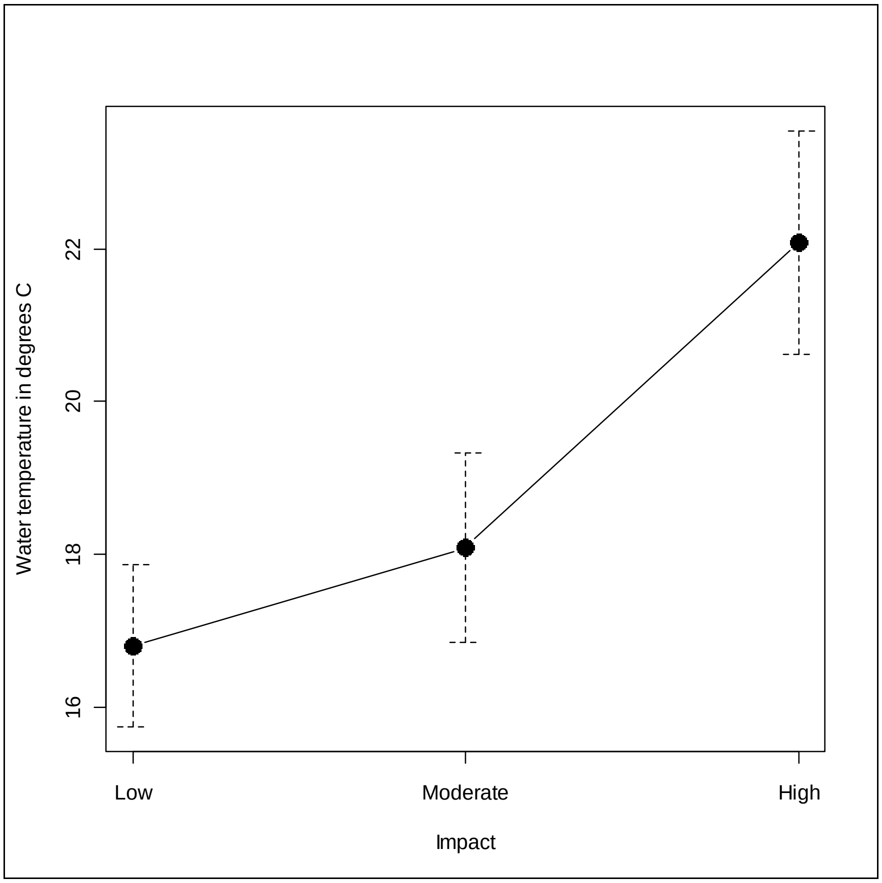

Fig. 6. Mean (+/- standard error) water temperature by impact category.

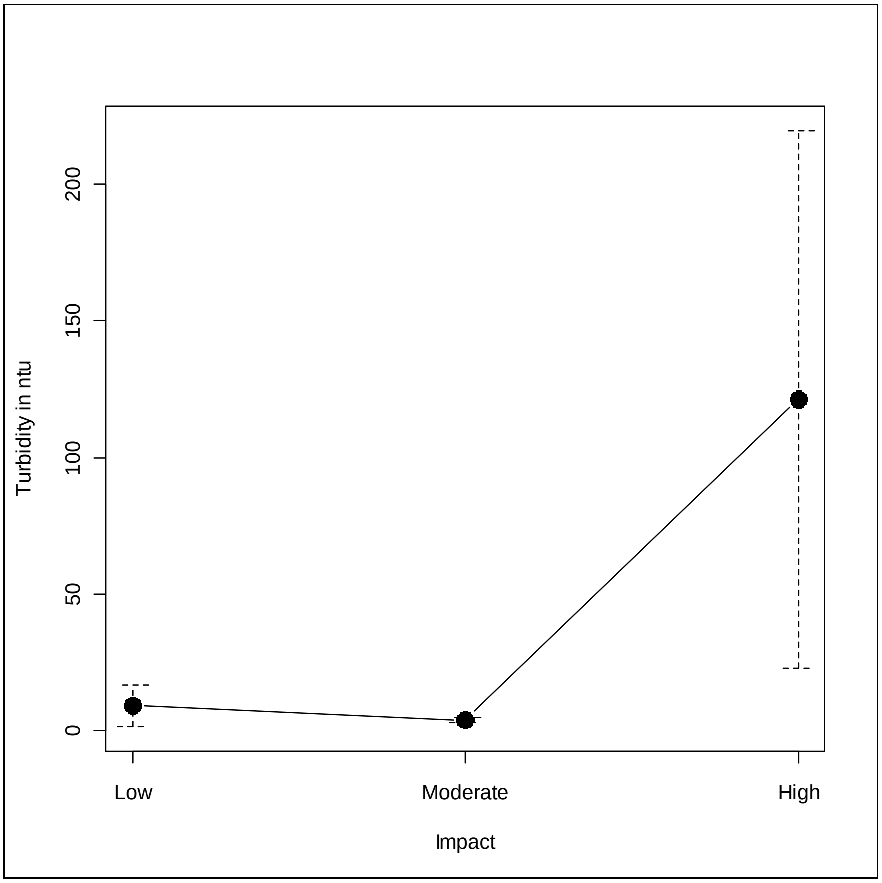

Fig. 7. Mean (+/- standard error) turbidity by impact category.

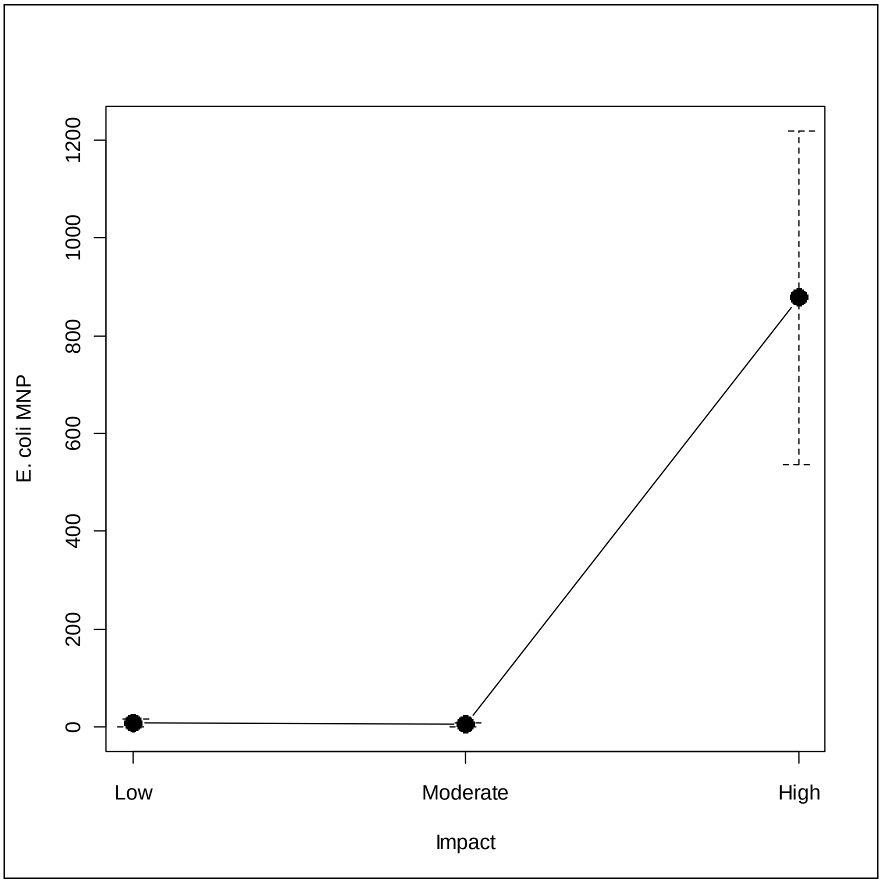

Fig. 8. Mean (+/- standard error) *E. coli* abundance by impact category.

Do physical habitat characteristics (especially sediment) vary along the gradient?
Substrate composition did not vary along a disturbance gradient (% bedrock, $\chi^2 = 0.956$, df = 2, p = 0.62; % cobble, $\chi^2 = 1.231$, df = 2, p = 0.54; % gravel, $\chi^2 = 2.113$, df = 2, p = 0.17; % fines, $\chi^2 = 3.519$, df = 2, p = 0.35).

Other findings
Total vegetation cover decreased as disturbance increased (Fig. 9; $\chi^2 = 7.372$, df = 2, p = 0.025). Overbank vegetation cover did not differ between impact categories ($\chi^2 = 1.024$, df = 2, p = 0.60).

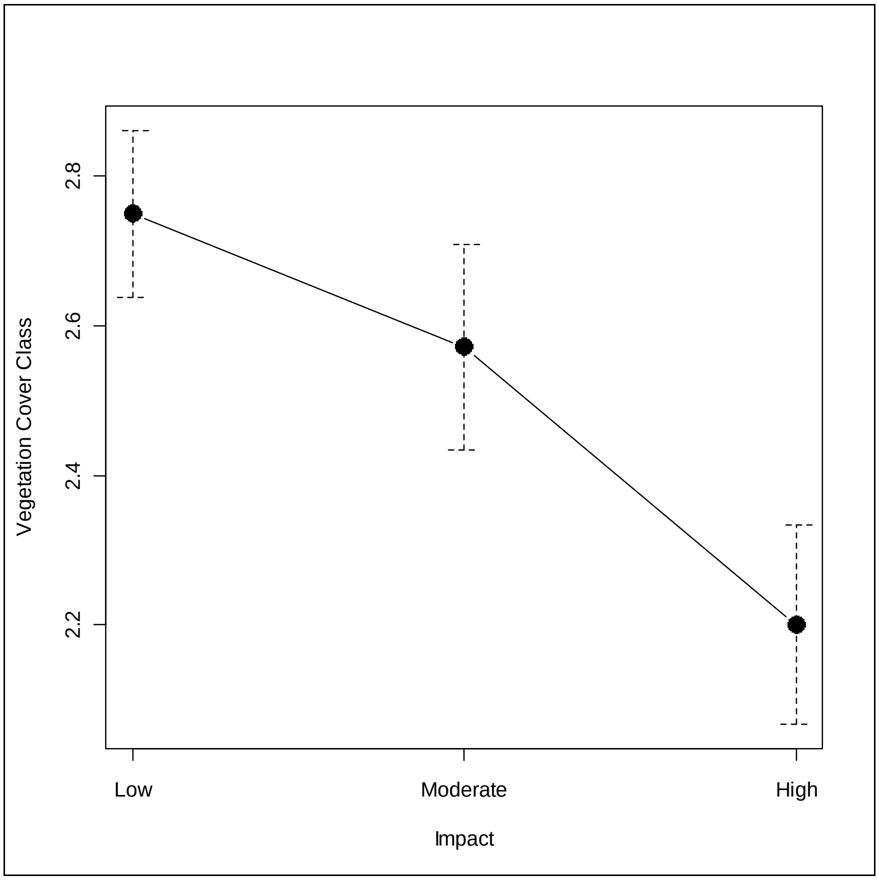

Fig. 9. Mean (+/- standard error) vegetation cover class by impact category.

Discussion

Do macroinvertebrate communities vary along a gradient of increasing anthropogenic activities?

Despite detecting differences in *E. coli*, vegetation, water temperature, and turbidity in high, medium and low sites, only a few tests indicated differences in macroinvertebrate assemblages between different levels of anthropogenic disturbance. Similarly to our findings that amphipods decreased at high impact sites, a study of artesian springs in the Great Basin region of Utah showed a decline in amphipod abundance with increasing disturbance (Keleher and Rader 2008). Overall patterns in our data indicate that aquatic macroinvertebrate assemblages and metrics do not differ between springs with different levels and types of anthropogenic impacts. There are a number of possible reasons for this apparent lack of effect.

1) There are no differences in macroinvertebrate communities in these spring systems.

- Springs on the Colorado Plateau are isolated and many are adapted to high levels of natural disturbance, including fluctuations in water temperature and availability. These conditions may select for macroinvertebrate communities that are highly adapted to disturbance even in springs with low levels of anthropogenic disturbance. In essence, all springs could be thought of as moderate to high impact sites, relative to the broader range of conditions found in streams, rivers, and lakes.

- Aridland springs may be adapted specifically to moderate disturbance from native ungulate grazing and translate that adaptation to livestock grazing, one of the most common impacts at high impact springs (Keleher and Rader 2008, Kodric-Brown and Brown 2007).

- Alternatively, the constant replenishment of pristine groundwater characteristic of springs could mute the effects of anthropogenic disturbance on macroinvertebrate communities, leading to better than expected habitat conditions even at sites with numerous anthropogenic disturbances. Differences in water temperature, turbidity and *E. coli* abundance in our sample weaken this hypothesis.

2) Our sampling methods were unable to detect differences in aquatic macroinvertebrate communities.

- Despite our attempts to define our population by limiting springs to sandstone aquifers within a given elevation range, it is possible that the springs sampled were not actually from one population. Keleher and Rader (2008) found that identifying reference classes based on physico-chemical characteristics and matching disturbed sites to those classes was important for detecting useful metrics for any single class. In their study, half of the useful metrics were unique to a single class. However, substrate is a major factor structuring aquatic macroinvertebrate communities, and substrates were similar across all impact categories in our study.

- Our study has a relatively small sample size, especially for high impact springs after post-hoc analysis of disturbance categories. Exacerbating this imbalance, two high impact springs were deleted from the multivariate analyses because multivariate analyses cannot meaningfully interpret sites with extremely low richness and/or abundance. These deletions may have skewed our results, as low species richness and abundance could be legitimate issues with high impact sites. However, univariate analyses included all of the springs, and the lack of difference in most macroinvertebrate metrics tested using all of the sites weakens this hypothesis.

Do water quality parameters and other habitat characteristics vary along a gradient of anthropogenic disturbance?
Environmental parameters showed a mixed response to disturbance. As hypothesized, several water quality parameters differed between high impact and low impact springs, with increasing water temperature, turbidity, and *E. coli* levels associated with increasing anthropogenic disturbance levels. Overall vegetation cover showed the opposite trend, decreasing as disturbance increased. However, many environmental parameters, including nutrient levels, dissolved oxygen, pH, specific conductivity, substrate composition, and overbank vegetation cover, did not show any differences between groups.

Recommendations for Monitoring

Based on our dataset, we recommend that aquatic macroinvertebrate sampling not be included in long-term monitoring as a surrogate method for determining anthropogenic impacts at springs. Sampling may still be appropriate for meeting other monitoring objectives, such as tracking aquatic macroinvertebrate diversity over time.

Literature Cited

Cuffney, T.F. 2003. User's manual for the National Water-Quality Assessment Program Invertebrate Data Analysis System (IDAS) software, ver. 3. U.S. Geological Survey, Open-File Report 03-172.

Cuffney, T.F., M.D. Bilger and A.M. Haigler. 2007. Ambiguous taxa: effects on the characterization and interpretation of invertebrate assemblages. Journal of the North American Benthological Society 26(2): 286-307.

Dufrene, M. and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67:345-366.

Erman, NA. 2002. Lessons from a long-term study of springs and spring invertebrates (Sierra Nevada, California, USA) and implications for conservation and management. Spring-fed Wetlands: Important Scientific and Cultural Resources of the Intermountain Region, Las Vegas, NV.

Erman, N.A. and D.C. Erman. 1995. Spring permanence, species richness and the role of drought. Pages 50-64 In, L.C. Ferrington, Jr. (ed.), Biodiversity of aquatic insects and other invertebrates in springs. Journal of the Kansas Entomological Society, 68, Supplement, Special Publication No. 1.

Grand Canyon Wildlands Council. 2002. Inventory of 100 Arizona Strip springs, seeps and natural ponds: final project report. Grand Canyon Wildlands Council, Flagstaff, AZ.

Hershler, R. and D.W. Sada. 2002. Biogeography of Great Basin aquatic snails of the genus Pyrgulopsis. Smithsonian Contributions to the Earth Sciences 33: 255-276.

Keleher, M. J. and R. B. Rader. 2008. Bioassessment of artesian springs in the Bonneville Basin, Utah, USA. Wetlands 28(4): 1048-1059.

Kodric-Brown, A. and J. H. Brown. 2007. Native fishes, exotic mammals, and the conservation of desert springs. Frontiers in Ecology and the Environment 5(10): 549-553.

Lenat, D.R. and M.T. Barbour. 1994. Using benthic macroinvertebrate community structure for rapid, cost-effective, water-quality monitoring: rapid bioassessment. Pages 187-215 in S.L. Loeb and A. Spacie, eds. Biological Monitoring of Aquatic Systems. Lewis, Boca Raton, FL.

McCune, B. and J.B. Grace. 2002. Analysis of ecological communities. MJM Software, Gleneden Beach, OR.

McCune, B. and M.J. Mefford. 2005. PC-ORD, Multivariate analysis of ecological data, Version 5.0. MjM Software, Gleneden Beach, Oregon, USA.

Mielke, P.W., Jr., and K.J. Berry. 2001. Permutation methods: A distance function approach. SpringerVerlag. 352pp.

R Development Core Team (2009). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Sada, D.W., E. Fleishman, and D.D. Murphy. 2005. Associations among spring-dependent aquatic assemblages and environmental and land use gradients in a Mojave Desert mountain range. Diversity and distributions 11: 91-99.

Sokal, R.R. and J.F. Rohlf. 1995. *Biometry*, 3rd ed. W. H. Freeman and Co., New York.

Springer, A.E. and L.E. Stevens. 2009. Spheres of discharge of springs. Hydrogeology Journal 17 (1): 83-93.

Stacey, P.B., J.C. Jones, A.L. Catlin, D. Duff, L.E. Stevens, and C. Gourley. 2007. A protocol for rapid assessment of southwestern stream-riparian ecosystems. Wild Utah Project. Available online at http://wildutahproject.org/programs/riparian/RSRA Accessed 12/18/09.

Appendix A. Spring Locations and Impact Categories

Table 1. Spring locations and impact categories. BLM = Bureau of Land Management, NPS = National Park Service. FO = Field Office, ARCH = Arches National Park, BLCA = Black Canyon of the Gunnison National Park, BLM = Bureau of Land Management, CANY = Canyonlands National Park, CURE = Curecanti National Recreation Area, HOVE = Hovenweep National Monument, NABR = Natural Bridges National Monument.

Owner	District	Spring Name	State	County	Zone	UTM Easting	UTM Northing	Elevation (m)	Impact
BLM	Moab FO	"Pouroff" Spring	UT	Grand	12	591731.1	4288977.6	1342	Moderate
BLM	Moab FO	Barlett Wash	UT	Grand	12	605387.9	4286002.1	1413	High
BLM	Moab FO	Courthouse	UT	Grand	12	610282.0	4285749.0	1375	High
BLM	Moab FO	Cow Canyon	UT	Grand	12	589881.0	4288185.8	1328	Moderate
BLM	Moab FO	Dripping Spring	UT	Grand	12	589654.0	4289046.4	1343	Moderate
BLM	Moab FO	Gatherer Canyon	UT	Grand	12	622557.4	4264264.2	1241	Moderate
BLM	Moab FO	Kane Springs	UT	San Juan	12	635137.1	4250837.8	1552	High
BLM	Moab FO	Mill Canyon	UT	Grand	12	609449.5	4284499.8	1375	High
BLM	Moab FO	Moonflower Canyon	UT	Grand	12	623591.1	4268216.7	1257	Moderate
BLM	Moab FO	Seven Mile Boundary	UT	Grand	12	617054.7	4281000.5	1300	Moderate
BLM	Moab FO	Tusher Canyon	UT	Grand	12	608105.3	4285113.6	1451	High
BLM	Monticello FO	"Dead Cow" Spring	UT	San Juan	12	600826.4	4123550.9	1398	High
BLM	Monticello FO	Bullseye	UT	San Juan	12	571580.7	4161251.5	1790	High
BLM	Monticello FO	Flag Butte Spring	UT	San Juan	12	604766.4	4119777.1	1346	Moderate
BLM	Monticello FO	Kane Gulch	UT	San Juan	12	596142.3	4153076.8	1905	Moderate
BLM	Monticello FO	Lime Creek #1	UT	San Juan	12	607653.7	4129122.2	1474	High
BLM	Monticello FO	Lime Creek #2	UT	San Juan	12	605903.7	4127312.1	1452	High
BLM	Monticello FO	Owl Creek	UT	San Juan	12	605003.4	4146828.3	1670	Moderate
BLM	Monticello FO	Red Canyon	UT	San Juan	12	568385.5	4160043.4	1661	n/a
NPS	ARCH	Freshwater Spring	UT	Grand	12	627925.6	4289097.7	1328	Low
NPS	ARCH	Lost Spring	UT	Grand	12	629071.8	4296008.7	1385	High
NPS	ARCH	Lower Courthouse Wash	UT	Grand	12	623655.8	4274763.2	1212	Low
NPS	ARCH	Poison Ivy Spring	UT	Grand	12	617358.0	4280722.0	1300	Low
NPS	ARCH	Sleepy Hollow	UT	Grand	12	618379.3	4281405.6	1287	Low

Owner	District	Spring Name	State	County	Zone	UTM Easting	UTM Northing	Elevation (m)	Impact
NPS	ARCH	Upper Courthouse Wash	UT	Grand	12	617045.0	4283017.9	1308	Low
NPS	BLCA	Lion Spring	CO	Montrose	13	263599.2	4273025.6	2375	High
NPS	BLCA	Poison Gulch	CO	Montrose	13	270838.8	4271728.5	2621	High
NPS	CANY	2.4 Mile Loop	UT	San Juan	12	604059.4	4222261.1	1530	Low
NPS	CANY	Alcove Spring	UT	San Juan	12	595311.7	4254008.4	1560	Low
NPS	CANY	Big Spring	UT	San Juan	12	603431.6	4226229.3	1457	Low
NPS	CANY	Cabin Spring	UT	San Juan	12	601235.0	4255272.9	1735	Low
NPS	CANY	Chocolate Drops	UT	Wayne	12	587311.0	4231219.2	1400	Moderate
NPS	CANY	Horseshoe Canyon	UT	Wayne	12	569800.3	4257343.6	1410	Moderate
NPS	CANY	Little Canyon Spring	UT	San Juan	12	605118.9	4226929.7	1487	Low
NPS	CANY	Lost Canyon Spring	UT	San Juan	12	607152.2	4219979.3	1558	Low
NPS	CANY	Maze Overlook	UT	Wayne	12	587938.8	4231626.7	1385	Low
NPS	CANY	Neck Spring	UT	San Juan	12	602797.4	4255958.6	1746	n/a
NPS	CANY	Old Bates Wilson Camp	UT	San Juan	12	607781.0	4213926.0	1645	Low
NPS	CANY	Peekaboo	UT	San Juan	12	609063.2	4219359.4	1500	Low
NPS	CURE	Cimarron Campground	CO	Montrose	13	277010.0	4258373.3	2085	Moderate
NPS	CURE	Dillon Gulch	CO	Gunnison	13	303354.0	4263140.0	2600	Moderate
NPS	CURE	Soap Creek	CO	Gunnison	13	298833.7	4264109.4	2280	Moderate
NPS	HOVE	Goodman Point	CO	Montezuma	12	701363.7	4142787.6	1996	Moderate
NPS	HOVE	Hackberry House	CO	Montezuma	12	674812.3	4141954.3	1645	Low
NPS	NABR	Kachina Alcove	UT	San Juan	12	586139.4	4161880.4	1768	n/a
NPS	NABR	Kachina Bridge	UT	San Juan	12	585576.3	4161543.7	1690	Moderate
NPS	NABR	Owachomo Bridge	UT	San Juan	12	587116.7	4159859.9	1770	Moderate
NPS	NABR	Sipapu	UT	San Juan	12	587586.8	4163883.9	1745	Low

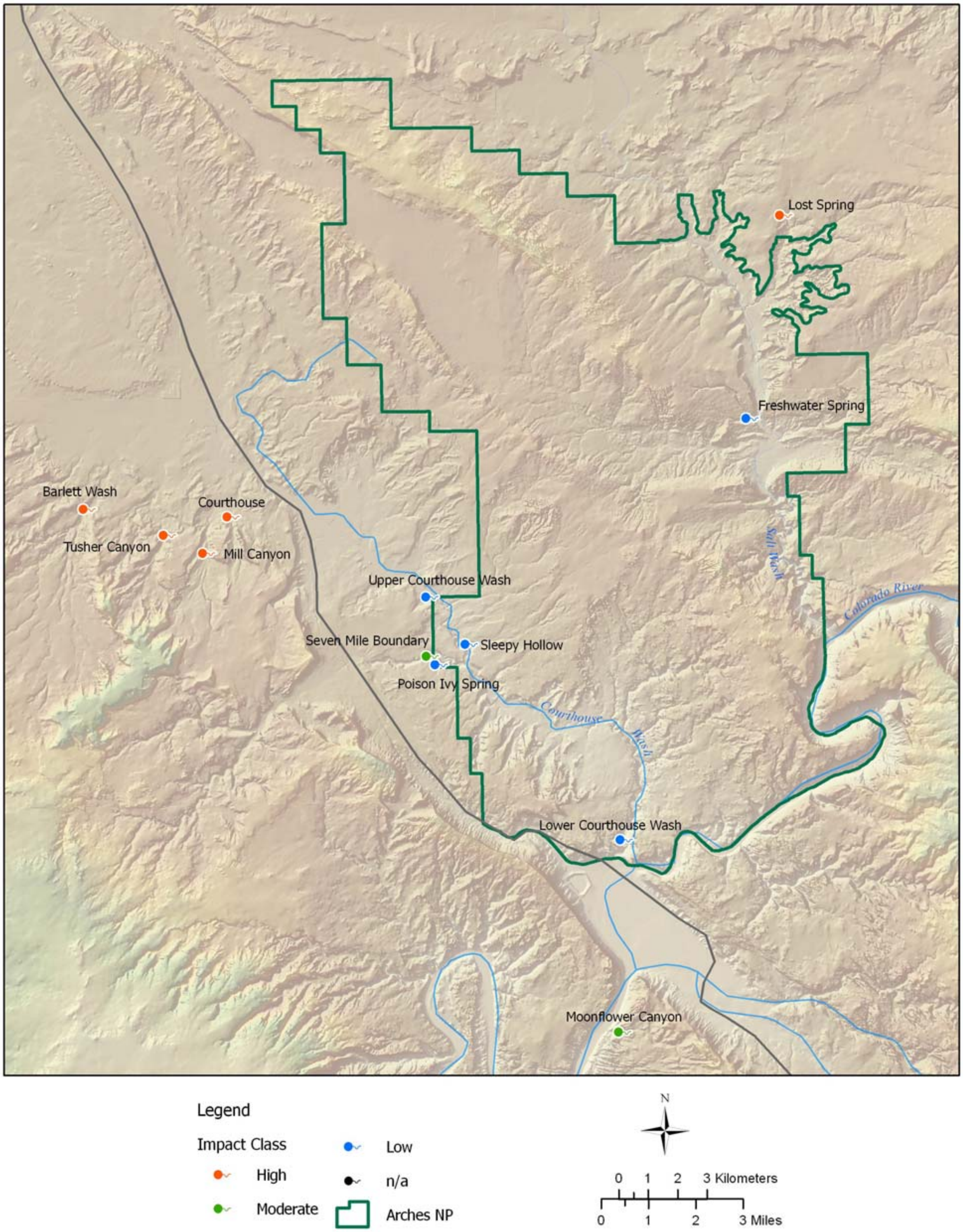

Fig. 1. Spring locations in Arches National Park and surrounding public lands.

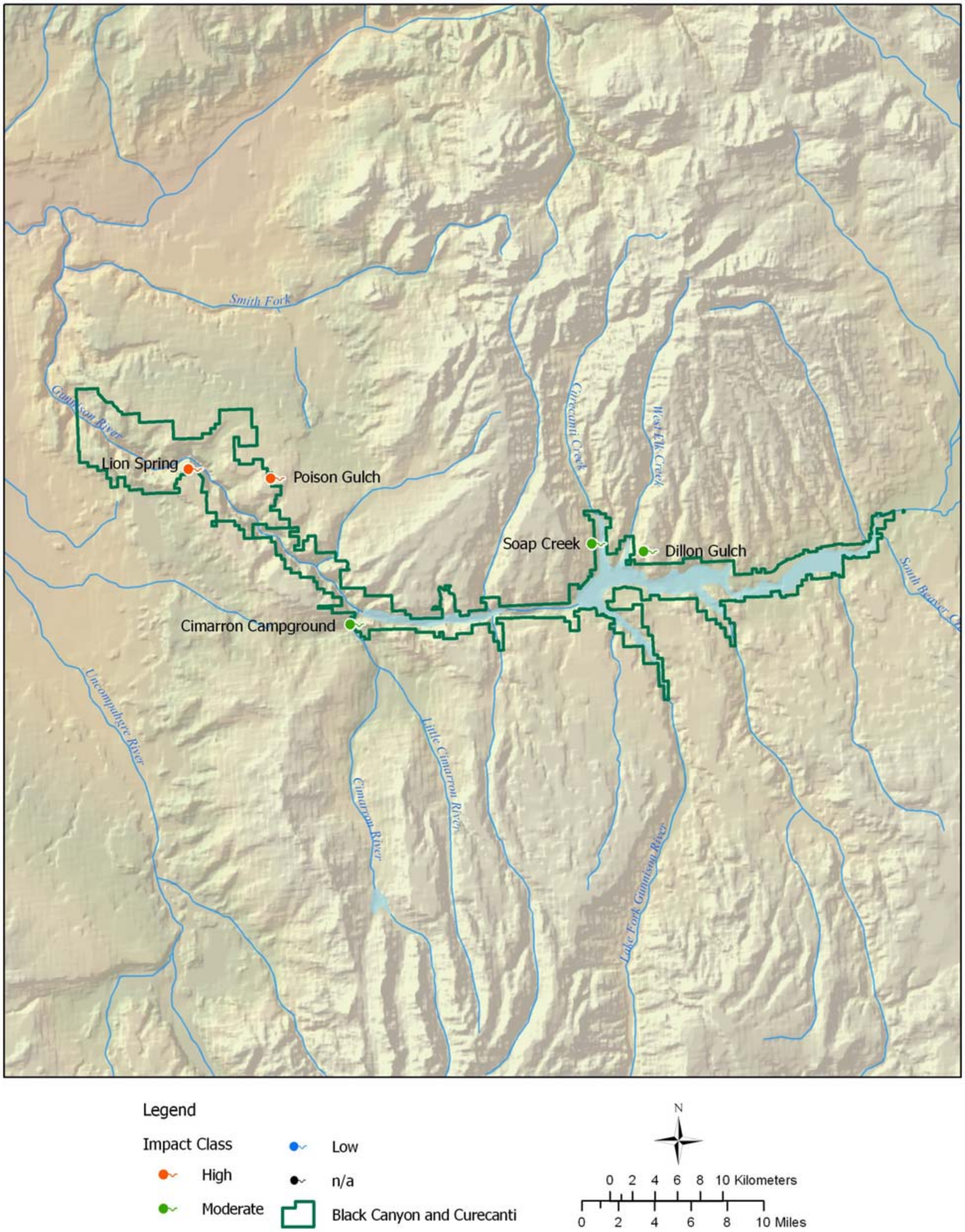

Fig. 2. Spring locations in Black Canyon of the Gunnison National Park and Curecanti National Recreation Area.

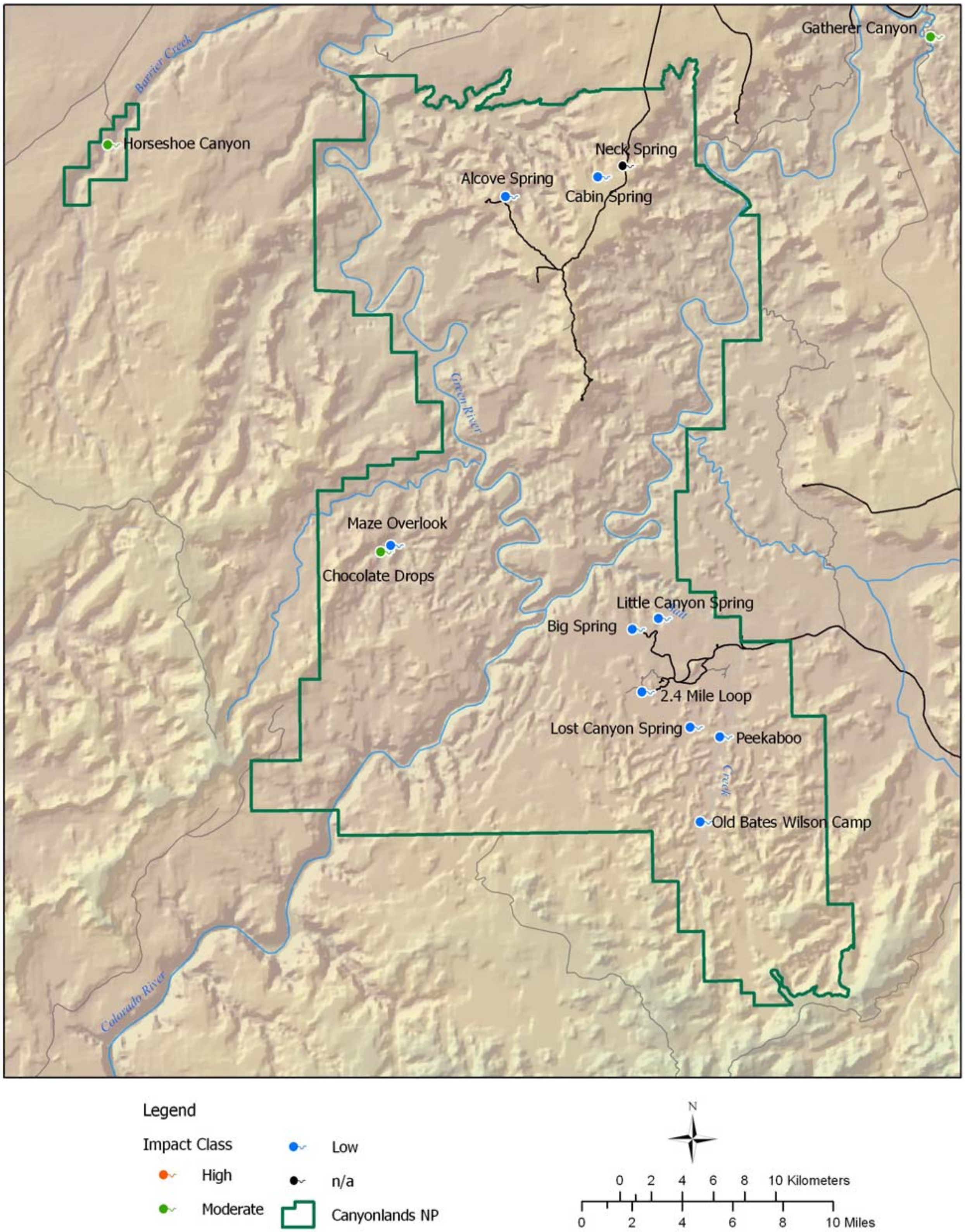

Fig. 3. Spring locations in Canyonlands National Park and surrounding public lands.

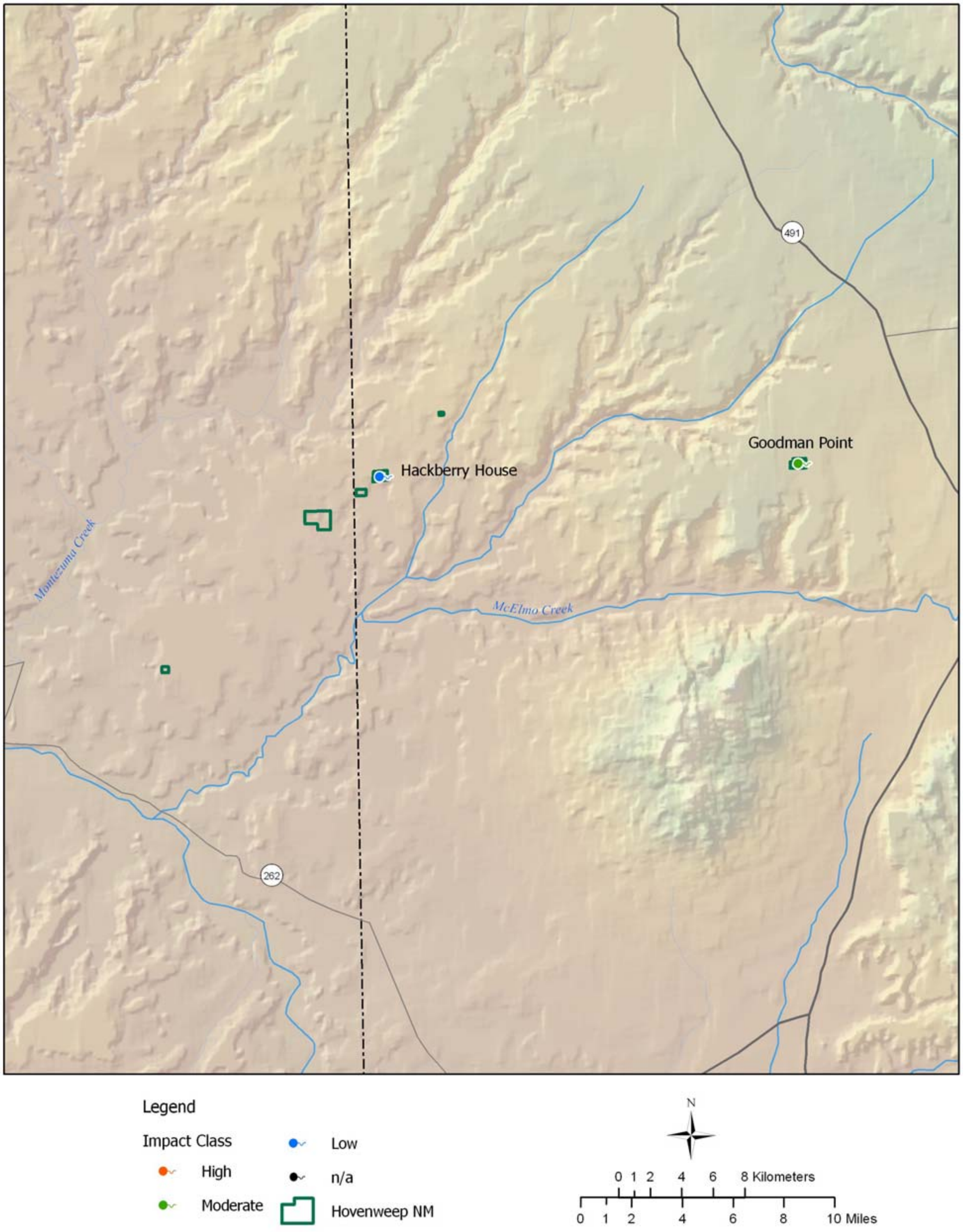

Fig. 4. Spring locations in Hovenweep National Monument.

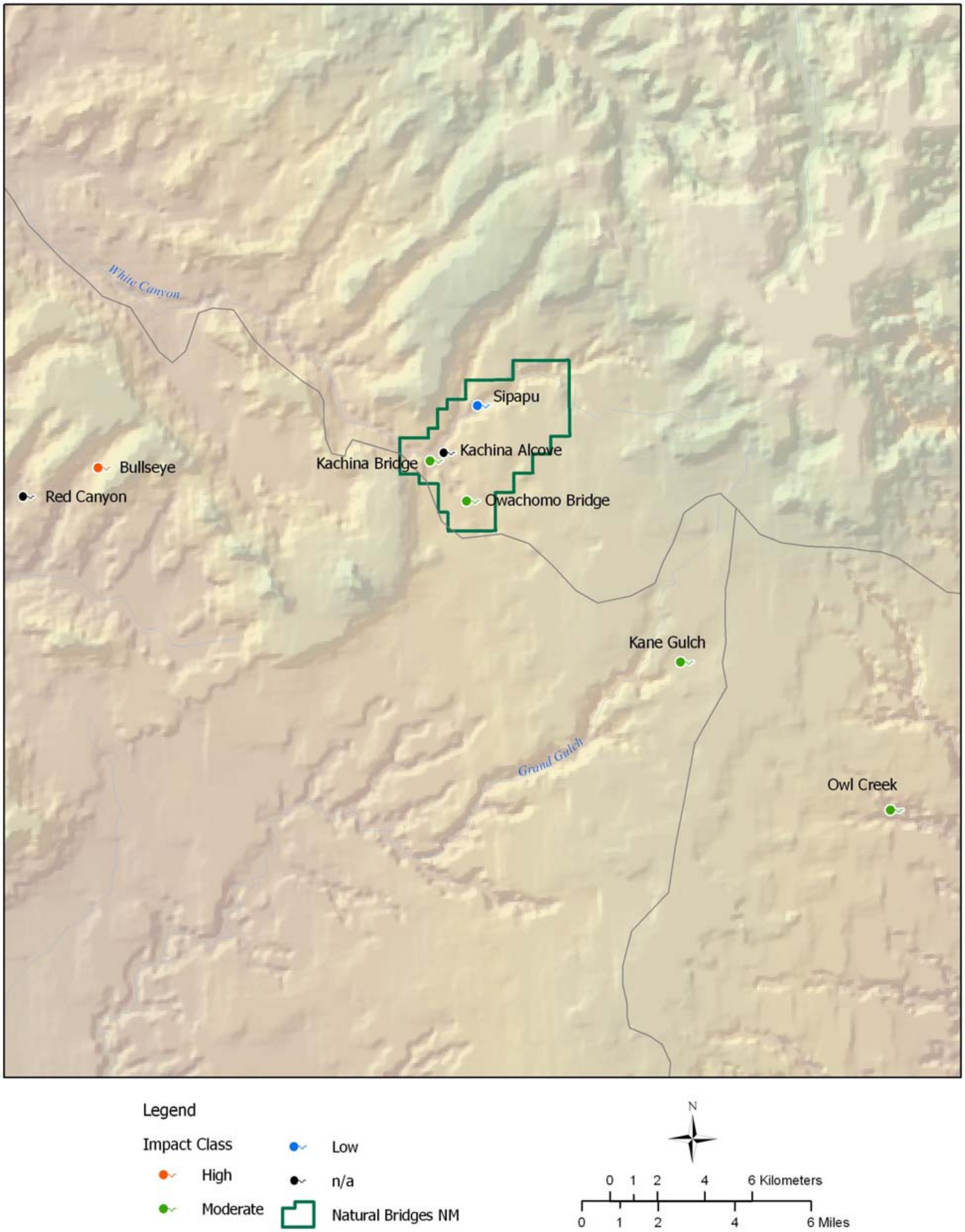

Fig. 5. Spring locations in Natural Bridges National Monument and surrounding public lands.

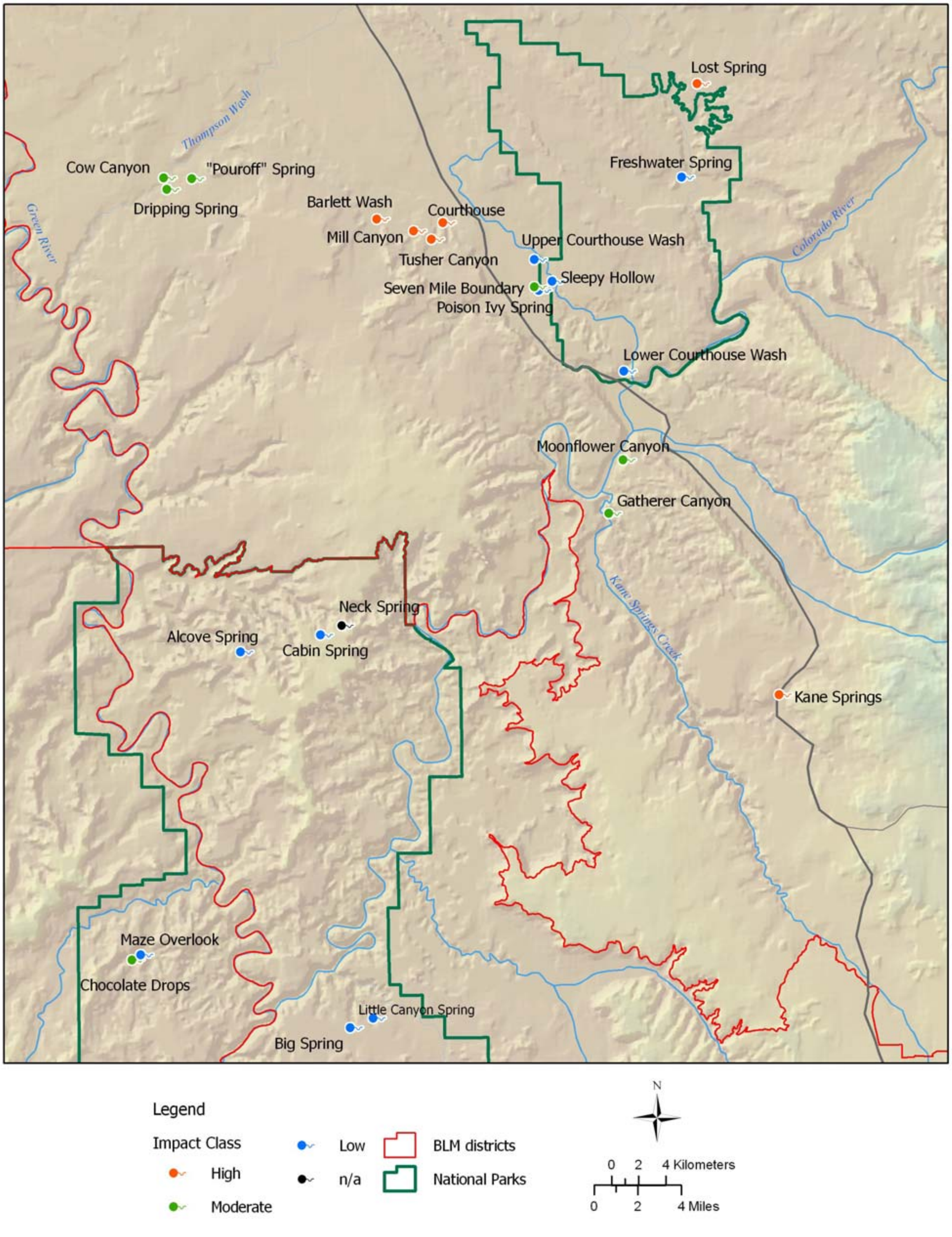

Fig. 6. Spring locations in the Moab Field District, Bureau of Land Management and adjacent National Park Service lands.

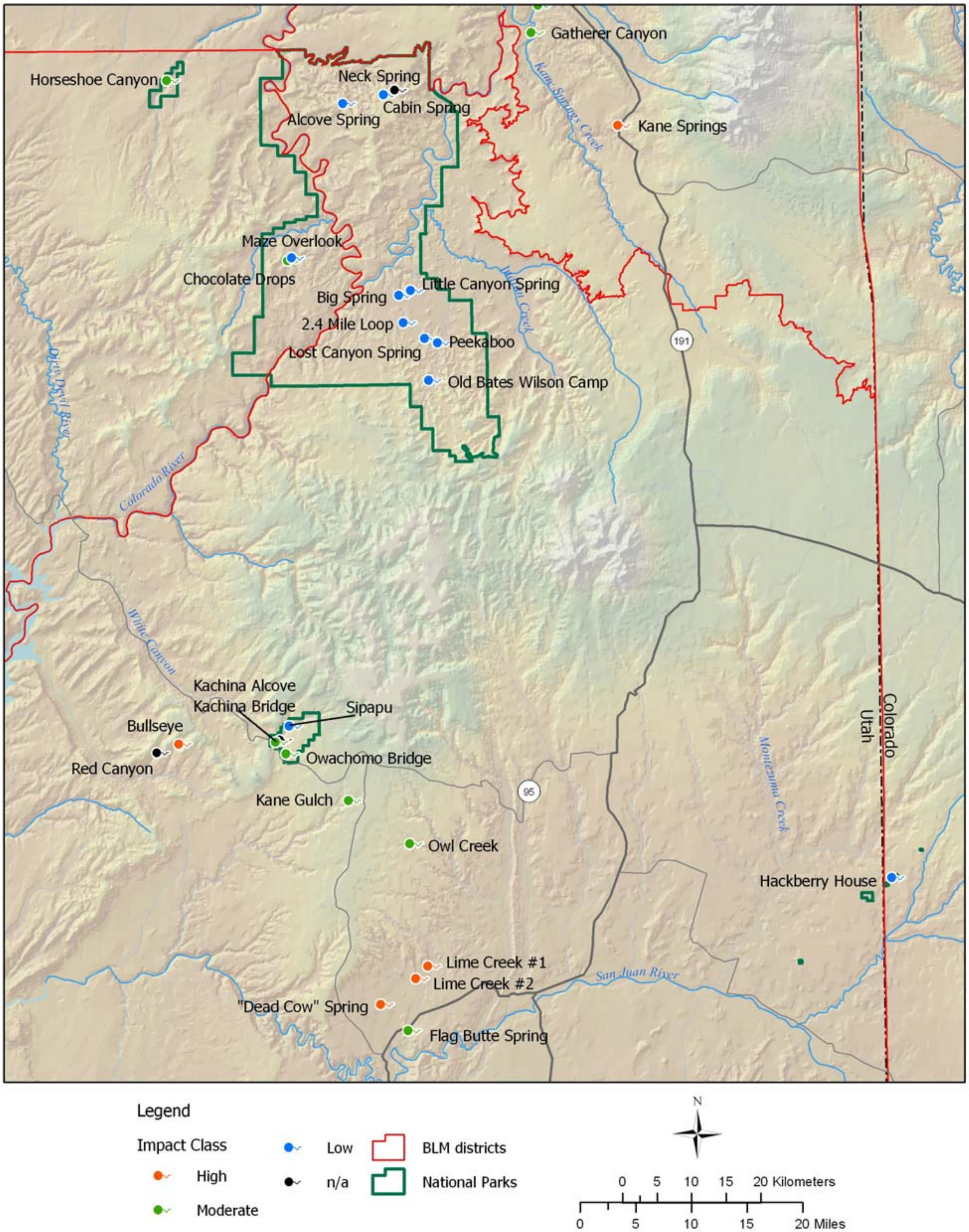

Fig. 7. Spring locations in the Monticello Field District, Bureau of Land Management and adjacent National Park Service lands.

Appendix B. Disturbances at Sampled Springs

Table 1. Summary of disturbances at sampled spring sites. ARCH = Arches National Park, BLCA = Black Canyon of the Gunnison National Park, BLM = Bureau of Land Management, CANY = Canyonlands National Park, CURE = Curecanti National Recreation Area, HOVE = Hovenweep National Monument, NABR = Natural Bridges National Monument. Vertical Bank Stability categories: 1 = >90% of channel banks are vertically unstable; 2 = 61 - 90% of banks are unstable; 3 = 31 - 60% of banks are unstable; 4 = 5 - 30% of banks are unstable; 5 = <5% of banks are unstable. Riparian Soil Integrity categories: 1 = >25% of surface riparian soil surface disturbed; 2 = 16 - 25% disturbed; 3 = 6 - 15% disturbed; 4 = 1 - 5% disturbed; 5 = <1% disturbed.

Owner	Site Name	Impact	Roads/OHV	Livestock	Trail	Recreation	Flow Modification	Visible from road or trail	Vertical Bank Stability	Riparian Soil Integrity
ARCH	Freshwater Spring	Low							5	5
ARCH	Lost Spring	High	x	x			x	x	5	2
ARCH	Lower Courthouse Wash	Low			x			x	5	5
ARCH	Poison Ivy Spring	Low			x				5	5
ARCH	Sleepy Hollow	Low			x				5	5
ARCH	Upper Courthouse Wash	Low	x					x	4	5
BLCA	Lion Spring	High	x	x			x	x	2	1
BLCA	Poison Gulch	High		x	x		x	x	2	1
BLM	"Dead Cow" Spring	High	x	x		x		x	4	1
BLM	"Pouroff" Spring	Moderate		x					5	1
BLM	Bartlett Wash	High	x	x	x	x		x	4	1
BLM	Bullseye	High	x	x			x	x	-	1
BLM	Courthouse	High	x	x	x			x	5	1
BLM	Cow Canyon	Moderate		x	x				4	2
BLM	Dripping Spring	Moderate	x	x		x			5	1
BLM	Flag Butte Spring	Moderate		x				x	5	2
BLM	Gatherer Canyon	Moderate	x		x	x	x	x	5	4
BLM	Kane Gulch	Moderate		x	x			x	5	3
BLM	Kane Springs	High	x	x		x		x	4	1
BLM	Lime Creek #1	High	x	x		x		x	4	1
BLM	Lime Creek #2	High	x	x	x	x		x	4	1

Owner	Site Name	Impact	Roads/OHV	Livestock	Trail	Recreation	Flow Modification	Visible from road or trail	Vertical Bank Stability	Riparian Soil Integrity
BLM	Mill Canyon	High	x	x	x			x	3	2
BLM	Moonflower Canyon	Moderate			x	x		x	5	2
BLM	Owl Creek	Moderate			x			x	1	4
BLM	Red Canyon	n/a	x	x				x	-	-
BLM	Seven Mile Boundary	Moderate			x				2	5
BLM	Tusher Canyon	High	x	x		x		x	4	1
CANY	2.4 Mile Loop	Low			x				5	4
CANY	Alcove Spring	Low			x			x	5	4
CANY	Big Spring	Low						x	4	5
CANY	Cabin Spring	Low			x				5	5
CANY	Chocolate Drops	Moderate			x			x	3	5
CANY	Horseshoe Canyon	Moderate			x	x		x	5	3
CANY	Little Canyon Spring	Low							4	5
CANY	Lost Canyon Spring	Low							4	5
CANY	Maze Overlook	Low			x			x	4	5
CANY	Neck Spring	n/a			x			x	-	-
CANY	Old Bates Wilson Camp	Low			x			x	5	4
CANY	Peekaboo	Low			x			x	5	5
CURE	Cimarron Campground	Moderate	x		x	x	x	x	5	4
CURE	Dillon Gulch	Moderate			x		x	x	5	5
CURE	Soap Creek	Moderate		x		x		x	5	4
HOVE	Goodman Point	Moderate			x			x	5	-
HOVE	Hackberry House	Low			x	x			5	4
NABR	Kachina Alcove	Low							-	-
NABR	Kachina Bridge	Moderate			x	x		x	5	5
NABR	Owachomo Bridge	Moderate			x	x		x	5	3
NABR	Sipapu	Low			x			x	5	4

Appendix C. Water Quantity and Water Quality Data for Sampled Springs

Table 1. Summary of hydrology data at sampled spring sites. ARCH = Arches National Park, BLCA = Black Canyon of the Gunnison National Park, BLM = Bureau of Land Management, CANY = Canyonlands National Park, CURE = Curecanti National Recreation Area, HOVE = Hovenweep National Monument, NABR = Natural Bridges National Monument. Flow: 0 = pooled water with no discernable flow. DO Sat% = Dissolved Oxygen percent saturation.

Owner	Spring Site	Date Sampled	Flow (cfs)	DO Sat%	Conductivity	Water Temp (deg C)	pH	E. Coli MPN	Turbidity (ntu)	Nitrate/Nitrite (mg/L)	Phosphorous (mg/L)
ARCH	Freshwater Spring	5/6/2009	-	92.65	385.00	23.97	7.93	<1	0.59	<0.01	<0.05
ARCH	Lost Spring	5/9/2008	0.0005	73.74	276.56	13.81	7.31	<1	4.24	1.2	0.098
ARCH	Lower Courthouse Wash	5/5/2009	-	107.68	864.90	17.23	8.07	111.23	124.00	0.52	0.58
ARCH	Poison Ivy Spring	5/31/2008	0.0050	83.45	226.23	16.37	8.14	<1	-	0.55	0.16
ARCH	Poison Ivy Spring	7/3/2008	0.0017	98.91	238.92	19.53	8.36	-	5.32	0.54	<0.05
ARCH	Sleepy Hollow	5/31/2008	0.0111	153.89	256.67	21.11	8.32	6.32	-	0.15	<0.05
ARCH	Sleepy Hollow	7/3/2008	0.0114	139.95	233.11	20.03	8.26	-	0.74	0.02	0.24
ARCH	Upper Courthouse Wash	5/5/2009	0.0033	68.54	818.90	21.40	7.73	2.02	4.77	0.02	<0.05
BLCA	Lion Spring	9/22/2008	0.0102	98.16	502.72	12.09	7.39	488.44	46.60	0.072	0.14
BLCA	Poison Gulch	9/19/2008	0.0012	60.25	462.69	16.99	7.17	51.22	35.30	0.11	0.18
BLM	"Dead Cow" Spring	5/22/2009	0.0012	48.77	4382.00	19.20	7.81	>2419.6	50.50	<0.01	<0.05
BLM	"Pouroff" Spring	5/20/2009	0.0	117.89	353.10	22.18	8.54	5.16	7.90	0.015	<0.05
BLM	Bartlett Wash	5/23/2009	0.0019	95.47	583.10	22.56	8.22	461.11	128.00	0.011	<0.05
BLM	Bullseye	7/15/2008	0.0004	100.17	796.95	26.99	8.89	<1	10.10	0.19	<0.05
BLM	Courthouse	7/17/2008	<0.01	14.33	839.41	20.44	7.03	178.21	5.36	<0.01	0.068
BLM	Cow Canyon	5/20/2009	0.0	106.16	512.20	22.53	7.72	52.91	1.76	0.028	<0.05
BLM	Dripping Spring	5/20/2009	-	90.79	943.10	20.01	7.80	3.06	5.15	<0.01	<0.05
BLM	Flag Butte Spring	5/22/2009	0.0027	118.06	3381.00	24.94	8.17	<1	0.98	1.3	<0.05
BLM	Gatherer Canyon	5/19/2009	0.0015	88.84	549.90	19.45	8.01	7.45	0.93	0.24	<0.05
BLM	Kane Gulch	7/16/2008	<0.01	65.95	1535.66	22.48	7.78	<1	11.20	<0.01	0.062
BLM	Kane Springs	5/19/2009	0.0131	73.24	756.70	17.91	7.62	15.63	2.40	0.13	<0.05
BLM	Lime Creek #1	5/21/2009	0.0	21.27	5999.00	23.12	7.90	>2419.6	>1000	<0.01	1.3
BLM	Lime Creek #2	5/21/2009	0.0011	150.08	1559.00	26.52	8.36	517.21	0.77	0.059	<0.05
BLM	Mill Canyon	7/17/2008	0.0001	97.43	682.01	29.14	8.16	2419.57	7.18	<0.01	0.15
BLM	Moonflower Canyon	5/19/2009	0.0057	131.82	285.20	18.22	8.68	<1	2.88	<0.01	<0.05
BLM	Owl Creek	7/16/2008	0.0	25.17	734.55	16.85	7.24	<1	1.64	<0.01	<0.05
BLM	Red Canyon	7/15/2008	no surface water present								
BLM	Seven Mile Boundary	5/31/2008	0.0400	75.59	245.91	11.99	7.86	<1	-	0.38	<0.05

Owner	Spring Site	Date Sampled	Flow (cfs)	DO Sat%	Conductivity	Water Temp (deg C)	pH	E. Coli MPN	Turbidity (ntu)	Nitrate/Nitrite (mg/L)	Phosphorous (mg/L)
BLM	Seven Mile Boundary	7/3/2008	0.0080	77.81	255.07	17.57	7.75	-	1.74	0.26	0.17
BLM	Tusher Canyon	5/23/2009	0.0014	94.61	341.80	21.17	8.10	344.8	5.26	0.53	<0.05
CANY	2.4 Mile Loop	5/7/2008	<0.01	37.68	599.12	11.25	7.45	<1	-	0.069	<0.05
CANY	Alcove Spring	5/8/2008	0.0002	106.68	444.96	18.82	8.49	<1	0.91	<0.01	<0.05
CANY	Big Spring	5/7/2009	0.0002	102.94	544.00	18.29	8.21	<1	0.94	0.33	<0.05
CANY	Cabin Spring	6/25/2008	0.0015	84.02	197.76	9.41	8.29	-	-	0.92	<0.05
CANY	Chocolate Drops	5/13/2008	0.0000	59.86	613.66	14.02	8.03	3.06	4.16	<0.01	<0.05
CANY	Horseshoe Canyon	5/15/2008	0.0018	35.80	1040.08	14.18	7.30	<1	3.54	<0.01	<0.05
CANY	Little Canyon Spring	6/10/2008	0.0160	75.14	810.39	14.59	7.20	<1	-	0.28	<0.05
CANY	Lost Canyon Spring	5/7/2009	0.0002	157.15	438.90	22.24	8.29	<1	1.03	<0.01	<0.05
CANY	Maze Overlook	5/13/2008	0.0096	112.10	565.29	18.46	8.41	<1	1.63	<0.01	<0.05
CANY	Neck Spring	6/25/2008	0.0000	-	-	-	-	-	-	<0.01	<0.05
CANY	Old Bates Wilson Camp	6/12/2008	0.1200	102.63	886.75	13.30	8.24	2.02	-	<0.01	0.24
CANY	Peekaboo	6/11/2008	0.0000	97.79	1175.24	14.02	7.43	<1	-	<0.01	<0.05
CURE	Cimarron Campground	9/20/2008	0.0000	-	-	-	-	<1	12.10	<0.01	0.82
CURE	Dillon Gulch	9/18/2008	0.0047	100.62	208.34	11.81	7.93	<1	0.00	0.46	0.23
CURE	Soap Creek	9/17/2008	0.0154	89.43	192.04	11.06	7.76	5.21	0.67	0.29	0.14
HOVE	Goodman Point	5/19/2008	0.0045	41.70	1198.74	10.64	7.51	<1	7.52	6.4	0.13
HOVE	Hackberry House	5/20/2008	0.0151	64.92	663.10	11.47	7.52	<1	-	11	0.072
NABR	Kachina Alcove	5/18/2008	no surface water present								
NABR	Kachina Bridge	5/18/2008	0.4500	88.31	456.23	9.36	8.40	<1	1.41	0.26	<0.05
NABR	Owachomo Bridge	5/21/2008	0.0000	102.15	506.71	20.84	8.28	<1	2.42	<0.01	<0.05
NABR	Sipapu	5/21/2008	0.0013	65.68	663.04	14.87	8.15	<1	4.72	<0.01	<0.05

Appendix D. Raw Macroinvertebrate Data for Sampled Springs

Table 1. Raw abundance of organisms at sampled springs in Arches National Park. OLI = Subclass Oligochaeta, COL = Coleoptera, DIP = Diptera, EPH = Ephemeroptera, HEM = Hemiptera, ODO = Odonata, TRI = Trichoptera, AMP = Amphipoda, DEC = Decapoda, BAS = Basommatophora

			Unit	ARCH	ARCH	ARCH	ARCH	ARCH	ARCH
			Location	Freshwater	Lost Spg	Lwr Courthouse	Poison Ivy	Sleepy Hollow	Upr Courthouse
			Sampling date	5/6/2009	5/9/2008	5/5/2009	6/9/2008	6/10/2008	5/5/2009
			Sampling method	Kick net	Aquarium net	Kick net	Aquarium net	Aquarium net	Kick net
			# of organisms	427	60	302	69	67	105
Order	**Family**	**Subfamily**	**Genus and species**						
OLI				0	0	0	0	0	1
COL	Dryopidae		*Helichus*	0	0	0	1	0	0
COL	Dytiscidae		*Agabus*	6	0	40	0	0	0
COL	Dytiscidae	Laccophilinae	*Laccophilus maculosus*	0	0	2	0	0	2
COL	Dytiscidae		*Liodessus obscurellus*	7	0	0	0	0	0
COL	Dytiscidae		*Rhantus*	1	0	0	0	0	0
COL	Dytiscidae		*Sanfilippodytes*	0	1	0	0	0	0
COL	Dytiscidae		*Stictotarsus*	0	0	0	0	0	72
COL	Dytiscidae			0	1	6	0	0	1
COL	Gyrinidae		*Gyrinus*	2	0	0	2	0	0
COL	Haliplidae		*Peltodytes*	0	0	0	0	2	0
COL	Hydrophilidae		*Berosus*	0	0	0	0	0	1
COL	Hydrophilidae		*Enochrus*	0	0	0	0	0	1
COL	Hydrophilidae		*Hydrochara*	0	0	0	0	0	1
COL	Hydrophilidae		*Paracymus*	0	5	0	2	0	0
COL	Hydrophilidae		*Tropisternus*	0	0	2	0	0	18
COL	Hydrophilidae			0	0	0	0	2	0
DIP	Ceratopogonidae	Ceratopogoninae	*Ceratopogon*	1	0	0	0	0	0
DIP	Chironomidae	Chironominae		82	3	28	3	0	0
DIP	Chironomidae	Orthocladiinae		3	2	3	0	0	1
DIP	Chironomidae	Tanypodinae		5	0	11	1	11	0
DIP	Chironomidae			2	2	5	0	4	0
DIP	Culicidae		*Culiseta*	0	2	0	0	0	0
DIP	Culicidae			1	0	3	0	0	0

Order	Family	Subfamily	Genus and species	Freshwater	Lost Spg	Lwr Courthouse	Poison Ivy	Sleepy Hollow	Upr Courthouse
DIP	Dixidae		*Dixella*	0	4	0	0	0	0
DIP	Dolichopodidae			0	0	1	0	0	0
DIP	Simuliidae		*Simulium*	1	0	32	0	0	0
DIP	Stratiomyidae		*Stratiomys*	2	0	0	0	0	0
DIP	Tabanidae		*Tabanus*	0	3	0	0	0	0
DIP	Tabanidae			1	0	0	0	0	0
DIP	Tipulidae		*Tipula*	0	0	0	1	0	0
EPH	Baetidae		*Callibaetis*	0	0	139	2	3	0
EPH	Baetidae			0	0	0	0	0	1
HEM	Corixidae	Corixinae	*Hesperocorixa*	2	0	0	0	0	0
HEM	Corixidae	Corixinae	*Sigara*	0	0	2	0	0	0
HEM	Corixidae			0	0	3	0	0	1
HEM	Gelastocoridae		*Gelastocoris*	0	0	0	0	0	2
HEM	Gerridae		*Aquarius*	0	0	0	5	0	0
HEM	Gerridae	Gerrinae	*Limnoporus*	0	0	0	0	0	2
HEM	Gerridae			3	0	3	0	3	0
HEM	Notonectidae		*Notonecta*	1	0	6	0	1	0
HEM	Notonectidae			0	0	0	0	10	0
ODO	Aeshnidae		*Aeshna umbrosa*	5	0	3	11	1	0
ODO	Aeshnidae		*Anax junius*	3	0	1	0	0	0
ODO	Aeshnidae			1	0	0	0	0	0
ODO	Coenagrionidae		*Argia*	0	37	0	2	0	0
ODO	Coenagrionidae		*Enallagma*	87	0	1	0	0	0
ODO	Coenagrionidae		*Ischnura*	17	0	0	0	0	0
ODO	Coenagrionidae			55	0	0	7	12	1
ODO	Lestidae		*Archilestes grandis*	0	0	0	1	0	0
ODO	Lestidae			25	0	0	0	0	0
ODO	Libellulidae		*Libellula saturata*	20	0	0	0	3	0
ODO	Libellulidae			3	0	0	0	0	0
TRI	Limnephilidae		*Limnephilus*	3	0	0	0	0	0
AMP	Gammaridae		*Gammarus*	0	0	0	21	0	0
AMP	Hyalellidae		*Hyalella*	22	0	0	0	0	0
DEC	Cambaridae	Cambarinae	*Orconectes virilis*	0	0	3	0	0	0

Order	Family	Subfamily	Genus and species	Freshwater	Lost Spg	Lwr Courthouse	Poison Ivy	Sleepy Hollow	Upr Courthouse
BAS	Physidae		*Physa*	66	0	8	10	15	0

Table 2. Raw abundance of organisms at sampled springs in Black Canyon of the Gunnison National Park and Curecanti National Recreation Area.

			Unit	BLCA	CURE	CURE	CURE
			Location	Poison Gulch	Cimarron Camp	Dillon Gulch	Soap Creek
			Sampling date	9/19/2008	9/20/2008	9/18/2008	9/17/2008
			Sampling method	Kick net	Aquarium net	Aquarium net	Kick net
			# of organisms	91	15	89	62
Order	**Family**	**Subfamily**	**Genus and species**				
Subclass Oligochaeta				7	0	0	2
Trombidiformes	Sperchontidae		Sperchon	0	0	5	0
Coleoptera	Dytiscidae		Agabus	15	0	1	0
Coleoptera	Dytiscidae		Dytiscus	1	0	0	0
Coleoptera	Dytiscidae		Hygrotus	2	0	0	0
Coleoptera	Dytiscidae		Liodessus	1	0	0	0
Coleoptera	Dytiscidae		Sanfilippodytes	0	4	0	0
Coleoptera	Elmidae		Heterlimnius corpulentus	0	0	3	4
Coleoptera	Helophoridae		Helophorus	2	0	0	0
Coleoptera	Hydraenidae		Hydraena	0	0	10	0
Coleoptera	Hydrophilidae		Hydrobius	1	4	0	0
Coleoptera	Hydrophilidae		Paracymus	0	2	0	1
Coleoptera	Scirtidae			0	0	9	1
Diptera	Chironomidae	Orthocladiinae		0	3	5	1
Diptera	Chironomidae	Tanypodinae		20	0	2	0
Diptera	Dixidae		Dixa	0	0	2	9
Diptera	Ephydridae			1	0	0	0
Diptera	Psychodidae		Maruina	0	0	1	2
Diptera	Simuliidae		Simulium	0	0	10	0
Diptera	Stratiomyidae		Euparyphus	0	2	0	0
Diptera	Stratiomyidae		Stratiomys	1	0	0	0
Diptera	Tipulidae		Antocha	0	0	1	0
Diptera	Tipulidae		Dicranota	0	0	2	1
Diptera	Tipulidae		Tipula	0	0	8	4
Ephemeroptera	Baetidae		Baetis	0	0	0	2

Order	Family	Subfamily	Genus and species	Poison Gulch	Cimarron Camp	Dillon Gulch	Soap Creek
Ephemeroptera	Baetidae		Callibaetis	34	0	0	0
Ephemeroptera	Baetidae			0	0	4	0
Heteroptera	Corixidae			1	0	0	0
Heteroptera	Gerridae		Aquarius	1	0	0	0
Heteroptera	Notonectidae		Notonecta	3	0	0	0
Odonata	Coenagrionidae			1	0	0	0
Plecoptera	Chloroperlidae		Sweltsa	0	0	0	6
Trichoptera	Limnephilidae		Hesperophylax	0	0	2	0
Trichoptera	Limnephilidae		Limnephilus	0	0	8	0
Trichoptera	Limnephilidae			0	0	6	2
Trichoptera	Rhyacophilidae		Rhyacophila vofixa group	0	0	0	1
Trichoptera	Uenoidae		Neothremma	0	0	0	7
Class Turbellaria				0	0	10	19

Table 3. Raw abundance of organisms at sampled springs in Canyonlands National Park, Island in the Sky and Maze Districts. ARTH = Arthropoda, CHOR = Chordata. TRO = Trombidiformes, COLL = Collembola, COL = Coleoptera, DIP = Diptera, EPH = Ephemeroptera, HEM = Hemiptera, ODO = Odonata, TRI = Trichoptera, ANU = Anura.

					Unit	ISKY	ISKY	ISKY	MAZE	MAZE	MAZE
					Location	Alcove Spg	Cabin Spg	Neck Spg	Chocolate Drops	Horseshoe Cyn	Maze Overlook
					Sampling date	5/8/2008	5/10/2008	5/10/2008	5/13/2008	5/15/2008	5/13/2008
					Sampling method	Aquarium net	Aquarium net	Aquarium net	Kick net	Kick net	Kick net
					# of organisms	14	30	22	122	109	68
Phylum	**Class**	**Order**	**Family**	**Subfamily**	**Genus and species**						
ARTH	Arachnida	TRO	Hydryphantidae		*Wandesia*	0	2	0	0	0	0
ARTH	Entognatha	COLL				0	1	0	0	0	0
ARTH	Insecta	COL	Dytiscidae		*Agabus*	2	0	0	8	1	1
ARTH	Insecta	COL	Dytiscidae		*Liodessus*	0	0	0	3	0	0
ARTH	Insecta	COL	Dytiscidae		*Rhantus*	0	0	0	0	3	0
ARTH	Insecta	COL	Dytiscidae		*Stictotarsus*	0	0	0	5	19	1
ARTH	Insecta	COL	Dytiscidae		*Thermonectus marmoratus*	0	0	0	2	0	1
ARTH	Insecta	COL	Dytiscidae		*Thermonectus*	0	0	0	6	0	0
ARTH	Insecta	COL	Dytiscidae		*Uvarus*	0	0	0	0	0	3
ARTH	Insecta	COL	Dytiscidae			1	0	0	5	26	8
ARTH	Insecta	COL	Gyrinidae		*Gyrinus*	0	0	0	6	2	8
ARTH	Insecta	COL	Hydraenidae		*Hydraena*	0	5	3	0	0	0
ARTH	Insecta	COL	Hydraenidae		*Ochthebius*	0	1	3	0	0	0
ARTH	Insecta	COL	Hydrophilidae		*Berosus*	0	0	0	1	0	0
ARTH	Insecta	COL	Hydrophilidae		*Paracymus*	1	1	1	0	1	0
ARTH	Insecta	COL	Hydrophilidae		*Tropisternus*	0	0	0	0	1	0
ARTH	Insecta	COL	Hydrophilidae			0	0	1	2	0	0
ARTH	Insecta	COL	Staphylinidae			0	5	3	0	0	0
ARTH	Insecta	DIP	Chironomidae	Chironominae		0	0	0	10	8	9
ARTH	Insecta	DIP	Chironomidae	Orthocladiinae		0	1	10	0	3	0
ARTH	Insecta	DIP	Chironomidae	Tanypodinae		2	0	0	0	0	3
ARTH	Insecta	DIP	Chironomidae			0	0	1	2	6	1
ARTH	Insecta	DIP	Culicidae		*Culiseta*	0	0	0	3	14	0
ARTH	Insecta	DIP	Stratiomyidae		*Caloparyphus*	1	4	0	0	0	0

Phylum	Class	Order	Family	Subfamily	Genus and species	Alcove Spg	Cabin Spg	Neck Spg	Chocolate Drops	Horseshoe Cyn	Maze Overlook
ARTH	Insecta	DIP				0	10	0	0	0	0
ARTH	Insecta	EPH	Baetidae		*Callibaetis*	6	0	0	28	11	12
ARTH	Insecta	HEM	Corixidae			0	0	0	1	0	0
ARTH	Insecta	HEM	Gerridae		*Aquarius*	0	0	0	0	2	1
ARTH	Insecta	HEM	Gerridae			0	0	0	6	4	5
ARTH	Insecta	HEM	Notonectidae		*Notonecta*	0	0	0	0	3	1
ARTH	Insecta	HEM	Notonectidae			0	0	0	3	2	9
ARTH	Insecta	ODO	Aeshnidae		*Aeshna umbrosa*	0	0	0	0	1	0
ARTH	Insecta	ODO	Aeshnidae			0	0	0	5	0	0
ARTH	Insecta	ODO	Coenagrionidae		*Argia*	1	0	0	6	0	2
ARTH	Insecta	ODO	Coenagrionidae			0	0	0	2	0	0
ARTH	Insecta	ODO	Lestidae		*Archilestes grandis*	0	0	0	14	0	2
ARTH	Insecta	ODO	Libellulidae		*Libellula saturata*	0	0	0	0	0	1
ARTH	Insecta	TRI	Limnephilidae		*Limnephilus*	0	0	0	1	0	0
CHOR	Amphibia	ANU	Bufonidae		*Bufo woodhousii*	0	0	0	3	2	0

Table 4. Raw abundance of organisms at sampled springs in Canyonlands National Park, Needles District. ARTH = Arthropoda, MOLL = Mollusca. TRO = Trombidiformes, COL = Coleoptera, DIP = Diptera, EPH = Ephemeroptera, HEM = Hemiptera, ODO = Odonata, TRI = Trichoptera, AMP = Amphipoda, BAS = Basommatophora.

					Unit	NEED	NEED	NEED	NEED	NEED	NEED
					Location	2.4 Mile Spg	Big Spg	Little Spg	Lost Cyn	Old Bates Wilson	Peekaboo Spg
					Sampling date	5/7/2008	5/7/2009	6/10/2008	5/7/2009	6/12/2008	6/11/2008
					Sampling method	Kick net	Kick net	Aquarium net	Kick net	Aquarium net	Aquarium net
					# of organisms	212	262	212	286	144	109
Phylum	**Class**	**Order**	**Family**	**Subfamily**	**Genus and species**						
ARTH	Arachnida	TRO	Arrenuridae		*Arrenurus*	0	0	0	1	0	0
ARTH	Arachnida	TRO	Sperchontidae		*Sperchon*	0	0	0	0	1	0
ARTH	Arachnida	TRO				0	0	0	3	0	0
ARTH	Insecta	COL	Dryopidae		*Helichus*	0	0	4	0	0	0
ARTH	Insecta	COL	Dytiscidae		*Agabus*	2	0	0	1	8	0
ARTH	Insecta	COL	Dytiscidae		*Dytiscus marginicollis*	0	0	0	2	0	0
ARTH	Insecta	COL	Dytiscidae		*Dytiscus*	0	0	0	2	0	0
ARTH	Insecta	COL	Dytiscidae	Laccophilinae	*Laccophilus maculosus*	0	0	0	1	0	0
ARTH	Insecta	COL	Dytiscidae		*Liodessus obscurellus*	0	0	0	3	0	0
ARTH	Insecta	COL	Dytiscidae		*Liodessus*	0	0	0	0	0	3
ARTH	Insecta	COL	Dytiscidae		*Rhantus*	0	2	1	0	0	0
ARTH	Insecta	COL	Dytiscidae		*Stictotarsus*	2	0	0	12	2	0
ARTH	Insecta	COL	Dytiscidae		*Thermonectus marmoratus*	0	1	0	0	0	0
ARTH	Insecta	COL	Dytiscidae			19	0	0	0	4	8
ARTH	Insecta	COL	Gyrinidae		*Gyrinus*	3	3	0	0	0	0
ARTH	Insecta	COL	Hydrophilidae		*Berosus*	0	0	0	11	0	0
ARTH	Insecta	COL	Hydrophilidae		*Tropisternus*	0	0	0	0	1	0
ARTH	Insecta	DIP	Ceratopogonidae	Ceratopogoninae	*Probezzia*	0	0	0	0	2	0
ARTH	Insecta	DIP	Chironomidae	Chironominae		12	50	74	5	25	18
ARTH	Insecta	DIP	Chironomidae	Orthocladiinae		0	25	0	0	6	0
ARTH	Insecta	DIP	Chironomidae	Tanypodinae		0	12	2	31	0	3
ARTH	Insecta	DIP	Chironomidae			0	0	2	4	1	0
ARTH	Insecta	DIP	Culicidae		*Culiseta*	2	0	3	0	0	17

Phylum	Class	Order	Family	Subfamily	Genus and species	2.4 Mile Spg	Big Spg	Little Spg	Lost Cyn	Old Bates Wilson	Peekaboo Spg
ARTH	Insecta	DIP	Dixidae		*Dixella*	0	0	15	0	0	0
ARTH	Insecta	DIP	Simuliidae		*Simulium*	0	0	0	0	37	0
ARTH	Insecta	EPH	Baetidae		*Baetis*	0	0	0	0	32	0
ARTH	Insecta	EPH	Baetidae		*Callibaetis*	101	109	44	45	1	1
ARTH	Insecta	EPH	Baetidae			0	0	0	0	0	2
ARTH	Insecta	HEM	Corixidae			0	0	0	1	0	0
ARTH	Insecta	HEM	Gelastocoridae		*Gelastocoris oculatus*	0	0	0	0	0	2
ARTH	Insecta	HEM	Gerridae		*Aquarius*	0	0	5	0	1	0
ARTH	Insecta	HEM	Gerridae	Gerrinae	*Limnoporus*	0	6	0	4	0	0
ARTH	Insecta	HEM	Gerridae			15	0	9	9	6	7
ARTH	Insecta	HEM	Notonectidae		*Notonecta*	0	4	0	24	0	0
ARTH	Insecta	HEM	Veliidae	Microveliinae	*Microvelia*	0	1	0	2	0	0
ARTH	Insecta	ODO	Aeshnidae		*Aeshna umbrosa*	0	12	5	0	1	0
ARTH	Insecta	ODO	Aeshnidae			0	0	10	4	0	0
ARTH	Insecta	ODO	Coenagrionidae		*Argia*	0	4	5	0	0	0
ARTH	Insecta	ODO	Coenagrionidae		*Enallagma*	0	4	0	37	0	0
ARTH	Insecta	ODO	Coenagrionidae		*Ischnura*	0	0	0	1	0	0
ARTH	Insecta	ODO	Coenagrionidae			0	6	0	75	0	0
ARTH	Insecta	ODO	Lestidae		*Archilestes grandis*	0	0	33	0	0	1
ARTH	Insecta	ODO	Lestidae			0	4	0	4	0	0
ARTH	Insecta	ODO	Libellulidae		*Libellula saturata*	0	1	0	1	0	0
ARTH	Insecta	ODO	Libellulidae			0	0	0	3	0	0
ARTH	Insecta	TRI	Limnephilidae		*Limnephilus*	32	17	0	0	0	0
ARTH	Insecta	TRI	Limnephilidae			0	1	0	0	0	0
ARTH	Malacostraca	AMP	Hyalellidae		*Hyalella azteca*	0	0	0	0	1	0
MOLL	Gastropoda	BAS	Physidae		*Physa*	0	0	0	0	15	47

Table 5. Raw abundance of organisms at sampled springs in Hovenweep National Monument and Natural Bridges National Monument. ANN = Annelida, ARTH = Arthropoda, MOLL = Mollusca. OLI = Subclass Oligochaeta, COL = Coleoptera, DIP = Diptera, EPH = Ephemeroptera, HEM = Hemiptera, ODO = Odonata, TRI = Trichoptera, BAS = Basommatophora.

					Unit	HOVE	HOVE	HOVE	NABR	NABR	NABR
					Location	Goodman Point	Hackberry 1	Hackberry 2	Sipapu	Owachomo	Kachina - Armstrong
					Sampling date	5/19/2008	5/20/2008	5/20/2008	5/21/2008	5/21/2008	5/22/2008
					Sampling method	Aquarium net	Aquarium net	Kick net	Kick net	Kick net	Kick net
					# of organisms	185	47	33	160	319	256
Phylum	**Class**	**Order**	**Family**	**Subfamily**	**Genus and species**						
ANN	Clitellata	OLI				4	0	0	0	1	1
ARTH	Insecta	COL	Dryopidae		*Helichus*	0	0	0	2	0	0
ARTH	Insecta	COL	Dytiscidae		*Liodessus obscurellus*	0	0	0	0	1	0
ARTH	Insecta	COL	Dytiscidae		*Sanfilippodytes*	3	0	0	1	3	0
ARTH	Insecta	COL	Dytiscidae		*Stictotarsus*	0	0	0	27	48	59
ARTH	Insecta	COL	Dytiscidae		*Uvarus*	0	0	0	4	0	0
ARTH	Insecta	COL	Dytiscidae			0	0	0	50	63	1
ARTH	Insecta	COL	Hydraenidae		*Ochthebius*	0	0	1	0	0	0
ARTH	Insecta	COL	Hydrophilidae		*Berosus*	0	0	0	0	5	0
ARTH	Insecta	COL	Hydrophilidae		*Paracymus*	13	0	0	0	0	0
ARTH	Insecta	DIP	Ceratopogonidae	Ceratopogoninae	*Probezzia*	0	0	0	0	0	1
ARTH	Insecta	DIP	Chironomidae	Chironominae		25	0	6	16	59	166
ARTH	Insecta	DIP	Chironomidae	Orthocladiinae		9	0	0	0	0	6
ARTH	Insecta	DIP	Chironomidae	Tanypodinae		0	30	20	0	3	0
ARTH	Insecta	DIP	Chironomidae			0	4	3	1	37	0
ARTH	Insecta	DIP	Culicidae		*Culiseta*	119	0	1	0	35	0
ARTH	Insecta	DIP	Muscidae			0	0	0	0	1	0
ARTH	Insecta	DIP	Tipulidae		*Tipula*	9	2	0	0	0	0
ARTH	Insecta	DIP	Tipulidae			3	0	0	1	0	0
ARTH	Insecta	EPH	Baetidae		*Callibaetis*	0	0	0	21	16	3
ARTH	Insecta	HEM	Corixidae			0	0	0	0	1	0
ARTH	Insecta	HEM	Gerridae		*Aquarius*	0	3	1	3	0	4
ARTH	Insecta	HEM	Gerridae			0	0	0	12	11	0
ARTH	Insecta	HEM	Notonectidae		*Notonecta*	0	0	0	2	3	0
ARTH	Insecta	HEM	Notonectidae			0	0	0	0	3	0

Phylum	Class	Order	Family	Subfamily	Genus and species	Goodman Point	Hackberry 1	Hackberry 2	Sipapu	Owachomo	Kachina - Armstrong
ARTH	Insecta	ODO	Aeshnidae		*Aeshna umbrosa*	0	0	0	1	4	11
ARTH	Insecta	ODO	Aeshnidae			0	0	0	0	3	0
ARTH	Insecta	ODO	Coenagrionidae		*Argia*	0	8	1	0	0	0
ARTH	Insecta	ODO	Lestidae		*Archilestes grandis*	0	0	0	0	1	0
ARTH	Insecta	TRI	Limnephilidae		*Limnephilus*	0	0	0	19	2	4
MOLL	Gastropoda	BAS	Physidae		*Physa*	0	0	0	0	19	0

Table 6. Raw abundance of organisms at sampled springs in the Moab Field Office, Part One. ANN = Annelida, ARTH = Arthropoda, CHOR = Chordata, MOLL = Mollusca. OLI = Subclass Oligochaeta, TRO = Trombidiformes, COL = Coleoptera, DIP = Diptera, EPH = Ephemeroptera, HEM = Hemiptera, ODO = Odonata, TRI = Trichoptera, ANU = Anura, BAS = Basommatophora.

					Unit	Moab FO	Moab FO	Moab FO	Moab FO	Moab FO
					Location	Pouroff Spg	Bartlett Wash	Courthouse	Cow Cyn	Dripping Spg
					Sampling date	5/20/2009	5/23/2009	7/17/2008	5/20/2009	5/20/2009
					Sampling method	Kick net	Aquarium net	Aquarium Net	Aquarium net	Kick net
					# of organisms	90	16	64	49	182
Phylum	**Class**	**Order**	**Family**	**Subfamily**	**Genus and species**					
ANN	Clitellata	OLI				0	1	14	2	0
ARTH	Arachnida	TRO	Arrenuridae		*Arrenurus*	0	0	0	0	3
ARTH	Arachnida	TRO				1	0	0	0	4
ARTH	Insecta	COL	Dytiscidae		*Agabus*	0	0	0	0	10
ARTH	Insecta	COL	Dytiscidae		*Dytiscus*	0	0	0	0	3
ARTH	Insecta	COL	Dytiscidae	Laccophilinae	*Laccophilus maculosus*	0	0	0	0	2
ARTH	Insecta	COL	Dytiscidae		*Liodessus obscurellus*	1	0	0	0	0
ARTH	Insecta	COL	Dytiscidae		*Rhantus*	0	0	2	0	0
ARTH	Insecta	COL	Dytiscidae		*Stictotarsus*	0	0	1	4	3
ARTH	Insecta	COL	Dytiscidae			2	0	2	0	6
ARTH	Insecta	COL	Gyrinidae		*Gyrinus*	3	0	0	0	1
ARTH	Insecta	COL	Haliplidae		*Peltodytes*	0	0	0	0	4
ARTH	Insecta	COL	Helophoridae		*Helophorus*	0	0	0	0	1
ARTH	Insecta	COL	Hydraenidae		*Hydraena*	0	0	0	1	0
ARTH	Insecta	COL	Hydraenidae		*Ochthebius*	0	2	0	1	0
ARTH	Insecta	COL	Hydrophilidae		*Berosus*	0	0	3	0	8
ARTH	Insecta	COL	Hydrophilidae		*Tropisternus*	0	0	5	0	7
ARTH	Insecta	DIP	Ceratopogonidae	Ceratopogoninae	*Ceratopogon*	0	0	0	0	2
ARTH	Insecta	DIP	Chironomidae	Chironominae		10	5	1	4	14
ARTH	Insecta	DIP	Chironomidae	Orthocladiinae		0	0	0	0	1
ARTH	Insecta	DIP	Chironomidae	Tanypodinae		1	0	1	2	5
ARTH	Insecta	DIP	Culicidae		*Anopheles*	0	0	0	0	5
ARTH	Insecta	DIP	Culicidae		*Culex*	0	7	0	0	1

Phylum	Class	Order	Family	Subfamily	Genus and species	Pouroff Spg	Bartlett Wash	Courthouse	Cow Cyn	Dripping Spg
ARTH	Insecta	DIP	Culicidae		*Culiseta*	2	0	3	31	0
ARTH	Insecta	DIP	Culicidae			0	0	0	0	1
ARTH	Insecta	DIP	Stratiomyidae		*Stratiomys*	0	0	4	0	0
ARTH	Insecta	DIP	Tabanidae		*Tabanus*	1	0	0	0	1
ARTH	Insecta	EPH	Baetidae		*Baetis*	0	0	0	0	3
ARTH	Insecta	EPH	Baetidae		*Callibaetis*	4	0	16	0	0
ARTH	Insecta	HEM	Corixidae			0	1	0	0	8
ARTH	Insecta	HEM	Gerridae	Gerrinae	*Limnoporus*	5	0	0	2	0
ARTH	Insecta	HEM	Gerridae			5	0	0	0	1
ARTH	Insecta	HEM	Notonectidae		*Notonecta*	9	0	1	0	12
ARTH	Insecta	ODO	Aeshnidae		*Aeshna californica*	4	0	0	0	0
ARTH	Insecta	ODO	Aeshnidae		*Aeshna umbrosa*	2	0	0	2	2
ARTH	Insecta	ODO	Aeshnidae		*Anax junius*	0	0	0	0	2
ARTH	Insecta	ODO	Coenagrionidae		*Enallagma*	4	0	0	0	17
ARTH	Insecta	ODO	Coenagrionidae		*Ischnura*	4	0	0	0	11
ARTH	Insecta	ODO	Coenagrionidae			7	0	3	0	8
ARTH	Insecta	ODO	Lestidae		*Lestes*	0	0	0	0	11
ARTH	Insecta	ODO	Lestidae			3	0	0	0	0
ARTH	Insecta	ODO	Libellulidae		*Libellula pulchella*	2	0	0	0	0
ARTH	Insecta	ODO	Libellulidae		*Libellula saturata*	0	0	1	0	1
ARTH	Insecta	ODO	Libellulidae			2	0	0	0	2
CHOR	Amphibia	ANU				5	0	0	0	3
MOLL	Gastropoda	BAS	Physidae		*Physa*	13	0	7	0	19

Table 7. Raw abundance of organisms at sampled springs in the Moab Field Office, Part Two. ARTH = Arthropoda, CHOR = Chordata, MOLL = Mollusca. COL = Coleoptera, DIP = Diptera, EPH = Ephemeroptera, HEM = Hemiptera, ODO = Odonata, TRI = Trichoptera, DEC = Decapoda, ANU = Anura, BAS = Basommatophora.

					Unit	Moab FO	Moab FO	Moab FO	Moab FO	Moab FO	Moab FO
					Location	Gatherer Cyn	Kane Spg	Mill Cyn	Moonflower	Seven Mile	Tusher Cyn
					Sampling date	5/19/2009	5/19/2009	7/17/2008	5/19/2009	6/10/2008	5/23/2009
					Sampling method	Kick net	Aquarium net	Aquarium Net	Kick net	Aquarium net	Aquarium net
					# of organisms	108	92	22	129	64	17
Phylum	Class	Order	Family	Subfamily	Genus and species						
ARTH	Insecta	COL	Dryopidae		*Helichus*	0	0	0	1	5	0
ARTH	Insecta	COL	Dytiscidae		*Agabus*	4	8	0	0	0	0
ARTH	Insecta	COL	Dytiscidae		*Hydroporus*	0	0	1	0	0	0
ARTH	Insecta	COL	Dytiscidae		*Rhantus*	3	0	1	5	2	0
ARTH	Insecta	COL	Dytiscidae		*Sanfilippodytes*	0	1	1	0	0	0
ARTH	Insecta	COL	Dytiscidae		*Stictotarsus*	0	4	7	0	0	0
ARTH	Insecta	COL	Dytiscidae		*Thermonectus marmoratus*	0	0	0	2	0	0
ARTH	Insecta	COL	Dytiscidae			1	4	0	0	0	0
ARTH	Insecta	COL	Gyrinidae		*Gyrinus*	10	0	0	8	6	0
ARTH	Insecta	COL	Hydraenidae		*Ochthebius*	0	1	1	0	0	0
ARTH	Insecta	COL	Hydrophilidae		*Enochrus*	0	1	0	0	0	0
ARTH	Insecta	COL	Hydrophilidae		*Hydrochara*	0	3	0	0	0	0
ARTH	Insecta	COL	Hydrophilidae		*Paracymus*	0	0	0	0	4	0
ARTH	Insecta	COL	Hydrophilidae		*Tropisternus*	1	3	0	0	0	0
ARTH	Insecta	DIP	Chironomidae	Chironominae		2	11	5	4	6	0
ARTH	Insecta	DIP	Chironomidae	Tanypodinae		5	2	0	3	1	0
ARTH	Insecta	DIP	Chironomidae			2	0	1	1	0	0
ARTH	Insecta	DIP	Culicidae		*Culex*	2	0	0	0	0	11
ARTH	Insecta	DIP	Culicidae			0	0	0	2	0	0
ARTH	Insecta	DIP	Dixidae		*Dixella*	5	0	0	2	0	0
ARTH	Insecta	DIP	Ephydridae			0	0	0	1	0	0
ARTH	Insecta	DIP	Simuliidae		*Simulium*	0	0	0	2	0	0
ARTH	Insecta	DIP	Stratiomyidae		*Euparyphus*	0	0	0	3	0	0
ARTH	Insecta	DIP	Tabanidae		*Tabanus*	0	0	0	0	4	0
ARTH	Insecta	DIP	Tipulidae			0	0	0	0	1	0

Phylum	Class	Order	Family	Subfamily	Genus and species	Gatherer Cyn	Kane Spg	Mill Cyn	Moonflower	Seven Mile	Tusher Cyn
ARTH	Insecta	EPH	Baetidae		*Baetis*	0	1	0	0	0	0
ARTH	Insecta	EPH	Baetidae		*Callibaetis*	26	1	0	0	1	0
ARTH	Insecta	EPH	Baetidae		*Fallceon quilleri*	0	7	0	0	0	0
ARTH	Insecta	EPH	Leptophlebiidae		*Paraleptophlebia*	0	0	0	0	1	0
ARTH	Insecta	HEM	Gerridae		*Aquarius*	0	0	4	0	5	0
ARTH	Insecta	HEM	Gerridae	Gerrinae	*Limnoporus*	0	4	0	2	0	0
ARTH	Insecta	HEM	Gerridae			3	0	0	3	0	4
ARTH	Insecta	HEM	Notonectidae		*Notonecta*	10	0	1	2	0	0
ARTH	Insecta	HEM	Veliidae	Microveliinae	*Microvelia*	0	0	0	1	0	0
ARTH	Insecta	ODO	Aeshnidae		*Aeshna umbrosa*	3	0	0	4	7	0
ARTH	Insecta	ODO	Aeshnidae			3	0	0	2	0	0
ARTH	Insecta	ODO	Coenagrionidae		*Argia*	0	1	0	14	5	0
ARTH	Insecta	ODO	Coenagrionidae		*Enallagma*	0	0	0	12	0	0
ARTH	Insecta	ODO	Coenagrionidae			0	0	0	16	0	0
ARTH	Insecta	ODO	Lestidae			8	0	0	3	0	0
ARTH	Insecta	ODO	Libellulidae		*Libellula saturata*	1	0	0	5	0	0
ARTH	Insecta	ODO	Libellulidae			3	0	0	1	0	0
ARTH	Insecta	TRI	Limnephilidae		*Limnephilus*	2	9	0	13	5	0
ARTH	Insecta	TRI	Limnephilidae			1	30	0	8	0	0
ARTH	Malacostraca	DEC	Cambaridae	Cambarinae	*Orconectes virilis*	1	0	0	0	0	0
CHOR	Amphibia	ANU				0	0	0	0	0	2
MOLL	Gastropoda	BAS	Physidae		*Physa*	12	1	0	9	11	0

Table 8. Raw abundance of organisms at sampled springs in the Monticello Field Office. ANN = Annelida, ARTH = Arthropoda, CHOR = Chordata, MOLL = Mollusca. OLI = Subclass Oligochaeta, TRO = Trombidiformes, COL = Coleoptera, DIP = Diptera, EPH = Ephemeroptera, HEM = Hemiptera, ODO = Odonata, TRI = Trichoptera, ANU = Anura, BAS = Basommatophora.

					Unit	Mont. FO	Mont. FO	Mont. FO	Mont. FO	Mont. FO	Mont. FO	Mont. FO
					Location	Dead Cow	Bull's Eye	Flag Butte	Kane Gulch	Lime Crk1	Lime Crk2	Owl Crk
					Sampling date	5/22/2009	7/15/2008	5/22/2009	7/16/2008	5/21/2009	5/21/2009	7/16/2008
					Sampling method	Aquarium net	Aquarium net	Kick net	Aquarium net	Kick net	Kick net	Aquarium net
					# of organisms	53	20	51	182	11	36	165
Phylum	Class	Order	Family	Subfamily	Genus and species							
ARTH	Insecta	COL	Dryopidae		*Helichus*	0	0	0	0	0	0	1
ARTH	Insecta	COL	Dytiscidae		*Agabus*	3	0	2	0	0	0	1
ARTH	Insecta	COL	Dytiscidae		*Dytiscus*	0	0	0	2	0	0	0
ARTH	Insecta	COL	Dytiscidae	Laccophilinae	*Laccophilus maculosus*	0	0	1	0	0	5	0
ARTH	Insecta	COL	Dytiscidae		*Liodessus obscurellus*	4	0	0	0	0	3	0
ARTH	Insecta	COL	Dytiscidae		*Rhantus*	0	0	1	0	0	0	0
ARTH	Insecta	COL	Dytiscidae		*Stictotarsus*	17	0	0	16	0	4	3
ARTH	Insecta	COL	Dytiscidae		*Uvarus*	0	0	0	0	0	0	3
ARTH	Insecta	COL	Dytiscidae			0	0	0	2	0	2	0
ARTH	Insecta	COL	Gyrinidae		*Gyrinus*	0	0	0	0	0	0	1
ARTH	Insecta	COL	Hydraenidae		*Ochthebius*	0	0	0	2	0	0	1
ARTH	Insecta	COL	Hydrophilidae		*Enochrus*	4	0	0	0	0	0	1
ARTH	Insecta	COL	Hydrophilidae		*Laccobius*	0	0	0	0	0	0	1
ARTH	Insecta	COL	Hydrophilidae		*Tropisternus*	0	0	1	0	0	1	0
ARTH	Insecta	COL	Hydrophilidae			0	0	0	0	0	0	1
ARTH	Insecta	DIP	Ceratopogonidae			2	0	0	0	0	0	0
ARTH	Insecta	DIP	Chironomidae	Chironominae		8	3	1	6	0	8	2
ARTH	Insecta	DIP	Chironomidae	Orthocladiinae		0	0	2	0	0	1	0
ARTH	Insecta	DIP	Chironomidae	Tanypodinae		0	0	3	2	0	0	26
ARTH	Insecta	DIP	Chironomidae			0	2	0	13	0	0	0
ARTH	Insecta	DIP	Culicidae		*Culex*	4	0	0	0	0	0	0
ARTH	Insecta	DIP	Culicidae		*Culiseta*	5	12	0	49	0	0	4
ARTH	Insecta	DIP	Tabanidae		*Tabanus*	1	0	0	0	0	2	0

Phylum	Class	Order	Family	Subfamily	Genus and species	Dead Cow	Bull's Eye	Flag Butte	Kane Gulch	Lime Crk1	Lime Crk2	Owl Crk
ARTH	Insecta	EPH	Baetidae		*Callibaetis*	1	3	12	64	0	2	103
ARTH	Insecta	HEM	Corixidae	Corixinae	*Corisella*	0	0	1	0	0	0	0
ARTH	Insecta	HEM	Corixidae	Corixinae	*Sigara*	0	0	1	0	0	0	0
ARTH	Insecta	HEM	Gelastocoridae		*Gelastocoris*	0	0	2	0	0	1	0
ARTH	Insecta	HEM	Gerridae		*Aquarius*	0	0	0	2	0	0	1
ARTH	Insecta	HEM	Gerridae			1	0	1	0	0	2	1
ARTH	Insecta	HEM	Notonectidae		*Notonecta*	0	0	1	2	0	0	0
ARTH	Insecta	HEM	Notonectidae			0	0	0	6	0	0	0
ARTH	Insecta	HEM	Veliidae	Microveliinae	*Microvelia*	1	0	1	0	0	0	0
ARTH	Insecta	ODO	Aeshnidae		*Aeshna umbrosa*	0	0	0	1	0	0	9
ARTH	Insecta	ODO	Aeshnidae		*Anax walsinghami*	0	0	2	0	0	0	0
ARTH	Insecta	ODO	Aeshnidae			0	0	0	0	0	0	2
ARTH	Insecta	ODO	Coenagrionidae		*Argia*	0	0	6	0	0	4	0
ARTH	Insecta	ODO	Coenagrionidae			0	0	4	0	0	0	0
ARTH	Insecta	ODO	Lestidae		*Archilestes grandis*	0	0	0	15	0	0	4
ARTH	Insecta	ODO	Libellulidae			0	0	7	0	0	0	0
ARTH	Ostracoda					0	0	0	0	11	0	0
CHOR	Amphibia	ANU	Pelobatidae		*Spea intermontana*	2	0	0	0	0	0	0
CHOR	Amphibia	ANU				0	0	0	0	0	1	0
MOLL	Gastropoda	BAS	Physidae		*Physa*	0	0	2	0	0	0	0