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Aquatic Macroinvertebrate and Physical Habitat Monitoring for Hermit Creek, Garden Creek, and Bright Angel Creek in Grand Canyon National Park

2010 Summary Report, revised March 2012

Natural Resource Data Series NPS/SCPN/NRDS—2012/265

ON THE COVER
Grand Canyon National Park
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Aquatic Macroinvertebrate and Physical Habitat Monitoring for Hermit Creek, Garden Creek, and Bright Angel Creek in Grand Canyon National Park

2010 Summary Report, revised March 2012

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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The corresponding author and project manager for this project is Stephen Monroe (stephen_monroe@nps.gov). Stacy Stumpf is the water resources crew leader for the project. The 2010 crew consisted of Kelly Lawrence and Melissa Dyer. SCPN staff provided support for the project.

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1 Introduction and background

The National Park Service Inventory and Monitoring Program was designed to determine the current status and monitor long-term trends in the condition of park natural resources, providing park managers with a strong scientific foundation for making decisions and working with other agencies and the public to protect park ecosystems. The Southern Colorado Plateau Network (SCPN) is monitoring aquatic macroinvertebrates as an overall indicator of aquatic ecosystem integrity (Thomas et al. 2006).

In 2009 SCPN implemented annual monitoring of aquatic macroinvertebrates and physical habitat on Hermit Creek in Grand Canyon National Park (GRCA). During 2010 the SCPN water resources field crew added a site on Garden Creek and on Bright Angel Creek. During 2010, aquatic macroinvertebrate samples and physical habitat data were collected from all three monitoring sites.

Hermit Creek below Tonto Trail (GRCAHER01), identified in this report as HER01 (see appendix A for list of locations, codes, and common names of sampling sites), is located just over 0.2 km downstream from the stream flow gauge—*Hermit Creek above Tonto Trail nr Grand Canyon, AZ* (09403043)—maintained by GRCA staff (fig. 1). The channel substrate at this site is primarily cobble and bedrock. The stream flows through a sparse willow (*Salix* sp.) shrubland with a dense monkey flower (*Mimulus* sp.) understory.

Garden Creek below Tonto Trail (GRCAGAR01), identified in this report as GAR01, is located approximately 5.8 miles (9.3 km) downstream from the Bright Angel Trailhead (fig. 2). Garden Creek flows parallel to the Bright Angel Trail, one of the most popular and traveled of trails in GRCA. The lower end of the creek crosses the trail multiple times before converging with Pipe Creek, which eventually flows into the Colorado River. The channel substrate is primarily fines and coarse gravels and flows through a dense willow (*Salix* sp.) shrubland with a sparse horsetail (*Equisetum* sp.) understory. Indian Gardens, a popular resting site for backcountry travelers on foot and by mule, is located adjacent to the stream approximately 0.6 miles (1 km) upstream from our sampling site. Additionally, a large campground is located at Indian Gardens. Grand Canyon staff are concerned with the impact of high level visitation on Garden Creek. The park pumps water from Roaring Springs on the North Rim up to Indian Gardens and the South Rim via the Transcanyon pipeline. At various time of the day, when pumping is not active, this water is returned to Garden Creek at Indian Gardens. It is unclear what the effect of this water is on the aquatic macroinvertebrate community in Garden Creek.

Bright Angel Creek below first footbridge (GRCABRI01), identified in this report as BRI01, is located upstream from Phantom Ranch, and downstream from the first large steel footbridge on the North Kaibab Trail (fig. 2). Bright Angel Creek flows from the North Rim of GRCA and runs parallel to the North Kaibab Trail before eventually draining into the Colorado River below Phantom Ranch. The channel substrate at this site is primarily cobbles and flows trough a willow (*Salix* sp.) shrubland with a horsetail (*Equisetum* sp.) understory.

The primary purpose of this report is to (a) document the monitoring activities that occurred in 2010, (b) summarize data that were collected, and (c) where appropriate, place these data in the context of aquatic habitat, biological condition, and management actions within the park through time.

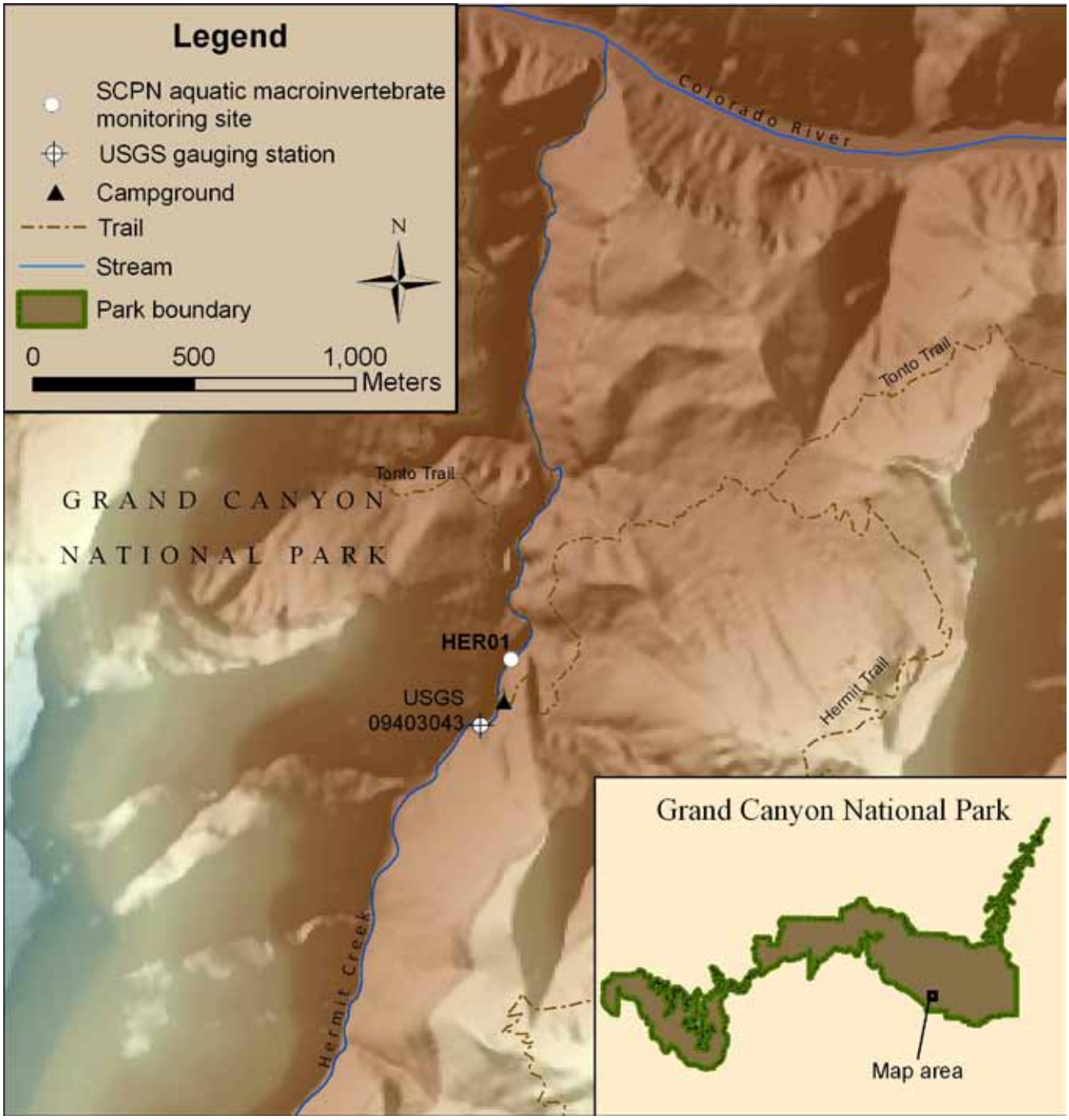


Figure 1. Map of Hermit Creek, Grand Canyon National Park, Arizona, with the location of the HER01 monitoring site in 2010

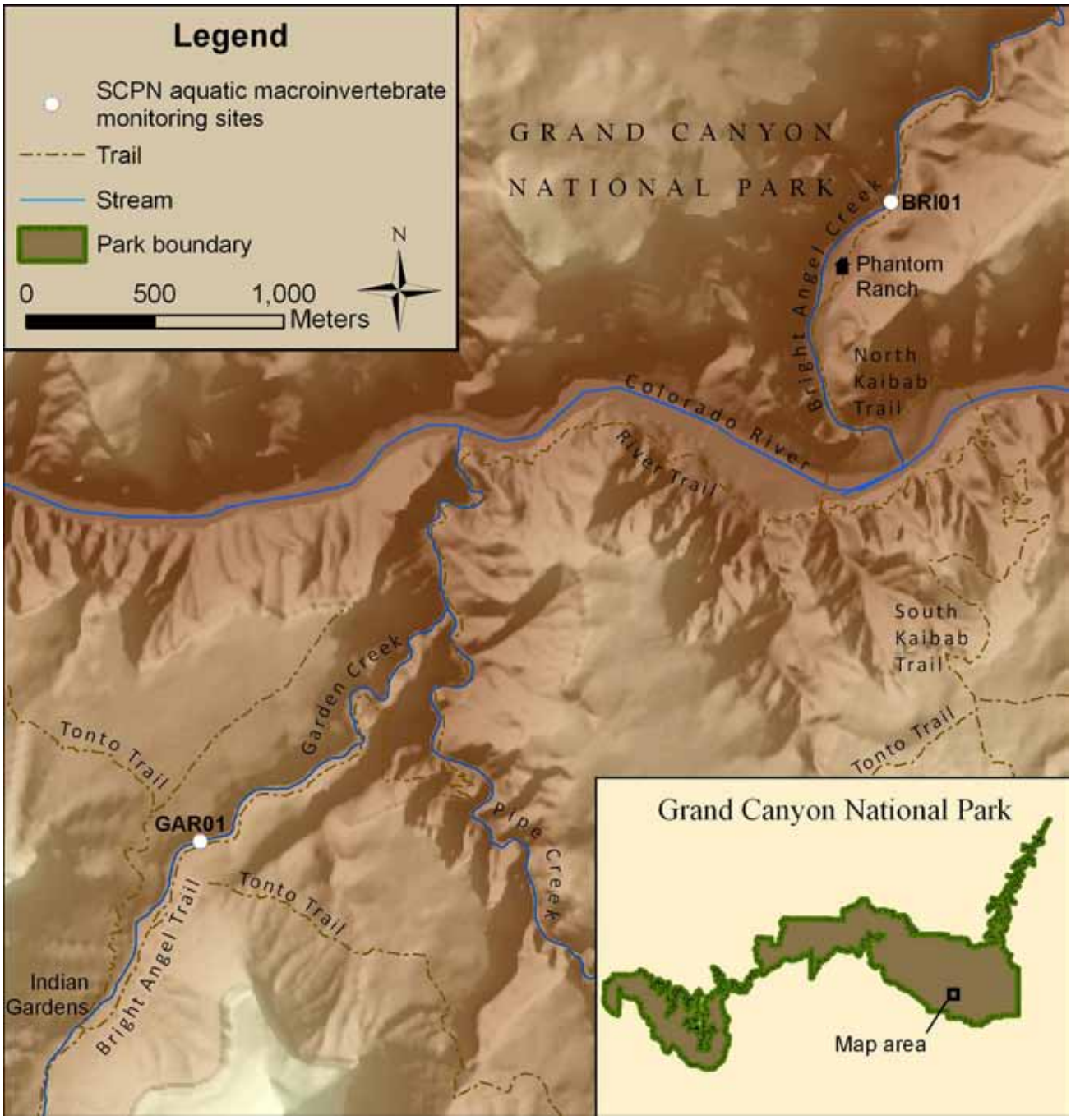


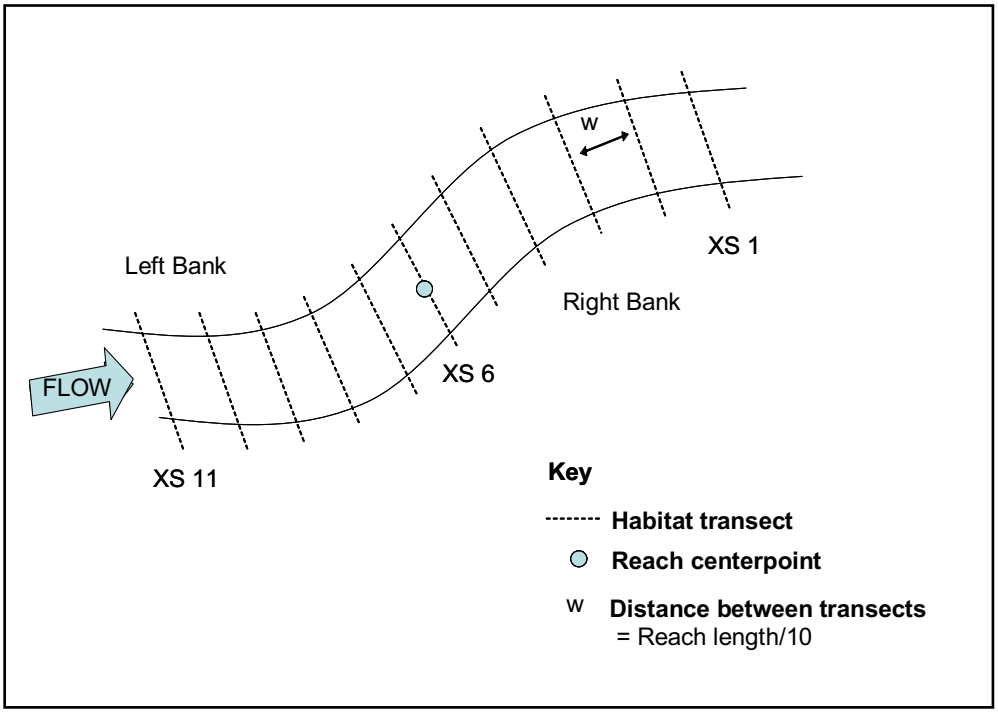
Figure 2. Map of the BRI01 (Bright Angel Creek) and the GAR01 (Garden Creek) monitoring sites in Grand Canyon National Park, Arizona, 2010

2 Methods

2.1 Field methods

In Arizona, the aquatic macroinvertebrate sampling window for streams <1,500 m elevation is from April to May (Arizona Department of Environmental Quality, Water Quality Division 2006). On April 12, 2010, we collected aquatic macroinvertebrate samples and physical habitat data at the monitoring site HER01. Aquatic macroinvertebrate and physical habitat samples were collected from GAR01 on April 26, 2010, and from BRI01 on October 19, 2010. BRI01 is a North Rim drainage which experiences annual spring stream flows above base flow due to snowmelt. Because of this we are unable to sample during the recommended sampling window. Instead SCPN has decided to implement a fall sampling strategy at BRI01 only. Each of these sites consists of a 150-meter reach, composed of 11 transects, spaced 15 m apart (fig. 3). A brief description of field methods is provided here, and a detailed description of sampling methods can be found in Brasher et al. (2011).

Figure 3. General aquatic macroinvertebrate sampling reach layout



We collected two types of aquatic macroinvertebrate samples from each site:

- Replicate quantitative samples were collected from five targeted riffle habitats to provide estimates of abundances of organisms. We used a Slack sampler to collect a timed sample from a 0.25 m^2 area at each targeted riffle.
- A qualitative sample was collected to develop a comprehensive list of species present in the reach. We used a Slack sampler to collect samples from all habitat types within the sampling reach and compiled them into one composite sample. A list of existing habitat types from which qualitative samples were collected can be found in section 3.2 of this report.

We collected physical habitat data at three spatial scales: microhabitat, transect, and reach:

- For each of the quantitative targeted riffle microhabitats, we
  - measured depth

  - measured velocity
  - measured substrate particle size
  - measured substrate particle embeddedness
- For each of the 11 transects, we
  - measured wetted and active channel widths
  - measured water depth, velocity, and canopy closure at five equally spaced points along each transect
  - observed and recorded the presence or absence, and types of aquatic macroinvertebrate habitats, represented by point data (5 points/transect) across the entire reach
  - measured geomorphic channel units (GCU) at five equally spaced points along each transect
- For the entire reach, we
  - identified and measured the length of GCUs (reach characterization data represents the proportion of the reach characterized by that particular GCU)
  - identified the dominant vegetation and land cover
  - recorded descriptions of flow conditions
  - recorded weather conditions
  - observed and recorded evidence of anthropogenic or natural disturbances
  - measured NPS core water quality parameters of temperature, specific conductivity, pH, dissolved oxygen, turbidity, and stream discharge
  - conducted a zig-zag pebble count measuring the size of a minimum of 400 randomly-selected particles using a modified Wolman pebble count across the length of the entire reach

2.2 Laboratory methods

Aquatic macroinvertebrate samples were sent to the National Aquatic Monitoring Center's Bug Lab, a Bureau of Land Management laboratory at Utah State University in Logan, Utah. There, samples were sorted under a dissecting scope at 10× magnification, and a 500-organism, fixed-count method was used for sub-sampling large samples. Ten percent of the sorted samples were re-sorted for quality assurance.

A taxonomist, certified by the North American Benthological Society, identified all aquatic macroinvertebrates to the family or genus level. To ensure data quality, 10 percent of the identified samples were re-identified by a second certified taxonomist.

Quantitative and qualitative aquatic macroinvertebrate samples will be maintained by the contract aquatic laboratory for at least five years to allow for repeat subsampling should any data questions arise. For a more detailed description of laboratory methods see Brasher et al. (2011).

2.3 Data analysis

In this report we summarize aquatic macroinvertebrate data in terms of community structure and function. Genera were classified into functional feeding guilds using the classifications presented in Barbour et al. (1999). If functional class information was not available for a particular genus, we applied a more generalized, family-level classification.

We selected aquatic macroinvertebrate metrics that are generally considered to be sensitive, reliable indicators of water quality and/or stream health (see appendix B for a table of metrics and their

definitions). Most of these metrics have been used to detect changes in water quality and habitat conditions in other streams in the Southern Rocky Mountains ecoregion (Griffith et al. 2005). They also enable a comprehensive assessment of multiple aspects of community structure because they represent a range of ecological characteristics. SCPN will periodically evaluate the interpretive value of the listed metrics and may drop or add additional metrics based upon these evaluations.

3 Results

3.1 Aquatic macroinvertebrate community data for Hermit Creek

Key metrics are presented in Table 1 (qualitative) and in Table 2 (quantitative), describing aquatic macroinvertebrate communities from samples collected at HER01 in 2009 and 2010. Figures in this section refer to quantitative data unless otherwise noted, and error bars represent one standard deviation from the mean. Appendix C lists all aquatic macroinverte-brate species detected at the site, from both quantitative and qualitative methods.

Table 1. Qualitative metrics for aquatic macroinvertebrate samples collected from HER01 at Hermit Creek in Grand Canyon National Park, Arizona, 2009–2010. Richness-based metrics are expressed as the percentage of taxa in a given order, tolerance or functional feeding group.

Qualitative metric	2009	2010
Taxa richness	23	27
Tolerance group		
Richness of tolerant taxa (%)	28.57	24.00
Richness of moderately tolerant taxa (%)	47.62	48.00
Richness of intolerant taxa (%)	23.81	28.00
Functional group		
Richness of collector-filterers (%)	9.09	7.69
Richness of collector-gatherers (%)	31.82	46.15
Richness of scrapers (%)	4.55	3.85
Richness of shredders (%)	0.00	3.85
Richness of predators (%)	54.55	38.46
Taxonomic group		
Number of EPT taxa	4	7
Richness of EPT taxa (%)	17.39	25.93
Richness of Ephemeroptera (%)	8.70	11.11
Richness of Plecoptera (%)	0.00	0.00
Richness of Trichoptera (%)	8.70	14.81
Richness of noninsect taxa (%)	21.74	18.52
Richness of Chironomid Diptera (%)	13.04	11.11
Richness of non-Chironomid Diptera (%)	34.78	29.63
Richness of Coleoptera (%)	4.35	7.41
Richness of Odonata (%)	8.70	7.41

Table 2. Quantitative metrics for aquatic macroinvertebrate samples collected from HER01 at Hermit Creek in Grand Canyon National Park, Arizona, 2009–2010. For a given order, tolerance or functional feeding group, abundance-based metrics are expressed as the percentage of individuals in the group, while richness-based metrics are expressed as the percentage of taxa in the group.

	2009		2010	
Quantitative metric	**Mean**	**SD**	**Mean**	**SD**
Total abundance	603.40	60.04	510.00	150.28
Total richness	20.20	1.64	17.60	3.05
Simpson's Diversity—taxonomic	0.69	0.08	0.73	0.06
Simpson's Diversity—functional group	0.35	0.15	0.22	0.07
Dominant taxa	46.91	10.51	44.80	10.48
Tolerance group				
Relative abundance of tolerant taxa (%)	16.83	20.65	2.17	1.05
Relative abundance of moderately tolerant taxa (%)	45.25	19.14	60.02	20.55
Relative abundance of intolerant taxa (%)	37.92	16.69	37.80	20.70
Richness of tolerant taxa (%)	22.56	4.44	18.05	7.37
Richness of moderately tolerant taxa (%)	46.06	3.26	53.31	5.09
Richness of intolerant taxa (%)	31.38	3.51	28.64	6.14
Functional group				
Relative abundance of collector-filterers (%)	2.89	1.85	5.18	5.00
Relative abundance of collector-gatherers (%)	72.97	20.60	87.53	4.38
Relative abundance of scrapers (%)	0.72	0.49	0.80	0.49
Relative abundance of shredders (%)	0.00	0.00	0.00	0.00
Relative abundance of predators (%)	23.42	20.36	6.50	2.20
Richness of collector-filterers (%)	10.48	4.02	10.68	3.81
Richness of collector-gatherers (%)	33.33	3.93	42.60	6.40
Richness of scrapers (%)	5.24	0.43	9.43	4.08
Richness of shredders (%)	0.00	0.00	0.00	0.00
Richness of predators (%)	50.95	4.14	37.29	9.75
Taxonomic group				
Number of EPT taxa	4.40	0.55	4.80	0.45
Relative abundance of EPT taxa (%)	4.43	1.59	20.42	13.39
Relative abundance of Ephemeroptera (%)	2.59	1.10	16.47	11.89
Relative abundance of Plecoptera (%)	0.00	0.00	0.00	0.00
Relative abundance of Trichoptera (%)	1.84	0.98	3.95	4.62
Relative abundance of noninsect taxa (%)	6.66	3.91	4.62	1.68
Relative abundance of Chironomid Diptera (%)	38.69	19.29	40.06	13.16
Relative abundance of non-Chironomid Diptera (%)	17.31	20.15	9.80	9.29
Relative abundance of Coleoptera (%)	31.96	16.70	24.51	23.95
Relative abundance of Odonata (%)	0.96	0.81	0.58	0.55

Abundance. Abundance of aquatic macroinvertebrates at the quantitative targeted riffle habitat averaged 510.00 individuals per riffle (fig. 4), and ranged from a high of 636 individuals to a low of 322 individuals.

Taxa richness. Taxa richness of quantitative targeted riffle habitat averaged 17.60 taxa (fig. 5). Richness ranged from a high of 20 taxa to a low of 13 taxa. Total richness for the qualitative multi-habitat sample was 27 taxa.

Diversity. We calculated taxonomic and functional diversity using the Simpson's Diversity Index (fig. 6). Taxonomic diversity, averaging 0.73 per riffle, was over 3 times as high as functional diversity, which averaged 0.22 per sample.

Anthropogenic stress tolerance. Moderately tolerant aquatic macroinvertebrates dominated the relative abundance of taxa grouped by their tolerance class, averaging 60.02% of the individuals collected (fig. 7a). Relative abundance of intolerant individuals averaged 37.80%, and tolerant individuals were the least abundant group, averaging 2.17%. Total richness by tolerance was dominated by moderately tolerant taxa, which averaged 53.31% (fig. 7b). Intolerant taxa richness averaged 28.64% and tolerant taxa richness averaged 18.05%.

EPT taxa. Relative abundance of EPT taxa (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]) at this monitoring site averaged 20.42% of all taxa collected (fig. 8). Ephemeroptera were the most abundant EPT group, averaging 16.47%. Trichoptera averaged 3.95% of the samples collected. There were no plecopterans found at HER01.

Aquatic macroinvertebrate orders. Of the aquatic macroinvertebrate orders collected from HER01, chironomids (midges) were the most abundant, making up 40.06% of the samples (fig. 9). Coleopterans (beetles) were the next most abundant order at 24.51%. Ephemeropterans averaged 16.47% followed by non-midge dipterans (flies) at 9.80%. Orders belonging to our category "Non-insect" averaged 4.62% of the samples and included organisms belonging to the orders Trombidiformes (water mites), Megoloptera (dobsonflies), Lepidoptera (moths), Collembola (springtails), and Hemiptera (true bugs).

Functional feeding groups. The majority of the organisms collected from the HER01 sampling site in 2010 belonged to the functional group collector-gatherers (87.53%) (fig. 10). Predators were the next most abundant at 6.50% followed by collector-filterers at 5.18%. Scrapers were the least abundant at 0.80%, and shredders were not detected in the quantitative samples in 2010.

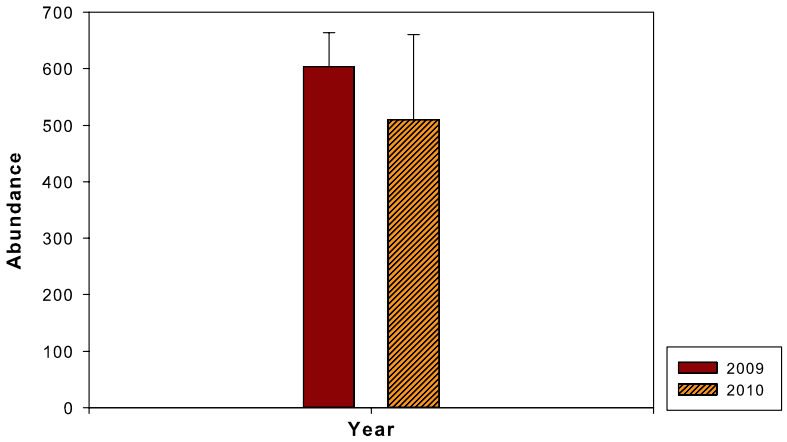


Figure 4. Total abundance expressed as the mean number of individuals in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2010

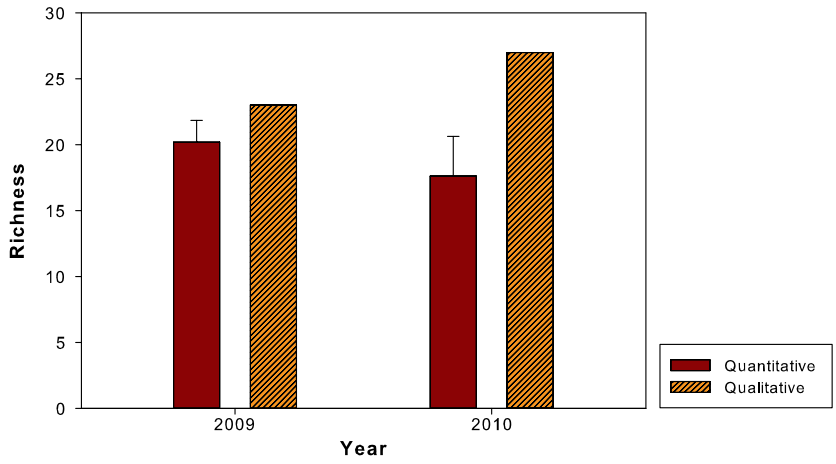


Figure 5. Mean taxa richness in quantitative targeted riffle and total taxa richness in qualitative multihabitat samples collected from HER01 at Hermit Creek in GRCA, 2009–2010

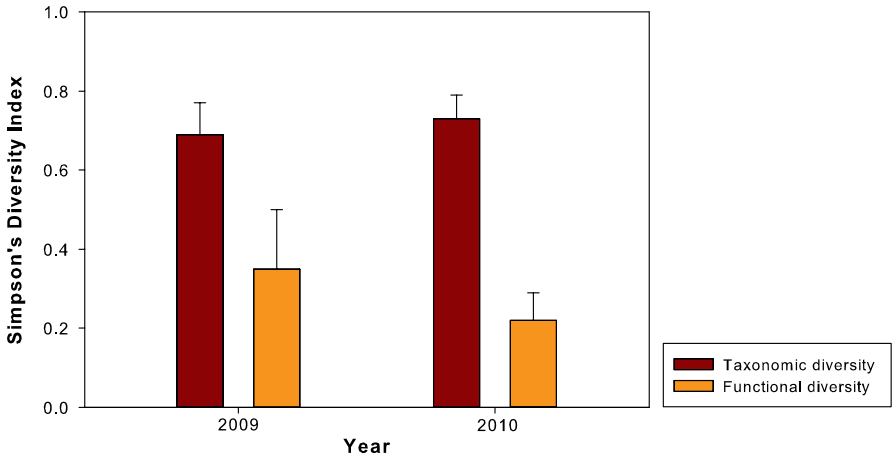


Figure 6. Simpson's Diversity Index for taxonomic and functional diversity in quantitative targeted riffle samples from HER01 at Hermit Creek in GRCA 2009–2010

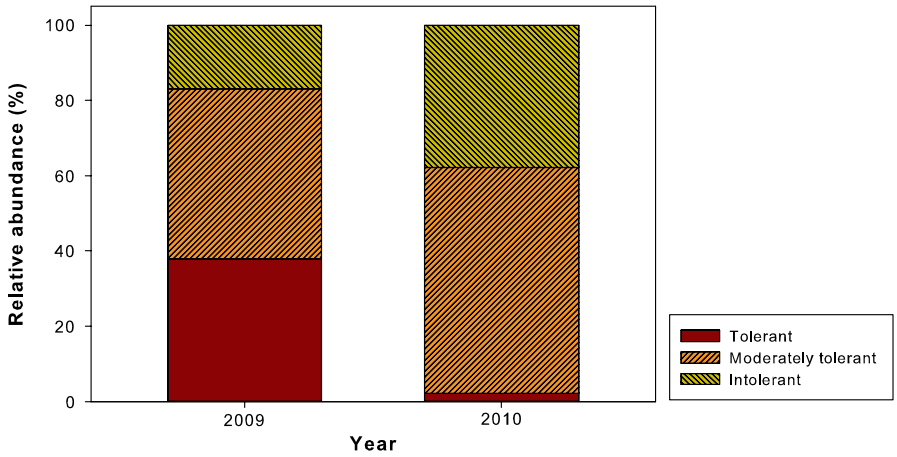


Figure 7a. Mean relative abundance of aquatic macroinvertebrate taxa in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2010, based on their tolerance to perturbation

Figure 7b. Mean richness of aquatic macroinvertebrate taxa in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2010, based on their tolerance to perturbation

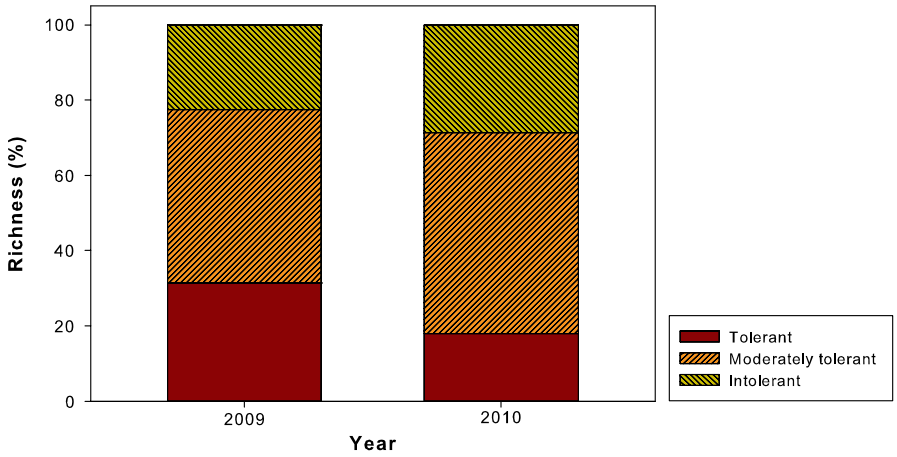


Figure 8. Relative abundance of EPT taxa in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2010

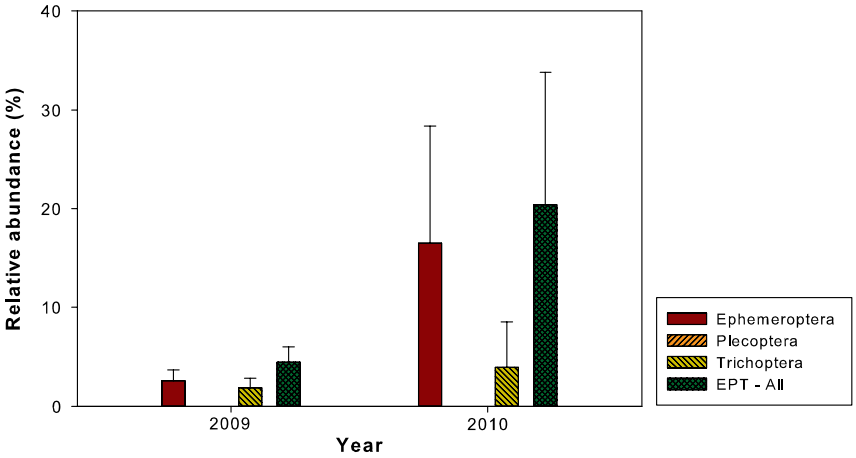
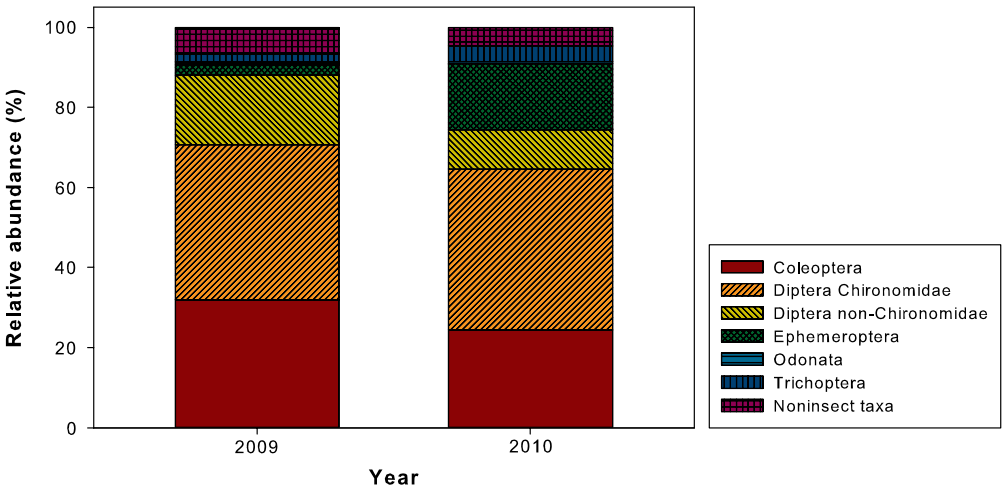


Figure 9. Relative abundance of individuals by taxonomic order in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2010



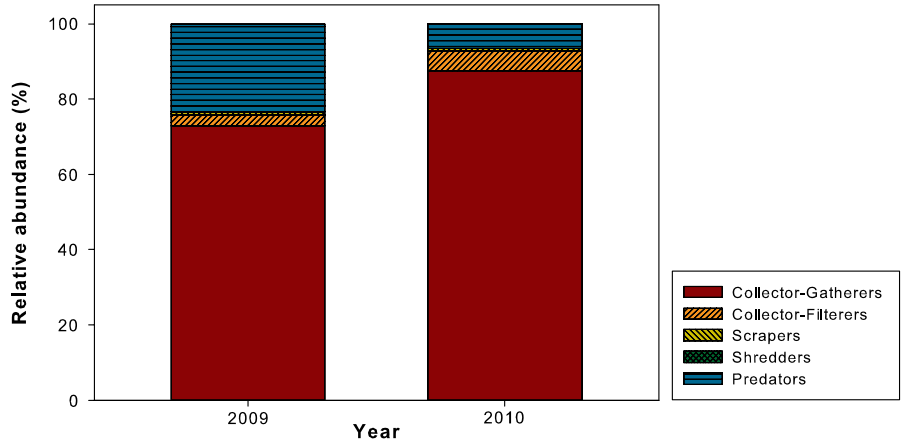


Figure 10. Relative abundance of functional feeding groups in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2010. Not all groups were found.

3.2 Physical habitat characteristics for Hermit Creek

This section presents data describing physical habitat characteristics collected at HER01 during 2010, summarized in Table 3. Additional transect data can be found in Appendix D.

Microhabitat level. Stream flow velocities at quantitative targeted riffle sites averaged 0.46 m/s (table 3). Depths averaged 0.11 m. On average, 53.1% of each particle was embedded by finer substrates.

Transect level. The average width of the active channel and wetted channel at the 11 physical habitat transects along the HER01 sampling reach was 7.0 m and 2.7 m, respectively (table 3). Average velocity of stream flow was 0.24 m/s. Depths at transects along HER01 averaged 0.08 m. Canopy cover along the sampling reach averaged 7.5%.

We found three different aquatic macroinvertebrate habitat types along transects in our sampling reach (fig. 11). Rock was the most abundant at 43.1%, followed by vegetation and algal mats at 7.8% each. Forty-one percent of the habitat along our transects represented the "Absence" category, meaning it did not fit one of the habitats we define as appropriate for aquatic macroinvertebrates.

Reach level. Channel structure dynamics are represented by particle size distributions based on modified Wolman pebble counts (fig. 12). The dominant size class along HER01 was boulders/bedrock (>256 mm), representing 23.9% of particles sampled in the reach. Cobbles (64–128 mm) and coarse gravels (32–64 mm) were the next most abundant, at 13.1% and 11.3%. Thirty-three percent of the particles we sampled were too embedded to pull from the streambed for measurement.

Cascades were the dominant GCU along the reach at our monitoring site (fig. 13), found along 37.9% of the reach. Runs were the second most abundant GCU at 22.6%. Glides were found along 8.2% of the reach followed by scour pools at 5.2%, dammed pools at 4.4% and falls at 4.1%.

3.3 Hydrologic conditions for Hermit Creek

3.3.1 SCPN field data

Water quality data collected at HER01 are presented in Table 3. These data represent measurements at or near midday of the sample date. The noon time temperature was recorded as 15.6°C. Specific conductivity and pH measured 575 µS/cm and 8.7 units, respectively. We were unable to measure dissolved oxygen due to sensor failure in the field. Turbidity measured 0.30 NTU.

Table 3. Physical habitat and hydrologic data from HER01 at Hermit Creek in Grand Canyon National Park, Arizona, 2009–2010. Particle embeddedness and canopy closure measurements are expressed as percentages.

	2009		2010	
Physical habitat metric	**Mean**	**SD**	**Mean**	**SD**
Microhabitat level				
Riffles				
Velocity (m/s)	0.42	0.15	0.46	0.33
Depth (m)	0.08	0.02	0.11	0.04
Embeddedness (%)	25.7	20.2	53.1	30.7
Transect level				
Channel dimensions				
Velocity (m/s)	0.19	0.11	0.24	0.18
Depth (m)	0.09	0.04	0.08	0.08
Wetted channel width (m)	1.9	0.7	2.7	1.1
Active channel width (m)	10.0	2.4	7.0	2.4
Riparian cover				
Canopy closure (%)	14.4	27.9	7.5	20.5
Reach level				
Water quality	**Value**		**Value**	
Temperature (°C)	17.4		15.6	
Specific conductivity (µS/cm)	429		575	
pH	8.4		8.7	
Dissolved oxygen (% saturation)	111		—	
Dissolved oxygen (mg/L)	11.1		—	
Turbidity (NTU)	0.41		0.30	

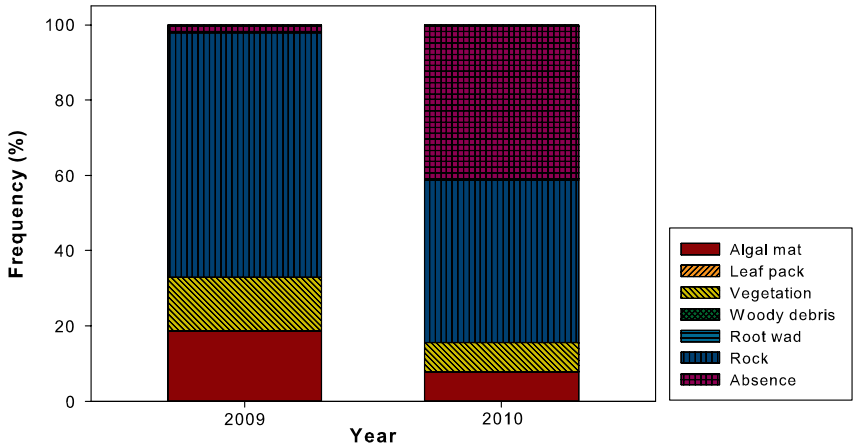


Figure 11. Aquatic macroinvertebrate habitat characterization based upon line point intercept data collected along habitat transects from HER01 at Hermit Creek in GRCA, 2009–2010. Some habitat structure types were not observed.

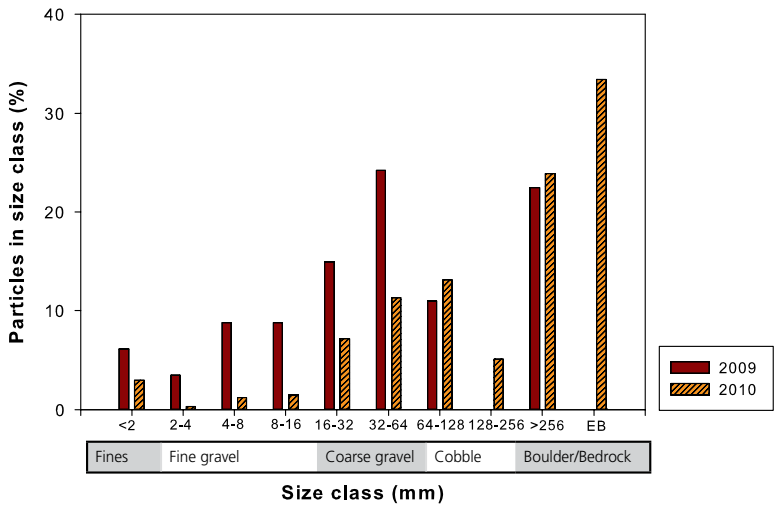


Figure 12. Particle size distribution based on modified Wolman pebble counts (minimum 400 particles), from HER01 at Hermit Creek in GRCA, 2010. EB on the x axis represents particles that are completely embedded into the stream channel, which precludes size measurements.

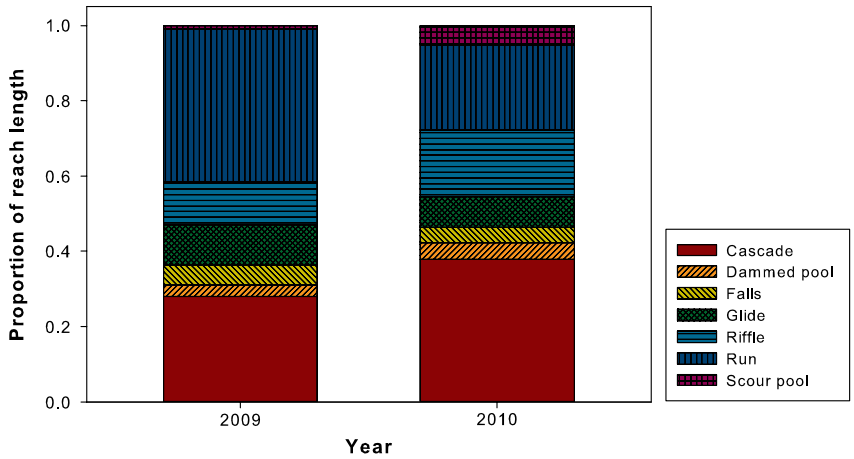


Figure 13. Geomorphic channel unit characterization from HER01 at Hermit Creek in GRCA, 2009–2010

On April 17, 2010, we installed data loggers to track air and water temperature in our sampling reach at Hermit Creek. Figure 14a presents water temperature data from 17 April to 31 December 2010. The average water temperature was 17.2°C. Water temperature reached a minimum of 3.7°C on 31 December at 0800 hrs, and a maximum of 29.0°C on 18 July at 1430. Air temperature at HER01 averaged 20.7°C for the period (fig. 14b). A minimum air temperature of -3.7°C was reached at 0800 on 31 December. A maximum air temperature of 44.3°C occurred at 1430 on 06 June.

3.3.2 NADP station data

Precipitation was monitored by the National Atmospheric Deposition Program (NADP) at Hopi Point (AZ03) in Grand Canyon (http://nadp.sws.uiuc.edu/sites/siteinfo.asp?net=NTN&id=AZ03). As expected, precipitation data suggests that the winter and monsoonal months contributed the most moisture to the area (fig. 15). Additional late season storms in October and November added to the total precipitation values for 2010.

Figure 14a. Daily water temperature statistics for April to December, 2010, from HER01 at Hermit Creek in GRCA

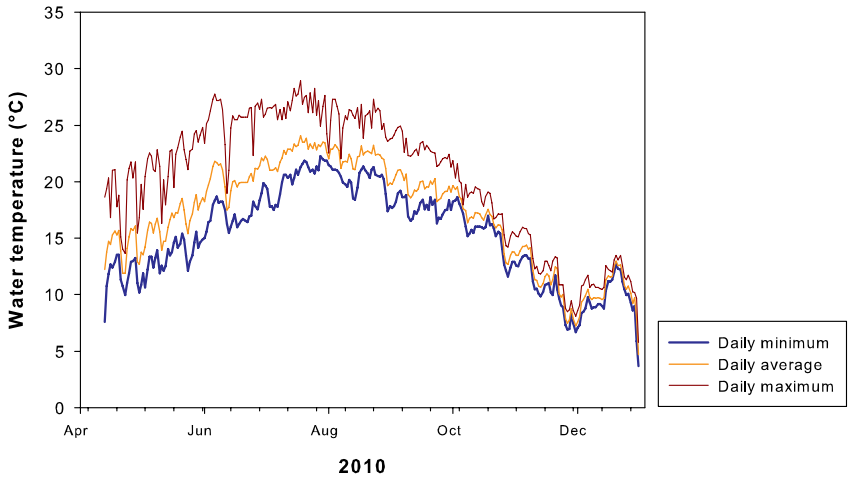


Figure 14b. Daily air temperature statistics for April to December, 2010, from HER01 at Hermit Creek in GRCA

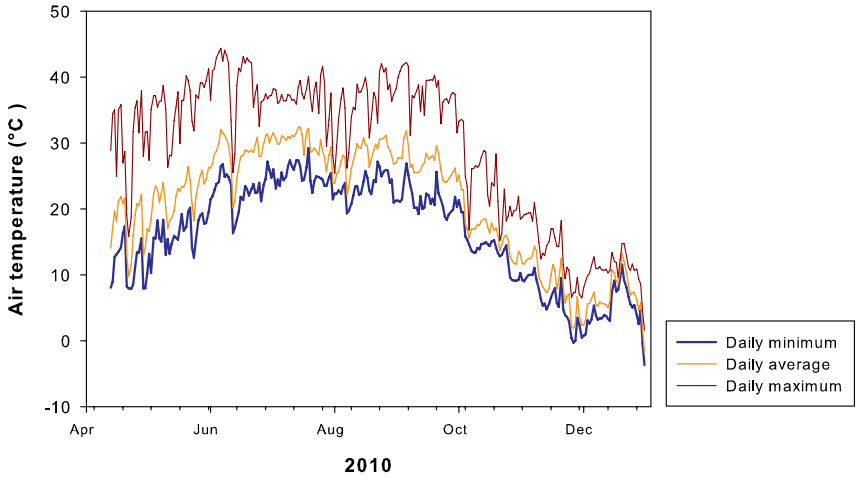
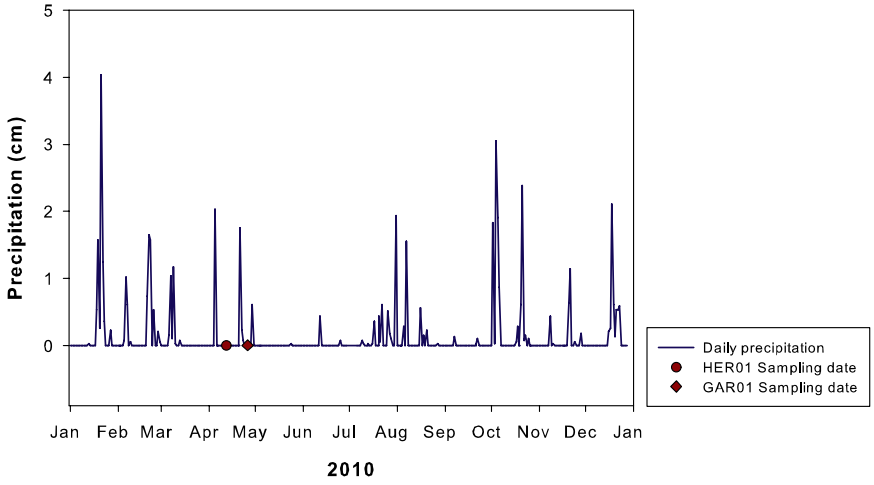


Figure 15. Daily precipitation values for 2010 from the NADP/NTN AZ03 monitoring station at Hopi Point in GRCA



3.4 Aquatic macroinvertebrate community data for Garden Creek

Key metrics are presented in Table 4 (qualitative) and Table 5 (quantitative), describing aquatic macroinvertebrate communities from samples collected at GAR01. Figures in this section refer to quantitative data unless otherwise noted, and error bars in figures represent one standard deviation from the mean. Appendix C lists all aquatic macroinvertebrate species detected at the site, from both quantitative and qualitative methods.

Abundance. Overall mean abundance for quantitative targeted riffle samples averaged 696.00 individuals. Riffle sample abundances ranged from a low 647 individuals to high of 746 individuals.

Taxa richness. Richness averaged 23.60 taxa per riffle (fig. 16). Riffle richness ranged from a low of 22 taxa to a high of 26 taxa. Total richness for the qualitative multihabitat sample was 28 taxa.

Diversity. Taxonomic and functional diversity were measured using the Simpson's Diversity Index (fig. 17). Taxonomic diversity averaged 0.84 while functional diversity averaged 0.47.

Anthropogenic stress tolerance. Relative abundance of taxa defined by their tolerance class was dominated by moderately tolerant taxa, which averaged 68.31% (fig. 18). Intolerant individuals averaged 29.76% of the samples and tolerant individuals represented only 1.93% of the samples. Taxa

Table 4. Qualitative metrics for aquatic macroinvertebrate samples collected from GAR01 at Garden Creek in Grand Canyon National Park, Arizona, 2010. Richness-based metrics are expressed as the percentage of taxa in a given order, tolerance or functional feeding group.

Qualitative metric	2010
Taxa richness	28
Tolerance group	
Richness of tolerant taxa (%)	7.41
Richness of moderately tolerant taxa (%)	48.15
Richness of intolerant taxa (%)	44.44
Functional group	
Richness of collector-filterers (%)	18.52
Richness of collector-gatherers (%)	33.33
Richness of scrapers (%)	11.11
Richness of shredders (%)	3.70
Richness of predators (%)	33.33
Taxonomic group	
Number of EPT taxa	10
Richness of EPT taxa (%)	35.71
Richness of Ephemeroptera (%)	14.29
Richness of Plecoptera (%)	0.00
Richness of Trichoptera (%)	21.43
Richness of noninsect taxa (%)	14.29
Richness of Chironomid Diptera (%)	10.71
Richness of non-Chironomid Diptera (%)	25.00
Richness of Coleoptera (%)	7.14
Richness of Odonata (%)	7.14

Table 5. Quantitative metrics for aquatic macroinvertebrate samples collected from GAR01 at Garden Creek in Grand Canyon National Park, Arizona, 2010. For a given order, tolerance or functional feeding group, abundance-based metrics are expressed as the percentage of individuals in the group, while richness-based metrics are expressed as the percentage of taxa in the group.

	2010	
Quantitative metric	**Mean**	**SD**
Total abundance	696.00	39.40
Total richness	23.60	1.82
Simpson's Diversity—taxonomic	0.84	0.04
Simpson's Diversity—functional group	0.47	0.07
Dominant taxa	28.38	9.11
Tolerance group		
Relative abundance of tolerant taxa (%)	1.93	0.85
Relative abundance of moderately tolerant taxa (%)	68.31	8.27
Relative abundance of intolerant taxa (%)	29.76	8.16
Richness of tolerant taxa (%)	8.22	3.22
Richness of moderately tolerant taxa (%)	56.08	6.10
Richness of intolerant taxa (%)	35.69	6.06
Functional group		
Relative abundance of collector-filterers (%)	15.25	3.17
Relative abundance of collector-gatherers (%)	70.15	6.35
Relative abundance of scrapers (%)	8.27	4.88
Relative abundance of shredders (%)	0.09	0.13
Relative abundance of predators (%)	6.25	2.67
Richness of collector-filterers (%)	14.40	4.83
Richness of collector-gatherers (%)	35.55	3.48
Richness of scrapers (%)	8.51	0.64
Richness of shredders (%)	2.62	4.01
Richness of predators (%)	38.91	5.79
Taxonomic group		
Number of EPT taxa	7.80	1.48
Relative abundance of EPT taxa (%)	58.52	4.41
Relative abundance of Ephemeroptera (%)	44.49	7.95
Relative abundance of Plecoptera (%)	0.00	0.00
Relative abundance of Trichoptera (%)	14.03	4.60
Relative abundance of noninsect taxa (%)	4.38	1.85
Relative abundance of Chironomid Diptera (%)	22.88	2.95
Relative abundance of non-Chironomid Diptera (%)	11.86	3.02
Relative abundance of Coleoptera (%)	1.63	1.41
Relative abundance of Odonata (%)	0.73	0.36

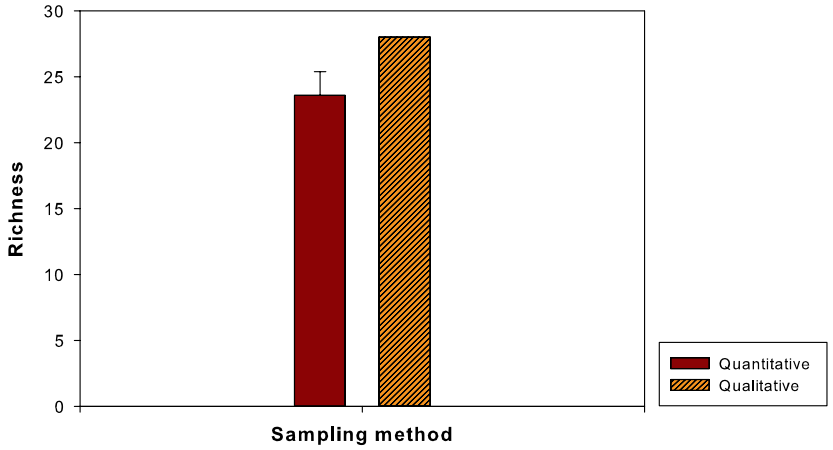


Figure 16. Mean taxa richness in quantitative targeted riffle habitat and total taxa richness in qualitative multihabitat samples collected from GAR01 at Garden Creek in GRCA 2010

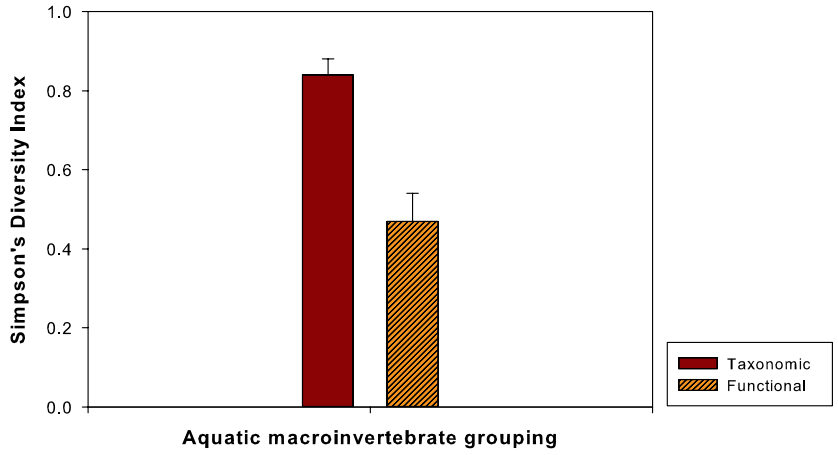


Figure 17. Simpson's Diversity Index for taxonomic and functional diversity in quantitative targeted riffle samples collected from GAR01 at Garden Creek in GRCA, 2010

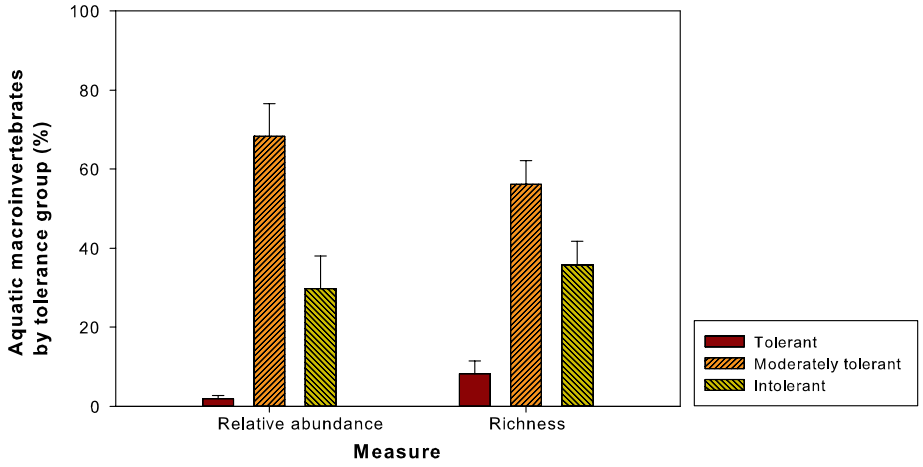


Figure 18. Mean relative abundance and richness of aquatic macroinvertebrate taxa in quantitative targeted riffle samples collected from GAR01 at Garden Creek in GRCA, 2010, based on their tolerance to perturbation

richness by tolerance class followed a similar pattern. Approximately fifty-six percent of the taxa collected belonged to the moderately tolerant taxa group. Intolerant taxa accounted for 35.69% of taxa collected. Only 8.22% of the taxa collected were considered tolerant to anthropogenic disturbance.

EPT taxa. Relative abundance of EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera) at GAR01 was dominated by taxa belonging to the order Ephemeroptera which averaged 44.49% of the taxa collected (fig. 19). Trichoptera taxa accounted for 14.03% of the taxa collected. No plecopterans were collected at this sampling site in 2010.

Aquatic macroinvertebrate orders. Ephemeroptera (44.49%) abundance was the greatest among all the different orders collected at GAR01 (fig. 20). Chironomids were the second most abundant order at 22.88%. Organisms belong to the category "Noninsect" accounted for 4.38% of the individuals collected. For GAR01, organisms belonging to "Noninsect" include Trombidiformes, Collembolla, Megoloptera, Lepidoptera, as well as the phyla Annelida (segmented worms) and Platyhelminthes (flat worms). Non-midge dipterans accounted for 11.86% of the individuals collected. Coleopterans made up only 1.63% of the individuals collected. Odonates (damselflies/dragonlflies) accounted for 0.73% of the individuals collected.

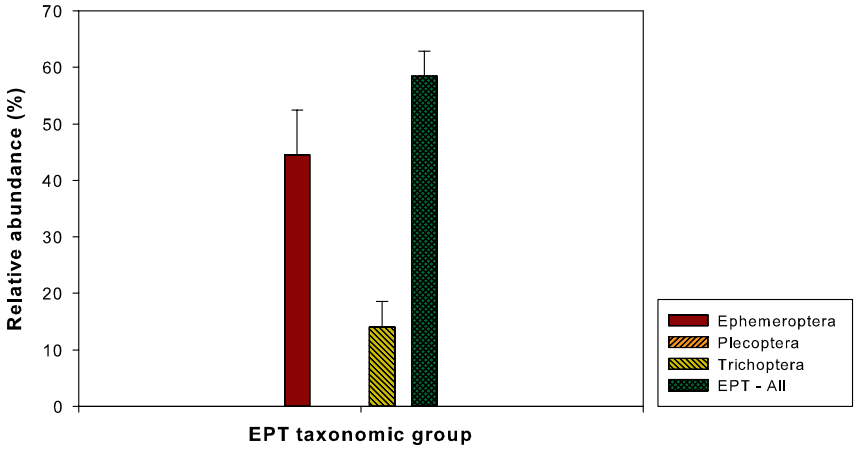


Figure 19. Relative abundance of sensitive EPT orders in quantitative targeted riffle samples from GAR01 at Garden Creek in GRCA, 2010. No Plecoptera were found in these samples.

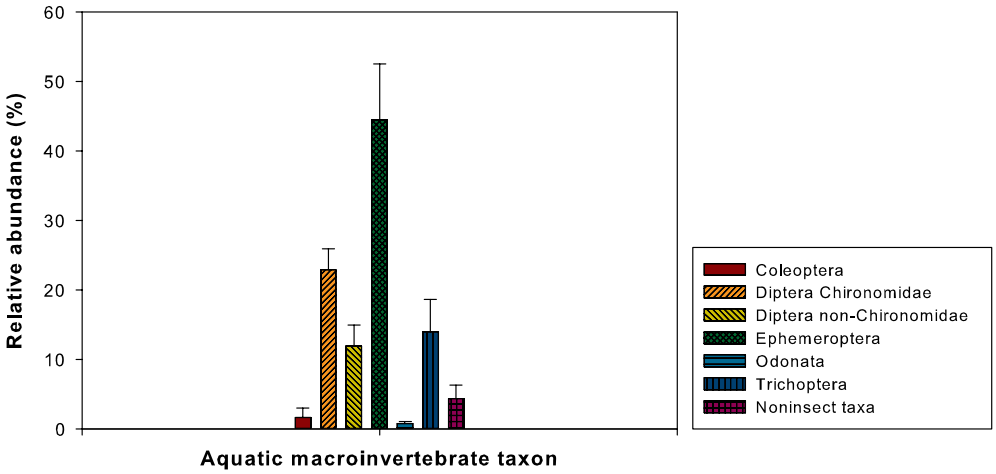


Figure 20. Relative abundance of individuals by taxonomic order in quantitative targeted riffle samples collected from GAR01 at Garden Creek in GRCA, 2010

Functional feeding groups. Collector-gatherers were the most abundant of the functional groups collected from GAR01, averaging 70.15% of the individuals collected (fig. 21). Collector-filterers were the second most abundant at 15.25%. Scrapers accounted for 8.27% and predators 6.25%. Shredders were the least abundant group at 0.09%.

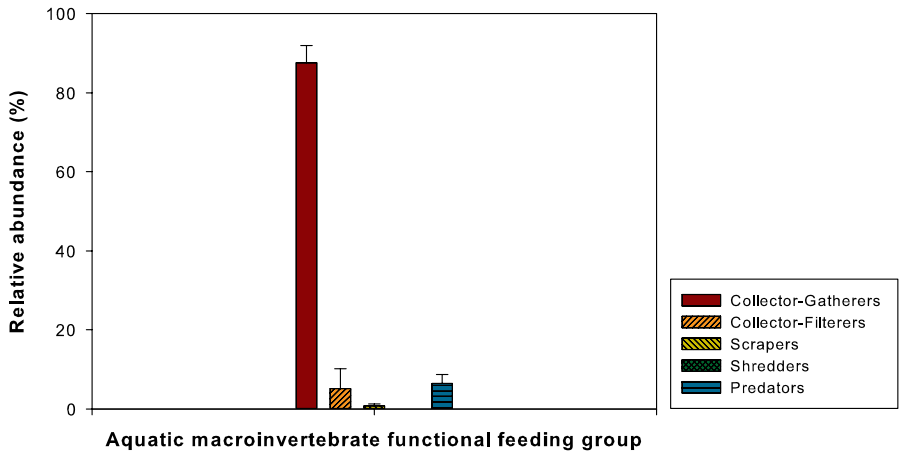


Figure 21. Relative abundance of functional feeding groups in quantitative targeted riffle samples collected from GAR01 at Garden Creek in GRCA, 2010

3.5 Physical habitat characteristics for Garden Creek

This section presents data describing physical habitat characteristics collected at GAR01 during 2010, summarized in Table 6. Additional transect data can be found in Appendix D.

Table 6. Physical habitat and hydrologic data from GAR01 at Garden Creek in Grand Canyon National Park, Arizona, 2010. Particle embeddedness and canopy closure measurements are expressed as percentages.

	2010	
Physical habitat metric	**Mean**	**SD**
Microhabitat level		
Riffles		
Velocity (m/s)	0.75	0.21
Depth (m)	0.13	0.02
Embeddedness (%)	34.1	16.0
Transect level		
Channel dimensions		
Velocity (m/s)	0.63	0.24
Depth (m)	0.08	0.02
Wetted channel width (m)	1.3	0.3
Active channel width (m)	6.6	2.7
Riparian cover		
Canopy closure (%)	70.8	28.7
Reach level		
Water quality	**Value**	
Temperature (°C)	15.3	
pH	8.9	

Microhabitat level. Stream flow velocity at the quantitative targeted riffle sites averaged 0.75 m/s and depths averaged 0.13 m (table 6). Embeddedness of particles in the quantitative sampling frame averaged 34.1%.

Transect level. Active channel widths and wetted channel widths at the 11 physical habitat transects averaged 6.6 m and 1.3 m, respectively (table 6). Velocity along the sampling reach averaged 0.63 m/s and depth averaged 0.08 m. Riparian vegetation canopy cover averaged 70.8% across the transects.

There were three different habitat types that dominated aquatic macroinvertebrate habitat at transects along the sampling reach (fig. 22). Algal mats were the most abundant habitat type, found along 33.8% of the reach. Vegetation and rock were the next most abundant at 28.8% and 25.0% respectively. Only 5.0% of the reach lacked habitat ("Absence") that SCPN has defined as appropriate for aquatic macroinvertebrates.

Reach level. Fines (<2 mm) were the most abundant particle size found along the sampling reach (fig. 23). Coarse gravels and cobbles were the next most abundant size classes at 20.4% and 11.8%, respectively. All other size classes were in abundances of less than 10%.

The most abundant geomorphic channel unit found along the GAR01 sampling reach was runs, which made up 52.0% of the sampling reach (fig. 24). Riffles and cascades were the next most abundant GCU's at 18.9% and 14.8%, respectively.

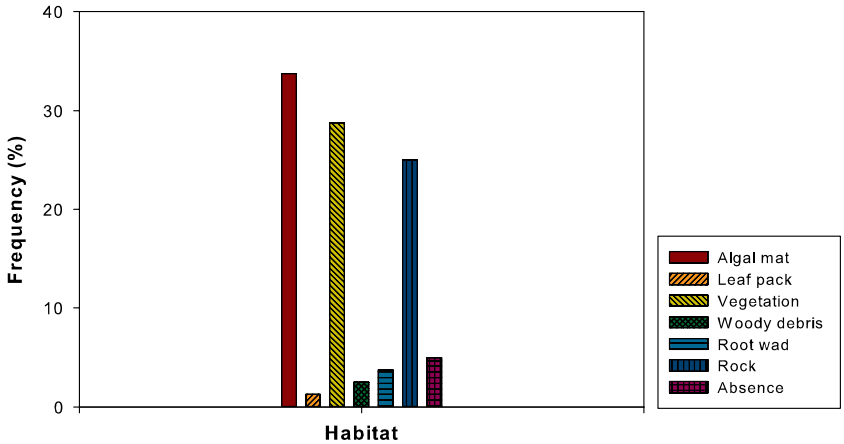


Figure 22. Aquatic macroinvertebrate habitat characterization based upon line point intercept data collected along habitat transects from GAR01 at Garden Creek in GRCA, 2010

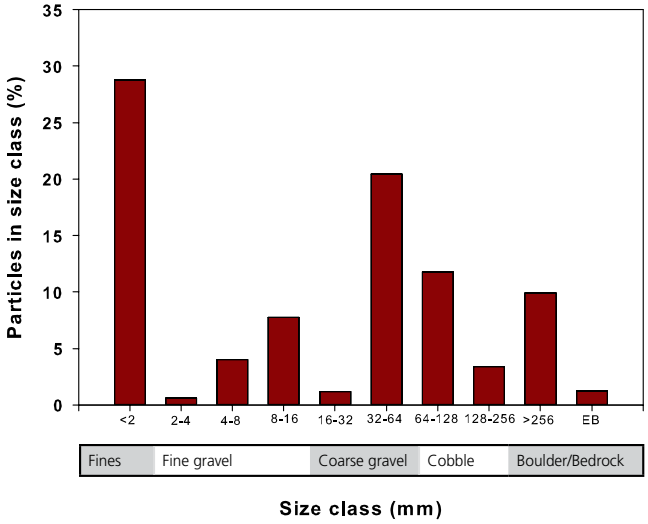


Figure 23. Particle size distribution based on modified Wolman pebble counts (minimum 400 particles), from GAR01 at Garden Creek in GRCA, 2010. EB on the x axis represents particles that are completely embedded into the stream channel, which precludes size measurements.

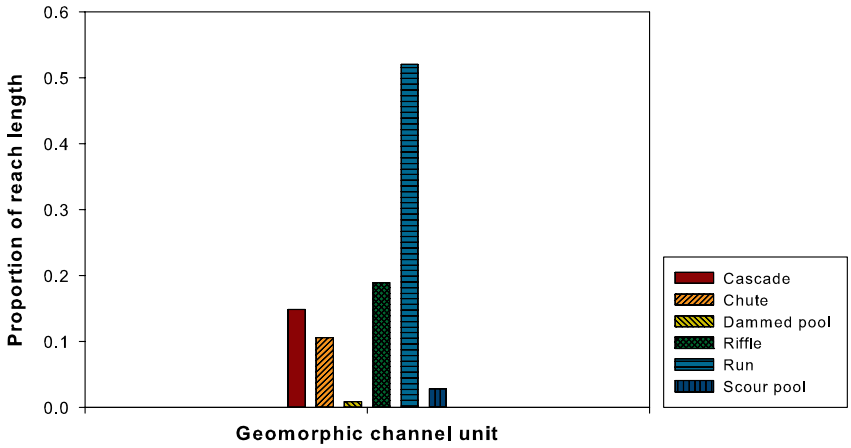


Figure 24. Geomorphic channel unit characterization from GAR01 at Garden Creek in GRCA, 2010

3.6 Hydrologic conditions for Garden Creek

3.6.1 SCPN field data

Water quality data collected at GAR01 are presented in Table 6. These data represent measurements at or near midday of the sample date. The noon time temperature was recorded as 15.3°C. pH was 8.9. We were unable to collect specific conductivity, turbidity, or stream discharge at GAR01 in 2010.

3.6.2 NADP station data

Precipitation values associated with Hermit Creek (fig. 15) are also applicable to Garden Creek.

3.7 Aquatic macroinvertebrate community data for Bright Angel Creek

Key metrics are presented in Table 7 (qualitative) and in Table 8 (quantitative), describing aquatic macroinvertebrate communities from samples collected at BRI01. Figures in this section refer to quantitative data unless otherwise noted, and error bars in figures represent one standard deviation from the mean. Appendix C lists all aquatic macroinvertebrate species detected at the site, from both quantitative and qualitative methods.

Abundance. Relative abundance values from quantitative targeted riffle samples at BRI01 were very robust . The mean relative abundance was 672.20 individuals. Sample abundances ranged from a low of 584 individuals to a high of 753 individuals.

Taxa richness. Taxonomic richness from quantitative targeted riffle samples at BRI01 averaged 18.60 taxa per sample (fig. 25). Quantitative samples ranged from a low of 14 taxa to a high of 24 taxa. Total taxa richness from our qualitative multihabitat sample was 26 taxa.

Diversity. We used the Simpson's Diversity Index to measure both taxonomic and functional diversity of quantitative samples from BRI01. Taxonomic diversity averaged 0.78. Samples ranged from a low of 0.39 to a high of 0.69 (fig. 26). Functional diversity was lower, averaging 0.50. Functional diversity ranged from a low of 0.24 to a high of 0.61.

Anthropogenic stress tolerance. Intolerant individuals were the most abundant, and intolerant taxa were the most common in samples collected from BRI01 (fig. 27). Intolerant relative abundance and richness averaged 71.37% and 52.18%, respectively. Moderately tolerant individuals and taxa were the second most common, with an average relative abundance of 28.32% and a richness of 43.71%. Very few tolerant individuals (0.31%) or taxa (4.11%) were found at BRI01.

Table 7. Qualitative metrics for aquatic macroinvertebrate samples collected from BRI01 at Bright Angel Creek in Grand Canyon National Park, Arizona, 2010. Richness-based metrics are expressed as the percentage of taxa in a given order, tolerance or functional feeding group.

Qualitative metric	2010
Taxa richness	26
Tolerance group	
Richness of tolerant taxa (%)	8.33
Richness of moderately tolerant taxa (%)	45.83
Richness of intolerant taxa (%)	45.83
Functional group	
Richness of collector-filterers (%)	11.54
Richness of collector-gatherers (%)	34.62
Richness of scrapers (%)	11.54
Richness of shredders (%)	0.00
Richness of predators (%)	42.31
Taxonomic group	
Number of EPT taxa	8
Richness of EPT taxa (%)	30.77
Richness of Ephemeroptera (%)	15.38
Richness of Plecoptera (%)	0.00
Richness of Trichoptera (%)	15.38
Richness of noninsect taxa (%)	19.23
Richness of Chironomid Diptera (%)	11.54
Richness of non-Chironomid Diptera (%)	19.23
Richness of Coleoptera (%)	7.69
Richness of Odonata (%)	11.54

Figure 25. Mean taxa richness in quantitative targeted riffle and total taxa richness in qualitative multihabitat samples collected from BRI01 at Bright Angel Creek in GRCA, 2010

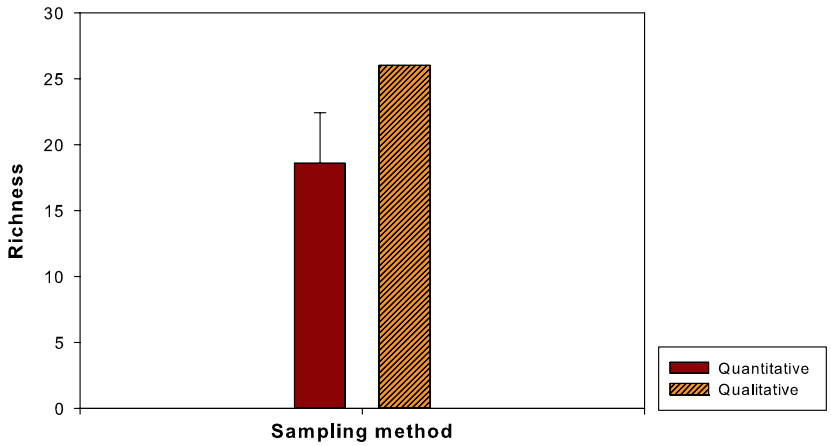


Table 8. Quantitative metrics for aquatic macroinvertebrate samples collected from BRI01 at Bright Angel Creek in Grand Canyon National Park, Arizona, 2010. For a given order, tolerance or functional feeding group, abundance-based metrics are expressed as the percentage of individuals in the group, while richness-based metrics are expressed as the percentage of taxa in the group.

	2010	
Quantitative metric	**Mean**	**SD**
Total abundance	672.20	69.16
Total richness	18.60	3.85
Simpson's Diversity—taxonomic	0.78	0.06
Simpson's Diversity—functional group	0.50	0.16
Dominant taxa	35.42	4.60
Tolerance group		
Relative abundance of tolerant taxa (%)	0.31	0.35
Relative abundance of moderately tolerant taxa (%)	28.32	13.16
Relative abundance of intolerant taxa (%)	71.37	13.07
Richness of tolerant taxa (%)	4.11	3.99
Richness of moderately tolerant taxa (%)	43.71	3.14
Richness of intolerant taxa (%)	52.18	4.99
Functional group		
Relative abundance of collector-filterers (%)	13.11	6.59
Relative abundance of collector-gatherers (%)	59.39	19.76
Relative abundance of scrapers (%)	24.91	20.68
Relative abundance of shredders (%)	0.00	0.00
Relative abundance of predators (%)	2.59	1.54
Richness of collector-filterers (%)	17.69	3.57
Richness of collector-gatherers (%)	36.51	1.12
Richness of scrapers (%)	20.01	5.30
Richness of shredders (%)	0.00	0.00
Richness of predators (%)	25.79	7.21
Taxonomic group		
Number of EPT taxa	7.40	0.89
Relative abundance of EPT taxa (%)	51.99	12.34
Relative abundance of Ephemeroptera (%)	35.93	13.04
Relative abundance of Plecoptera (%)	0.00	0.00
Relative abundance of Trichoptera (%)	16.06	8.74
Relative abundance of noninsect taxa (%)	2.86	1.86
Relative abundance of Chironomid Diptera (%)	11.25	7.04
Relative abundance of non-Chironomid Diptera (%)	21.59	17.72
Relative abundance of Coleoptera (%)	11.31	9.56
Relative abundance of Odonata (%)	0.99	0.78

Figure 26. Simpson's Diversity Index for taxonomic and functional diversity in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010

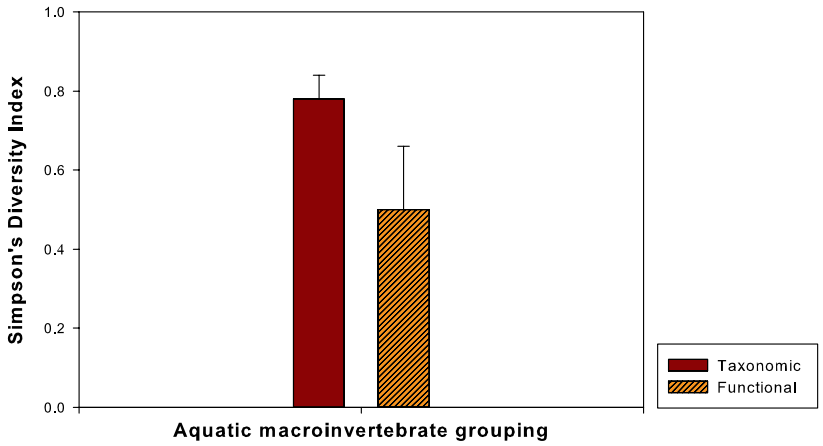
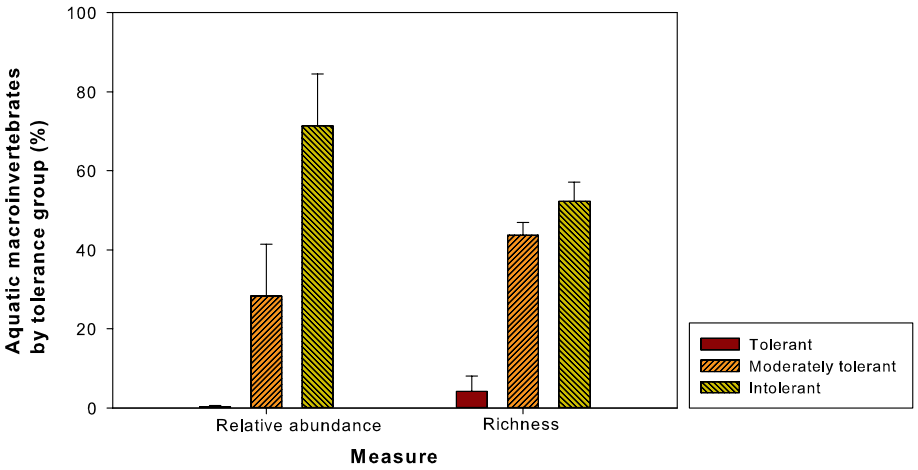
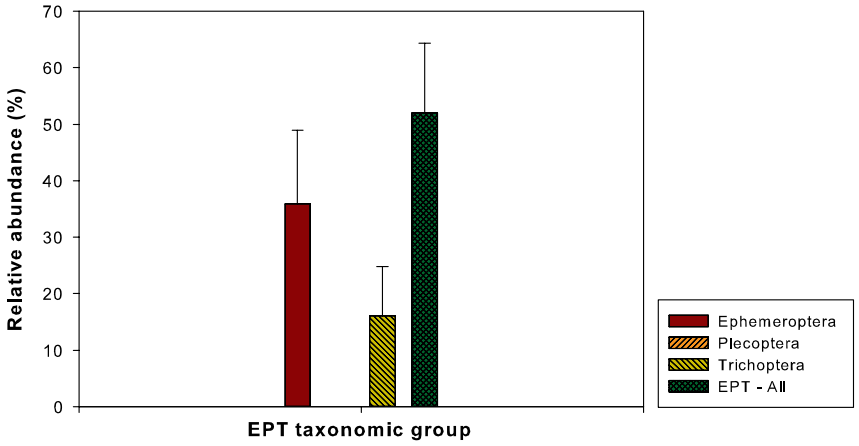


Figure 27. Mean relative abundance and richness of aquatic macroinvertebrates in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010, based on their tolerance to perturbation



EPT taxa. Relative abundance of individuals in sensitive EPT orders was very robust. On average, over half of the organisms collected (51.99%) from quantitative samples belonged to either Ephemeroptera, Plecoptera , or Trichoptera (fig. 28). Of that 51.99%, 35.93% were Ephemeroptera, 16.06% were Trichoptera, and no plecopterans were found at BRI01 in 2010.

Figure 28. Relative abundance of sensitive EPT orders in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010. No Plecoptera were found at this site.



Aquatic macroinvertebrate orders. Ephemeropterans were the most abundant group of aquatic macroinvertebrates collected from BRI01 (fig. 29). Non-chironomid dipterans were the second most abundant, with a relative abundance of 21.59%. Trichopterans were next, followed by coleopterans at 11.31%, chironomid dipterans at 11.25%, and noninsect taxa at 2.86%. Noninsect taxa for this monitoring site included worm, water mites and water striders. Very few odonates were collected (0.99%).

Functional feeding groups. Collector-gatherers were the most abundant functional feeding group of aquatic macroinvertebrates in our samples (fig. 30). Relative abundance of collector-gatherers was 59.39%. Scrapers were the second most abundant at 24.91%. Collector-filterers averaged 13.11% and predators were the least abundant at 2.59%.

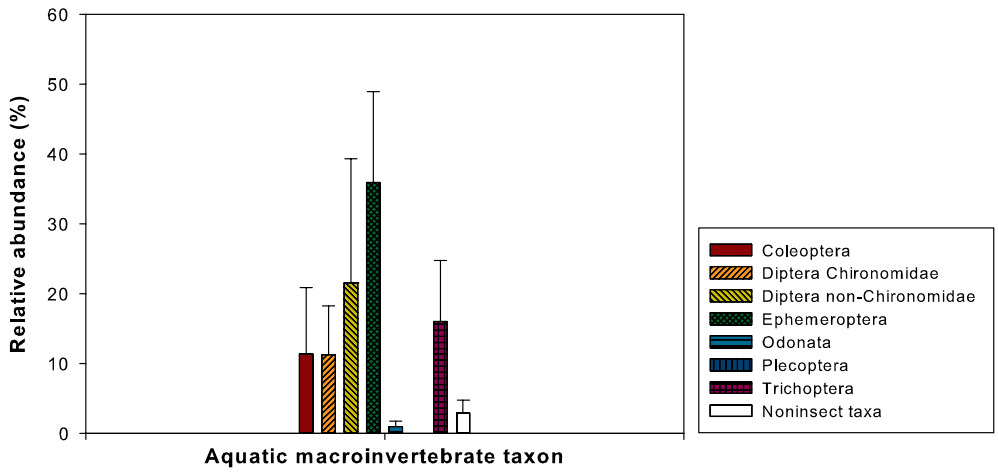


Figure 29. Relative abundance of individuals by taxonomic order in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010

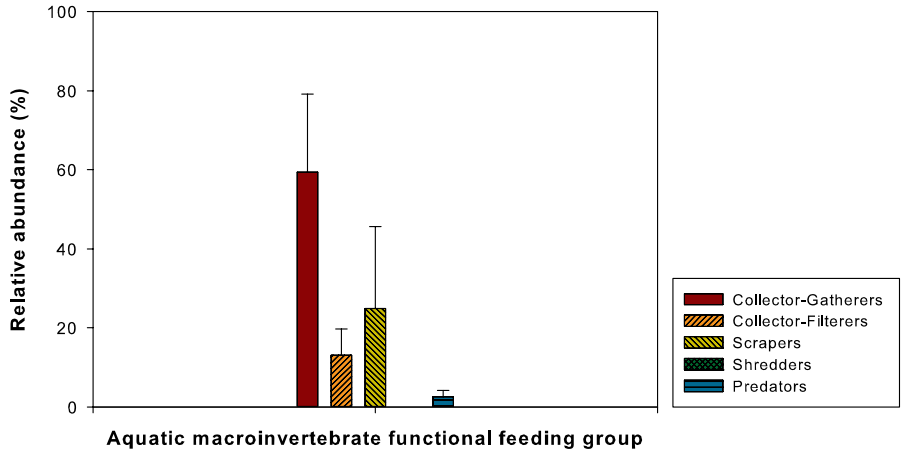


Figure 30. Relative abundance of functional feeding groups in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010

3.8 Physical habitat characteristics for Bright Angel Creek

This section presents data describing physical habitat characteristics collected at BRI01 during 2010, summarized in Table 9. Additional transect data can be found in Appendix D.

Microhabitat level. Velocity at the five targeted riffle sample locations averaged 0.56 m/s. Depths at these locations averaged 0.15 m. Individual particles were 23.6% embedded, on average (table 9).

Table 9. Physical habitat and hydrologic data from BRI01 at Bright Angel Creek in Grand Canyon National Park, Arizona, 2010. Particle embeddedness and canopy closure measurements are expressed as percentages.

	2010	
Physical habitat metric	**Mean**	**SD**
Microhabitat level		
Riffles		
Velocity (m/s)	0.56	0.26
Depth (m)	0.15	0.07
Embeddedness (%)	23.6	15.3
Transect level		
Channel dimensions		
Velocity (m/s)	0.48	0.19
Depth (m)	0.22	0.05
Wetted channel width (m)	6.9	2.5
Active channel width (m)	17.6	5.0
Riparian cover		
Canopy closure (%)	11.8	23.9
Reach level		
Water quality	**Value**	
Temperature (°C)	13.8	
Specific conductivity (µS/cm)	352	
pH	8.6	
Dissolved oxygen (% saturation)	100.5	
Dissolved oxygen (mg/L)	9.4	
Turbidity (NTU)	0.60	
Discharge (cfs)	21.3	

Transect level. The average active channel width at the 11 physical habitat transects was 17.6 m. Wetted channel width averaged 6.9 m. Velocity and depth at our habitat transects averaged 0.48 m/s and 0.22 m, respectively (table 9).

We found three aquatic macroinvertebrate habitat types along the physical habitat transects (fig. 31). Rock was the dominant habitat type and was found along 70.0% of the transects. Vegetation was found along 10.0% of the transects, and root wads were found along 2.9%. The remaining 17.1% of the habitat was represented by the "Absence" category, meaning that it did not fit into a category that SCPN defines as appropriate for aquatic macroinvertebrates.

Reach level. Particle size distribution was dominated by larger size grains (coarse gravels to bedrock) (fig. 32). The most abundant size class was cobble, which was found along 26.1% of the sampling reach. Boulder/bedrock was the next most abundant size class, at 20.3%. No size class smaller than 16 mm was found in abundance greater than 5%.

Riffles were the dominant GCU type found along the sampling reach (fig. 33). Riffles made up 40.5% of the reach. Cascades were the next most abundant at 24.0%, followed by runs at 19.2% and scour pools at 16.3%.

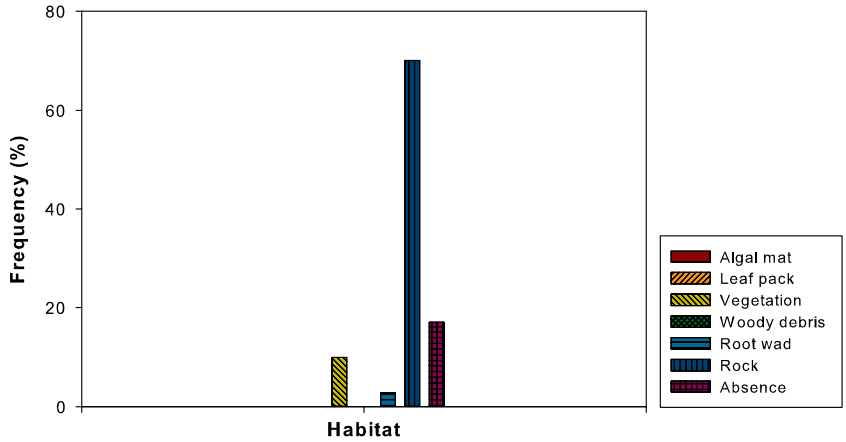


Figure 31. Aquatic macroinvertebrate habitat characterization based upon line point intercept data collected along habitat transects from BRI01 at Bright Angel Creek in GRCA, 2010. Some habitat structures were not observed.

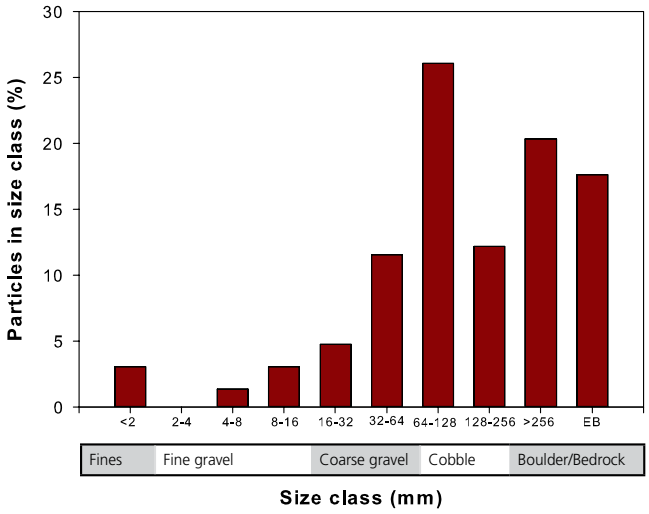


Figure 32. Particle size distribution based on modified Wolman pebble counts (minimum 400 particles), from BRI01 at Bright Angel Creek in GRCA, 2010. EB on the x axis represents particles that are completely embedded into the stream channel, which precludes size measurements.

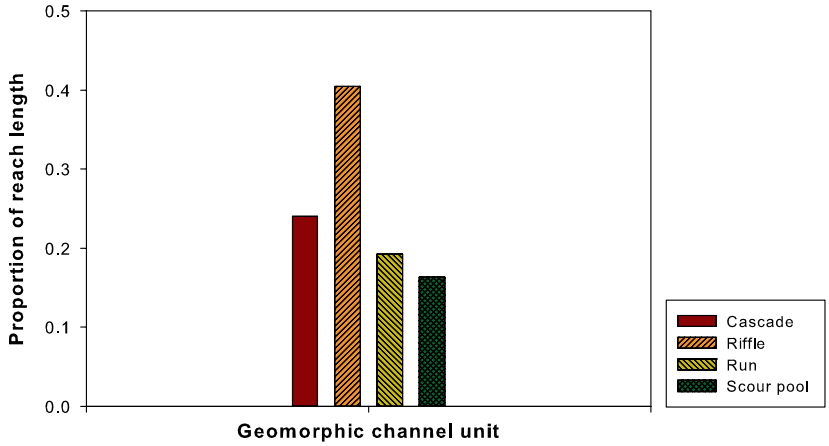


Figure 33. Geomorphic channel unit characterization from BRI01 at Bright Angel Creek in GRCA, 2010

3.9 Hydrologic conditions for Bright Angel Creek

We collected water quality data at BRI01(table 9). These data represent measurements at or near midday of the sample date. The noon time temperature was 13.8°C. Specific conductivity was 352 μS/cm and pH measured 8.6. Dissolved oxygen measured 9.4 mg/L and 100.5% saturation. Turbidity was 0.60 NTU. Stream discharge for the reach at the time of our visit was 21.3 cfs.

4 Discussion

This report presents data from SCPN's second year of monitoring aquatic macroinvertebrates and physical habitat at Hermit Creek and its first year of monitoring at Garden Creek and Bright Angel Creek in Grand Canyon National Park, Arizona. We stress that the data included in this report are not to be interpreted as ecologically significant trends, as trends cannot be determined by one year of sampling data.

Differences may be attributed to multiple factors, including ecological variability and sampling error or may be a result of observer bias. SCPN attempts to minimize sampling error and observer bias by thoroughly training crew members in the proper field techniques prior to each sampling season.

4.1 Aquatic macroinvertebrate communities

Aquatic macroinvertebrate abundance and richness were quite robust at all monitoring sites in Grand Canyon. Samples from Garden Creek and Bright Angel Creek in 2010 exhibited some of the highest abundance and richness values of any sites monitored by SCPN within our network. Similarly, taxonomic diversity was also high at all sampling sites.

Aquatic macroinvertebrate taxa differ in their ability to withstand degradation or disturbance occurring in the aquatic environment. As a result, aquatic ecologists have divided taxa into tolerance classes based on their susceptibility to anthropogenic perturbation. Separating taxa based on these tolerance classes allows us to make some inferences about how the community is responding to stream conditions at the time of our visit. In 2010, relative abundance and richness values of moderately tolerant aquatic macroinvertebrates dominated samples from Hermit Creek and Garden Creek. At Bright Angel Creek intolerant individuals and taxa dominated samples. Relative abundance of tolerant individuals ranged from a high of 2.17% at Hermit Creek to a low of 0.31% at Bright Angel Creek. These results suggest that conditions for aquatic macroinvertebrates were favorable at all three streams. The large abundance values of intolerant and moderately tolerant individuals suggest that any anthropogenic disturbance that may have been occurring in the stream at the time of our visit was having little or no effect on aquatic macroinvertebrate community structure.

As further support for favorable stream conditions, relative abundances of EPT taxa, which are sensitive to degradation of water quality, were high at both Garden and Bright Angel Creeks. Over half of the individuals collected from both streams belonged to one of the EPT orders.

4.2 Physical habitat

There were very few differences in physical habitat data between monitoring sites. Garden Creek stream velocity and depth were greater on average at riffle and transects than the other two sites. The largest difference we found in any habitat measure was the difference in canopy cover at Garden Creek. Riparian canopy was found along 70% of our reach at Garden Creek, compared to 11.8% and 7.5% at Bright Angel and Hermit Creeks, respectively. This is important because riparian vegetation adds available habitat, food resources through woody debris and leaf packs, and regulates stream temperature through shading.

Aquatic macroinvertebrate habitat types were more diverse at Garden Creek than at the other two sites. Hermit and Bright Angel Creeks were dominated by rocky habitats. At both of those streams our category "Absence" was the next most abundant. This suggests that rocky substrate is the primary habitat type available for aquatic macroinvertebrates in those streams. Nearly 63% of the habitat at Garden Creek was dominated by algal mats and vegetation, two categories that provide habitat and forage for some aquatic macroinvertebrate taxa. These differences in habitat types and food resources may be attributing to the higher abundance, richness, and diversity values found at the Garden Creek monitoring site.

The data in this report should be viewed as a snapshot of conditions existing within the aquatic community at the time of our visit. Data and analyses in this report are provisional and are subject to change. When sufficient data are available, SCPN plans to produce an interpretive report including trend analysis of aquatic macroinvertebrate metrics and physical habitat data at monitored streams in Grand Canyon.

5 Literature cited

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Appendix A Description of monitoring sites at Grand Canyon National Park, Arizona, 2010

Site code	Common name	Report name	UTM X	UTM Y	Elevation (m)
GRCABRI01	Bright Angel below first footbridge	BRI01	402061	9337091	821
GRCAGAR01	Garden Creek below Tonto Trail	GAR01	399029	3993992	1085
GRCAHER01	Hermit Creek below Tonto Trail	HER01	390736	3993596	865

Appendix B Selected aquatic macroinvertebrate metrics

Metric type	Metric	Definition
Abundance/Richness/ Diversity	Total abundance	Total number of individuals.
	Taxa richness	Total number of taxa (measures the overall variety of aquatic macroinvertebrates in a sample).
	Simpson's diversity	A measure of the variety of taxa that takes into account the relative abundance of each taxon. $D = \sum(n_i(n_i - 1)/N(N-1))$
Tolerance	Dominant taxa	Measures the dominance of the most abundant taxa. Typically calculated as dominant 2, 3, 4, or 5 taxa.
	Relative abundance tolerant taxa	Percent of individuals considered to be sensitive to perturbation.
	Percent richness of tolerant taxa	Percent of taxa considered to be sensitive to perturbation.
Functional-Feeding	Relative abundance collector-filterers	Percent of individuals that filter fine particulate organic matter from the water column.
	Percent richness collector-filterers	Percent of taxa that filter fine particulate matter from the water column.
	Relative abundance scrapers	Percent of individuals that scrape or graze upon periphyton.
Functional-Habit	Relative abundance burrowers	Percent of individuals that move between substrate particles (typically fine substrates).
	Percent richness burrowers	Percent of taxa that move between substrate particles (typically fine substrates).
	Relative abundance clingers	Percent of individuals that have fixed retreats or adaptations for attachment to surfaces in flowing water.
	Percent richness clingers	Percent of taxa that have fixed retreats or adaptations for attachment to surfaces in flowing water.
Composition	Number of EPT taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).
	Relative abundance EPT	Percent of individuals in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).
	Relative abundance Ephemeroptera	Percent of individuals that are mayflies.
	Relative abundance Plecoptera	Percent of individuals that are stoneflies (for streams >1,500 m in elevation).
	Relative abundance Trichoptera	Percent of individuals that are caddisflies.
	Hydroptilidae+ Hydropsychidae/Trichoptera	Percent of trichopteran individuals in Hydroptilidae plus Hydropsychidae (ratio of tolerant caddisfly abundance to total caddisfly abundance).
	Relative abundance noninsect taxa	Percent of individuals that are not insects.
	Relative abundance Chironomidae	Percent of individuals that are midges.

Source: Data from Brasher et al. (2011)

Appendix C Aquatic macroinvertebrate species list from the three monitoring sites in Grand Canyon National Park, Arizona, 2010

Phylum	Class	Order	Family	SubFamily	Genus	Species	Common name	BRI01	GAR01	HER01
Annelida							segmented worms	**X**	**X**	
Arthropoda	Arachnida	Trombidiformes					water mites		**X**	
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		*Lebertia* sp.		water mites			X
Arthropoda	Arachnida	Trombidiformes	Sperchonidae		*Sperchon* sp.		water mites	**X**	**X**	X
Arthropoda	Arachnida	Trombidiformes	Sperchonidae		*Sperchonopsis*		water mite		**X**	
Arthropoda	Arachnida	Trombidiformes	Sperchonidae				water mites	**X**		
Arthropoda	Arachnida	Trombidiformes	Torrenticolidae		*Torrenticola* sp.		water mites			X
Arthropoda	Arachnida	Trombidiformes	Torrenticolidae				water mites			X
Arthropoda	Entognatha	Collembola					springtails		**X**	**X**
Arthropoda	Insecta	Coleoptera	Dytiscidae				predaceous diving beetle		**X**	
Arthropoda	Insecta	Coleoptera	Elmidae				riffle beetles	**X**	**X**	X
Arthropoda	Insecta	Coleoptera	Elmidae		*Heterelmis* sp.		riffle beetles	**X**		
Arthropoda	Insecta	Coleoptera	Elmidae		*Microcylloepus*	*pusillus*	pusillanimous riffle beetle	**X**	**X**	X
Arthropoda	Insecta	Coleoptera	Haliplidae		*Peltodytes* sp.		crawling water beetles		**X**	**X**
Arthropoda	Insecta	Coleoptera	Hydrophilidae				water scavenger beetles		**X**	
Arthropoda	Insecta	Diptera					flies	**X**		**X**
Arthropoda	Insecta	Diptera	Ceratopogonidae				biting midges			X
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia* sp.		biting midges			**X**
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	*Probezzia* sp.		biting midges	**X**	**X**	X
Arthropoda	Insecta	Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea* sp.		biting midges			**X**
Arthropoda	Insecta	Diptera	Chironomidae				midges	**X**	**X**	X
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae			midges	**X**	**X**	X
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae			non-biting midges	**X**	**X**	X
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae			midges	**X**	**X**	X
Arthropoda	Insecta	Diptera	Dixidae		*Dixa* sp.		meniscus midges			**X**
Arthropoda	Insecta	Diptera	Dolichopodidae				longlegged flies	**X**		
Arthropoda	Insecta	Diptera	Empididae				dance flies	**X**	**X**	X
Arthropoda	Insecta	Diptera	Empididae	Hemero-dromiinae	*Hemerodromia* sp.		dance flies		**X**	X
Arthropoda	Insecta	Diptera	Empididae		*Clinocera*		dance flies		**X**	
Arthropoda	Insecta	Diptera	Empididae		*Neoplasta* sp.		dance flies		**X**	X
Arthropoda	Insecta	Diptera	Empididae		*Wiedemannia*		dance flies		**X**	

Appendix C (*continued*)

Phylum	Class	Order	Family	SubFamily	Genus	Species	Common name	BRI01	GAR01	HER01
Arthropoda	Insecta	Diptera	Muscidae				house flies		**X**	
Arthropoda	Insecta	Diptera	Stratiomyidae				solider flies	**X**	**X**	
Arthropoda	Insecta	Diptera	Stratiomyidae		*Caloparyphus* sp.		soldier flies		**X**	X
Arthropoda	Insecta	Diptera	Stratiomyidae		*Euparyphus* sp.		soldier flies		**X**	X
Arthropoda	Insecta	Diptera	Stratiomyidae		*Odontomyia* sp.		soldier flies			**X**
Arthropoda	Insecta	Diptera	Tabanidae				horse flies	**X**		
Arthropoda	Insecta	Diptera	Tabanidae		*Tabanus* sp.		horse flies	**X**	**X**	X
Arthropoda	Insecta	Diptera	Psychodidae		*Maruina* sp.		moth flies	**X**		
Arthropoda	Insecta	Diptera	Psychodidae		*Pericoma*		moth flies		**X**	
Arthropoda	Insecta	Diptera	Simuliidae	Simuliinae	*Simulium* sp.		black flies	**X**	**X**	X
Arthropoda	Insecta	Diptera	Simuliidae				black flies	**X**		X
Arthropoda	Insecta	Diptera	Tipulidae				crane flies		**X**	
Arthropoda	Insecta	Diptera	Tipulidae		*Dicranota* sp.		crane flies	**X**		
Arthropoda	Insecta	Ephemeroptera	Baetidae				small minnow mayflies	**X**	**X**	X
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Acentrella* sp.		small minnow mayflies	**X**		
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Baetis* sp.		small minnow mayflies	**X**	**X**	X
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Baetodes* sp.		small minnow mayflies	**X**	**X**	**X**
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Fallceon*	*quilleri*	small minnow mayflies	**X**	**X**	X
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae		*Ephemerella*	*excrucians*	spiny crawler mayflies			X
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae				pronggilled mayflies	**X**	**X**	
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae		*Paraleptophlebia* sp.		pronggilled mayflies	**X**	**X**	
Arthropoda	Insecta	Hemiptera	Gerridae	Gerrinae	*Aquarius* sp.		water striders			**X**
Arthropoda	Insecta	Hemiptera	Veliidae	Microveliinae	*Microvelia* sp.		small water striders	**X**		X
Arthropoda	Insecta	Hemiptera	Veliidae	Rhagoveliinae	*Rhagovelia* sp.		small water striders	**X**		
Arthropoda	Insecta	Lepidoptera	Crambidae	Nymphulinae	*Petrophila* sp.		crambid snout moths	**X**	**X**	X
Arthropoda	Insecta	Megaloptera	Corydalidae	Corydalinae	*Corydalus*	*cornutus*	eastern dobsonflies	**X**	**X**	X
Arthropoda	Insecta	Odonata					damselflies/dragonflies			**X**
Arthropoda	Insecta	Odonata					damselflies	**X**		
Arthropoda	Insecta	Odonata	Aeshnidae				darners		**X**	X
Arthropoda	Insecta	Odonata	Libellulidae				skimmers	**X**		X
Arthropoda	Insecta	Odonata	Calopterygidae		*Hetaerina* sp.		broad-winged damselflies	**X**	**X**	
Arthropoda	Insecta	Odonata	Calopterygidae				broad-winged damselflies	**X**		

Appendix C (*continued*)

Phylum	Class	Order	Family	SubFamily	Genus	Species	Common name	BRI01	GAR01	HER01
Arthropoda	Insecta	Odonata	Coenagrionidae		*Argia* sp.		narrow-winged damsel-flies	**X**	**X**	X
Arthropoda	Insecta	Odonata	Coenagrionidae				windged damselflies	**X**	**X**	X
Arthropoda	Insecta	Trichoptera					caddisflies	**X**		X
Arthropoda	Insecta	Trichoptera	Brachycentridae		*Micrasema*		humpless casemaker caddisflies		**X**	
Arthropoda	Insecta	Trichoptera	Helicopsychidae		*Helicopsyche* sp.		snail case caddisflies	**X**	**X**	
Arthropoda	Insecta	Trichoptera	Hydropsychidae				net spinning caddisflies	**X**	**X**	X
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychinae	*Hydropsyche* sp.		netspinning caddisflies	**X**		X
Arthropoda	Insecta	Trichoptera	Hydroptilidae				microcaddisflies	**X**	**X**	X
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	*Hydroptila* sp.		microcaddisflies			X
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	*Leucotrichia*		microcaddisflies	**X**	**X**	
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	*Ochrotrichia* sp.		microcaddisflies	**X**		**X**
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	*Oxyethira* sp.		microcaddisflies			X
Arthropoda	Insecta	Trichoptera	Philopotamidae				fingernet caddisflies	**X**		
Arthropoda	Insecta	Trichoptera	Philopotamidae	Chimarrinae	*Chimarra* sp.		little black caddisflies	**X**	**X**	
Arthropoda	Insecta	Trichoptera	Philopotamidae	Philopotaminae	*Wormaldia*		fingernet caddisflies		**X**	
Arthropoda	Insecta	Trichoptera	Polycentropodidae				tube maker caddisflies	**X**		
Arthropoda	Insecta	Trichoptera	Rhyacophilidae		*Rhyacophila* sp.		green sedge caddisflies	**X**		
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	Lymnaeinae			pond snails		**X**	
Platyhelminthes	Turbellaria						flat worms		**X**	

Appendix D Measured velocity and channel characteristics at three monitoring sites in Grand Canyon National Park, Arizona, 2010

	Velocity (m/s)		Depth (m)		Wetted channel width (m)	Active channel width (m)
Transect	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Value**	**Value**
BRI01						
1	0.41	0.36	0.25	0.17	4.0	30.0
2	0.61	0.62	0.32	0.10	3.0	22.6
3	0.50	0.33	0.24	0.11	6.0	14.9
4	0.91	0.28	0.19	0.11	5.2	15.9
5	0.36	0.49	0.25	0.31	11.4	14.5
6	0.42	0.29	0.14	0.14	9.7	19.3
7	0.60	0.15	0.17	0.09	7.9	11.9
8	0.25	0.22	0.21	0.14	9.1	14.5
9	0.29	0.29	0.22	0.11	7.5	15.4
10	0.36	0.15	0.24	0.11	6.0	18.5
11	0.56	0.55	0.19	0.13	5.8	16.4
GAR01						
1	0.44	0.05	0.07	0.05	1.0	8.3
2	0.61	0.40	0.11	0.07	1.2	5.9
3	0.94	0.19	0.08	0.04	1.8	5.5
4	0.91	0.21	0.08	0.09	1.3	3.7
5	0.81	0.49	0.07	0.05	2.0	7.7
6	0.83	0.14	0.07	0.05	1.2	8.3
7	0.50	0.33	0.09	0.06	1.5	5.7
8	0.22	0.08	0.07	0.08	1.5	10.2
9	0.32	0.20	0.10	0.04	0.9	10.9
10	0.67	0.55	0.05	0.03	1.1	3.8
11	0.69	0.37	0.09	0.05	1.1	2.7
HER01						
1	0.20	0.08	0.31	0.46	2.9	7.9
2	0.15	0.19	0.08	0.02	2.2	4.8
3	0.03	0.05	0.08	0.09	5.6	10.4
4	0.15	0.21	0.04	0.04	2.4	8.5
5	0.12	0.13	0.13	0.08	1.8	5.3
6	0.02	0.03	0.04	0.06	1.1	7.6
7	0.26	0.38	0.08	0.08	3.2	5.5
8	0.23	0.24	0.04	0.02	3.1	4.3
9	0.62	n.a.[a]	0.02	0.01	2.6	4.0
10	0.34	0.07	0.04	0.06	2.5	7.9
11	0.48	0.35	0.03	0.04	2.2	11.1

[a]Not applicable; only one record.