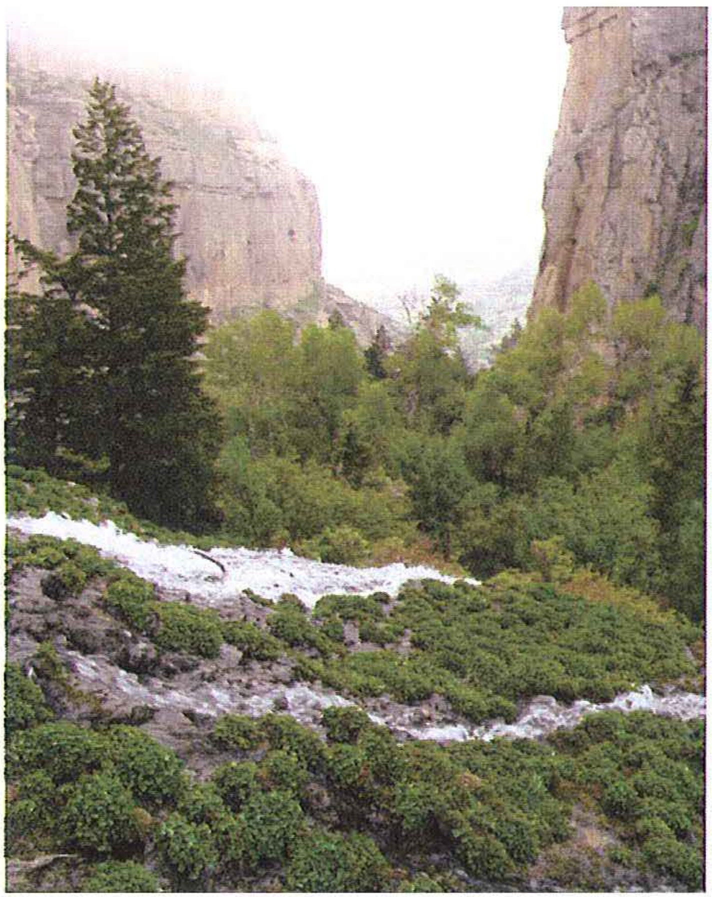
07-01

Aquatic Macroinvertebrate Inventory & Assessment of Springs and Seeps within Bighorn Canyon National Recreation Area (BICA)

Prepared for the:
Western National Parks Association and the Greater Yellowstone Network Inventory & Monitoring Program, National Park Service



Layout Creek Spring looking downstream

By:
David M. Stagliano
Aquatic Ecologist
March 2008

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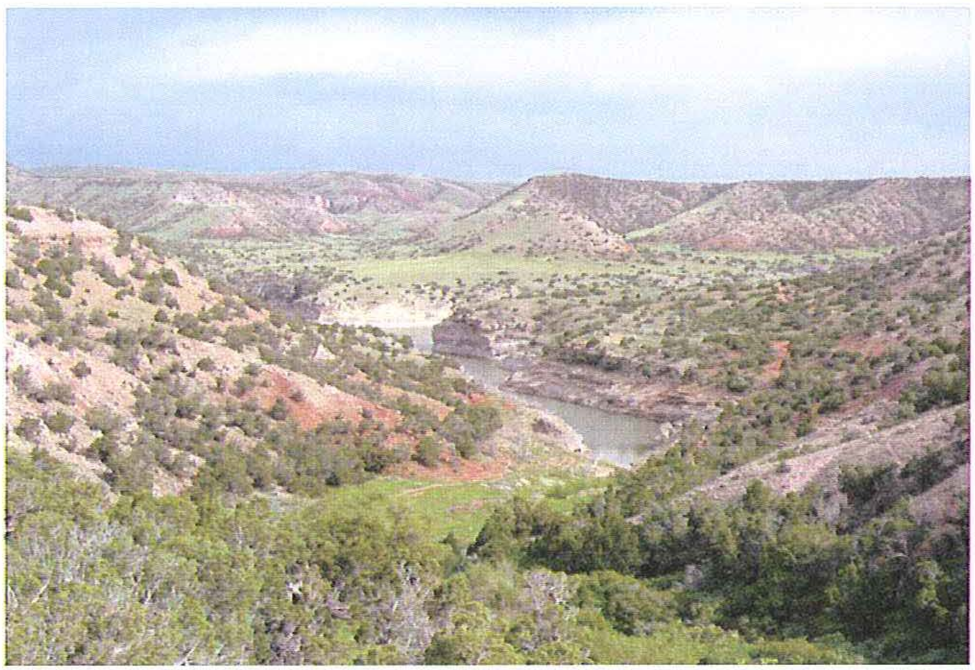

Acknowledgements

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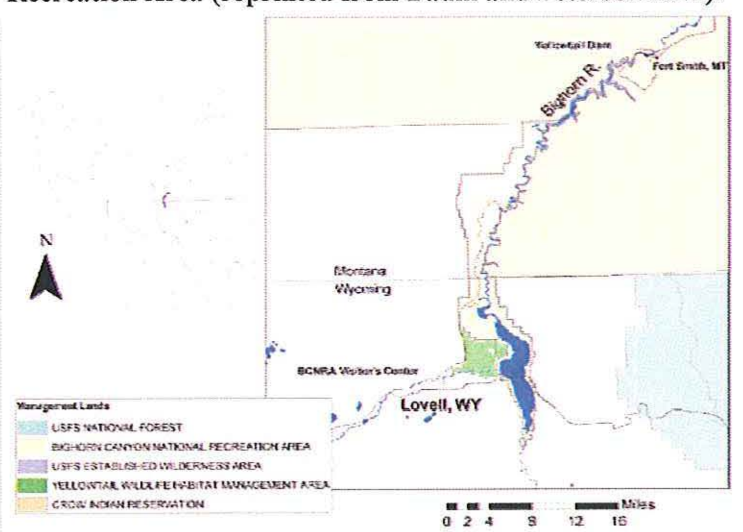
All photos in the report were taken by MTNHP personnel, unless otherwise noted

INTRODUCTION

Spring ecosystems in arid regions are oftentimes the only permanent water source in the uplands and provide essential habitat for a myriad of aquatic and terrestrial organisms (Erman 2002); they are essentially aquatic islands in a sea of desert (Thompson et al 2002). Riparian areas adjacent to springs can provide habitat to up to 75% of the available species diversity in arid regions (Shepard 1993). Spring ecosystems have evolved within a narrow set of environmental conditions strictly dependent on groundwater discharge (Shepard 1993). Discharge of springs within Bighorn Canyon National Recreation Area (BICA) has been found to be dependent on snowmelt-based groundwater reaching outflows as recently as weeks after melting, to as long as years after (D. Schmitz, pers. comm.). The mosaic of microhabitats in springs is largely due to stable, long-term flow rates (Perla & Stevens 2003), and perennial discharge has been linked to diverse, unique and often endemic flora and fauna (Myers 1995, Sada and Vinyard 2002). Aquatic macroinvertebrates can make up a substantial proportion of spring biodiversity. Aquatic species in spring ecosystems can display a high degree of endemism, often evolving to subtle cues in water chemistry (Arsufi 1993, Heino et al. 2003; Sada et al. 2005). Macroinvertebrate populations in springs of the Great Basin, Sierra Nevada, and Colorado Plateau are known to support endemic aquatic macroinvertebrates (Erman 2002; Hershler and Sada 2002; Sada and Herbst 2001). An initial survey of Great Basin Springs reported four new species of aquatic invertebrates (Myers 1995). A new species of the springsnail, *Pyrgalopsis* (the only species reported east of the continental divide) has recently been found in a Missouri River (Montana) spring (Hershler and Gustafson 2002). Even though most spring locations in BICA have been documented on USGS topographic maps, there has been no documentation of aquatic fauna occurring within these ecosystems.

Figure 1. Overview location of Bighorn Canyon National Recreation Area (reprinted from Baum and Peterson 2001).



Spring flora and fauna in BICA have only been investigated for the occurrence of rare riparian and wetland plants (ex. *Sullivantia hapemanii var. hapemanii*) (Heidel and Fertig 2000).

Therefore, a survey of spring fauna will substantially increase the known BICA species and document potentially rare, endemic or endangered species. Surveys in this area will fill data gaps, serve as a reference point for change detection, provide a baseline necessary for evaluating the rarity of different spring ecosystem types, and form an understanding of biological diversity and integrity at the local and ecoregional level. Many spring species have narrow environmental ranges (specialists) and therefore are susceptible to changes in water chemistry and habitat quality.

Our main objectives for this study include 1) an initial aquatic invertebrate faunal survey and bioassessment of targeted perennial BICA springs, 2) determining the environmental factors that determine biointegrity of the aquatic macroinvertebrate communities spring ecosystem, and 3) provide a sampling scheme and identify indicator measures (species richness, abundance, target species (i.e. endemics), etc.) with which to monitor spring diversity and biointegrity in the future. Achieving our objectives, especially the third, will allow park managers to monitor the status and changes of aquatic macroinvertebrate indicators over time within BICA springs. This process can be repeated every five years for any proposed spring-type monitoring protocol: an impaired (cattle or human impacted) sample and a reference (pristine) condition sample from each spring type.

Macroinvertebrate Collection & Analysis

We collected macroinvertebrate samples and habitat data May 19-22, 2007 from 21 priority BICA spring & seep sites (D. Schmitz, pers. comm.). Protocols dictated sampling for macroinvertebrates within 100m of origination of the spring, and this distance was usually much shorter (~0-25m from the orifice), especially for wall seeps. Additionally, we collected samples from the run-out channels of 5 springs where changing water & habitat conditions can lead to different invertebrate assemblages (Bear Spring, Layout Creek, Picket's Wall and Lockhart Springhouse{2}). Sampling methodology was site-specific, and largely dependent on the length and magnitude of the spring flow. Semi-quantitative field sampling protocols employed a minimum of 10 randomized 0.5m jabs or kicks allocated to all habitats within a spring reach using a standard 500 micron D-frame net or in shallow, low flow situations, an aquarium net. All substrates were disturbed and washed into the net (Photo 1, taken by D. Sasse). The contents of the ten individual samples were placed in a 40L bucket, washed and elutriated allowing mineral matter to remain on the bottom of the bucket, while inverts and organic materials are collected onto a 500 micron sieve, and placed in a 1L Nalgene container filled with 95% Ethanol (ETOH) for preservation. The mineral portion on the bottom of the bucket was scanned for caddisfly cases, snail or clam shells before returning it to the spring. For spring reaches at least 40m long and at least 10cm in depth a reach-wide composite type sample (EMAP reach-wide 10 transect protocol, Lazorchak et al. 1998) was used. Since EMAP protocols call for equal spacing of samples in the reach, this sampling can be more easily replicated for monitoring capabilities. The samples were processed (sorting, identification, and data analysis) by the author in Helena following MT Department of Environmental Quality's protocols (MT DEQ 2005).

Table 1. Impairment determinations from MMI and O/E (RIVPACS) models (from Jessup 2005, Feldman 2006).

Ecoregion	RIVPACS	MMI	Impairment Determination
Mountain	≥ 0.8 or ≤ 1.2	≥ 63	Not impaired
	< 0.8 or > 1.2	< 63	Impaired
Low Valley	≥ 0.8 or ≤ 1.2	≥ 48	Not impaired
	< 0.8 or > 1.2	< 48	Impaired
Eastern Plains	≥ 0.8 or ≤ 1.2	≥ 37	Not impaired
	< 0.8 or > 1.2	< 37	Impaired

Macroinvertebrates were enumerated & identified to the lowest taxonomic level using a 4-40x Stereo-zoom Microscope, imported into an Access-based EDAS database, and multimetric macroinvertebrate (MMI) metrics were calculated from the data (Jessup et al. 2005, Feldman 2006). Metric results were then scored using the MT DEQ criteria and each sample categorized as non-impaired or impaired according to specific threshold values (Table 1). Most BICA spring sites are categorized as Low Mountain/Valley (LVAL) and rated accordingly, although we did run an alternate MMI, as mountain or prairie for a QC check. The impairment threshold set by MT DEQ for the LVAL Index is **48**, thus any score above this threshold are considered unimpaired. The MMI score is based on metrics that measure attributes of benthic macroinvertebrate communities that change in response to stream condition changes (anthropogenically caused). Expected reference condition indicator species for perennial spring macroinvertebrate communities were derived from springs in the Northwestern Great Plains (NWGP)(Stagliano et al. 2006).

Spring Habitat Classification

The landscape surrounding the springs of the BICA is typical of the Pryor-Big Horn Foothills / Wyoming Basin ecoregion (Woods et al. 2002). Twenty-one springs identified as Wyoming Basin Perennial Spring Aquatic Ecological System Types (AES S005) were visited (Figure 2). All springs are initially classified into 2 types: *Limnocrenes*— non-linear flowing springs, lentic spring ecosystems that resemble small wetlands **(WPSS-Wetland /Ponded Seep Springs)**, and *Rheocrenes* – flowing water springs that may flow into perennial or ephemeral streams or may disappear into the ground some distance from their source (Table 2 & 3). Headgate Seep and Pentagon Spring were included into the WPPS classification because of their wetland seepage characteristics, but had some degree of directional flow. Secondarily, Rheocrenes can be separated into dispersed wall spring seeps, a.k.a. hanging gardens **(LVWS-Low, MVWS-Med or High Volume Wall Springs & Seeps)** or linear flowing channelized springs **(STCS-Single Thread Channel Springs) (Figure 2, Table 2)**. A rare form of hanging garden within BICA is the Karst wall rheocrene (photo left). Karst hanging gardens are assemblages of aquatic and semi-aquatic plants, including the sensitive *Sullivantia hapemanii*, and animals occurring at seeps on calcareous (limestone) canyon walls.

Pickett's Wall, a Karst wall rheocrene

Spring Habitat Evaluations. Overall, 6 of the 21 spring sites ranked good-excellent and 8 had fair habitat quality assessed by EPA's field RBP protocols (Table 2). Five sites were ranked slightly impaired, and 2 moderately to severely impaired. Highest site habitat scores were MVWS, LVWS wall seeps and STCS increasing in distance from previously occupied areas. Highest deductions to the riparian assessment scores were in-stream sediment, bare ground and bank trampling by cattle intrusions into the riparian zone. These intrusions were specifically noticeable and had very high impacts at North Davis and Lockhart Stockpond Springs. Human impacts on springs at historic ranches (intended or inadvertent) have resulted in many of the impairments seen at BICA springs, including the occurrence of non-native species. *Rorippa nasturtium* (watercress) is an obvious example of an introduced plant species occurring at 9 of 21 spring sites (personal observation), most of these sites are within the Hillsboro, Lockhart or Ewing-Snell Ranch areas or are adjacent to roadways.

Table 2. Spring Station information. Spring classes (LVWS, MVWS, STCS, WPSS) are assigned and described in the text. HHR=Habitat Health rank by riparian/stream evaluations (++) good-excellent, (+) fair-good, (-) poor, (--) degraded. C=conductivity in µs/sec, T=temp °C, Q=flow in liters/sec.

Station ID	Station Name	SPR#	Spring Class	UTM83 X	UTM83 Y	HHR	pH	C	Temp	Q L/s
B_BEARSPR_run	Bear Spring run	22	WPSS	717270	5002620	+	7.12	na	14.0	na
B_BEARSPR1	Bear Spring	22	WPSS	717270	5002620	-	7.10	na	12.0	na
B_CASS_SPR1	Cass Spring	33	STCS	716094	4999499	++	7.14	182	10.0	6.800
B_CATTRKSPR1	Cattrack Spring	13	STCS	717230	4998805	+	7.11	2004	11.3	0.078
B_FINLEYSPR1	Finley Spring nr Barrys Landing	29	STCS	45.1158	108.2106	++	6.97	1867	10.8	0.215
B_HDGTSEEP1	Headgate Seep	24	WPSS	713576	4996931	+	7.27	399	13.1	na
B_HIDDENSPR1	Hidden Spring	0	STCS	718192	4998344	++	6.88	1367	11.6	9.000
B_HLSBMNSPR1	Hillsboro Main Spring	7	MVWS	717144	4997926	++	7.20	578	10.2	9.883
B_HLSBSDSPR2	Hillsboro Side Spring2	6	LVWS	717230	4997814	+	7.48	479	9.9	0.027
B_LAYOUTSPR1	Layout Spring	4	MVWS	712782	4997451	++	7.74	316	5.4	6.097
B_LAYOUT_dn	Layout Bottom	4	MVWS	712782	4997451	++	7.74	316	8.0	6.097
B_LCKHOSSPR1	Lockhart Springhouse	19	STCS	716942	5001986	-	6.98	1260	10.0	0.308
B_LCKHOS_Run	Lockhart Spring run	19	STCS	716942	5001986	+	6.98	1260	12.0	0.308
B_LCKHOS_Run2	Lockhart spring run2	19	STCS	716942	5001986	+	6.98	1260	13.0	0.308
B_LCKSOSPR1	Lockhart South Spring	18	STCS	716744	5001901	+	6.88	1445	10.0	0.008
B_LOCKPNDSP1	Lockhart Stockpond	17	WPSS	716456	5001682	- -	7.18	2383	10.7	0.040
B_MASLOVSPR1	Mason-Lovell Spring	1	WPSS	724616	4967924	-	6.88	1514	15.5	0.013
B_NDAVISPR1	N Davis Spring	21	STCS	716466	5002406	- -	7.13	1746	10.3	0.015
B_PENTAGSPR1	Pentagon Spring	15	WPSS	714074	4998991	-	6.77	433	8.8	na
B_PICKETSPR1	Pickett's Wall Seep	10	LVWS	717541	4998619	+	6.89	875	8.7	na
B_PICKETS_run	Pickett's Wall_ runout	10	LVWS	717541	4998619	+	7.20	875	12.0	na
B_RICKSSPR1	Rick's Spring	20	STCS	716910	5002153	+	6.66	1195	11.5	0.150
B_SORENSPR1	Sorenson spring	3	STCS	715222	4995906	-	7.58	427	9.4	4.410
B_TRCPGDSPR1	Trail Creek CG-Main	27	MVWS	718131	4998500	++	6.86	1844	10.8	0.660
B_TRCPGDSPR2	Trail Creek CG 2	28	LVWS	718131	4998517	+	6.72	1286	9.5	0.230
B_TYLTORSPR1	Tyler's Torrent	8	STCS	717473	4998020	+	6.94	1105	9.4	0.238

Figure 2. Location (A), classification (B) and biointegrity (C) of sampled BICA springs with magnification of MT spring sites; only one spring was sampled in WY (Mason-Lovell, Spr #1-white circle). Spring number, biointegrity rankings and class types (LVWS, MVWS, STCS, WPSS) are assigned and described in the text and in Table 3.

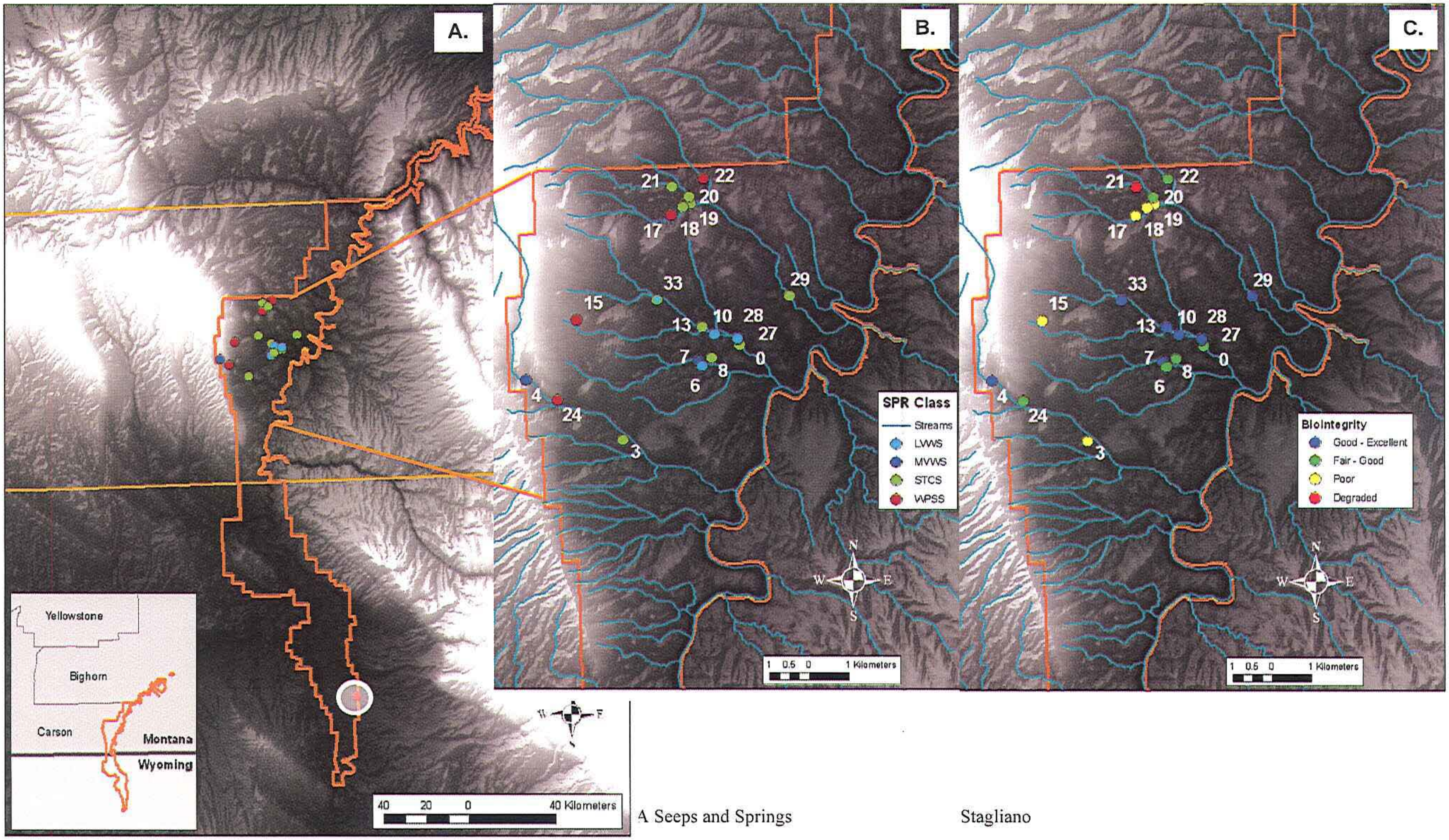


Table 3. Spring Habitat Types with representatives of differing ecological integrity classes.

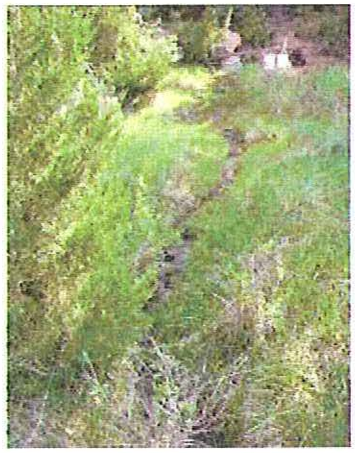
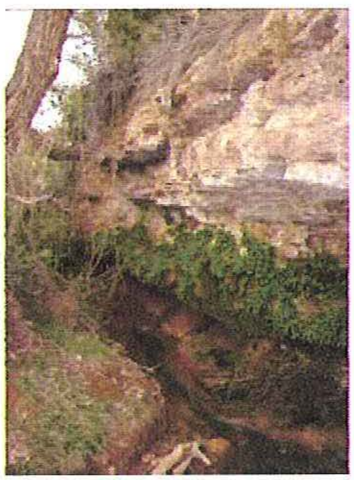
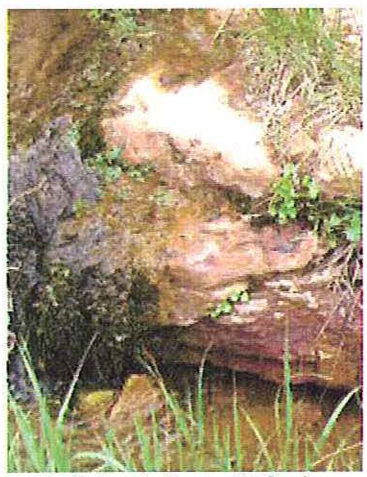
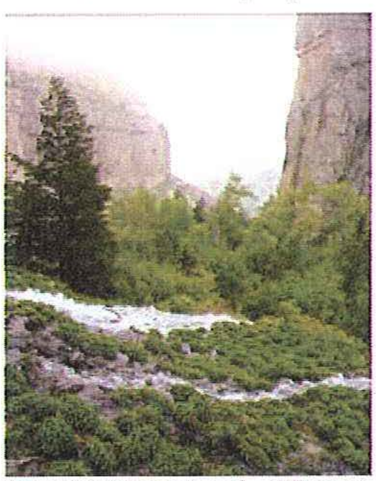
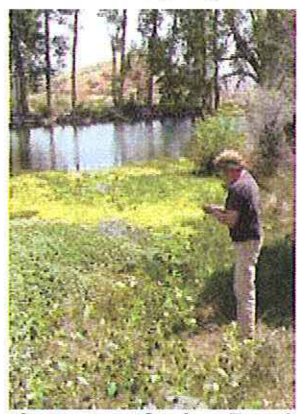
BICA Spring Classification	High Quality Ecological Condition	Moderate Ecological Condition	Impaired Ecological Condition
Rheocrenes **– directional flowing water springs & seeps that may flow into perennial or ephemeral streams.**			
1) Single Thread Channel Springs (STCS)	 Cass, Finley Spring (photo), Lockhart Spring Run	 Cattrack, Hidden, Rick's (photo), Sorenson, Tyler's Torrent Spring	 North Davis (photo), Lockhart South Spring Lockhart Springhouse
2) Low Volume Wall Springs & Seeps (LVWS)	 Pickett's Wall Spring	 Trail Creek Camp #2 Spring (Above), Hillsboro Side Spring	No representative of an impaired wall spring
3) Med-High Volume Wall Springs & Seeps (MVWS)	 Layout Spring (above), Hillsboro Main Spring	 Trail Creek Campground Main Spring	No representative of an impaired wall spring

Table 3 (cont).

BICA Spring Classification	Non-Impaired	Slightly-Impaired	Impaired
Limnocrenes **– non-linear flowing spring water, lentic spring ecosystems that resemble small wetlands**			
1) Wetland / Ponded Seep Springs (WPSS)	 **Headgate Seep Spring**	 **Bear (above) & Pentagon Spring**	 **Mason-Lovell Spring**
2) Artificially Created Wetland / Ponded Springs (WPSS)	**No representative of an un-impaired ponded spring**	 **Sorenson Spring Pond**	 **Lockhart Stockpond**

Aquatic Macroinvertebrate Community Results

Overall, 146 macroinvertebrate taxa were identified from 21 springs (26 samples) within the 4 habitat types. Diptera (true flies) were the richest order with 69 taxa, followed by Trichoptera (caddisflies) and Coleoptera (beetles) with 19 taxa apiece (Appendix A). The most diverse site was Layout Spring with 33 total taxa, and the most diverse spring class type is the Med-High Volume Wall Spring (n=4) averaging 27 taxa per sample. Low Volume Wall Springs (n=4) and Single Thread Channel Springs (n=11) had similar avg. richness at ~20 taxa, while Wetland Seep Springs (n=7) had significantly lower richness averaging ~13 taxa. Twenty-four of the 26 samples were processed completely (every invertebrate was picked), and in 20 of those cases, the minimum number of organisms was still not reached (only 2 had to sub-sampled).

No species of concern, threatened or endangered invertebrate species were collected during the surveys. Two introduced species were reported, the wide-ranging amphipod, *Hyalella azteca*

(Sorenson Spring), and the snail, *Pseudosuccinea columella* (Hidden, Pickett's & Sorenson Springs). A number of cold-water, habitat-restricted, sensitive taxa (14 spp.) were found only at Layout Creek spring (see table), with a few of those taxa found additionally at Hidden, Rick's, Pickett's Wall, Trail Creek Campground Main and the runout of Lockhart Springs. Four free-living, predatory caddisflies: *Rhyacophila verrula* (photo 3), *R. oreta, R. brunnea gr. & R. rotunda* were only found together at Layout Spring (Inset Table).

Unique "Cool" Taxon	Layout Creek	Other BICA Sites
Stoneflies		
Malenka sp.	+	-
Paraperla cf. frontalis	+	-
Sweltsa sp.	+	-
Zapada oregonensis	+	-
Mayflies	+	
Ameletus similior		-
Baetis bicaudatus	+	-
Caddisflies		
Rhyacophila verrula	+	-
Rhyacophila oreta	+	+(3)
Rhyacophila brunnea gr.	+	+(1)
Rhyacophila rotunda	+	-
Homophylax	+	-
Neothremma alicia	+	-
True Flies		
Boreochlus persimilis	-	+
Cardiocladius	+	+(2)
Paraphaenocladius	+	+(2)
Pagastia	+	-
Diplocladius	+	-
Eukiefferiella brehmi gr.	+	+(2)
E. devonica gr.	+	-
E. pseudomontana gr.	+	-
Krenosmittia	+	+(1)

- Ecologically-important spring indicator taxa (Stagliano 2006), the stonefly-*Amphinemura banksi*, the riffle beetle-*Optioservus quadrimaculatus* and the mayfly-*Baetis tricaudatus* were reported from 16 BICA spring sites, the tipulids *Dicranota* and *Tipula* at 10 sites, the diptera, *Caloparyphus* (7), the beetle, *Hydroporus* (7), and the caddisfly, *Hesperophylax designatus* at 6 sites (Table 3). Indicator taxa of ecologically "healthy" springs at BICA, that were not reported from NWGP springs, were the Chironomidae *Brillia;* the riffle beetle, *Heterlimnius corpulentus*; caddisfly-*Lepidostoma unicolor;* and predatory stonefly; *Hesperoperla pacifica* (photo 4) found at 16, 14, 12 & 13 sites, respectively (Table 3, Appendix I).

- Total taxa richness at a site was not a good overall indicator of biointegrity. For example Bear Spring run, Cattrack and Finley's had low richness for a STCS (13-15 taxa), but still reported good ecological rankings. Conversely, Lockhart Stockpond, Mason-Lovell and N. Davis Springs had 17 taxa, but were ecologically impaired.

Photo 3. *Rhyacophila verrula,* a sensitive caddisfly reported only from Layout Spring

Photo 4. *Hesperoperla pacifica,* a predatory stonefly "healthy spring" indicator species.

Table 3. Indicator taxa of good to excellent ecological integrity in NWGP and BICA rheocrene perennial springs. (++) = highly significant indicator, (+) = significant, (-) = not significant or not found in spring ecosystem.

Indicator Taxon	NWGP	BICA
Stoneflies		
Amphinemura banksi	++	++
Hesperoperla pacifica	-	++
Mayfly		
Baetis tricaudatus	++	++
Caddisflies		
Hesperophylax cf. designatus	++	+
Lepidostoma unicolor	-	++
Damselfly		
Argia	+	-
Beetles		
Optioservus	++	++
Heterlimnius corpulentus	-	++
Hydroporus	+	+
Oreodytes	+	-
Diptera (True Flies)		
Brillia	-	++
Caloparyphus	+	+
Dicranota	+	+
Dixa	+	+
Euparyphus	-	+
Heleniella	+	-
Odontomesa	+	-
Ormosia	+	+
Pedicia	+	-
Parametriocnemus	-	++
Pseudodiamesa	+	-
Radotanypus	+	-
Tvetenia bavarica Gr.	-	++
Tipula	+	+

- Lower taxa richness was recorded directly at the spring orifice than in samples taken just a few meters downstream (Pickett's Wall, Trail Creek Campground Main), and this is especially true of modified springs (ex. Sorenson's, Lockhart Springhouse). In addition, the runouts from spring origins acquired additional taxa along an increasing temperature and habitat gradient. ****Example***: Bear Spring's (a slightly-impaired WPSS) runout just 20m from the source gained enough rheocrene indicator taxa to classify as a non-impaired STCS (Table 4).

- Using MT DEQ's MMI, 15 of the 26 spring samples sites were ranked non-impaired (good to excellent biological integrity), 8 were slightly impaired and 3 was severely impaired (Table 4). There were numerous discrepancies between biological community scores & ecological health. ****Example 1:*** Mason-Lovell is a silted, impaired WPSS with low numbers of macroinvertebrates, but ranked high with both MMI evaluations. ****Example 2:*** Hidden Spring is in good ecological health, has high taxa richness and # of BICA indicator species, but ranked severely impaired by both MMI evaluations.
- Pickett's Wall run and Layout Creek Spring were the only samples to be ranked similarly by all integrity measures. Without considering the alternative MMI and NWGP taxa (Table 4), the sites with the highest ranking agreements are: Bear_run, Cass, Headgate, Hillsboro Main and Side Springs, Layout (both), Trail Creek Campground Main and #2 Springs.

Results from the habitat and macroinvertebrate surveys combined to rank the following sites:

***Overall BICA Perennial Spring Aquatic Ecological System Condition and Biological Integrity* (in order of highest integrity to worst by spring class type):**

1) **Med-High Volume Wall Springs (MVWS)-**1) Layout Creek, 2) Trail Creek Campground Main and 3) Hillsboro Main Spring.
2) **Low Volume Wall Springs (LVWS)-**1) Pickett's Wall Spring + run, 2) Trail Creek Campground #2, 3) Hillsboro Side Spring.
3) **Single Thread Channel Springs (STCS)-** 1) Cass, 2) Finley 3) Rick's 4) Lockhart Spring Run, 5) Hidden, 6) Cattrack 7) Sorenson, 8) Tyler's Torrent, 9) Lockhart South 10) Lockhart Springhouse, 11) North Davis Spring
4) **Wetland / Ponded Springs (WPSS)-**1) Headgate Seep, 2) Bear, 3) Pentagon 4) Mason-Lovell Spring, 5) Lockhart Pond Spring

Table 4. Aquatic integrity ranking of all inventoried sites. Total number of invertebrates, total taxa richness (T_Taxa), LVAL and Alternative (MTN or Plains) MMI scores and expected aquatic communities assessed against similarly classified reference sites (Observed/ Expected). (++) = high biological integrity, (+) = good integrity, (-) = slightly impaired, (--) = moderate to severely impaired biological community. Shaded-cells represent good to excellent scores above set thresholds.

StationID	Spr #	Total Ind.	T_Taxa	LVAL MMI Score	MMI Rank	Alt. MMI Score	Alt. MMI Rank	# NWGP spring taxa	% ref. spring taxa	# BICA ID taxa	% BICA spring taxa
B_BEARSPR_run	22	106	13	49.8	+	53.9	+	3	18.8	7	41.2
B_BEARSPR1 (L)	22	64	11	56.2	+	31.9	-	3	18.8	0	0.0
B_CASS_SPR1	33	186	24	56.9	+	48.6	-	5	31.3	11	64.7
B_CATTRKSPR1	13	183	15	80.0	++	49.6	-	4	23.5	5	29.4
B_FINLEYSPR1	29	175	15	57.5	+	40.4	-	5	31.3	7	41.2
B_HDGTSEEP1(L)	24	386	24	66.3	++	38.3	-	6	35.3	7	41.2
B_HIDDENSPR1	0	80	26	28.2	--	26.5	--	4	25.0	7	41.2
B_HLSBMNSPR1	7	123	24	65.2	+	48.7	-	5	31.3	10	58.8
B_HLSBSDSPR2	6	210	22	49.8	+	37.9	-	5	31.3	10	58.8
B_LAYOUT_LOW	4	154	24	83.0	++	61.4	+	5	31.3	8	47.1
B_LAYOUTSPR1	4	272	33	68.1	+	63.9	++	6	37.5	7	41.2
B_LCKHOS_Run	19	150	18	19.7	--	21.9	--	5	31.3	9	52.9
B_LCKHOS_Run2	19	161	20	32.6	-	28.3	-	5	31.3	9	52.9
B_LCKHOSSPR1	19	23	6	33.5	-	4.6	--	0	0.0	0	0.0
B_LCKSOSPR1	18	297	17	19.7	--	21.7	--	3	18.8	10	58.8
B_LOCKPNDSP	17	207	13	34.5	-	19.6	--	0	0.0	1	5.9
B_MASLOVSP (L)	1	96	17	76.5	++	69.5	++	2	11.8	2	11.8
B_NDAVISPR	21	106	17	49.4	+	31.1	-	3	18.8	2	11.8
B_PENTAGSP (L)	15	40	7	36.4	-	15.1	--	3	18.8	2	11.8
B_PICKETS_run	10	146	24	47.2	+	53.5	+	7	43.8	10	58.8
B_PICKETSPR1	10	31	8	57.2	+	35.2	-	4	25.0	4	23.5
B_RICKSSPR1	20	388	29	34.8	-	31.1	-	9	56.3	9	52.9
B_SORENSPR1	3	256	21	37.8	-	30.9	-	4	25.0	4	23.5
B_TRCPGDSPR1	27	261	27	56.4	+	46.5	-	6	37.5	14	82.4
B_TRCPGDSPR2	28	345	25	51.0	+	43.2	-	6	37.5	14	82.4
B_TYLTORSPR1	8	357	17	33.2	-	42.1	-	4	25.0	6	35.3

Discussion

Although we did not discover any new species during our initial BICA spring surveys, the potential for documenting additional macroinvertebrate taxa in these systems certainly exists. Many of these aquatic insects can only be taxonomically identified to species with adult male specimens. Thus, without collecting adults which can be time consuming and labor intensive, we may never know if a "new species to science" dwells within the spring ecosystems of BICA. It is very likely that intensive surveys over multiple seasons could conceivably double our 146 aquatic taxa list. Although in a study that intensively collected invertebrates from 28 springs in the Great Basin, a total of 141 taxa were documented, 58 of these were caddisfly species (Myers and Resh 2002). We identified almost 3 times the number of Diptera (true fly) taxa than that study, but only 19 caddisfly species. Further, faunal responses to environmental gradients tend to be individualistic and taxon-specific, and since we have identified multiple taxa to the genus-level, species shifts from one spring to the next would occur without detection. Springs and wetlands in arid landscapes are characterized by isolation and unpredictable colonization events—BICA springs may be in close enough proximity to mountain stream taxa (Pryors and Bighorns) to allow population connectivity and genetic flow preventing speciation events. During this study, we have documented important sources of aquatic biodiversity within this arid recreation area, and sampled those using protocols that are repeatable and scientifically credible for park resource managers to implement in long-term monitoring programs. Given limited funding and time, we did not get a chance to analyze water chemistry parameters and macroinvertebrate community structure. Spring permanence, discharge and disturbance are the primary diversity drivers in most spring ecosystems, but further discriminant analysis has indicated even small changes in temperature, conductivity, alkalinity, and elevation were responsible for further explanation of species composition structure across spring ecosystems (Myers and Resh 2002). The widest variation of the water chemistry parameters in BICA was conductivity (182-2343 µs/sec), and in some cases this was correlated with low-flow, impacted ponded areas (Lockhart Pond Spring and Mason-Lovell), but in others, high values were more related to subsurface geology (Trail Creek Campground Springs). How naturally high levels of ions in BICA springs effects macroinvertebrate communities is worth further study.

Conclusions & Recommendations

Spring macroinvertebrate diversity and richness in BICA is positively related to discharge (water flow) and negatively related to anthropogenic factors (spring diversions, orifice manipulations, stream habitat degradation). Wall springs were least likely to be human-impacted due to there position in the landscape. Medium-high volume wall springs had the highest macroinvertebrate diversity and biointegrity, and taxa richness decreased down the gradient with single thread channel springs, until the lowest diversity was recorded at impaired low flow wetland springs.

- In terms of monitoring BICA spring macroinvertebrate communities: 10 composite dipnet samples per site often did not collect the minimum number of organisms (300) for the MMI metrics. <u>Low numbers of macroinvertebrates are known to cause discrepancies with MMI scores (Feldman, pers. comm).</u> Replicate samples within a spring reach could be added to obtain more organisms, but this will increase field and lab processing time and costs.
- <u>The DEQ Low Mountain/Valley MMI performed fairly well at determining biological integrity of rheocrenes, although limnocrene spring-types and low invertebrate numbers in the samples seemed to affect it's detection capabilities significantly</u> (Mason-Lovell & Bear Spring were over-ranked, while Lockhart South and Hidden Spring were under-ranked).
- Expected reference condition indicator species for spring macroinvertebrate communities that were derived from springs in the Northwestern Great Plains (NWGP) did not perform well in distinguishing ecological integrity of BICA springs, <u>therefore, we derived a new set of indicator species reflecting reference condition rheocrene spring conditions.</u>
- <u>Good to excellent macroinvertebrate community integrity of rheocrene springs had at least 7 of the 17 BICA Indicator Species present, and usually more than 20 total taxa.</u> For limnocrene (WPSS) biointegrity, the LVAL MMI usually over-valued their condition.
- Significant anthropogenic factors (i.e. water diversions, improper grazing practices) still exist and historic or current agricultural activities (e.g. Lockhart, Ewing-Snell Ranches) are continuing to threaten biological integrity of numerous springs in BICA. **<u>The easiest recommendation to make is to maintain adequate cattle fencing around these sensitive riparian spring areas.</u>** Springs undergoing riparian protection measures (i.e. fencing, revegetation) can be monitored for water and biological quality improvements on a yearly or multiple-year basis, until habitat quality and biointegrity trends start to improve.

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Appendix A. Macroinvertebrate Species List for all BICA samples. Number of samples the taxon occurred (# of S) and the Frequency of Occurrence (F of O). Grey Shaded =*Rheocrene* Indicator taxa, Underlined = Coldwater Dependent taxa, Red Shaded are introduced species.

Order	Family	Final Taxa ID	# of S	% Fof O
Beetles				
Coleoptera	Dryopidae	*Helichus lithophilus*	2	7.7
Coleoptera	Dytiscidae	*Agabus*	4	15.4
Coleoptera	Dytiscidae	*Coptotomus longulus*	1	3.8
Coleoptera	Dytiscidae	*Hydroporus*	7	26.9
Coleoptera	Dytiscidae	*Laccophilus*	1	3.8
Coleoptera	Elmidae	*Cleptelmis addenda*	2	7.7
Coleoptera	**Elmidae**	***Heterlimnius corpulentus***	12	46.2
Coleoptera	Elmidae	*Microcylloepus pusillus*	1	3.8
Coleoptera	Elmidae	*Narpus concolor*	3	11.5
Coleoptera	**Elmidae**	***Optioservus sp.***	3	11.5
Coleoptera	**Elmidae**	***Optioservus quadrimaculatus***	16	61.5
Coleoptera	Elmidae	*Ordobrevia nubifera*	2	7.7
Coleoptera	Haliplidae	*Haliplus*	2	7.7
Coleoptera	Haliplidae	*Peltodytes*	1	3.8
Coleoptera	Hydraenidae	*Hydraena*	1	3.8
Coleoptera	Hydrophilidae	*Hydrobius*	7	26.9
Coleoptera	Hydrophilidae	*Laccobius*	1	3.8
Coleoptera	Hydrophilidae	*Paracymus*	1	3.8
Coleoptera	Hydrophilidae	*Tropisternus lateralis*	1	3.8
True Flies				
Diptera	Ceratopogonidae	*Bezzia/Palpomyia*	3	11.5
Diptera	Ceratopogonidae	*Ceratopogon*	2	7.7
Diptera	Ceratopogonidae	*Culicoides*	4	15.4
Diptera	Ceratopogonidae	*Dasyhelea*	1	3.8
Diptera	Ceratopogonidae	*Probezzia*	2	7.7
Diptera	Chironomidae	*Boreochlus persimilus*	1	3.8
Diptera	**Chironomidae**	***Brillia***	14	53.8
Diptera	Chironomidae	*Cardiocladius*	5	19.2
Diptera	Chironomidae	*Chaetocladius*	5	19.2
Diptera	Chironomidae	*Corynoneura*	3	11.5
Diptera	Chironomidae	*Cricotopus*	7	26.9
Diptera	Chironomidae	*Cricotopus bicinctus Gr.*	2	7.7
Diptera	Chironomidae	*Cryptochironomus*	1	3.8
Diptera	Chironomidae	*Diamesa*	2	7.7
Diptera	Chironomidae	*Dicrotendipes*	2	7.7
Diptera	Chironomidae	*Diplocladius*	1	3.8
Diptera	Chironomidae	*Doithrix*	1	3.8
Diptera	Chironomidae	*Eukiefferiella*	2	7.7
Diptera	Chironomidae	*Eukiefferiella Brehmi Gr.*	2	7.7
Diptera	Chironomidae	*Eukiefferiella Devonica Gr.*	1	3.8
Diptera	Chironomidae	*Eukiefferiella Pseudomontana Gr.*	1	3.8
Diptera	**Chironomidae**	***Heleniella***	3	11.5
Diptera	Chironomidae	*Hydrobaenus*	2	7.7
Diptera	Chironomidae	*Krenosmittia*	2	7.7

Appendix A (cont).

Diptera	Chironomidae	*Limnophyes*	5	19.2
Diptera	Chironomidae	*Macropelopia*	4	15.4
Diptera	Chironomidae	*Metriocnemus*	4	15.4
Diptera	Chironomidae	*Micropsectra*	15	57.7
Diptera	**Chironomidae**	***Odontomesa***	2	7.7
Diptera	Chironomidae	*Orthocladius*	4	15.4
Diptera	Chironomidae	*Pagastia*	1	3.8
Diptera	Chironomidae	*Parachironomus*	1	3.8
Diptera	Chironomidae	*Parakiefferiella*	5	19.2
Diptera	Chironomidae	*Paralauterborniella nigrohalteris*	1	3.8
Diptera	Chironomidae	*Parametriocnemus*	9	34.6
Diptera	Chironomidae	*Paraphaenocladius*	3	11.5
Diptera	Chironomidae	*Polypedilum*	3	11.5
Diptera	Chironomidae	*Procladius*	2	7.7
Diptera	Chironomidae	*Psectrocladius*	1	3.8
Diptera	Chironomidae	*Pseudochironomus*	1	3.8
Diptera	**Chironomidae**	***Pseudodiamesa***	4	15.4
Diptera	Chironomidae	*Psilometriocnemus*	6	23.1
Diptera	Chironomidae	*Radotanypus*	2	7.7
Diptera	Chironomidae	*Tanytarsus*	1	3.8
Diptera	Chironomidae	*Thienemanniella*	4	15.4
Diptera	Chironomidae	*Thienemannimyia Gr.*	1	3.8
Diptera	**Chironomidae**	***Tvetenia Bavarica Gr.***	12	46.2
Diptera	Chironomidae	*Tvetenia vitracies Gr.*	1	3.8
Diptera	**Dixidae**	***Dixa***	6	23.1
Diptera	Dolichopodidae	*Dolichopodidae*	1	3.8
Diptera	Empididae	*Clinocera*	3	11.5
Diptera	Empididae	*Hemerodromia*	3	11.5
Diptera	Psychodidae	*Pericoma*	1	3.8
Diptera	Ptychopteridae	*Ptychoptera*	1	3.8
Diptera	Stratiomyidae	*Stratiomyia*	1	3.8
Diptera	**Stratiomyidae**	***Caloparyphus***	7	26.9
Diptera	**Stratiomyidae**	***Euparyphus***	6	23.1
Diptera	Tabanidae	*Chrysops*	2	7.7
Diptera	Tabanidae	*Tabanus*	1	3.8
Diptera	Tipulidae	*Dactylabis*	1	3.8
Diptera	**Tipulidae**	***Dicranota***	8	30.8
Diptera	Tipulidae	*Gonomyia*	2	7.7
Diptera	Tipulidae	*Hexatoma*	1	3.8
Diptera	Tipulidae	*Limnophila*	1	3.8
Diptera	Tipulidae	*Limonia*	4	15.4
Diptera	Tipulidae	*Limonia (Dicronomyia)*	1	3.8
Diptera	Tipulidae	*Ormosia*	3	11.5
Diptera	Tipulidae	*Ormosia (Scleroprocta)*	1	3.8
Diptera	**Tipulidae**	***Tipula***	10	38.5
Mayflies				
Ephemeroptera	Ameletidae	*Ameletus simiilor*	1	3.8
Ephemeroptera	Baetidae	*Baetis bicaudatus*	1	3.8
Ephemeroptera	**Baetidae**	***Baetis tricaudatus***	16	61.5
Ephemeroptera	Baetidae	*Callibaetis ferrugineus*	1	3.8
Ephemeroptera	Baetidae	*Callibaetis fluctuans*	1	3.8

Appendix A (cont).

Ephemeroptera	Baetidae	*Diphetor hageni*	3	11.5
Dragonflies/Damselflies				
Odonata	Aeshnidae	*Aeshna*	1	3.8
Odonata	Aeshnidae	*Aeshna umbrosa*	1	3.8
Odonata	Coenagrionidae	*Argia*	2	7.7
Odonata	Coenagrionidae	*Amphiagrion abbreviatum*	1	3.8
Odonata	Coenagrionidae	*Coenagrion/Enallagma*	1	3.8
Stoneflies				
Plecoptera	Chloroperlidae	*Sweltsa*	2	7.7
Plecoptera	Chloroperlidae	*Paraperla cf.frontalis*	1	3.8
Plecoptera	**Nemouridae**	***Amphinemura banksi***	**16**	**61.5**
Plecoptera	Nemouridae	*Malenka*	6	23.1
Plecoptera	Nemouridae	*Zapada oregonensis*	1	3.8
Plecoptera	**Perlidae**	***Hesperoperla pacifica***	**13**	**50.0**
Plecoptera	Perlodidae	*Perlodidae*	1	3.8
Caddisflies				
Trichoptera	Hydropsychidae	*Hydropsyche californica*	2	7.7
Trichoptera	Hydropsychidae	*Hydropsyche confusa*	6	23.1
Trichoptera	Hydropsychidae	*Hydropsyche morosa gr.*	3	11.5
Trichoptera	Hydroptilidae	*Ochrotrichia*	6	23.1
Trichoptera	Hydroptilidae	*Hydroptila*	1	3.8
Trichoptera	Lepidostomatidae	*Lepidostoma*	2	7.7
Trichoptera	Lepidostomatidae	*Lepidostoma pluviale*	3	11.5
Trichoptera	**Lepidostomatidae**	***Lepidostoma unicolor***	**12**	**46.2**
Trichoptera	**Limnephilidae**	***Hesperophylax designatus***	**6**	**23.1**
Trichoptera	Limnephilidae	*Homophylax*	1	3.8
Trichoptera	Limnephilidae	*Limnephilus*	5	19.2
Trichoptera	Limnephilidae	*Nemotaulius hostilis*	1	3.8
Trichoptera	Philopotamidae	*Dolophilodes*	1	3.8
Trichoptera	Rhyacophilidae	*Rhyacophila Brunnea Gr.*	3	11.5
Trichoptera	Rhyacophilidae	*Rhyacophila oreta*	3	11.5
Trichoptera	Rhyacophilidae	*Rhyacophila rotunda*	2	7.7
Trichoptera	Rhyacophilidae	*Rhyacophila verrula*	2	7.7
Trichoptera	Uenoidae	*Neothremma alicia*	2	7.7
Peaclams				
Veneroida	Pisidiidae	*Sphaerium*	4	15.4
Veneroida	Pisidiidae	*Pisidium casertanum*	1	3.8
Snails				
Basommatophora	Lymnaeidae	*Fossaria humilis*	4	15.4
Basommatophora	Lymnaeidae	*Fossaria obrussa*	2	7.7
Basommatophora	Lymnaeidae	*Lymnaea stagnalis*	1	3.8
Basommatophora	Lymnaeidae	*Pseudosuccinea columella*	3	11.5
Basommatophora	Physidae	*Physella*	19	73.1
Basommatophora	Physidae	*Physella zionensis*	1	3.8
Heterostropha	Planorbidae	*Planorbula campestris*	3	11.5
Heterostropha	Valvatidae	*Valvata sincera*	5	19.2
Heterostropha	Valvatidae	*Valvata lewisi*	9	34.6
Non-Insect Oligochaeta Worms / Flatworms				
Turbellaria		*Polycelis coronata*	4	15.4

Appendix A (cont).

Turbellaria		Turbellaria	1	3.8
Nematoda		*Nematoda*	2	7.7
Haplotaxida	Lumbricidae	*Lumbricina*	1	3.8
Haplotaxida	Tubificidae	Tubificidae	1	3.8
Lumbriculida	Lumbriculidae	Lumbriculidae	2	7.7
Crustacea				
Amphipoda	Hyalellidae	*Hyalella azteca*	1	3.8
Ostracoda		Ostracoda	4	15.4
Mites				
Trombidiformes	Hygrobatidae	*Tyrellia*	1	3.8
Trombidiformes	Hygrobatidae	*Hygrobates*	1	3.8
Trombidiformes	Limnocharidae	*Rhyncholimnochares*	1	3.8