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

2013 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2014/737

ON THE COVER
Hermit Creek in Grand Canyon National Park
Photograph courtesy of SCPN

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

2013 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2014/737

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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 scientific foundation for making decisions and working with other agencies and the public to protect park ecosystems. Water-related vital signs are the fundamental components defining overall riparian and aquatic ecosystem integrity. The Southern Colorado Plateau Network (SCPN) has identified 7 vital signs pertaining to riparian and spring ecosystems, the first 2 of which we focus on in this report: 1) aquatic macroinvertebrates, 2) stream water quality, 3) streamflow and depth to groundwater, 4) spring water quality, 5) fluvial geomorphology, 6) riparian vegetation, composition, and structure, and 7) spring ecosystems. These vital signs are closely related and are all included in the *Vital Signs Monitoring Plan for the Southern Colorado Plateau Network* (Thomas et al. 2006). The context and ecological significance of these vital signs are further explained in Scott et al. (2005).

In 2009 SCPN implemented annual monitoring of aquatic macroinvertebrates and physical habitat on Hermit Creek in Grand Canyon National Park (GRCA) (Stumpf and Monroe 2011). During 2010 the SCPN water resources field crew added a site on Garden Creek and one on Bright Angel Creek (Stumpf and Monroe 2012). Appendix A lists locations, codes, and common names of all sampling sites. Criteria used to select reach locations included the presence of riffle habitats, the feasibility of using sampling equipment throughout the reach, the absence of artificial structures, and the lack of tributary or spring inflows. During 2013, aquatic macroinvertebrate samples and physical habitat data were collected from all 3 monitoring sites.

Hermit Creek below Tonto Trail (GRCAHER01), identified in this report as HER01, is an index site that is located downstream from the Hermit Creek Camp and the Tonto Trail crossing and just over 0.2 km downstream from the site of a recently destroyed streamflow gage—*Hermit Creek above Tonto Trail nr Grand Canyon, AZ* (Figure 1). The streamflow gage was established on Hermit Creek by the USGS in 1994, and was operated in recent years by GRCA staff. The gaging station was destroyed during a flash flood event in September 2011 and plans for reinstallation are uncertain. The channel substrate at this site is primarily cobble and bedrock. The stream flows through a sparse willow (*Salix* sp.) shrubland. The Hermit Fault acts as one of the main pathways for the flow of groundwater from the south rim. Consequently, Hermit Creek is one of the larger streams in this section of the Grand Canyon. Aquatic macroinvertebrate data have been collected sporadically at Hermit Creek by the state of Arizona from 1992 to 2009 (Lawson 2007; Arizona Department of Environmental Quality, unpublished data). SCPN's monitoring site is just downstream of the popular Hermit Creek campground and one of the criteria for selecting this site was to assess potential impacts on Hermit Creek resulting from human activities associated with the campground.

Garden Creek below Tonto Trail (GRCAGAR01), identified in this report as GAR01, is an index site that is located approximately 9.3 km downstream from the Bright Angel Trailhead (Figure 2). GAR01 is co-located with an SCPN water quality monitoring site. 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. 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. This trail is frequented by the hiking public as well as concessionaires who provide transportation through the inner canyon via mule. Up to 10 mule trips a day can occur along the Bright Angel Trail. Indian Gardens, a popular resting site for backcountry travelers on foot and by mule, is located adjacent to the stream, approximately 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. One specific reason for selecting this site was to assess impacts downstream of the campground and the livestock corral. Another factor potentially influencing this site is external water input. 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 and riparian ecosystems of Garden Creek.

Bright Angel Creek below first footbridge (GRCABRI01), identified in this report as BRI01, is an index site and is located upstream from Phantom Ranch, and downstream from the first large steel footbridge on the North Kaibab Trail (Figure 2). The site was located upstream of Phantom Ranch to avoid the effects of ranch and visitor activities on the stream. 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 through a willow (*Salix* sp.) shrubland with a horsetail (*Equisetum* sp.) understory. USGS gaging station, *Bright Angel Creek near Grand Canyon, AZ* 09403000, monitors streamflow, as well as air and water temperature, near the confluence of Bright Angel Creek and the Colorado River. During the fall and winter months of 2002–2003, the park began a trout reduction project in Bright Angel Creek. The goal of the project was to reduce the number of nonnative brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) from the creek. This project continued during the fall and winter months of 2006–2007, 2010–2011, 2011–2012, and 2012–2013. It is unclear how the removal efforts will affect aquatic macroinvertebrate taxa. A large flow event, measuring 2,695 cfs, occurred in Bright Angel Creek on 11 September 2011. These data represent the second year of postflood data.

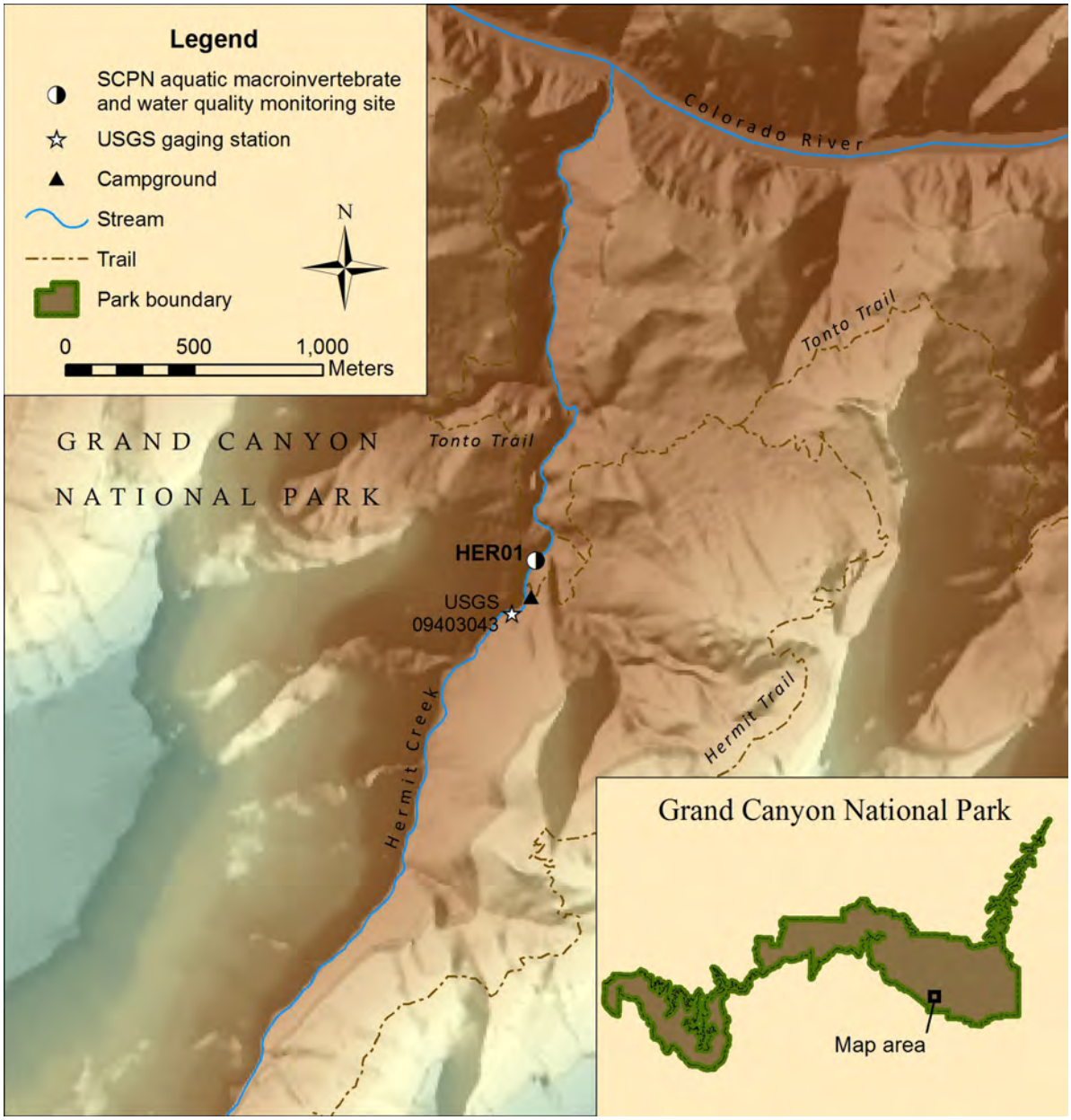


Figure 1. Map of the HER01 (Hermit Creek) monitoring site in Grand Canyon National Park, Arizona, 2013. The USGS gaging station was destroyed by flooding in 2011, but the site is still included on this map for reference.

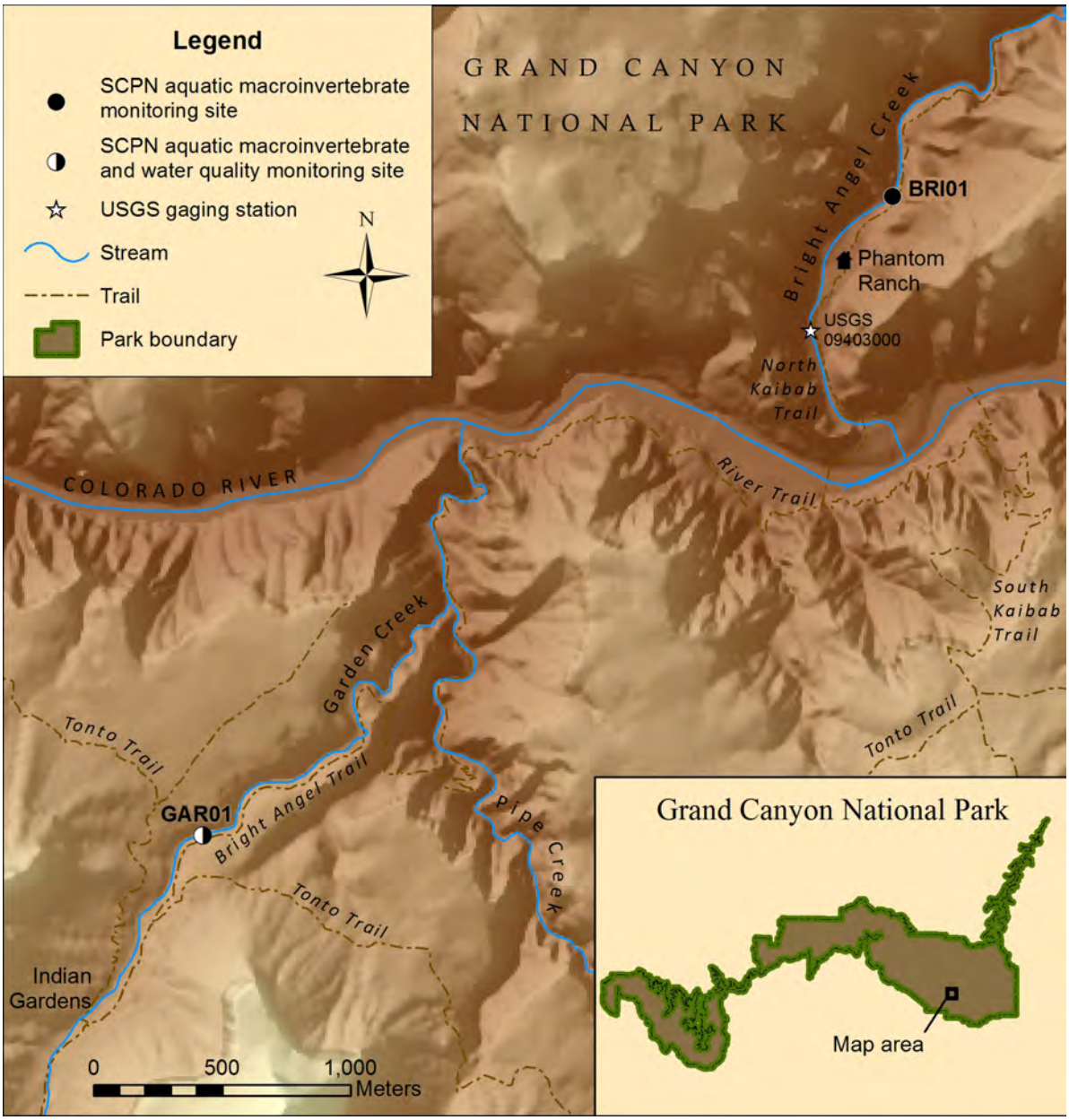


Figure 2. Map of the BRI01 (Bright Angel Creek) and the GAR01 (Garden Creek) monitoring sites in Grand Canyon National Park, Arizona, 2013.

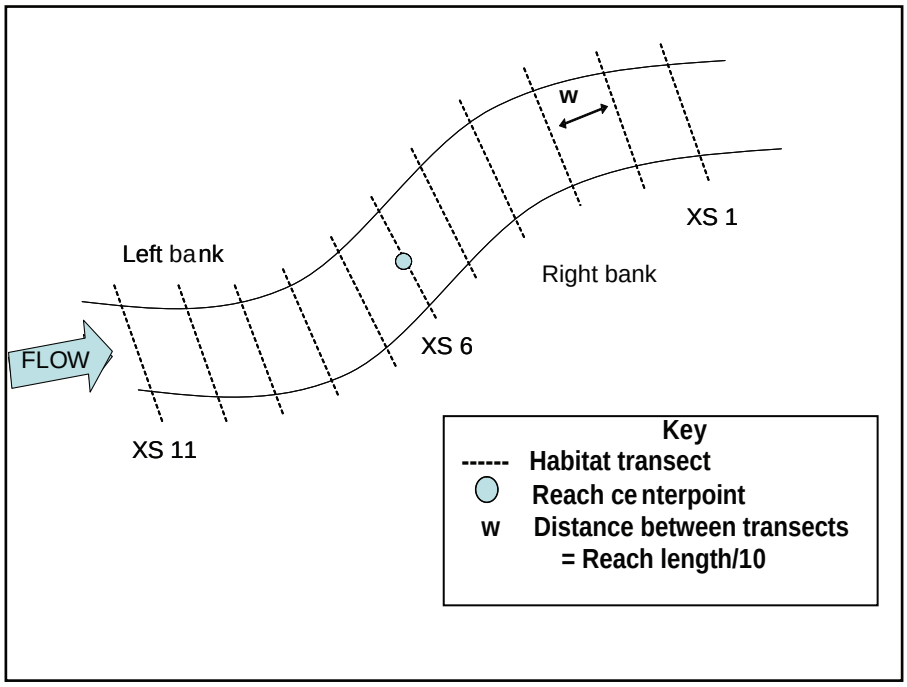
The purpose of this report is to (a) document SCPN aquatic macroinvertebrate monitoring activities that occurred at Hermit Creek, Garden Creek, and Bright Angel Creek in GRCA in 2013, (b) summarize the data collected, and (c) where appropriate, place the data in the context of current environmental conditions.

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 18 April 2013, we collected aquatic macroinvertebrate samples and physical habitat data at the monitoring site, HER01. We collected aquatic macroinvertebrate and physical habitat samples from GAR01 on 25 April 2013 and from BRI01 on 22 October 2013. BRI01 is a North Rim drainage which experiences annual spring streamflows 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 (Figure 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 2 types of aquatic macroinvertebrate samples from each site:

- Replicate quantitative samples were collected from 5 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 site. We used a Slack sampler to collect samples from all habitat types within the monitoring site and compiled them into one composite sample.

We collected physical habitat data at 3 spatial scales—microhabitat, transect, and reach:

- For each of the targeted riffle micro habitats where quantitative samples are collected 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
  - estimated canopy closure at both ends and at the center of each transect
  - measured water depth and velocity at 5 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 site
  - identified and recorded geomorphic channel units (GCU) at 5 equally spaced points along each transect
- For the entire reach, we
  - identified and measured the length of GCUs (the proportion of the reach representing each 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 site

2.2 Hydrologic data collection

Hydrologic data presented in this report were collected at a weather station at Hopi Point, and at a USGS streamflow gaging station on Bright Angel Creek in GRCA.

For hydrologic conditions applicable to Hermit Creek and Garden Creek, daily precipitation measurements were collected at the National Atmospheric Deposition Program (NADP) station at Hopi Point (AZ03) (National Atmospheric Deposition Program 2014). For Bright Angel Creek, we report discharge, as well as air and water temperature data collected by USGS streamflow gaging station #09403000 (U.S. Geological Survey 2013).

2.3 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 10X magnification, and a 500-organism, fixed-count method was used for subsampling 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 5 years to allow for repeat subsampling should any data questions arise. For a more detailed description of laboratory methods, see Brasher et al. (2011).

2.4 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.

For quantitative aquatic macroinvertebrate data, we calculate means and standard deviations from the 5 replicate samples collected. For those parameters measured along transects (such as habitat characterization), we calculate means and standard deviations from the 11 transect values.

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

We present key metrics calculated from aquatic macroinvertebrate community data collected at HER01 from 2009 to 2013. 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 macroinvertebrate species detected at the site, from both quantitative and qualitative methods. All data values corresponding to figures in this section are available in table format in Appendix D (Tables D1, D2).

Abundance. Abundance of aquatic macroinvertebrates at the quantitative targeted riffle habitat averaged 690.40 individuals per riffle (Figure 4), and ranged from a high of 755 individuals to a low of 645 individuals in 2013.

Taxa richness. Total richness at quantitative targeted riffle habitat averaged 19.20 taxa in 2013 (Figure 5). Richness ranged from a high of 22 taxa to a low of 16 taxa. Richness for the qualitative sample was 20 taxa.

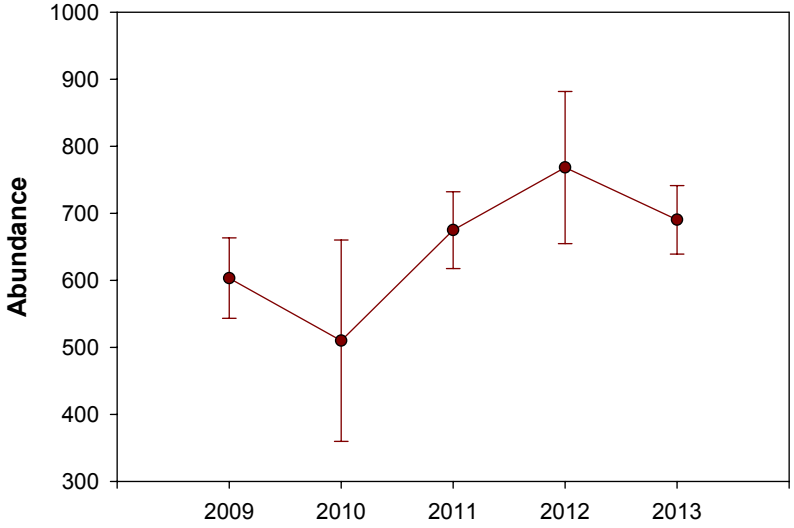


Figure 4. Aquatic macroinvertebrate abundance in samples from HER01 at Hermit Creek in GRCA, 2009–2013.

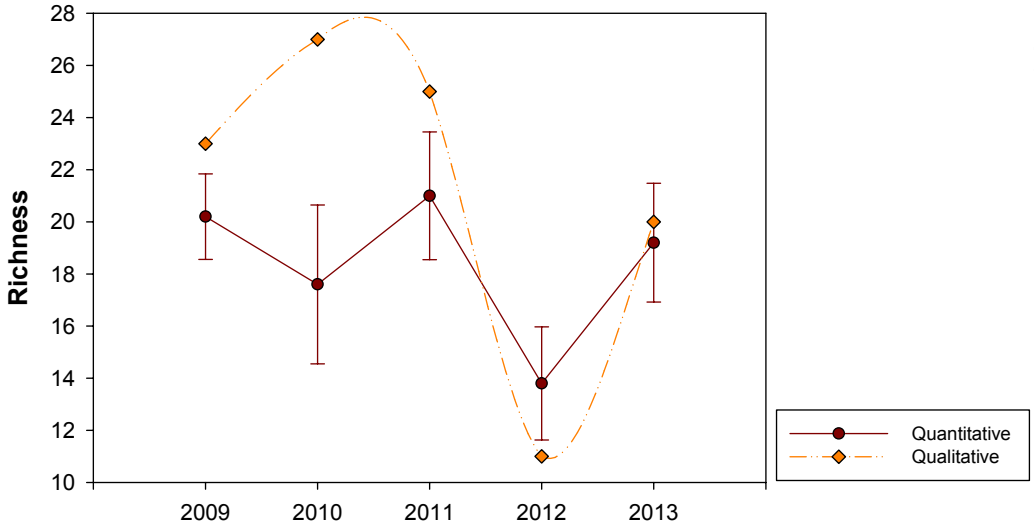


Figure 5. Taxa richness in quantitative and qualitative samples from HER01 at Hermit Creek in GRCA, 2009–2013.

Diversity. We calculated taxonomic and functional diversity using the Simpson's Diversity Index (Figure 6). Taxonomic diversity in 2013 averaged 0.74 per riffle, and was over 3 times as high as functional diversity, which averaged 0.24 per sample.

Stress tolerance. Taxa that are moderately tolerant of disturbance were the most abundant at HER01 in 2013. The relative abundance of moderately tolerant aquatic macroinvertebrates averaged 54.05% (Figure 7). Relative abundance of intolerant individuals averaged 44.88%, and tolerant individuals were the least abundant group, averaging 1.06%.

EPT taxa. Relative abundance of EPT taxa (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]) at this monitoring site averaged 67.37% of all taxa collected in 2013 (Figure 8). Ephemeroptera was the overwhelmingly dominant EPT order, averaging 64.87% of individuals. Trichoptera averaged 2.38% of individuals collected. In 2013, as with the previous 4 years, there were no Plecoptera taxa found at HER01.

Aquatic macroinvertebrate orders. Of the aquatic macroinvertebrate orders collected from HER01, Ephemeroptera had the most individuals in 2013 (Figure 9). Chironomidae (midges) were the next most abundant aquatic macroinvertebrates, at 20.42%. Non-Chiromomidae Diptera (flies) averaged 9.22% of the samples collected, followed by Trichoptera (2.38%), noninsect taxa (water mites) (1.37%), Coleoptera (beetles) (0.88%), and Odonata (damselflies/dragonflies), at 0.44%.

Functional feeding groups. The majority of the organisms collected from HER01 in 2013 belonged to the collector-gatherers functional group (86.38%) (Figure 10). Collector-filterers and predators were the next most abundant, at 7.87% and 2.99%, respectively. Scrapers were the least abundant, at 2.99%, and shredders were not detected in the quantitative samples in 2013.

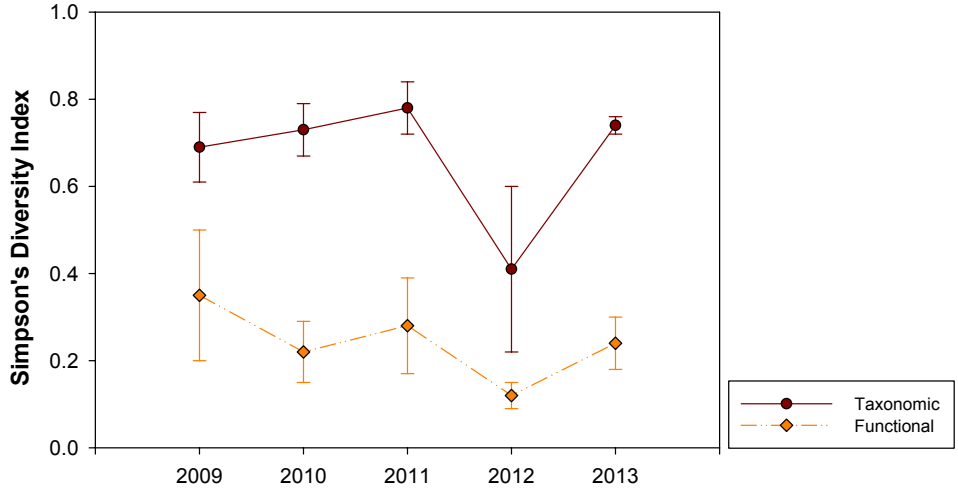


Figure 6. Taxonomic and functional diversity in samples from HER01 at Hermit Creek in GRCA 2009–2013.

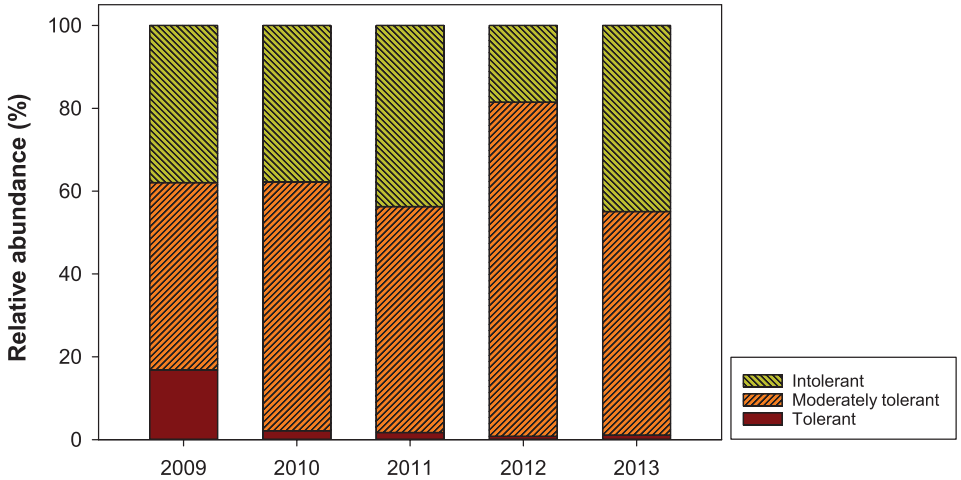


Figure 7. Mean relative abundance by tolerance group in aquatic macroinvertebrate samples from HER01 at Hermit Creek in GRCA, 2009–2013.

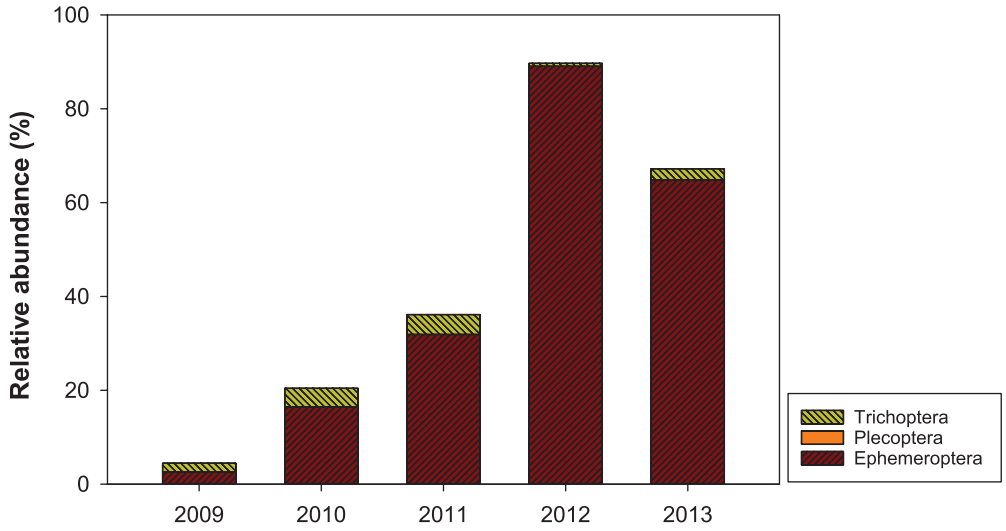


Figure 8. Mean relative abundance of aquatic macroinvertebrates belonging to sensitive EPT orders in samples from HER01 at Hermit Creek in GRCA, 2009–2013. No Plecoptera were found in these 5 years.

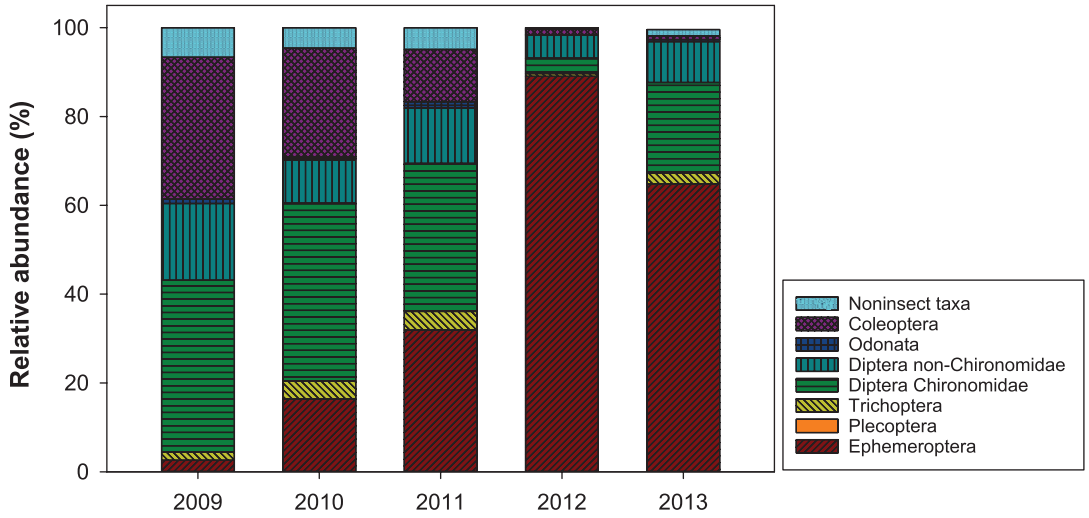


Figure 9. Mean relative abundance by taxonomic order in samples from HER01 at Hermit Creek in GRCA, 2009–2013.

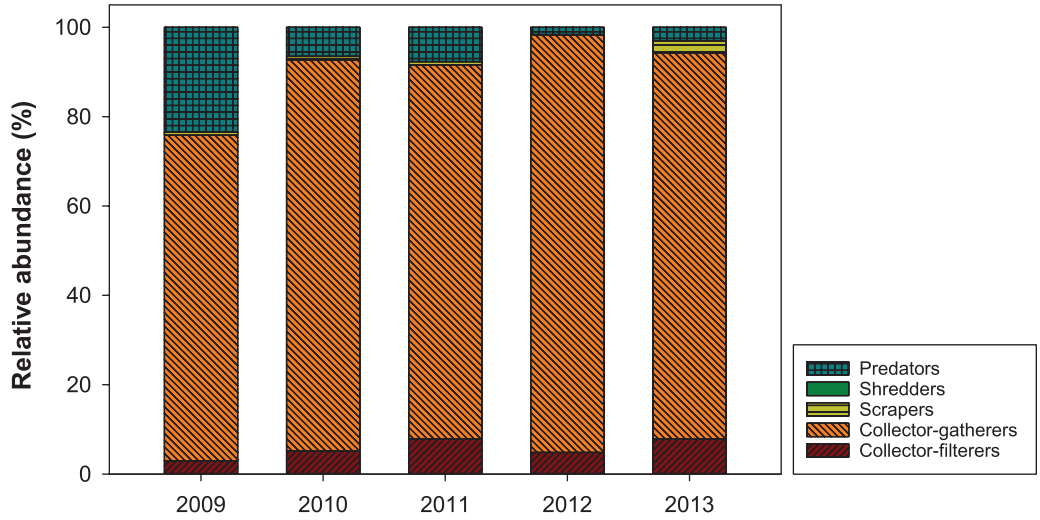


Figure 10. Mean relative abundance by functional feeding group in aquatic macroinvertebrate samples from HER01 at Hermit Creek in GRCA, 2009–2013. Some groups were not observed.

3.2 Physical habitat characteristics for Hermit Creek

We present data describing physical habitat characteristics collected at HER01 from 2009 to 2013 in this section. These data, as well as additional transect data, are summarized in table format in Appendix D (Tables D3, D4).

Microhabitat level. Streamflow velocities at quantitative targeted riffle sites averaged 0.60 m/s in 2013. Average depth was 0.10 m, and an average of 26.2% of each particle was embedded in finer substrates.

Transect level. The average width of the active channel and wetted channel at the 11 physical habitat transects at HER01 in 2013 was 5.0 m and 3.8 m, respectively. Average velocity of streamflow was 0.20 m/s. Depths at transects along HER01 averaged 0.04 m. There was no riparian cover found along this reach in 2013.

Rock and algae were the only aquatic macroinvertebrate habitat types found along transects in our monitoring site in 2013, representing 11.8% and 14.5% of the sampling reach, respectively (Figure 11). Substrate fitting the category "Absence," meaning it lacked habitat that we define as appropriate for aquatic macroinvertebrates, occurred along 73.7% of the site.

Reach level. Channel structure dynamics are represented by particle size distributions in Figure 12, based on modified Wolman pebble counts. In 2013, the dominant particle size class along HER01 was gravel (3–64 mm), representing 58.5% of particles sampled at the site. Cobble (65–250 mm) and bedrock (>4000 mm) were the next

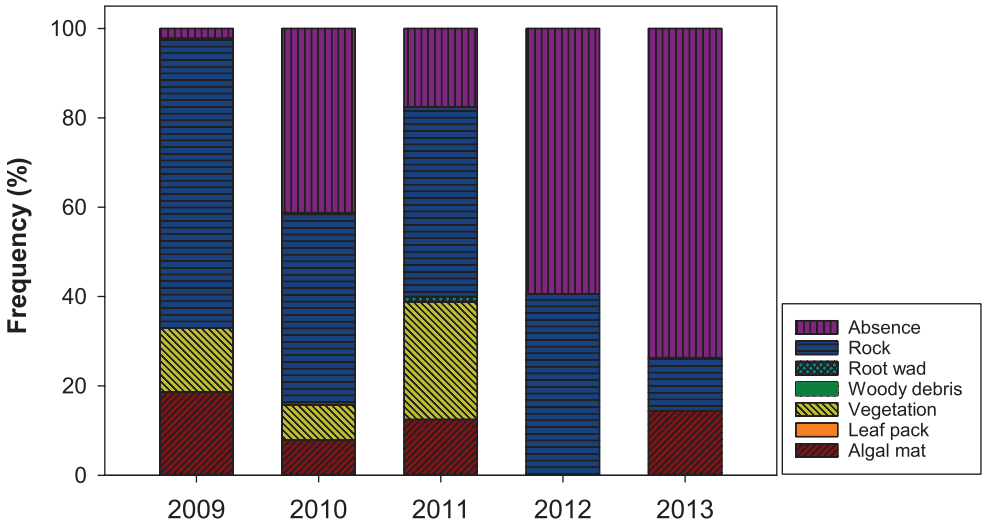


Figure 11. Habitat characterization expressed as frequency of occurrence along transects from HER01 at Hermit Creek in GRCA, 2009–2013. Some habitat structure types were not observed.

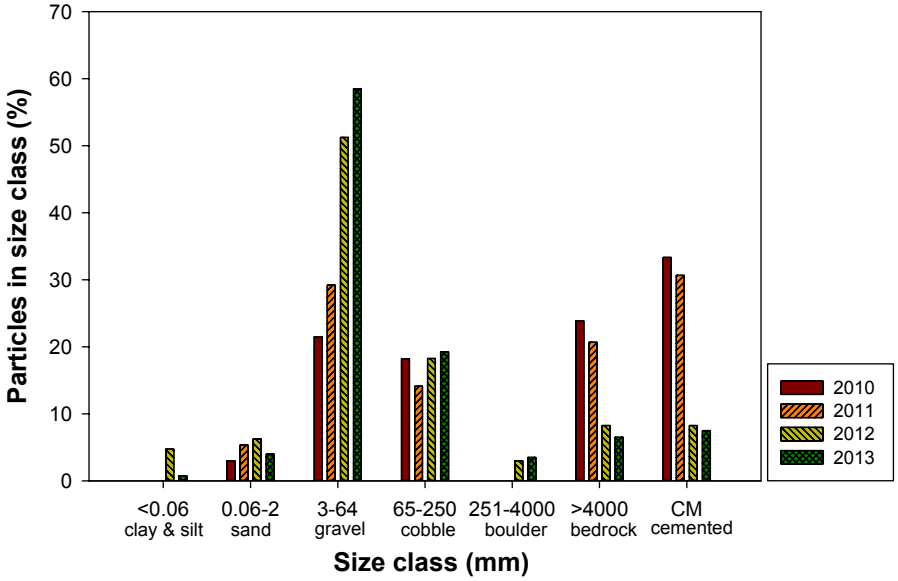


Figure 12. Particle size distribution from HER01 at Hermit Creek in GRCA, 2010–2013. Particles that are completely cemented into the stream channel preclude size measurements.

most abundant, at 19.3% and 6.5% of the particles sampled, respectively. Particles that were too cemented to pull from the streambed for measurement comprised 7.5% of the samples. Sand (0.06–2 mm) and boulder (251–4000 mm) made up 4.0% and 3.5% of the sample, respectively. Silt (<0.06 mm) was the least abundant particle size class, representing 0.8% of the sample.

Runs were the dominant geomorphic channel unit (GCU) along the reach at our monitoring site in 2013, found along 63.0% of the site (Figure 13). Cascades were the next most abundant GCU, at 22.0%. Glides made up 10.0% of the site. Riffles and scour pools were the least abundant, at 3.0% and 2.0%, respectively.

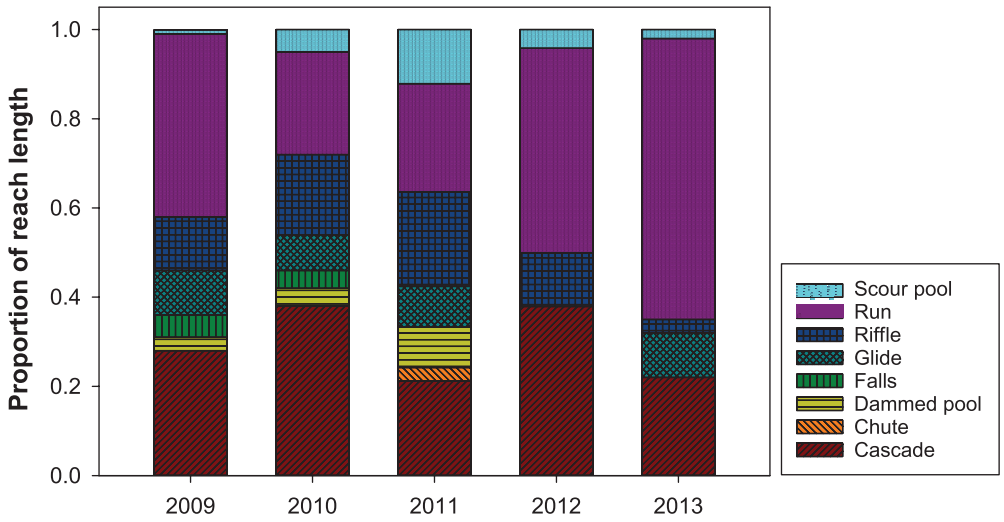


Figure 13. Geomorphic channel unit characterization of HER01 at Hermit Creek in GRCA, 2009–2013.

3.3 Hydrologic conditions for Hermit Creek

3.3.1 SCPN water quality core parameter data

We report NPS core water quality measurements collected at or near midday of the sample date for Hermit Creek in 2013. Data from all years of sampling at Hermit Creek (2009–2013) are available in table format in Appendix D (Table D3).

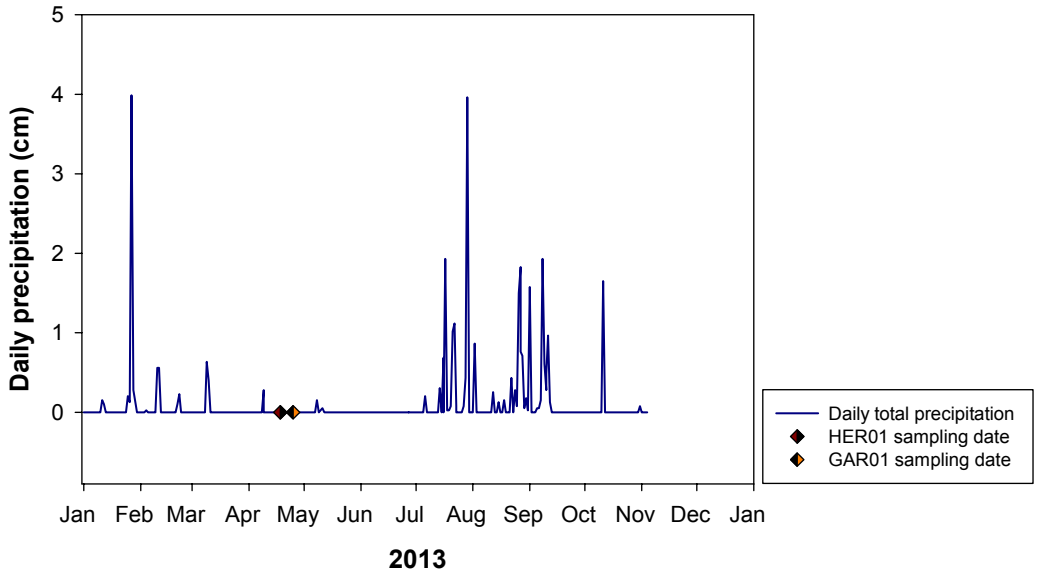
In 2013, the noontime water temperature at HER01 on our sampling day was 15.7°C. Specific conductivity and pH measured 462 µS/cm and 8.8 units, respectively. Dissolved oxygen measured 100.8% saturation and 9.1 mg/L. Stream discharge at the time of our visit was 0.6 cfs. Turbidity was 2.2 NTU.

We were not able to collect continuous air or water temperature data because of the flood event that occurred on 11 September 2011, which destroyed the *Hermit Creek above Tonto Trail* gaging station and data loggers.

3.3.2 NADP precipitation data

Daily precipitation from the NADP/NTN AZ03 monitoring station at Hopi Point is shown in Figure 14. Moisture events were abundant and evenly spread across the summer months following the typical monsoon pattern in 2013 (Figure 14). There was a large winter storm at the end of January. The driest portion of the year was during the early summer months of late May to mid-July.

Figure 14. Total daily precipitation from the NADP/NTN AZ03 monitoring station at Hopi Point in GRCA in 2013. Precipitation data from this station are applicable to HER01 and GAR01.



3.4 Aquatic macroinvertebrate community data for Garden Creek

We present key metrics calculated from sampling aquatic macroinvertebrate communities from 2010 to 2013 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. All corresponding data values are available in table format in Appendix E (Tables E1, E2). Appendix C lists all aquatic macroinvertebrate species detected at the site, from both quantitative and qualitative methods.

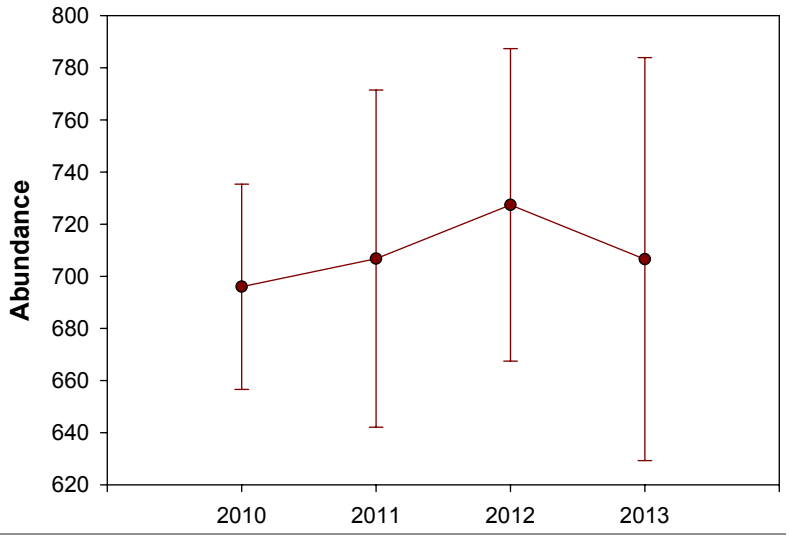
Abundance. Total abundance for quantitative targeted riffle samples averaged 706.60 individuals in 2013 (Figure 15). Riffle sample abundances ranged from a low of 593 individuals to a high of 743 individuals.

Taxa richness. Total richness from quantitative riffle samples averaged 22.40 taxa per riffle in 2013 (Figure 16). Riffle richness ranged from a low of 19 taxa to a high of 25 taxa. Richness from the qualitative sample was 5 taxa.

Diversity. Taxonomic and functional diversity were measured using the Simpson's Diversity Index (Figure 17). In 2013, taxonomic diversity averaged 0.80, while functional diversity averaged 0.56.

Stress tolerance. Taxa that are moderately tolerant to disturbance dominated the relative abundance of aquatic macroinvertebrates in 2013, averaging 80.21% (Figure 18). Intolerant individuals averaged 18.19% of the samples, and tolerant individuals represented, on average, only 1.60% of the samples.

Figure 15. Aquatic macroinvertebrate abundance from GAR01 at Garden Creek in GRCA, 2010–2013.



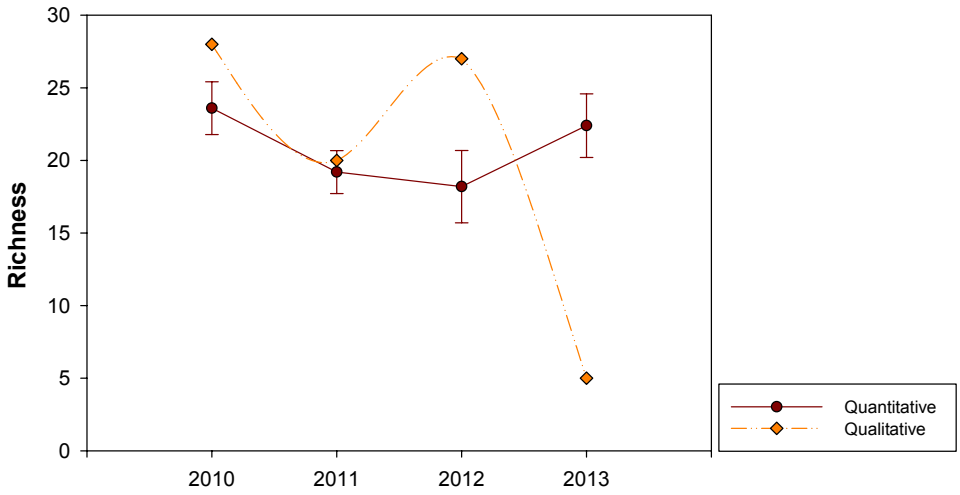


Figure 16. Taxa richness in quantitative and qualitative samples from GAR01 at Garden Creek in GRCA, 2010–2013.

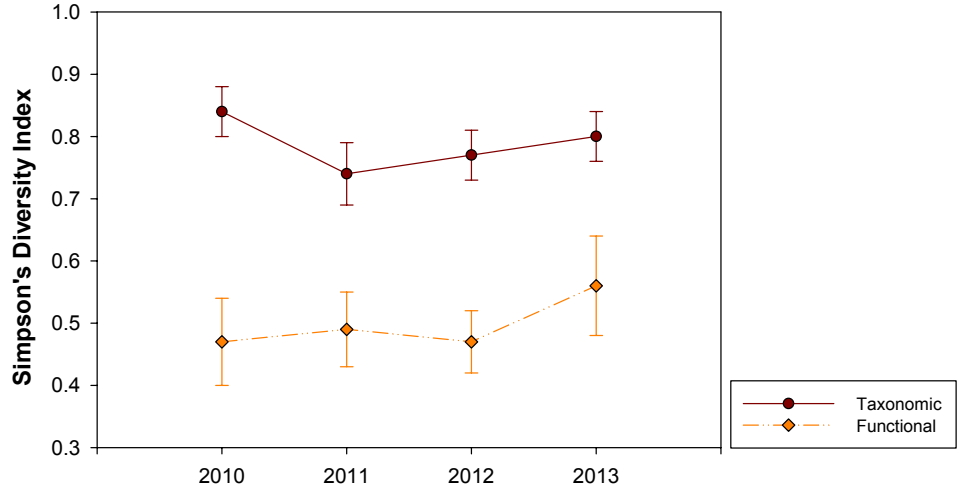


Figure 17. Taxonomic and functional diversity in samples from GAR01 at Garden Creek in GRCA, 2010–2013.

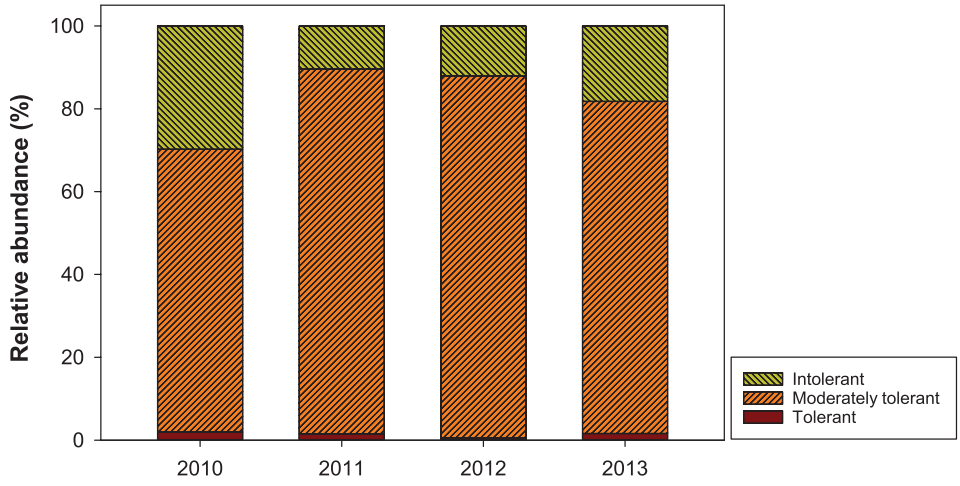


Figure 18. Mean relative abundance by tolerance group of aquatic macroinvertebrate samples from GAR01 at Garden Creek in GRCA, 2010–2013.

EPT taxa. Relative abundance of individuals in EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera) at GAR01 in 2013 was highest for the order Ephemeroptera, which averaged 18.42% of the sample (Figure 19). Trichoptera accounted for 11.80% of the individuals collected. No Plecoptera were collected at this sampling site in 2013, or in the 3 previous years. Abundance of all 3 EPT taxa combined accounted for 30.22% of the total individuals collected at GAR01.

Aquatic macroinvertebrate orders. Diptera in the family Chironomidae (29.94%) were the most abundant aquatic macroinvertebrates collected at GAR01 in 2013 (Figure 20). Non-Chironomidae Diptera were the second most abundant, at 29.63%. Coleoptera and Odonata were low in abundance, at 5.17% and 3.84%, respectively. For GAR01, "noninsect" taxa included Trombidiformes, as well as the phyla Annelida (segmented worms) and Platyhelminthes (flat worms), which together accounted for 1.20% of all individuals collected.

Functional feeding groups. Collector-gatherers were the most abundant of the functional groups collected from GAR01 in 2013, averaging 52.90% of the individuals collected (Figure 21). Collector-filterers were the second most abundant, at 34.92%. Predators accounted for 6.50% of the samples, and scrapers were at 5.39%. Shredders were the least abundant group, at 0.28%.

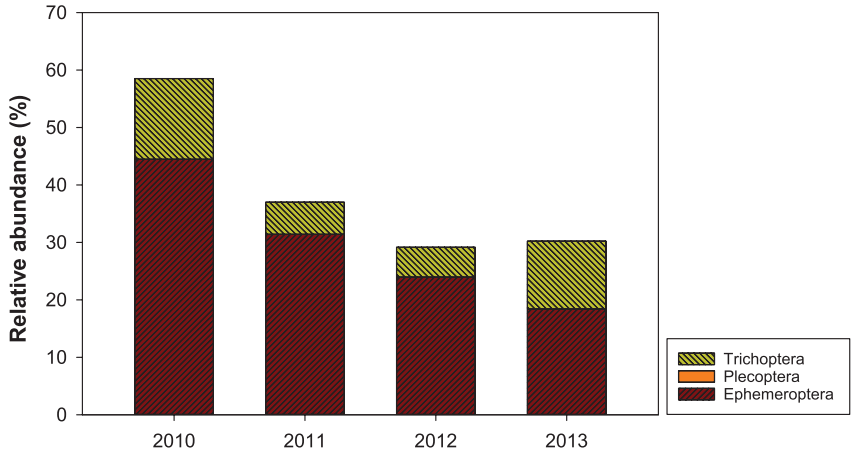


Figure 19. Mean relative abundance of aquatic macroinvertebrates belonging to sensitive EPT orders in samples from GAR01 at Garden Creek in GRCA, 2010–2013. No Plecoptera were found in these sampales during the past 4 years.

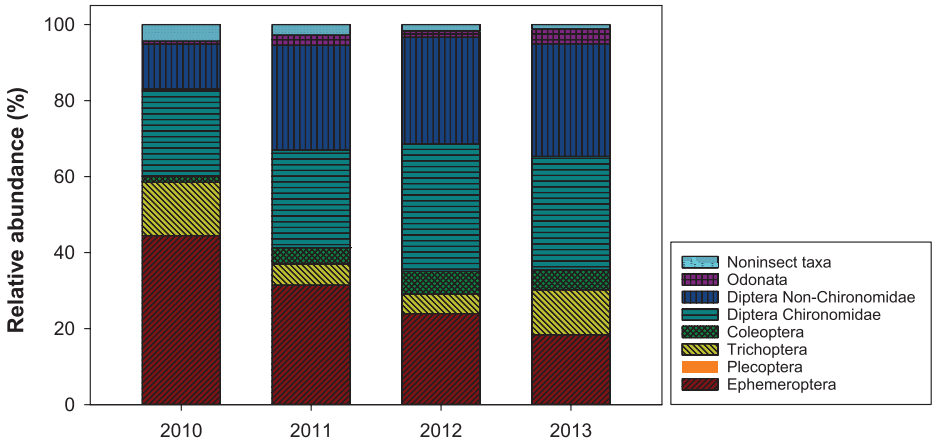


Figure 20. Mean relative abundance by taxonomic order in samples from GAR01 at Garden Creek in GRCA, 2010–2013. No Plecoptera were found in these samples during the past 4 years.

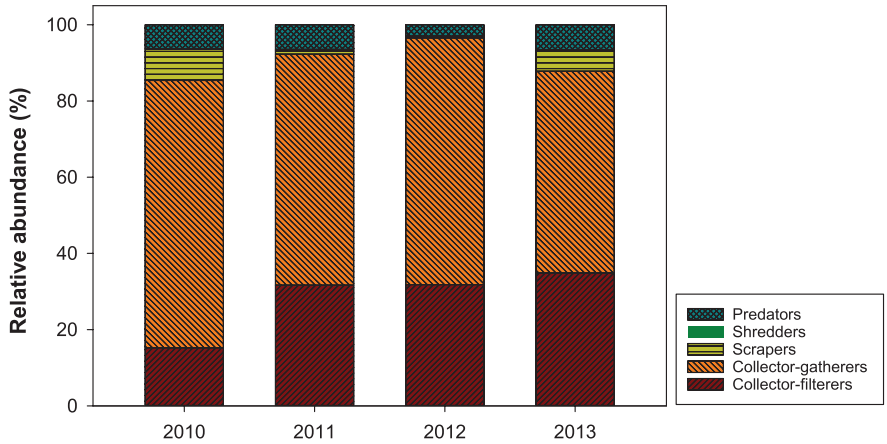


Figure 21. Mean relative abundance by functional feeding group in aquatic macroinvertebrate samples from GAR01 at Garden Creek in GRCA, 2010–2013.

3.5 Physical habitat characteristics for Garden Creek

Here we present data describing physical habitat characteristics collected at GAR01 from 2010 to 2013. These data, as well as additional transect data, are summarized in table format in Appendix E (Tables E3 and E4).

Microhabitat level. Streamflow velocity at the quantitative targeted riffle sites averaged 0.60 m/s, and depths averaged 0.13 m in 2013. Embeddedness of particles in the quantitative sampling frame averaged 19.6%.

Transect level. Active channel widths and wetted channel widths at the 11 physical habitat transects in 2013 averaged 10.2 m and 1.0 m, respectively. Streamflow velocity at the monitoring site averaged 0.38 m/s, and depth averaged 0.13 m. Riparian vegetation canopy closure averaged 76.0% across the transects.

Root wad was the dominant aquatic macroinvertebrate habitat sampled along our monitoring site in 2013 (Figure 22). Root wad accounted for 40.3% of the samples. Vegetation was the next most abundant habitat type, at 26.0%. Woody debris represented 1.3% of the samples. Substrate fitting the category "Absence", meaning it lacked habitat that we define as appropriate for aquatic macroinvertebrates, occurred along 32.5% of the site.

Reach level. Gravel was the most abundant particle size found along the monitoring site in 2013 (Figure 23). Gravel accounted for 53.5% of the particles sampled. Sand was found along 17.8% of the monitoring site. Cobble was found along 14.5% of the monitoring site. Bedrock accounted for 6.0% of the particles sampled. Less than 1% of the particles sampled were too cemented into the channel for measurement.

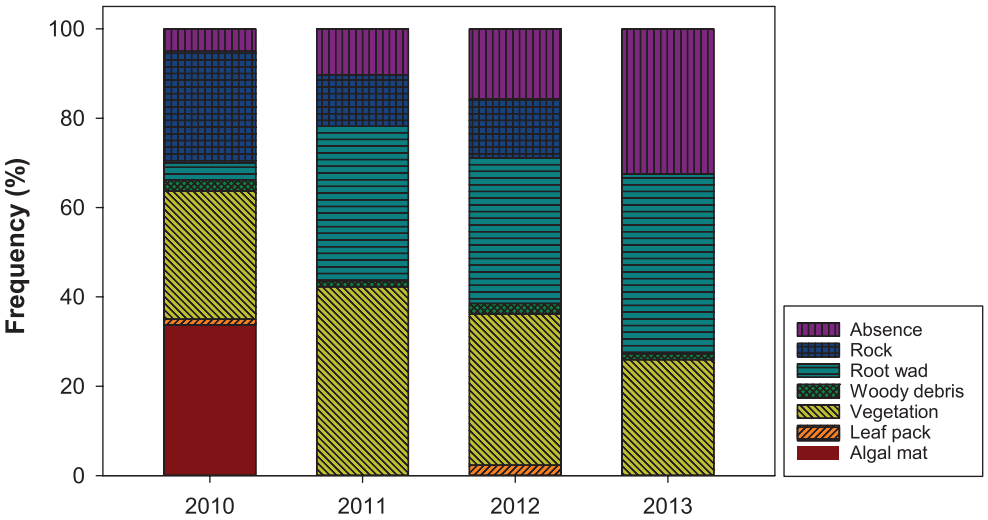


Figure 22. Habitat characterization expressed as frequency of occurrence along transects from GAR01 at Garden Creek in GRCA, 2010–2013.

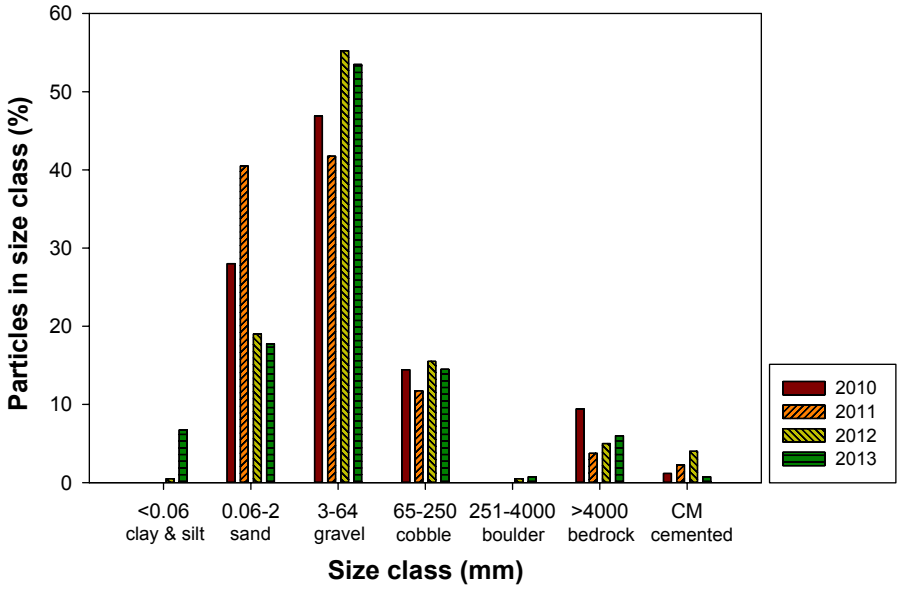
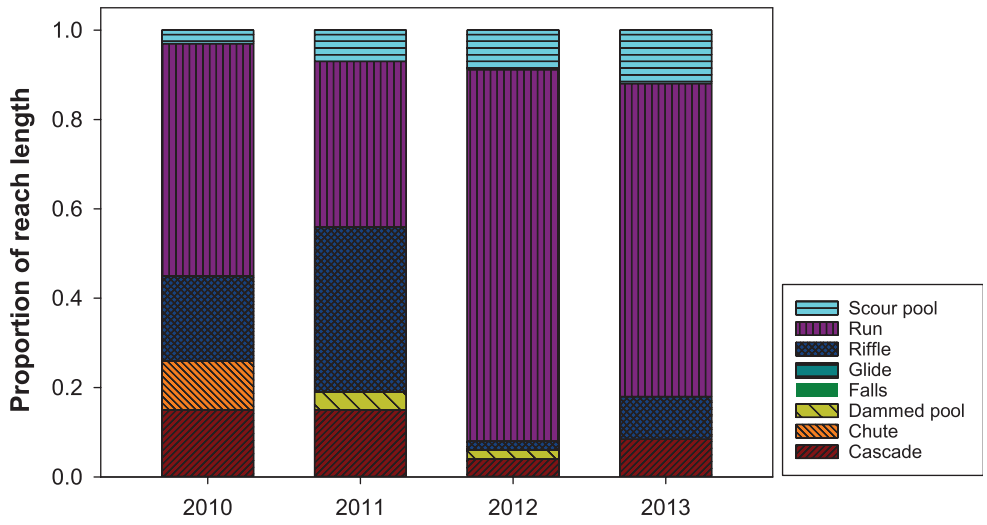


Figure 23. Particle size distribution from GAR01 at Garden Creek in GRCA, 2010–2013. Particles that are completely cemented into the stream channel preclude size measurements.

Run was the most abundant GCU found along our monitoring site in 2013, accounting for 70.1% of the area sampled (Figure 24). Scour pools were found along 12.0% of the site, and riffles were found along 9.6% of the site. Cascades accounted for 8.4% of the area sampled.

Figure 24. Geomorphic channel unit characterization of GAR01 at Garden Creek in GRCA, 2010–2013.



3.6 Hydrologic conditions for Garden Creek

3.6.1 SCPN water quality core parameter data

We report NPS core water quality measurements collected at or near midday of the sample date for Garden Creek in 2013. Data from all years of sampling at Garden Creek (2010–2013) are available in table format in Appendix E (Table E3).

In 2013, the noontime water temperature was 15.0°C. Specific conductivity measured 358 µS/cm, and pH was 8.4. Dissolved oxygen measured 96.4% saturation and 8.5 mg/L. Turbidity was 1.6 NTU. Stream discharge at the time of our visit was 2.1 cfs.

3.6.2 NADP precipitation data

Precipitation values associated with Hermit Creek (Figure 14) are also applicable to Garden Creek.

3.7 Aquatic macroinvertebrate community data for Bright Angel Creek

We present key metrics calculated from sampling aquatic macroinvertebrate communities from 2010 to 2013 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. All corresponding data values are available in table format in Appendix F (Tables F1, F2). Appendix C lists all aquatic macroinvertebrate species detected at the site, from both quantitative and qualitative methods.

Abundance. Total abundance values from quantitative targeted riffle samples at BRI01 averaged 550.00 individuals in 2013 (Figure 25). Sample abundances ranged from a low of 402 individuals to a high of 705.

Taxa richness. Total taxonomic richness from quantitative targeted riffle samples at BRI01 in 2013 averaged 17.20 taxa per sample (Figure 26). Quantitative samples ranged from a low of 16 taxa to a high of 18 taxa. Richness from our qualitative sample was 20 taxa.

Diversity. We used the Simpson's Diversity Index to measure both taxonomic and functional diversity of quantitative samples from BRI01 in 2013 (Figure 27). Taxonomic diversity averaged 0.70. Functional diversity was lower, averaging 0.38.

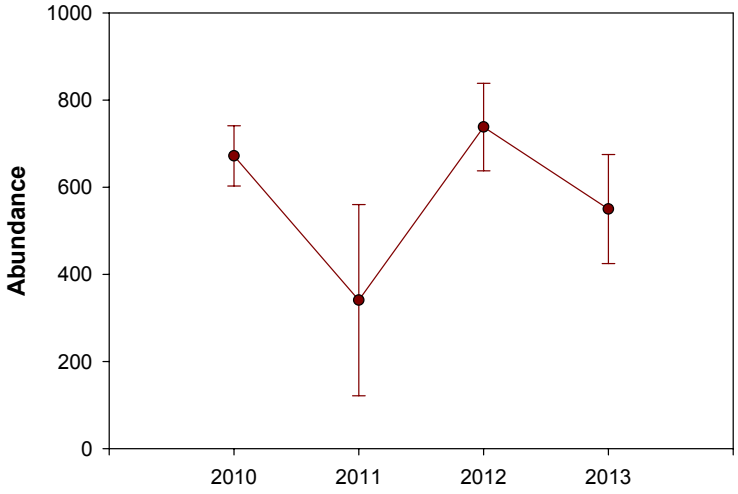


Figure 25. Aquatic macroinvertebrate abundance in samples from BRI01 at Bright Angel Creek in GRCA, 2010–2013.

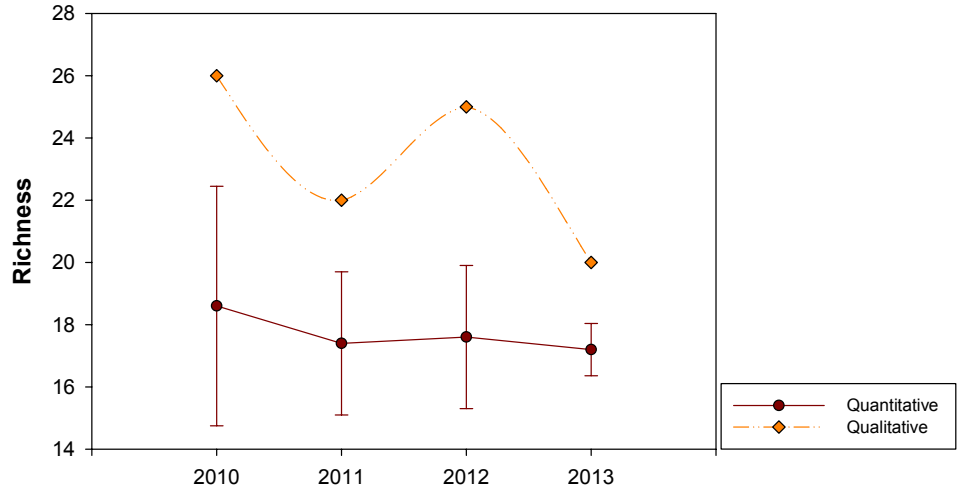


Figure 26. Taxa richness in quantitative and qualitative samples from BRI01 at Bright Angel Creek in GRCA, 2010–2013.

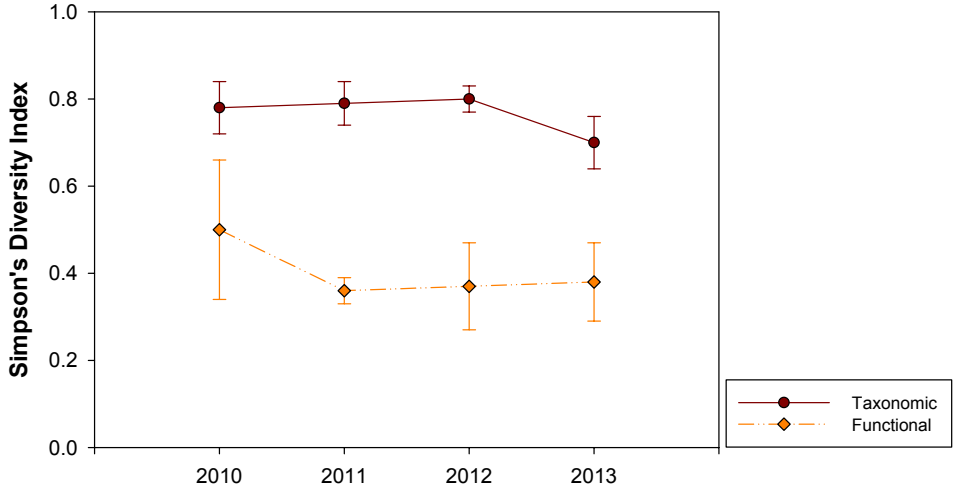


Figure 27. Taxonomic and functional diversity in samples from BRI01 at Bright Angel Creek in GRCA, 2010–2013.

Stress tolerance. Individuals moderately tolerant to disturbance were the most abundant group at BRI01 in 2013, averaging 73.21% of the sample (Figure 28). Intolerant individuals accounted for 26.26% of the sample. Few tolerant taxa (0.53%) were collected.

EPT taxa. The relative abundance of individuals in sensitive EPT orders was dominated by Ephemeroptera in 2013 (Figure 29). Ephemeroptera accounted for 62.53% of the individuals collected from BRI01 in 2013. Relative abundance of Trichoptera individuals was 3.53%. Plecoptera abundance was less than 0.1%.

Aquatic macroinvertebrate orders. Ephemeroptera was the most abundant group of aquatic macroinvertebrates collected from BRI01 in 2013, at 62.53% (Figure 30). Non-Chironomidae Diptera was the next most abundant group, at 17.31%, followed by Chironomidae (6.65%), Coleoptera (6.30%), Trichoptera (3.53%), noninsect (water mites) (3.05%), and Odonata (0.54%). Plecoptera was the least abundant group sampled in 2013, comprising less than 0.1% of the samples.

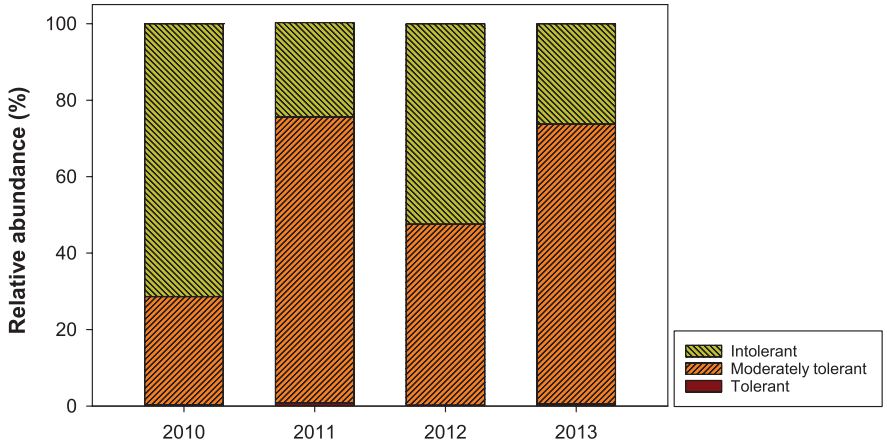


Figure 28. Mean relative abundance by tolerance group in aquatic macroinvertebrate samples from BRI01 at Bright Angel Creek in GRCA, 2010–2013. Tolerant taxa comprised less than 1% of samples during the past 4 years.

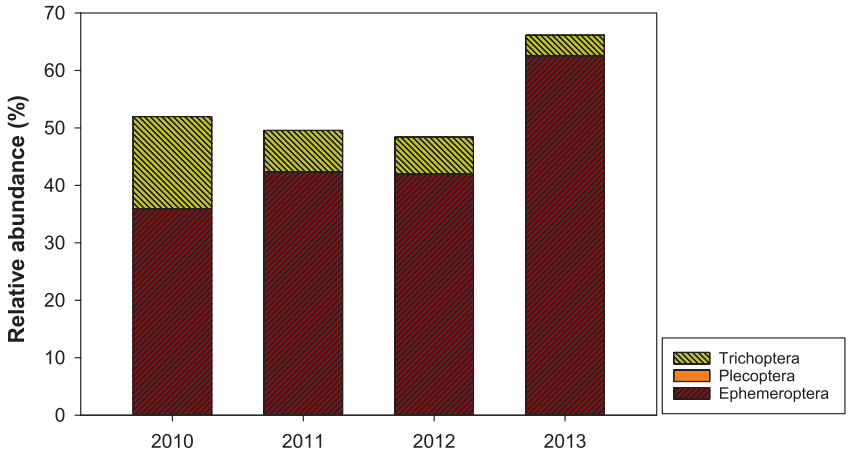


Figure 29. Mean relative abundance of aquatic macroinvertebrates belonging to sensitive EPT orders in samples from BRI01 at Bright Angel Creek in GRCA, 2010–2013. Plectopera never comprised more than 0.1% of the samples during the past 4 years.

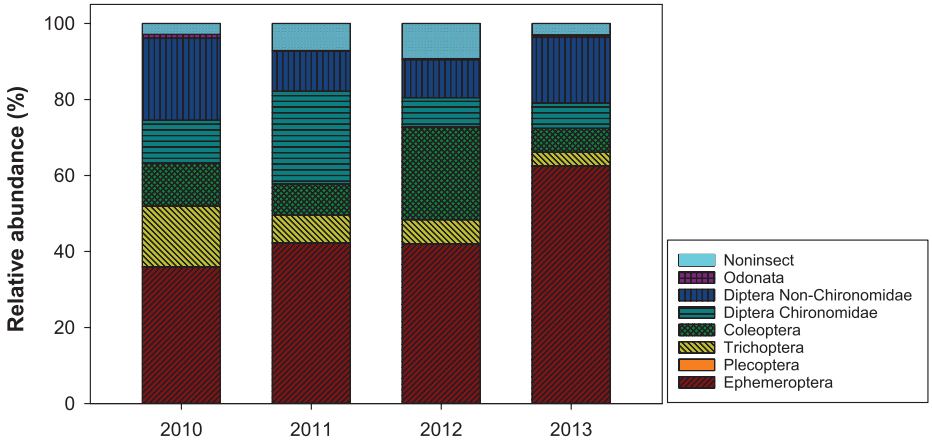


Figure 30. Mean relative abundance by taxonomic order in samples from BRI01 at Bright Angel Creek in GRCA, 2010–2013. Plectopera never comprised more than 0.1% of the samples during the past 4 years.

Functional feeding groups. Collector-gatherers were the most abundant aquatic macroinvertebrates in our 2013 samples (Figure 31). Relative abundance of collector-gatherers was 75.34%. Collector-filterers were the second most abundant, at 19.17%. Predators averaged 4.01%, and scrapers averaged 1.39%. Shredders were the least abundant, at 0.08%.

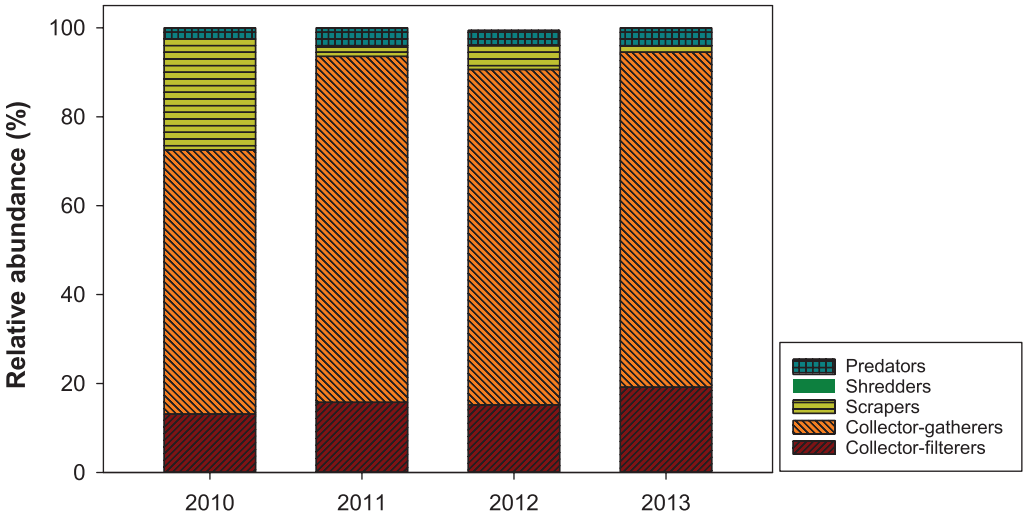


Figure 31. Mean relative abundance by functional feeding group in aquatic macroinvertebrate samples from BRI01 at Bright Angel Creek in GRCA, 2010–2013. Shredders never comprised more than 0.1% of the samples during the past 4 years.

3.8 Physical habitat characteristics for Bright Angel Creek

Here we present data describing physical habitat characteristics collected at BRI01 from 2010 to 2013. These data, as well as additional transect data, are summarized in table format in Appendix F (Tables F3, F4).

Microhabitat level. Streamflow velocity at the 5 targeted riffle samples averaged 0.55 m/s in 2013. Depths at these locations averaged 0.15 m. An average of 32.8% of each particle was embedded in finer substrates

Transect level. The average active channel width at the 11 physical habitat transects in 2013 was 15.9 m. Wetted channel width averaged 6.3 m. Velocity and depth averaged 0.41 m/s and 0.17 m, respectively.

Rock was the dominant habitat type and was found along 57.3% of the transects in 2013 (Figure 32). Vegetation was found along 5.3% of the transects. Substrate fitting the category "Absence", meaning it lacked habitat that we define as appropriate for aquatic macroinvertebrates, occurred along 37.3% of the site.

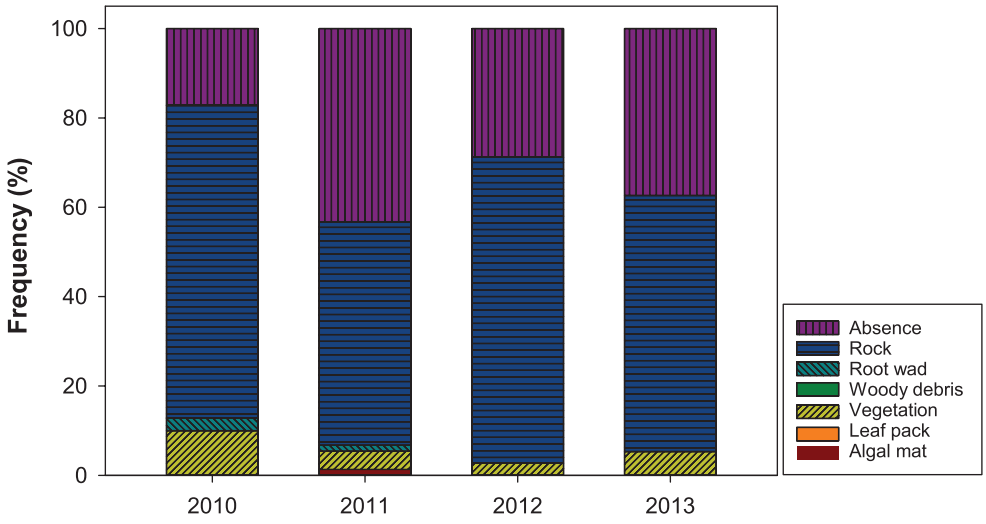


Figure 32. Habitat characterization expressed as frequency of occurrence along transects at BRI01 on Bright Angel Creek in GRCA, 2010–2013. Not all habitat structures were observed.

Reach level. Particle size distribution was dominated by gravel, which made up 42.0% of the particles sampled in 2013 (Figure 33). The next most abundant size class was cobble, comprising 26.3% of particles. Boulder comprised 7.0% of the particles. Clay and silt comprised 3.0% of the sample. Sand and bedrock, at opposite ends of the size spectrum, comprised 2.5% and 2.0% of the sample, respectively. Cemented particles, those that we were unable to remove from the stream bottom, accounted for 17.3% of the particles sampled.

Riffles were the dominant GCU found along the monitoring site in 2013 (Figure 34). Riffles made up 58.2% of the site. Cascades were the next most abundant, at 28.8%, followed by scour pools at 6.5%, and runs at 6.4%.

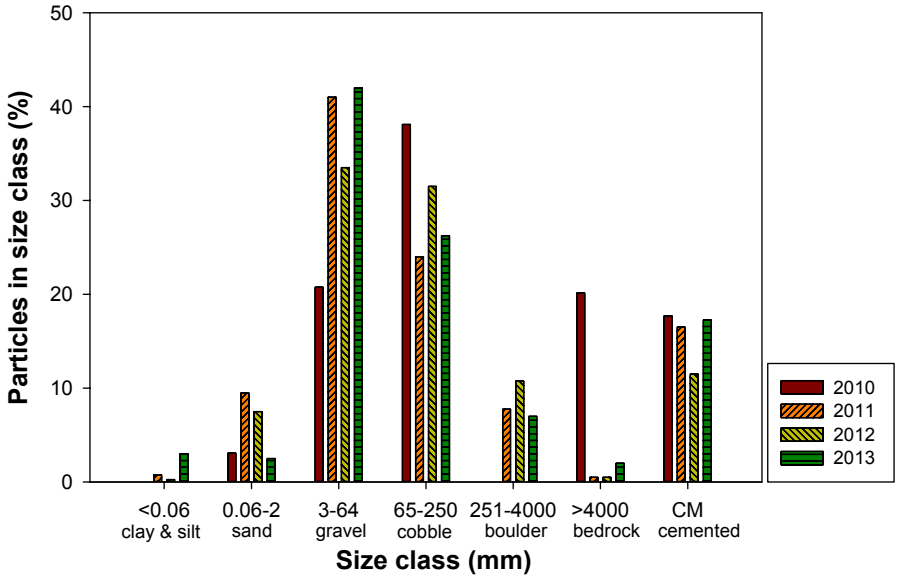


Figure 33. Particle size distribution along the reach at BRI01 at Bright Angel Creek in GRCA, 2010–2013. Particles that are completely cemented into the stream channel preclude size measurements.

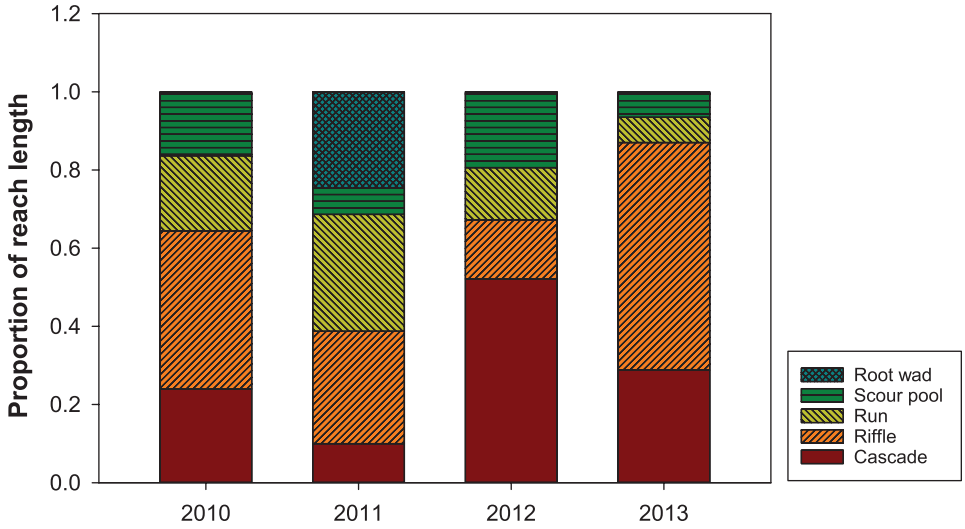


Figure 34. Geomorphic channel unit characterization of BRI01 at Bright Angel Creek in GRCA, 2010–2013.

3.9 Hydrologic conditions for Bright Angel Creek

3.9.1 SCPN water quality core parameter data

We report NPS core water quality measurements collected at or near midday of the sample date for Bright Angel Creek in 2013. Data from all years of sampling at Bright Angel Creek (2010–2013) are available in table format in Appendix F (Table F3).

In 2013, the noontime water temperature was 11.3°C. Specific conductivity was 351 µS/cm, and pH measured 8.7. Dissolved oxygen measured 102.9% saturation and 10.3 mg/L. Turbidity was 1.1 NTU. Stream discharge for the site at the time of our visit was 24.0 cfs.

3.9.2 USGS streamflow and temperature data

Figure 35 shows discharge recorded at 15 minute intervals at the USGS streamflow gaging station, Bright Angel Creek near Grand Canyon, AZ (09403000), for the period 01 January 2013 to 31 December 2013 (USGS 2014). Increased flows follow the typical pattern of snowmelt in the early spring months from late March to late May. Large pulses occurring during the summer of July–September follow the monsoon pattern typical for this region during those months. The gage measured a maximum streamflow of 136.7 cfs on 20 July. The lowest flow recorded, 13.5 cfs, occurred on 31 July.

The USGS station also measured air and water temperatures from Bright Angel Creek every 15 minutes during 2013 (Figure 36a, b). The average air temperature at Bright Angel Creek was 16.3°C. Air temperatures reached a high of 45.2°C on 27 June and a low of -1.8°C on 16 January. The average water temperature was 13.7°C. Water temperatures ranged from a high of 28.5°C on 03 July to a low of 1.1°C on 15 January.

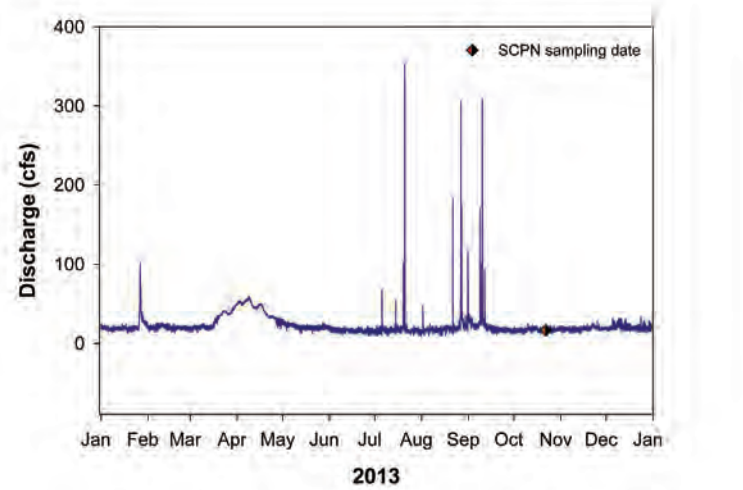


Figure 35. Discharge recorded at 15 minute intervals at Bright Angel Creek in 2013, from USGS streamflow gaging station #09403000.

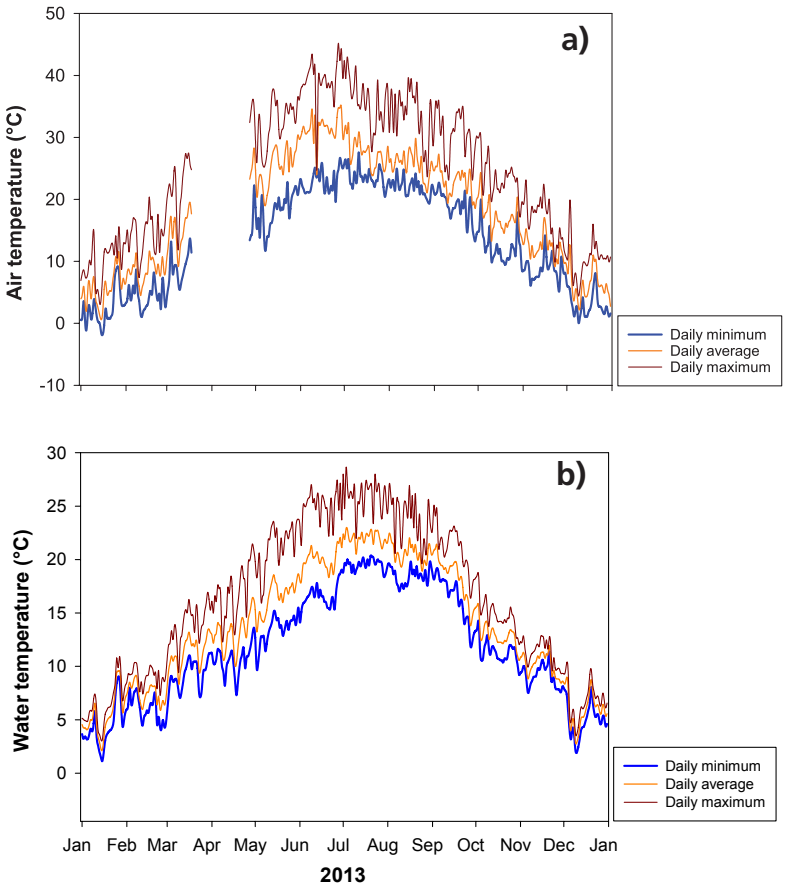


Figure 36. Air (a) and water (b) temperature recorded at 15 minute intervals in 2013 from Bright Angel Creek in GRCA, by USGS station #09403000.

4 Discussion

This report presents data from SCPN's fifth year of monitoring aquatic macroinvertebrates and physical habitat at Hermit Creek and the fourth 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 a few years 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.

At Hermit Creek, aquatic macroinvertebrate taxa richness appears to be recovering from the postflood values we sampled in 2012, and is closer to the average values we have seen since 2009. Quantitative taxa richness was 19.20 in 2013 and averaged 18.15 from 2009 to 2012. Qualitative taxa richness in 2013 was 20, showing a large increase compared to 2012, but remains just below the 2009-2012 average of 21.5 for Hermit Creek. Similarly, we found large increases in both taxonomic and functional diversity values in 2013 compared to 2012 averages. Taxonomic diversity was slightly higher in 2013 (0.74) than the 2009–2012 average of 0.65. Functional diversity for 2013 (0.24) was exactly the same as the 2009–2012 average. Interestingly, in contrast to the recovery of aquatic macroinvertebrate abundance and diversity following the 2012 flood, the frequency of aquatic macroinvertebrate habitat types within the reach was still below preflood levels. While 2013 saw an increase in habitat types over 2012 levels, we also found a decrease in rock habitat at the site, from 40.5% in 2012 down to 11.8% in 2013. Habitat unsuitable for aquatic macroinvertebrates ("Absence" category) increased from 59.5% in 2012 to 73.7% in 2013. These data show that habitat diversity is yet to recover to preflood conditions, where rock was the dominant habitat type, and vegetation, woody debris and root wads were also present.

On 27 July 2013, a large flood occurred on Garden Creek. Visual observations of the stream at our monitoring site indicated a shift in stream location on the canyon bottom as well as a loss of streamside vegetation along portions of our monitoring reach. However this large flow event did not seem to have as many detrimental effects on the aquatic macroinvertebrate community as we saw at other sites after flooding in 2012. Abundance in 2013 averaged 706.60 individuals per sample, compared to the 710.07 average from 2010 to 2012. Over the three years from 2010 to 2012, quantitative sample taxa richness averaged 20.33, compared with 22.40 in 2013. Qualitative richness appears to be the metric with the greatest postflood decline. Prior to 2013, qualitative richness averaged 25 taxa; in 2013 it dropped to 5. The loss in qualitative taxa richness, a metric which is calculated by sampling all available habitat types along the monitoring site, may be explained by the lack of habitat diversity after the flood. Aquatic macroinvertebrate habitat data from 2013 show declines in the percent frequency of all habitat types, with the exception of root wads. The increase in root wads may be a result of the scouring that occurred at the time of the large flow event. Our habitat category "Absence," which refers to a lack of appropriate habitat, increased from the 2010–2012 average of 10.3% to 32.5% in 2013.

Data collected in 2013 from Bright Angel Creek continue to demonstrate a robust aquatic macroinvertebrate community. Average abundance for 2013 (550.00) was slightly lower than the 2010–2012 average of 583.80 individuals per sample. There were small declines in diversity at Bright Angel Creek. Taxonomic diversity for 2013 was 0.70 compared to the 2010–2012 average of 0.79. Similarly, functional diversity was slightly lower for 2013 (0.38) compared to the 2010–2012 average of 0.41. Habitat metrics such as geomorphic channel units and aquatic macroinvertebrate habitat have not yet reached their preflood diversity at Bright Angel Creek, which may explain the lower taxonomic and functional diversity numbers.

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 National Park.

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Appendix A Southern Colorado Plateau Network aquatic macroinvertebrate monitoring sites on Bright Angel Creek, Garden Creek, and Hermit Creek in Grand Canyon National Park, Arizona, 2013

Site code	Common name	Report name	UTM Easting	UTM Northing	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

Note: Horizontal coordinates are reported in Universal Transverse Mercator (UTM) Projection, Zone 12, North American Datum of 1983 (NAD 83). Vertical (elevation) coordinates are referenced to the North American Vertical Datum of 1988 (NAVD 88).

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 aquatic macroinvertebrate monitoring sites on Bright Angel Creek, Garden Creek, and Hermit Creek in Grand Canyon National Park, Arizona, 2013

Phylum	Class	Order	Family	SubFamily	Genus	Species	Common name	Funct group[1]	Tol group[2]	HER01	GAR01	BRI01
Annelida	Clitellata						segmented worms	coll-gath	n/a	x	x	x
Arthropoda	Arachnida	Trombidiformes	Arrenuridae		*Arrenurus* sp.		water mites	pred	n/a		x	
Arthropoda	Arachnida	Trombidiformes	Hygrobatidae				water mites	pred	tol	NEW		
Arthropoda	Arachnida	Trombidiformes	Sperchonidae		*Sperchon* sp.		water mites	pred	tol	x		x
Arthropoda	Arachnida	Trombidiformes	Sperchonidae		*Sperchonopsis* sp.		water mites	pred	tol	x		x
Arthropoda	Arachnida	Trombidiformes	Sperchonidae				water mites	pred	tol			x
Arthropoda	Arachnida	Trombidiformes	Torrenticolidae		*Torrenticola* sp.		water mites	pred	n/a	x	x	
Arthropoda	Arachnida	Trombidiformes					water mites	n/a	n/a	x	x	x
Arthropoda	Entognatha	Collembola					springtails	coll-gath	tol		x	
Arthropoda	Insecta	Coleoptera	Dytiscidae	Agabinae	*Agabus* sp.		predaceous diving beetle	pred	tol			NEW
Arthropoda	Insecta	Coleoptera	Dryopidae		*Helichus* sp.		long-toed water beetles	shredder	mod tol			NEW
Arthropoda	Insecta	Coleoptera	Elmidae		*Microcylloepus*	*pusillus*	riffle beetles	coll-gath	intol	x	x	x
Arthropoda	Insecta	Coleoptera	Elmidae				riffle beetles	coll-gath	intol	x		
Arthropoda	Insecta	Diptera	Empididae	Hemerodromiinae	*Hemerodromia* sp.		dance flies	pred	mod tol	x		
Arthropoda	Insecta	Diptera	Empididae		*Neoplasta* sp.		dance flies	pred	mod tol	x	x	
Arthropoda	Insecta	Diptera	Empididae		*Wiedemannia* sp.		dance flies	pred	mod tol			x
Arthropoda	Insecta	Diptera	Empididae				dance flies	pred	mod tol	x	x	x
Arthropoda	Insecta	Diptera	Stratiomyidae		*Caloparyphus* sp.		soldier flies	coll-gath	mod tol	x		
Arthropoda	Insecta	Diptera	Stratiomyidae		*Euparyphus* sp.		soldier flies	coll-gath	n/a	x		
Arthropoda	Insecta	Diptera	Tabanidae		*Tabanus* sp.		striped horse fly	pred	mod tol	x	x	
Arthropoda	Insecta	Diptera	Tabanidae				horse/deer flies	pred	tol		x	x
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	*Probezzia* sp.		biting midges	pred	mod tol	x	x	
Arthropoda	Insecta	Diptera	Ceratopogonidae				biting midges	pred	mod tol	x	x	
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae			midges	coll-gath	mod tol	x	x	x
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae			midges	coll-gath	mod tol	x	x	x
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae			midges	pred	tol	x	x	x
Arthropoda	Insecta	Diptera	Chironomidae				midges	coll-gath	mod tol	x	x	

Phylum	Class	Order	Family	SubFamily	Genus	Species	Common name	Funct group[1]	Tol group[2]	HER01	GAR01	BRI01
Arthropoda	Insecta	Diptera	Dixidae		*Dixa* sp.		meniscus midges	coll-gath	intol	x		x
Arthropoda	Insecta	Diptera	Psychodidae		*Maruina* sp.		moth flies	scraper	intol	NEW	NEW	
Arthropoda	Insecta	Diptera	Psychodidae		*Pericoma* sp.		moth flies	coll-gath	mod tol		x	
Arthropoda	Insecta	Diptera	Simuliidae	Simuliinae	*Simulium* sp.		black flies	coll-filt	mod tol	x	x	x
Arthropoda	Insecta	Diptera	Simuliidae				black flies	coll-filt	mod tol	x	x	x
Arthropoda	Insecta	Diptera	Tipulidae	Tipulinae	*Tipula* sp.		large crane flies	shredder	mod tol		x	
Arthropoda	Insecta	Diptera	Tipulidae		*Hexatoma* sp.		large crane flies	pred	intol		NEW	
Arthropoda	Insecta	Diptera	Tipulidae				large crane flies	shredder	intol		x	
Arthropoda	Insecta	Diptera					flies	n/a	mod tol		x	
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae		*Thraulodes* sp.		pronggilled mayflies	coll-gath	intol		NEW	
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae				pronggilled mayflies	coll-gath	intol		x	
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Acentrella* sp.		small minnow mayflies	coll-gath	intol	x		
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Baetis* sp.		small minnow mayflies	coll-gath	mod tol	x	x	x
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Baetodes* sp.		small minnow mayflies	coll-gath	intol	x	x	x
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Callibaetis* sp.		small minnow mayflies	coll-gath	tol			NEW
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Fallceon*	*quilleri*	small minnow mayflies	coll-gath	n/a	x	x	x
Arthropoda	Insecta	Ephemeroptera	Baetidae				small minnow mayflies	coll-gath	intol	x	x	
Arthropoda	Insecta	Lepidoptera	Crambidae	Nymphulinae	*Petrophila* sp.		crambid snout moths	scraper	intol			x
Arthropoda	Insecta	Megaloptera	Corydalidae	Corydalinae	*Corydalus*	*cornutus*	eastern dobsonflies	pred	intl	x	x	x
Arthropoda	Insecta	Odonata	Aeshnidae		*Oplonaeschna*	*armata*	darners	pred	intol		NEW	
Arthropoda	Insecta	Odonata	Aeshnidae				darners	pred	intol	x	x	
Arthropoda	Insecta	Odonata	Cordulegastridae		*Cordulegaster* sp.		spiketail dragonflies	pred	intol		NEW	
Arthropoda	Insecta	Odonata	Corduliidae	Corduliinae			emerald dragonflies	pred	intol			NEW
Arthropoda	Insecta	Odonata	Libellulidae				skimmers	pred	tol	x		x
Arthropoda	Insecta	Odonata	Calopterygidae		*Hetaerina* sp.		broad-winged damselflies	pred	mod tol	NEW	x	
Arthropoda	Insecta	Odonata	Calopterygidae				broad-winged damselflies	pred	mod tol	x		x
Arthropoda	Insecta	Odonata	Coenagrionidae		*Argia* sp.		narrow-winged damselflies	pred	mod tol	x	x	x
Arthropoda	Insecta	Odonata	Coenagrionidae				narrow-winged damselflies	pred	tol	x	x	x
Arthropoda	Insecta	Plecoptera	Capniidae	Capniinae			small winter stoneflies	shredder	intol			NEW
Arthropoda	Insecta	Trichoptera	Brachycentridae		*Micrasema* sp.		humpless casemaker caddisflies	n/a	intol		x	

Phylum	Class	Order	Family	SubFamily	Genus	Species	Common name	Funct group[1]	Tol group[2]	HER01	GAR01	BRI01
Arthropoda	Insecta	Trichoptera	Helicopsychidae		*Helicopsyche* sp.		snail-case caddisflies	scraper	intol		x	
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychinae	*Hydropsyche* sp.		netspinning caddisflies	coll-filt	intol	x	x	x
Arthropoda	Insecta	Trichoptera	Hydropsychidae				netspinning caddisflies	coll-filt	intol		x	x
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	*Hydroptila* sp.		microcaddisflies	scraper	mod tol	x		NEW
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	*Leucotrichia* sp.		ring horn microcaddisflies	scraper	mod tol	NEW	x	x
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	*Ochrotrichia* sp.		microcaddisflies	scraper	mod tol			x
Arthropoda	Insecta	Trichoptera	Hydroptilidae				microcaddisflies	n/a	intol	x	x	x
Arthropoda	Insecta	Trichoptera	Leptoceridae	Leptocerinae	*Oecetis* sp.		long-horned caddisflies	pred	mod tol		x	
Arthropoda	Insecta	Trichoptera	Limnephilidae		*Limnephilus* sp.		northern caddisflies	shredder	intol	x		
Arthropoda	Insecta	Trichoptera	Philopotamidae	Chimarrinae	*Chimarra* sp.		little black caddisflies	coll-filt	intol			x
Arthropoda	Insecta	Trichoptera	Philopotamidae	Philopotaminae			fingernet caddisflies	coll-filt	intol	NEW	x	
Arthropoda	Insecta	Trichoptera	Rhyacophilidae		*Rhyacophila*	vagrita group	green sedge caddisflies	pred	intol			NEW
Arthropoda	Insecta	Trichoptera	Rhyacophilidae		*Rhyacophila* sp.		green sedge caddisflies	pred	intol			x
Arthropoda	Insecta	Trichoptera					caddisflies	n/a	n/a		x	
Nemata							roundworms	n/a	n/a		x	
Platyhelminthes	Turbellaria						flatworms	pred	intol		x	

Note: "NEW" under the site column denotes a new record for this SCPN monitoring site.

[1]Functional group abbreviations: coll-gath = collector-gatherer, coll-filt = collector-filterer, pred = predator.

[2]Tolerance group abbreviations: tol = tolerant, mod tol = moderately tolerant, intol = intolerant.

Appendix D Aquatic macroinvertebrate community and physical habitat data from the aquatic macroinvertebrate monitoring site on Hermit Creek in Grand Canyon National Park, Arizona, 2009–2013

Table D1. Quantitative aquatic macroinvertebrate community metrics from HER01 on Hermit Creek in Grand Canyon NP. 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 for all years are expressed as the percentage of taxa in the group.

	2009 (*n* = 5)	2010 (*n* = 5)	2011 (*n* = 5)	2012 (*n* = 5)	2013 (*n* = 5)
Quantitative metric	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Total abundance	603.40 (60.04)	510.00 (150.28)	675.00 (57.22)	768.40 (113.49)	690.40 (51.10)
Total richness	20.20 (1.64)	17.60 (3.05)	21.00 (2.45)	13.80 (2.17)	19.20 (2.28)
Simpson's Diversity—taxonomic	0.69 (0.08)	0.73 (0.06)	0.78 (0.06)	0.41 (0.19)	0.74 (0.02)
Simpson's Diversity—functional group	0.35 (0.15)	0.22 (0.07)	0.28 (0.11)	0.12 (0.03)	0.24 (0.06)
Dominant taxa	46.91 (10.51)	44.80 (10.48)	34.65 (11.62)	72.54 (15.53)	39.12 (4.87)
Tolerance group					
Relative abundance of tolerant taxa (%)	16.83 (20.65)	2.17 (1.05)	1.74 (1.14)	0.81 (0.42)	1.06 (0.41)
Relative abundance of moderately tolerant taxa (%)	45.25 (19.14)	60.02 (20.55)	54.54 (21.33)	80.64 (13.69)	54.05 (6.53)
Relative abundance of intolerant taxa (%)	37.92 (16.69)	37.80 (20.70)	43.72 (21.10)	18.55 (13.55)	44.88 (6.43)
Richness of tolerant taxa (%)	22.56 (4.44)	18.05 (7.37)	17.94 (3.80)	17.15 (7.37)	18.39 (1.52)
Richness of moderately tolerant taxa (%)	46.06 (3.26)	53.31 (5.09)	56.40 (5.40)	50.58 (7.06)	51.71 (7.18)
Richness of intolerant taxa (%)	31.38 (3.51)	28.64 (6.14)	25.66 (6.45)	32.27 (6.36)	29.90 (7.01)
Functional group					
Relative abundance of collector-filterers (%)	2.89 (1.85)	5.18 (5.00)	7.82 (6.91)	4.85 (1.19)	7.87 (4.05)
Relative abundance of collector-gatherers (%)	72.97 (20.60)	87.53 (4.38)	83.74 (7.85)	93.46 (1.86)	86.38 (3.82)
Relative abundance of scrapers (%)	0.72 (0.49)	0.80 (0.49)	0.77 (0.60)	0.00 (0.00)	2.76 (0.96)
Relative abundance of shredders (%)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.08 (0.11)	0.00 (0.00)
Relative abundance of predators (%)	23.42 (20.36)	6.50 (2.20)	7.67 (2.51)	1.62 (1.22)	2.99 (0.93)
Richness of collector-filterers (%)	10.48 (4.02)	10.68 (3.81)	9.80 (1.07)	15.12 (1.99)	11.45 (1.60)
Richness of collector-gatherers (%)	33.33 (3.93)	42.60 (6.40)	43.05 (5.43)	50.83 (6.84)	35.50 (6.37)
Richness of scrapers (%)	5.24 (0.43)	9.43 (4.08)	5.79 (4.20)	0.00 (0.00)	11.74 (4.75)
Richness of shredders (%)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	3.15 (4.40)	0.00 (0.00)
Richness of predators (%)	50.95 (4.14)	37.29 (9.75)	41.36 (8.12)	30.89 (6.39)	41.31 (9.75)
Taxonomic group					
Number of EPT taxa	4.40 (0.55)	4.80 (0.45)	4.80 (1.64)	3.60 (0.55)	6.20 (2.28)
Relative abundance of EPT taxa (%)	4.43 (1.59)	20.42 (13.39)	36.12 (13.30)	89.70 (3.87)	67.37 (5.92)
Relative abundance of Ephemeroptera (%)	2.59 (1.10)	16.47 (11.89)	31.91 (14.73)	89.07 (4.15)	64.87 (6.59)
Relative abundance of Plecoptera (%)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Relative abundance of Trichoptera (%)	1.84 (0.98)	3.95 (4.62)	4.21 (5.22)	0.63 (0.44)	2.38 (0.95)
Relative abundance of noninsect taxa (%)	6.66 (3.91)	4.62 (1.68)	4.88 (2.10)	0.33 (0.23)	1.37 (0.77)
Relative abundance of Chironomidae Diptera (%)	38.69 (19.29)	40.06 (13.16)	33.35 (9.99)	3.45 (1.88)	20.42 (8.49)
Relative abundance of non-Chironomidae Diptera (%)	17.31 (20.15)	9.80 (9.29)	12.41 (10.24)	5.16 (1.26)	9.22 (4.35)
Relative abundance of Coleoptera (%)	31.96 (16.70)	24.51 (23.95)	11.75 (12.80)	1.26 (1.03)	0.88 (0.61)
Relative abundance of Odonata (%)	0.96 (0.81)	0.58 (0.55)	1.49 (1.13)	0.10 (0.21)	0.44 (0.21)

Table D2. Qualitative aquatic macroinvertebrate community metrics from HER01 on Hermit Creek in Grand Canyon NP. Richness-based metrics are expressed as the percentage of taxa in a given order, tolerance or functional feeding group.

Qualitative metric	2009	2010	2011	2012	2013
Taxa richness	23	27	25	11	20
Tolerance group					
Richness of tolerant taxa (%)	28.57	24.00	18.18	20.00	31.58
Richness of moderately tolerant taxa (%)	47.62	48.00	50.00	60.00	52.63
Richness of intolerant taxa (%)	23.81	28.00	31.82	20.00	15.79
Functional group					
Richness of collector-filterers (%)	9.09	7.69	8.33	10.00	10.00
Richness of collector-gatherers (%)	31.82	46.15	37.50	50.00	35.00
Richness of scrapers (%)	4.55	3.85	4.17	0.00	5.00
Richness of shredders (%)	0.00	3.85	4.17	0.00	5.00
Richness of predators (%)	54.55	38.46	45.83	40.00	45.00
Taxonomic group					
Number of EPT taxa	4	7	5	2	6
Richness of EPT taxa (%)	17.39	25.93	20.00	18.18	30.00
Richness of Ephemeroptera (%)	8.70	11.11	12.00	18.18	15.00
Richness of Plecoptera (%)	0.00	0.00	0.00	0.00	0.00
Richness of Trichoptera (%)	8.70	14.81	8.00	0.00	15.00
Richness of noninsect taxa (%)	21.74	18.52	20.00	9.10	15.00
Richness of Chironomidae Diptera (%)	13.04	11.11	12.00	27.27	15.00
Richness of non-Chironomidae Diptera (%)	34.78	29.63	32.00	18.18	30.00
Richness of Coleoptera (%)	4.35	7.41	8.00	18.18	0.00
Richness of Odonata (%)	8.70	7.41	8.00	9.09	10.00

Table D3. Physical habitat and hydrologic data at the microhabitat, transect, and reach levels, from HER01 on Hermit Creek in Grand Canyon NP. Particle embeddedness and canopy closure measurements are expressed as percentages.

	2009		2010		2011		2012		2013	
Physical habitat metric	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Microhabitat level (*n* = 5)										
Riffles										
Velocity (m/s)	0.42	0.15	0.46	0.33	0.58	0.18	0.59	0.20	0.60	0.19
Depth (m)	0.08	0.02	0.11	0.04	0.16	0.13	0.07	0.02	0.10	0.03
Embeddedness (%)	25.7	20.2	53.1	30.7	16.1	7.5	18.0	12.0	26.2	10.1
Transect level (*n* = 11)										
Channel dimensions										
Velocity (m/s)	0.18	0.11	0.15	0.09	0.14	0.12	0.17	0.14	0.20	0.13
Depth (m)	0.08	0.04	0.08	0.07	0.11	0.08	0.05	0.03	0.04	0.04
Wetted channel width (m)	1.9	0.7	2.7	1.1	2.2	1.1	3.4	2.8	3.8	3.0
Active channel width (m)	10.0	2.4	7.0	2.4	9.2	2.9	4.7	6.5	5.0	3.2
Riparian cover										
Canopy closure (%)	14.4	27.9	7.5	20.5	6.6	14.6	0.0	0.0	0.0	0.0
Reach level (*n* = 1)										
Water quality	**Value**		**Value**		**Value**		**Value**		**Value**	
Temperature (°C)	17.4		15.6		13.3		16.7		15.7	
Specific conductivity (µS/cm)	429		575		435		442		462	
pH	8.4		8.7		8.6		8.4		8.8	
Dissolved oxygen (% saturation)	111.0		—		100.9		99.9		100.8	
Dissolved oxygen (mg/L)	11.1		—		9.5		8.7		9.1	
Turbidity (NTU)	0.41		0.30		—		5.8		2.2	
Discharge (cfs)	—		—		0.8		0.6		0.6	

Table D4. Measured stream velocity and channel characteristics from transects at HER01 on Hermit Creek in Grand Canyon NP, 2013.

	Velocity (m/s) (*n* = 5)		Depth (m) (*n* = 5)		Wetted channel width (m)	Active channel width (m)
Transect	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Value**	**Value**
1	0.05	0.12	0.01	0.02	8.0	8.0
2	0.02	0.04	0.00	0.01	9.9	9.9
3	0.23	0.16	0.07	0.04	1.3	1.3
4	0.21	0.18	0.13	0.10	1.3	1.3
5	0.31	0.14	0.04	0.03	2.7	7.3
6	0.39	0.12	0.04	0.02	1.8	1.8
7	0.40	0.26	0.07	0.04	0.9	2.3
8	0.05	0.12	0.00	0.01	6.3	7.6
9	0.15	0.26	0.01	0.02	4.0	4.0
10	0.12	0.18	0.04	0.05	2.2	8.1
11	0.30	0.61	0.02	0.03	3.8	3.8

Appendix E Aquatic macroinvertebrate community and physical habitat data from the aquatic macroinvertebrate monitoring site on Garden Creek in Grand Canyon National Park, Arizona, 2010–2013

Table E1. Quantitative aquatic macroinvertebrate community metrics from GAR01 on Garden Creek in Grand Canyon NP. 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 for all years are expressed as the percentage of taxa in the group.

	2010 (*n* = 5)		2011 (*n* = 5)		2012 (*n* = 5)		2013 (*n* = 5)	
Quantitative metric	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Total abundance	696.00	39.40	706.80	64.69	727.40	59.96	706.60	77.31
Total richness	23.60	1.82	19.20	1.48	18.20	2.49	22.40	2.19
Simpson's Diversity—taxonomic	0.84	0.04	0.74	0.05	0.77	0.04	0.80	0.04
Simpson's Diversity—functional group	0.47	0.07	0.49	0.06	0.47	0.05	0.56	0.08
Dominant taxa	28.38	9.11	38.10	9.41	32.08	3.71	35.18	8.13
Tolerance group								
Relative abundance of tolerant taxa (%)	1.93	0.85	1.56	0.79	0.60	0.60	1.60	1.01
Relative abundance of moderately tolerant taxa (%)	68.31	8.27	88.07	6.84	87.38	6.85	80.21	8.43
Relative abundance of intolerant taxa (%)	29.76	8.16	10.37	7.31	12.02	6.73	18.19	9.36
Richness of tolerant taxa (%)	8.22	3.22	11.96	6.09	6.45	0.97	4.69	3.01
Richness of moderately tolerant taxa (%)	56.08	6.10	59.47	6.40	53.76	7.12	54.73	5.61
Richness of intolerant taxa (%)	35.69	6.06	28.58	3.92	39.79	7.80	40.59	4.63
Functional group								
Relative abundance of collector-filterers (%)	15.25	3.17	31.67	16.55	31.81	7.62	34.92	13.30
Relative abundance of collector-gatherers (%)	70.15	6.35	60.61	14.85	64.77	7.31	52.90	14.20
Relative abundance of scrapers (%)	8.27	4.88	1.03	0.93	0.14	0.26	5.39	2.15
Relative abundance of shredders (%)	0.09	0.13	0.24	0.19	0.30	0.23	0.28	0.24
Relative abundance of predators (%)	6.25	2.67	6.45	2.00	2.97	0.47	6.50	0.45
Richness of collector-filterers (%)	14.40	4.83	20.07	3.27	20.55	1.81	15.33	2.05
Richness of collector-gatherers (%)	35.55	3.48	27.72	5.65	38.98	6.35	36.03	2.65
Richness of scrapers (%)	8.51	0.64	8.87	4.86	2.11	2.90	10.79	2.06
Richness of shredders (%)	2.62	4.01	5.84	4.44	6.14	0.96	4.54	0.46
Richness of predators (%)	38.91	5.79	37.50	8.55	32.22	7.69	33.31	2.15
Taxonomic group								
Number of EPT taxa	7.80	1.48	5.40	1.52	5.40	1.95	7.60	0.55
Relative abundance of EPT taxa (%)	58.52	4.41	37.02	10.98	29.14	4.09	30.22	3.41
Relative abundance of Ephemeroptera (%)	44.49	7.95	31.43	12.28	23.96	3.03	18.42	7.01
Relative abundance of Plecoptera (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative abundanceof Trichoptera (%)	14.03	4.60	5.59	3.14	5.19	5.30	11.80	7.42
Relative abundance of noninsect taxa (%)	4.38	1.85	2.77	1.25	1.71	0.68	1.20	1.20
Relative abundance of Chironomidae Diptera (%)	22.88	2.95	25.70	5.39	33.52	6.28	29.94	13.72
Relative abundance of non-Chironomidae Diptera (%)	11.86	3.02	27.58	15.49	28.08	6.49	29.63	12.33
Relative abundance of Coleoptera (%)	1.63	1.41	4.27	4.79	5.91	5.15	5.17	2.49
Relative abundance of Odonata (%)	0.73	0.36	2.66	0.92	1.63	0.54	3.84	1.47

Table E2. Qualitative aquatic macroinvertebrate community metrics from GAR01 on Garden Creek in Grand Canyon NP. Richness-based metrics are expressed as the percentage of taxa in a given order, tolerance or functional feeding group.

Qualitative metric	2010	2011	2012	2013
Taxa richness	28	20	27	5
Tolerance group				
Richness of tolerant taxa (%)	7.41	6.25	8.70	0.00
Richness of moderately tolerant taxa (%)	48.15	56.25	56.52	40.00
Richness of intolerant taxa (%)	44.44	37.50	34.78	60.00
Functional group				
Richness of collector-filterers (%)	18.52	18.75	16.67	0.00
Richness of collector-gatherers (%)	33.33	31.25	25.00	20.00
Richness of scrapers (%)	11.11	0.00	8.33	0.00
Richness of shredders (%)	3.70	6.25	8.33	0.00
Richness of predators (%)	33.33	43.75	41.67	80.00
Taxonomic group				
Number of EPT taxa	10	5	7	1
Richness of EPT taxa (%)	35.71	25.00	25.93	20.00
Richness of Ephemeroptera (%)	14.29	10.00	3.70	0.00
Richness of Plecoptera (%)	0.00	0.00	0.00	0.00
Richness of Trichoptera (%)	21.43	15.00	22.22	20.00
Richness of noninsect taxa (%)	14.29	30.00	25.93	20.00
Richness of Chironomidae Diptera (%)	10.71	15.00	11.11	0.00
Richness of non-Chironomidae Diptera (%)	25.00	10.00	18.52	0.00
Richness of Coleoptera (%)	7.14	10.00	7.41	20.00
Richness of Odonata (%)	7.14	10.00	11.11	40.00

Table E3. Physical habitat and hydrologic data at the microhabitat, transect, and reach levels, from GAR01 on Garden Creek in Grand Canyon NP. Particle embeddedness and canopy closure measurements are expressed as percentages.

	2010		2011		2012		2013	
Physical habitat metric	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Microhabitat level (*n* = 5)								
Riffles								
Velocity (m/s)	0.75	0.21	0.70	0.15	0.84	0.33	0.60	0.25
Depth (m)	0.13	0.02	0.16	0.04	0.10	0.03	0.13	0.02
Embeddedness (%)	34.1	16.0	33.6	10.1	20.8	8.8	19.6	16.5
Transect level (*n* = 11)								
Channel dimensions								
Velocity (m/s)	0.59	0.25	0.39	0.12	0.61	0.19	0.38	0.22
Depth (m)	0.08	0.02	0.09	0.04	0.09	0.03	0.13	0.10
Wetted channel width (m)	1.3	0.3	1.5	0.5	1.4	0.5	1.0	0.5
Active channel width (m)	6.6	2.7	11.0	2.1	10.8	1.6	10.2	2.8
Riparian cover								
Canopy closure (%)	70.8	28.6	64.2	34.5	70.9	27.0	76.0	26.8
Reach level (*n* = 1)								
Water quality	**Value**		**Value**		**Value**		**Value**	
Temperature (°C)	15.3		15.2		15.7		15.0	
Specific conductivity (µS/cm)	—		267		304		358	
pH	8.9		8.6		8.3		8.4	
Dissolved oxygen (% saturation)	—		96.5		102.1		96.4	
Dissolved oxygen (mg/L)	—		8.5		8.9		8.5	
Turbidity (NTU)	—		8.3		14		1.6	
Discharge (cfs)	—		2.3		1.8		2.1	

Table E4. Measured stream velocity and channel characteristics from transects at GAR01 on Garden Creek in Grand Canyon NP, 2013.

	Velocity (m/s) (*n* = 5)		Depth (m) (*n* = 5)		Wetted channel width (m)	Active channel width (m)
Transect	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Value**	**Value**
1	0.27	0.11	0.14	0.04	0.7	8.9
2	0.27	0.19	0.11	0.05	1.0	7.9
3	0.43	0.32	0.08	0.03	1.3	10.8
4	0.23	0.18	0.10	0.07	2.2	9.0
5	0.51	0.42	0.07	0.05	1.0	11.8
6	0.06	0.07	0.41	0.50	1.1	7.3
7	0.43	0.07	0.15	0.02	0.6	5.6
8	0.25	0.14	0.05	0.02	0.4	11.5
9	0.20	0.39	0.09	0.06	0.9	10.4
10	0.76	0.33	0.10	0.03	1.1	14.4
11	0.74	0.25	0.12	0.01	0.9	14.2

Appendix F Aquatic macroinvertebrate community and physical habitat data from the aquatic macroinvertebrate monitoring site on Bright Angel Creek in Grand Canyon National Park, Arizona, 2010–2013

Table F1. Quantitative aquatic macroinvertebrate community metrics from BRI01 on Bright Angel Creek in Grand Canyon NP. 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 for all years are expressed as the percentage of taxa in the group.

	2010 (*n* = 5)		2011 (*n* = 5)		2012 (*n* = 5)		2013 (*n* = 5)	
Quantitative metric	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Total abundance	672.20	69.16	340.80	219.59	738.40	100.42	550.00	125.18
Total richness	18.60	3.85	17.40	2.30	17.60	2.30	17.20	0.84
Simpson's Diversity—taxonomic	0.78	0.06	0.79	0.05	0.80	0.03	0.70	0.06
Simpson's Diversity—functional group	0.50	0.16	0.36	0.06	0.37	0.10	0.38	0.09
Dominant taxa	35.42	4.60	35.96	6.41	33.96	5.52	47.07	10.82
Tolerance group								
Relative abundance of tolerant taxa (%)	0.31	0.35	0.88	1.01	0.22	0.22	0.53	0.59
Relative abundance of moderately tolerant taxa (%)	28.32	13.16	74.73	9.23	47.36	10.16	73.21	6.28
Relative abundance of intolerant taxa (%)	71.37	13.07	24.69	9.01	52.42	10.19	26.26	6.23
Richness of tolerant taxa (%)	4.11	3.99	7.58	4.71	5.35	5.22	7.60	5.26
Richness of moderately tolerant taxa (%)	43.71	3.14	41.58	2.78	46.15	9.26	46.75	4.09
Richness of intolerant taxa (%)	52.18	4.99	50.85	2.78	48.50	5.66	45.65	3.34
Functional group								
Relative abundance of collector-filterers (%)	13.11	6.59	15.76	5.11	15.24	14.04	19.17	11.64
Relative abundance of collector-gatherers (%)	59.39	19.76	77.82	4.78	75.95	12.14	75.34	9.82
Relative abundance of scrapers (%)	24.91	20.68	2.07	1.90	5.40	1.00	1.39	0.89
Relative abundance of shredders (%)	0.00	0.00	0.04	0.09	0.06	0.14	0.08	0.12
Relative abundance of predators (%)	2.59	1.54	4.30	1.91	3.34	1.34	4.01	2.06
Richness of collector-filterers (%)	17.69	3.57	19.05	2.73	17.46	2.34	15.11	3.09
Richness of collector-gatherers (%)	36.51	1.12	38.72	5.71	35.16	5.95	38.28	3.77
Richness of scrapers (%)	20.01	5.30	11.08	4.76	16.48	5.89	11.72	4.30
Richness of shredders (%)	0.00	0.00	1.05	2.35	1.43	3.19	2.36	3.24
Richness of predators (%)	25.79	7.21	30.09	3.79	29.47	4.70	35.52	2.25
Taxonomic group								
Number of EPT taxa	7.40	0.89	6.80	1.48	7.00	0.71	7.20	0.45
Relative abundance of EPT taxa (%)	51.99	12.34	49.57	5.78	48.41	8.45	66.14	11.10
Relative abundance of Ephemeroptera (%)	35.93	13.04	42.28	3.99	41.96	10.30	62.53	9.90
Relative abundance of Plecoptera (%)	0.00	0.00	0.08	0.19	0.00	0.00	0.08	0.12
Relative abundanceof Trichoptera (%)	16.06	8.74	7.21	3.05	6.45	2.34	3.53	1.65
Relative abundance of noninsect taxa (%)	2.86	1.86	7.09	4.20	9.36	3.66	3.05	1.23
Relative abundance of Chironomidae Diptera (%)	11.25	7.04	24.39	8.20	7.72	2.23	6.65	2.65
Relative abundance of non-Chironomidae Diptera (%)	21.59	17.72	10.47	3.08	9.98	12.39	17.31	12.56
Relative abundance of Coleoptera (%)	11.31	9.56	8.21	3.78	24.37	8.75	6.30	6.63
Relative abundance of Odonata (%)	0.99	0.78	0.27	0.31	0.15	0.13	0.54	0.95

Table F2. Qualitative aquatic macroinvertebrate community metrics from BRI01 on Bright Angel Creek in Grand Canyon NP. Richness-based metrics are expressed as the percentage of taxa in a given order, tolerance or functional feeding group.

Qualitative metric	2010	2011	2012	2013
Taxa richness	26	22	25	20
Tolerance group				
Richness of tolerant taxa (%)	8.33	9.52	13.04	16.67
Richness of moderately tolerant taxa (%)	45.83	33.33	43.48	44.44
Richness of intolerant taxa (%)	45.83	57.14	43.48	38.89
Functional group				
Richness of collector-filterers (%)	11.54	15.00	16.00	10.00
Richness of collector-gatherers (%)	34.62	35.00	36.00	40.00
Richness of scrapers (%)	11.54	15.00	12.00	10.00
Richness of shredders (%)	0.00	10.00	0.00	5.00
Richness of predators (%)	42.31	25.00	36.00	35.00
Taxonomic group				
Number of EPT taxa	8	8	9	6
Richness of EPT taxa (%)	30.77	36.36	36.00	30.00
Richness of Ephemeroptera (%)	15.38	13.64	16.00	15.00
Richness of Plecoptera (%)	0.00	0.00	0.00	0.00
Richness of Trichoptera (%)	15.38	22.73	20.00	15.00
Richness of noninsect taxa (%)	19.23	13.62	24.00	20.00
Richness of Chironomidae Diptera (%)	11.54	13.64	12.00	10.00
Richness of non-Chironomidae Diptera (%)	19.23	27.27	16.00	15.00
Richness of Coleoptera (%)	7.69	4.55	4.00	15.00
Richness of Odonata (%)	11.54	4.55	8.00	10.00

Table F3. Physical habitat and hydrologic data at the microhabitat, transect, and reach levels, from BRI01 on Bright Angel Creek in Grand Canyon NP. Particle embeddedness and canopy closure measurements are expressed as percentages.

	2010		2011		2012		2013	
Physical habitat metric	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Microhabitat level (*n* = 5)								
Riffles								
Velocity (m/s)	0.56	0.26	0.75	0.31	0.68	0.30	0.55	0.23
Depth (m)	0.15	0.07	0.24	0.06	0.20	0.04	0.15	0.07
Embeddedness (%)	23.6	15.3	30.8	14.0	48.0	11.9	32.8	10.0
Transect level (*n* = 11)								
Channel dimensions								
Velocity (m/s)	0.42	0.18	0.50	0.18	0.54	0.21	0.41	0.17
Depth (m)	0.20	0.06	0.25	0.09	0.19	0.11	0.17	0.06
Wetted channel width (m)	6.9	2.5	5.9	1.7	5.9	2.0	6.3	1.4
Active channel width (m)	17.6	5.0	17.7	5.7	15.1	3.6	15.9	4.5
Riparian cover								
Canopy closure (%)	12.4	24.2	2.1	7.7	2.8	15.8	2.4	8.1
Reach level (*n* = 1)								
Water quality	**Value**		**Value**		**Value**		**Value**	
Temperature (°C)	13.8		13.3		14.4		11.3	
Specific conductivity (µS/cm)	352		343		335		351	
pH	8.6		8.8		8.8		8.7	
Dissolved oxygen (% saturation)	100.5		99.7		102.1		102.9	
Dissolved oxygen (mg/L)	9.4		9.4		8.6		10.3	
Turbidity (NTU)	0.60		2.7		1.7		1.1	
Discharge (cfs)	21.3		21.7		19.8		24.0	

Table F4. Measured stream velocity and channel characteristics from transects at BRI01 on Bright Angel Creek in Grand Canyon NP, 2013.

	Velocity (m/s) (*n* = 5)		Depth (m) (*n* = 5)		Wetted channel width (m)	Active channel width (m)
Transect	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Value**	**Value**
1	0.64	0.44	0.16	0.13	7.0	28.9
2	0.66	0.50	0.16	0.04	5.6	21.6
3	0.37	0.09	0.30	0.07	5.5	10.4
4	0.36	0.27	0.17	0.10	5.6	13.5
5	0.20	0.27	0.10	0.11	8.8	17.0
6	0.49	0.39	0.11	0.06	8.9	17.8
7	0.25	0.30	0.21	0.24	4.3	11.1
8	0.31	0.38	0.24	0.10	5.9	12.5
9	0.58	0.37	0.16	0.11	5.2	15.1
10	0.46	0.27	0.17	0.07	6.3	15.8
11	0.21	0.28	0.10	0.07	6.0	11.4

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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