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

2011 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2012/418

ON THE COVER
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

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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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This report is available from the Southern Colorado Plateau Network website (http://science.nature.nps.gov/im/units/scpn/) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

The corresponding author and project manager for this project is Stephen Monroe (stephen_monroe@nps.gov). Stacy Stumpf is the water resources lead technician for the project. The 2011 crew consisted of Kelly Lawrence, Melissa Dyer, and Tim Sullivan. 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 scientific foundation for making decisions and working with other agencies and the public to protect park ecosystems. Hydrologic 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) stream flow and depth to groundwater, 4) spring water quality, 5) channel morphology, 6) riparian vegetation, composition, and structure, and 7) spring, seep and tinaja 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 on Bright Angel Creek (Stumpf and Monroe 2012). 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 2011, 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 (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 gage—*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. 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. *The Hermit Creek above Tonto Trail* streamflow gaging station was established in 1994 and GRCA monitors streamflow and periodically samples water quality at the site. Aquatic macroinvertebrate data has been collected sporadically at Hermit Creek by the state of Arizona from 1992–2009 (Lawson 2007). One of the specific reasons for selecting this site was to assess impacts downstream of the Hermit Creek campground. Unfortunately, the *Hermit Creek above Tonto Trail* gaging station was destroyed during a flash flood event in September 2011. We were unable to retrieve any data from the gage for 2011 prior to the flood.

Garden Creek below Tonto Trail (GRCAGAR01), identified in this report as GAR01, is located approximately 9.3 km downstream from the Bright Angel Trailhead (fig. 2). 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 12 mule trips a day can occur along the Bright Angel Trail. The effects of mules on water quality in Garden Creek are poorly understood. 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. 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.

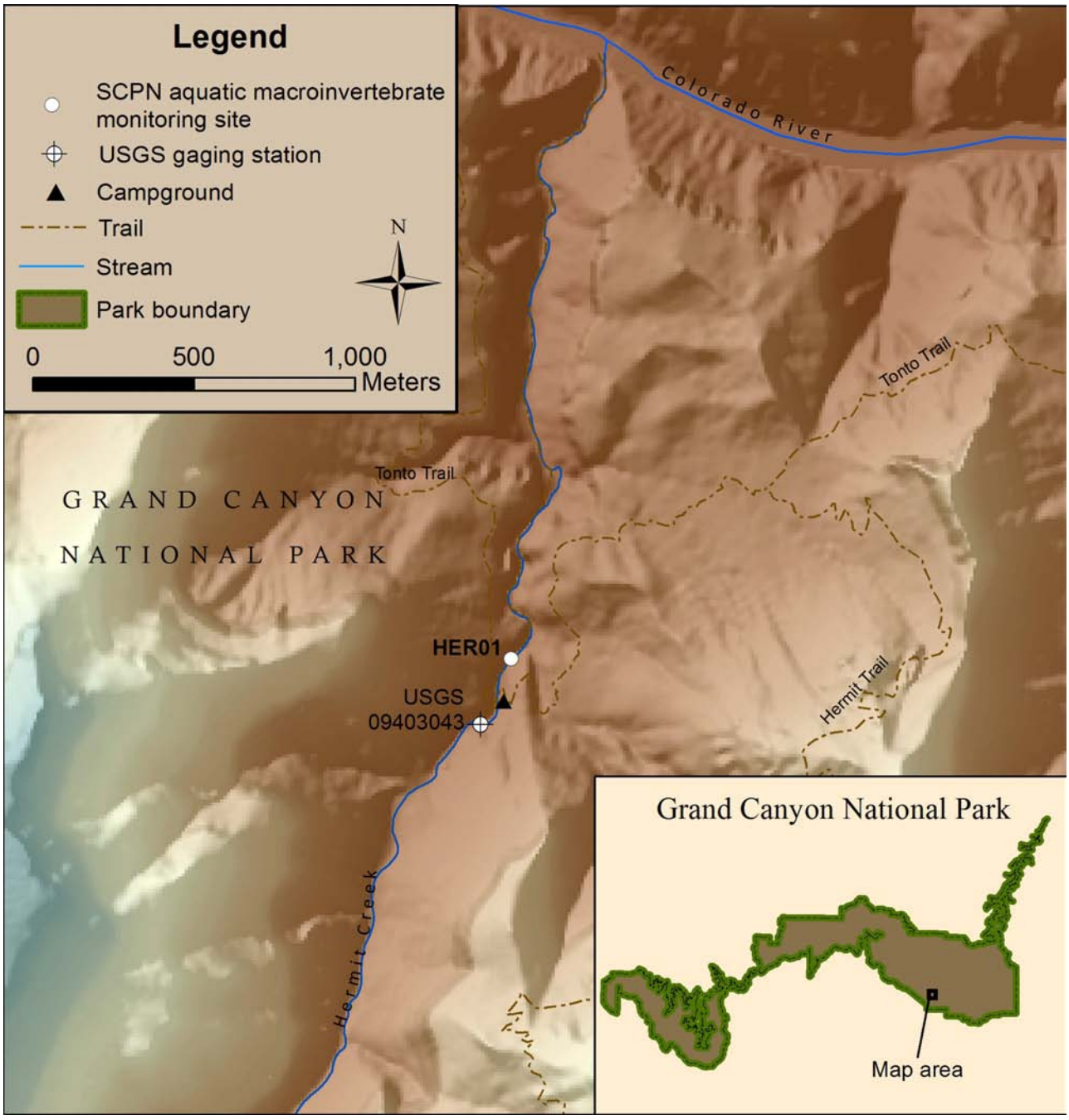


Figure 1. Map of the HER01 (Hermit Creek) monitoring site in Grand Canyon National Park, Arizona, 2011

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). The site was located above Phantom Ranch to avoid Ranch impacts on streamflow. 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. 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 of months of 2006–2007 and 2010–2011, and an additional effort is scheduled for 2011–2012. It is unclear how the removal efforts will affect aquatic macroinvertebrate taxa.

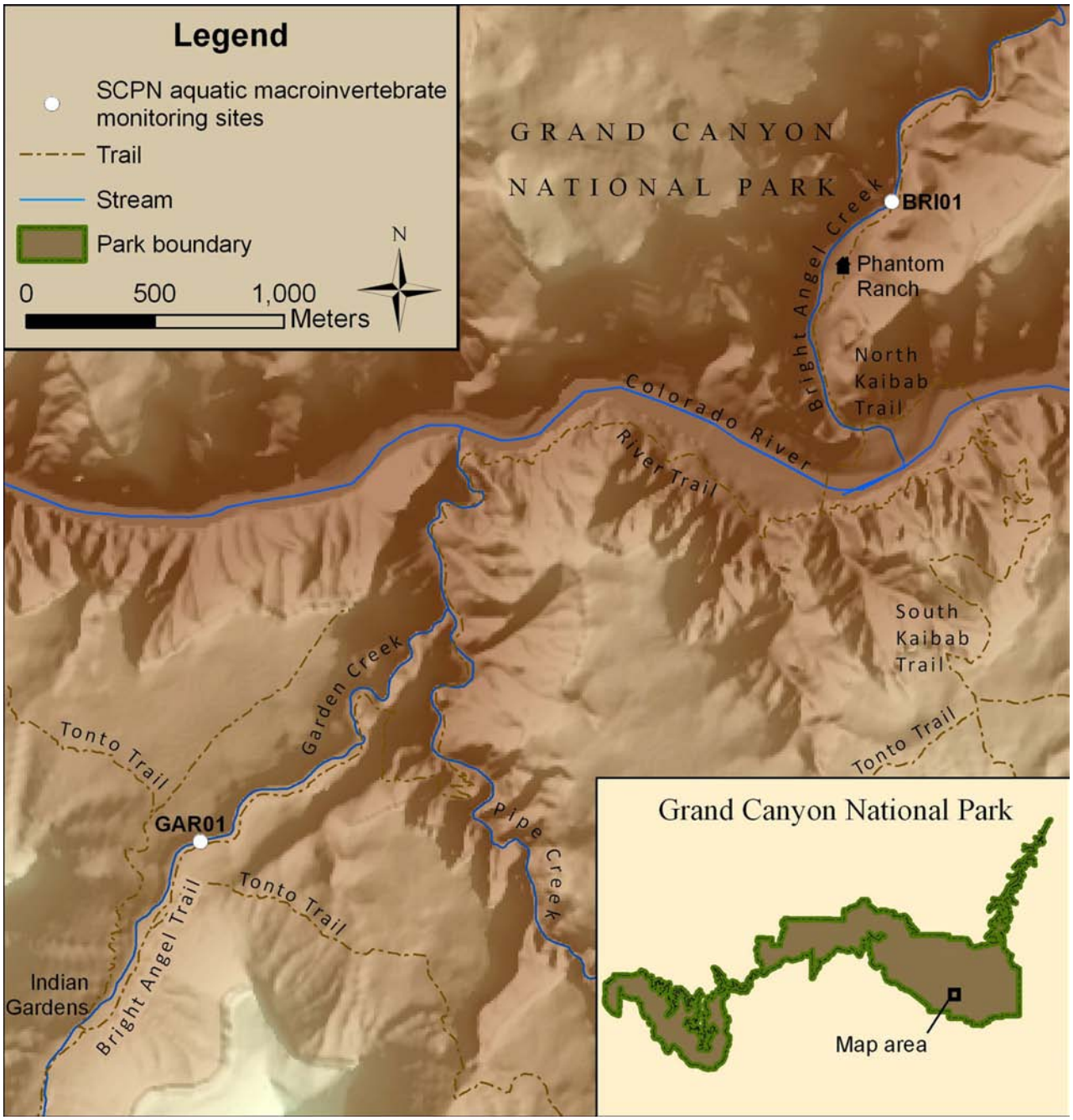


Figure 2. Map of the BRI01 (Bright Angel Creek) and the GAR01 (Garden Creek) monitoring sites in Grand Canyon National Park, Arizona, 2011

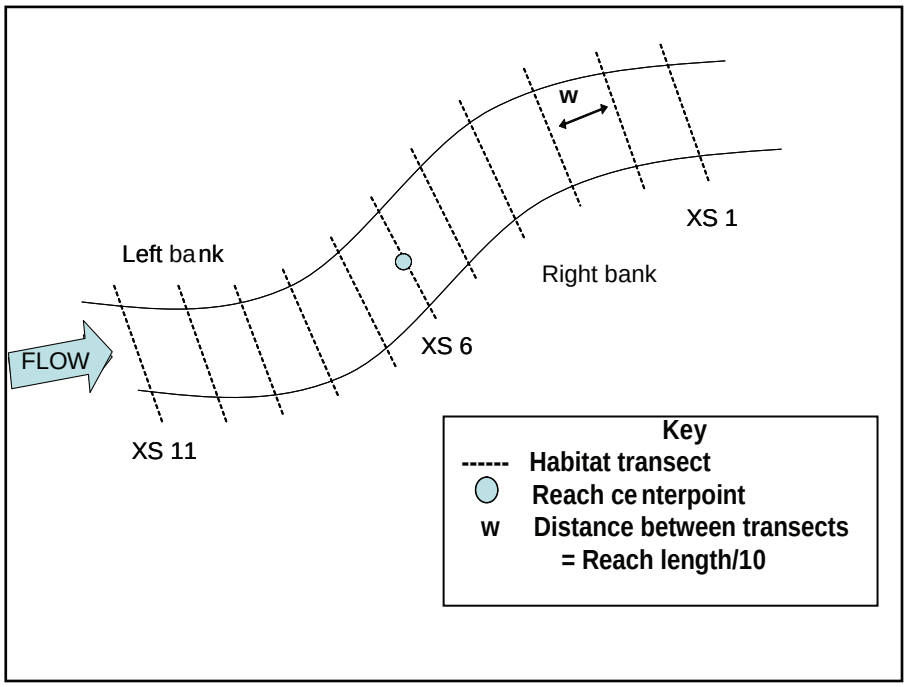
The purpose of this report is to (a) document SCPN aquatic macroinvertebrate monitoring activities that occurred at Hermit Creek, Garden Creek, and Bright Angel Creek in GRCA in 2011, (b) summarize the data collected, and (c) where appropriate, place the data in the context of current environmental conditions.

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 11 April 2011, 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 20 April 2011, and from BRI01 on 12 October 2011. 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 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. 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 3 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 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
  - measured geomorphic channel units (GCU) at 5 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 representing 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 site

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 10X 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 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).

2.3 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 from 2009 to 2011. 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.

Table 1. Qualitative metrics for aquatic macroinvertebrate samples collected from HER01 at Hermit Creek in Grand Canyon National Park, Arizona, 2009–2011. Richness-based metrics are expressed as the percentage of taxa in a given order, tolerance or functional feeding group.

Qualitative metric	2009	2010	2011
Taxa richness	23	27	25
Tolerance group			
Richness of tolerant taxa (%)	28.57	24.00	18.18
Richness of moderately tolerant taxa (%)	47.62	48.00	50.00
Richness of intolerant taxa (%)	23.81	28.00	31.82
Functional group			
Richness of collector-filterers (%)	9.09	7.69	8.33
Richness of collector-gatherers (%)	31.82	46.15	37.50
Richness of scrapers (%)	4.55	3.85	4.17
Richness of shredders (%)	0.00	3.85	4.17
Richness of predators (%)	54.55	38.46	45.83
Taxonomic group			
Number of EPT taxa	4	7	5
Richness of EPT taxa (%)	17.39	25.93	20.00
Richness of Ephemeroptera (%)	8.70	11.11	12.00
Richness of Plecoptera (%)	0.00	0.00	0.00
Richness of Trichoptera (%)	8.70	14.81	8.00
Richness of noninsect taxa (%)	21.74	18.52	20.00
Richness of Chironomid Diptera (%)	13.04	11.11	12.00
Richness of non-Chironomid Diptera (%)	34.78	29.63	32.00
Richness of Coleoptera (%)	4.35	7.41	8.00
Richness of Odonata (%)	8.70	7.41	8.00

Abundance. Abundance of aquatic macroinvertebrates at the quantitative targeted riffle habitat averaged 675.00 individuals per riffle (fig. 4), and ranged from a high of 753 individuals to a low of 621 individuals.

Taxa richness. Total richness of quantitative targeted riffle habitat averaged 21.00 taxa (fig. 5). Richness ranged from a high of 25 taxa to a low of 19 taxa. Taxa richness for the qualitative multihabitat sample was 25 taxa.

Diversity. We calculated taxonomic and functional diversity using the Simpson's Diversity Index (fig. 6). Taxonomic diversity, averaging 0.78 per riffle, was nearly 3 times as high as functional diversity, which averaged 0.28 per sample.

Table 2. Quantitative metrics for aquatic macroinvertebrate samples collected from HER01 at Hermit Creek in Grand Canyon National Park, Arizona, 2009–2011. 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		2011	
Quantitative metric	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Total abundance	603.40	60.04	510.00	150.28	675.00	57.22
Total richness	20.20	1.64	17.60	3.05	21.00	2.45
Simpson's Diversity—taxonomic	0.69	0.08	0.73	0.06	0.78	0.06
Simpson's Diversity—functional group	0.35	0.15	0.22	0.07	0.28	0.11
Dominant taxa	46.91	10.51	44.80	10.48	34.65	11.62
Tolerance group						
Relative abundance of tolerant taxa (%)	16.83	20.65	2.17	1.05	1.74	1.14
Relative abundance of moderately tolerant taxa (%)	45.25	19.14	60.02	20.55	54.54	21.33
Relative abundance of intolerant taxa (%)	37.92	16.69	37.80	20.70	43.72	21.10
Richness of tolerant taxa (%)	22.56	4.44	18.05	7.37	17.94	3.80
Richness of moderately tolerant taxa (%)	46.06	3.26	53.31	5.09	56.40	5.40
Richness of intolerant taxa (%)	31.38	3.51	28.64	6.14	25.66	6.45
Functional group						
Relative abundance of collector-filterers (%)	2.89	1.85	5.18	5.00	7.82	6.91
Relative abundance of collector-gatherers (%)	72.97	20.60	87.53	4.38	83.74	7.85
Relative abundance of scrapers (%)	0.72	0.49	0.80	0.49	0.77	0.60
Relative abundance of shredders (%)	0.00	0.00	0.00	0.00	0.00	0.00
Relative abundance of predators (%)	23.42	20.36	6.50	2.20	7.67	2.51
Richness of collector-filterers (%)	10.48	4.02	10.68	3.81	9.80	1.07
Richness of collector-gatherers (%)	33.33	3.93	42.60	6.40	43.05	5.43
Richness of scrapers (%)	5.24	0.43	9.43	4.08	5.79	4.20
Richness of shredders (%)	0.00	0.00	0.00	0.00	0.00	0.00
Richness of predators (%)	50.95	4.14	37.29	9.75	41.36	8.12
Taxonomic group						
Number of EPT taxa	4.40	0.55	4.80	0.45	4.80	1.64
Relative abundance of EPT taxa (%)	4.43	1.59	20.42	13.39	36.12	13.30
Relative abundance of Ephemeroptera (%)	2.59	1.10	16.47	11.89	31.91	14.73
Relative abundance of Plecoptera (%)	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
Relative abundance of noninsect taxa (%)	6.66	3.91	4.62	1.68	4.88	2.10
Relative abundance of Chironomid Diptera (%)	38.69	19.29	40.06	13.16	33.35	9.99
Relative abundance of non-Chironomid Diptera (%)	17.31	20.15	9.80	9.29	12.41	10.24
Relative abundance of Coleoptera (%)	31.96	16.70	24.51	23.95	11.75	12.80
Relative abundance of Odonata (%)	0.96	0.81	0.58	0.55	1.49	1.13

Figure 4. Total abundance expressed as the mean number of individuals in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2011

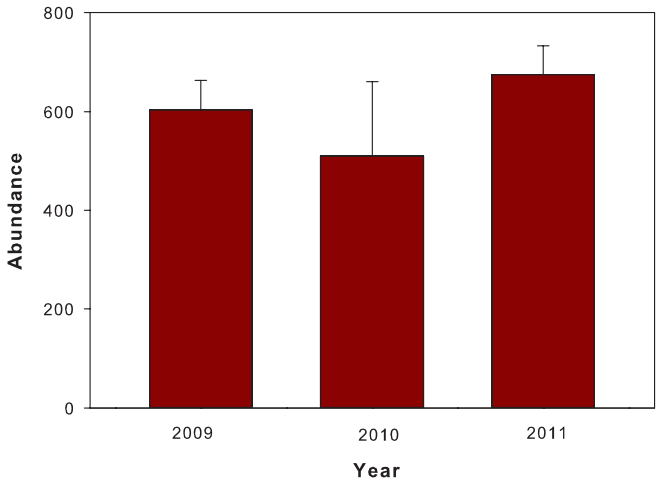


Figure 5. Mean taxa richness in quantitative targeted riffle and total taxa richness in qualitative multihabitat samples collected from HER01 at Hermit Creek in GRCA, 2009–2011

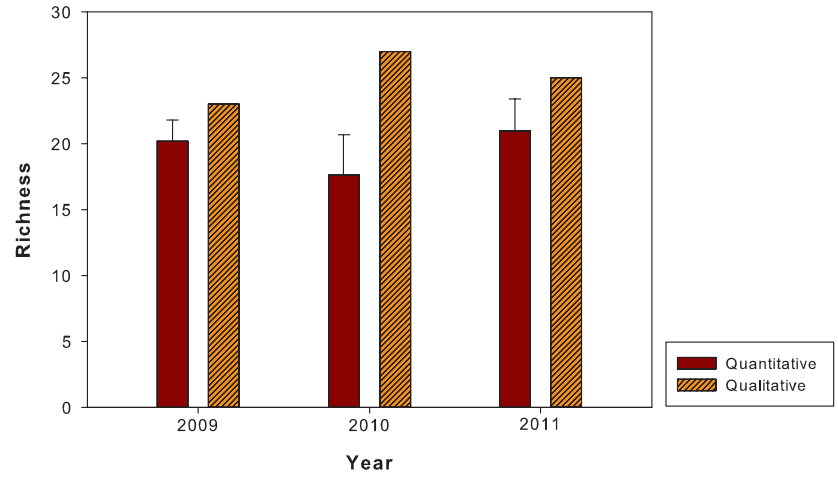
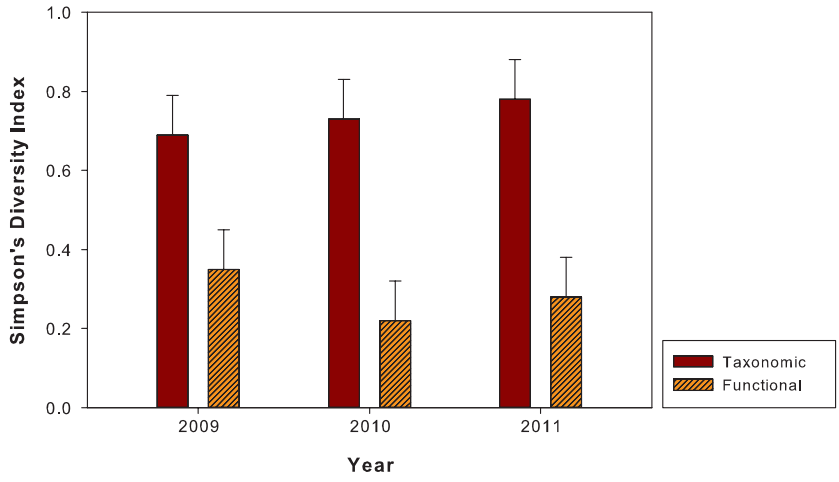


Figure 6. Simpson's Diversity Index for taxonomic and functional diversity in quantitative targeted riffle samples from HER01 at Hermit Creek in GRCA 2009–2011



Stress tolerance. Taxa which are moderately tolerant of disturbance dominated the relative abundance of aquatic macroinvertebrates, averaging 54.54% of the individuals collected (fig. 7a). Relative abundance of intolerant individuals averaged 43.72%, and tolerant individuals were the least abundant group, averaging 1.74%. Total richness by tolerance group was dominated by moderately tolerant taxa, which averaged 56.40% (fig. 7b). Intolerant taxa richness averaged 25.66% and tolerant taxa richness averaged 17.94%.

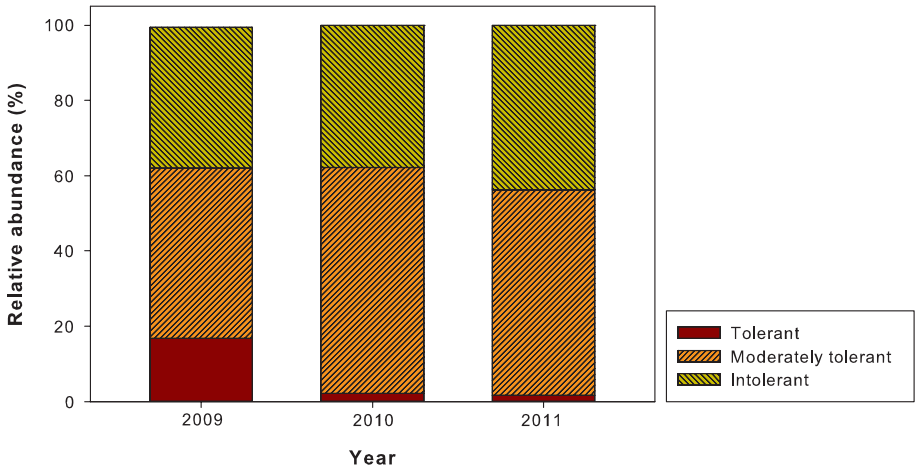


Figure 7a. Mean relative abundance of aquatic macroinvertebrate taxa in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2011, based on their tolerance to perturbation

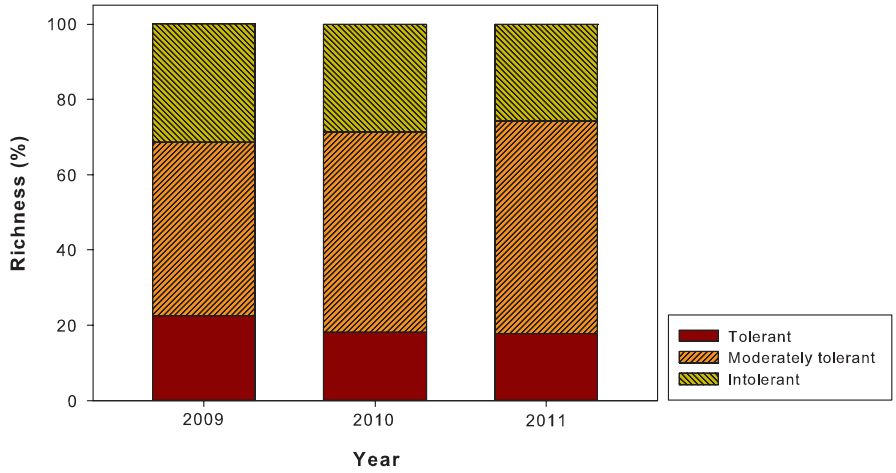


Figure 7b. Mean richness of aquatic macroinvertebrate taxa in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2011, based on their tolerance to perturbation

EPT taxa. Relative abundance of EPT taxa (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]) at this monitoring site averaged 36.12% of all taxa collected (fig. 8). Ephemeropterans were the most abundant EPT group, averaging 31.91%. Trichopterans averaged 4.21% of the samples collected. Like 2009 and 2010, there were no plecopterans found at HER01 in 2011.

Aquatic macroinvertebrate orders. Of the aquatic macroinvertebrate orders collected from HER01, chironomids (midges) were the most abundant, making up 33.35% of the samples (fig. 9). As mentioned in Figure 8, above, ephemeropterans were the next most abundant order, at 31.91%. Non-chironomid dipterans (flies) averaged 12.41% of the samples and coleopterans (beetles) averaged 11.75%. Individuals classified as "Noninsect" averaged 4.88% of the samples and included organisms belonging to the orders Trombidiformes (water mites), Megoloptera (dobsonflies), Lepidoptera (moths), and Collembola (springtails). Trichopterans averaged 4.21%, and odonates (damselflies/dragonflies) were the least abundant order, at 1.50%.

Functional feeding groups. The majority of the organisms collected from HER01 in 2011 belonged to the collector-gatherers functional group (83.7%) (fig. 10). Collector-filterers and predators were the next most abundant, both at 7.7%. Scrapers were the least abundant, at 0.8%, and shredders were not detected in the quantitative samples in 2011.

Figure 8. Relative abundance of EPT taxa in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2011. No Plecoptera were found in these 3 years.

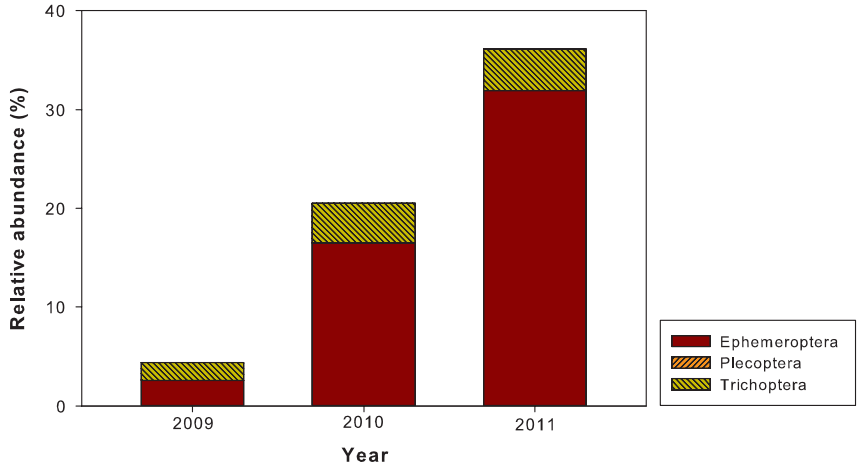


Figure 9. Relative abundance of individuals by taxonomic order in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2011

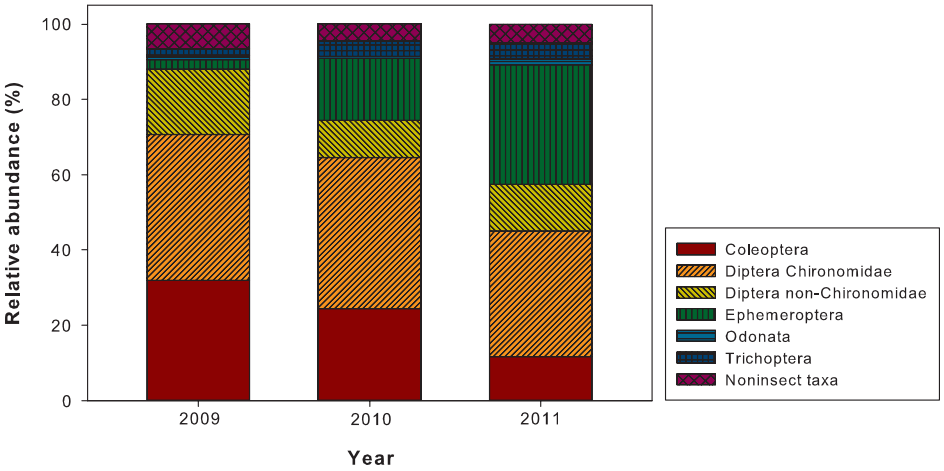
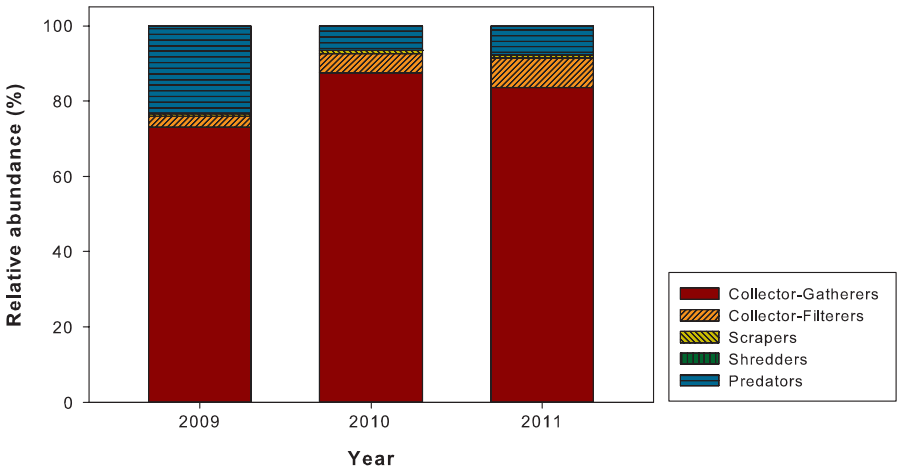


Figure 10. Relative abundance of functional feeding groups in quantitative targeted riffle samples collected from HER01 at Hermit Creek in GRCA, 2009–2011. Not all groups were found.



3.2 Physical habitat characteristics for Hermit Creek

Physical habitat characteristics collected at HER01 during 2011 are summarized in Table 3. Additional transect data can be found in Appendix D.

Microhabitat level. Stream flow velocities at quantitative targeted riffle sites averaged 0.58 m/s (table 3). Depths averaged 0.16 m. On average, 16.1% 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 the HER01 monitoring site was 9.2 m and 2.2 m, respectively (table 3). Average velocity of stream flow was 0.16 m/s. Depths at transects along HER01 averaged 0.12 m. Canopy cover along the monitoring site averaged 6.7%.

Table 3. Physical habitat and hydrologic data from HER01 at Hermit Creek in Grand Canyon National Park, Arizona, 2009–2011. Particle embeddedness and canopy closure measurements are expressed as percentages.

	2009		2010		2011	
Physical habitat metric	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Microhabitat level						
Riffles						
Velocity (m/s)	0.42	0.15	0.46	0.33	0.58	0.18
Depth (m)	0.08	0.02	0.11	0.04	0.16	0.13
Embeddedness (%)	25.7	20.2	53.1	30.7	16.1	7.5
Transect level						
Channel dimensions						
Velocity (m/s)	0.19	0.11	0.24	0.18	0.16	0.11
Depth (m)	0.09	0.04	0.08	0.08	0.11	0.07
Wetted channel width (m)	1.9	0.7	2.7	1.1	2.2	1.1
Active channel width (m)	10.0	2.4	7.0	2.4	9.2	2.9
Riparian cover						
Canopy closure (%)	14.4	27.9	7.5	20.5	6.7	14.4
Reach level						
Water quality	**Value**		**Value**		**Value**	
Temperature (°C)	17.4		15.6		13.3	
Specific conductivity (µS/cm)	429		575		435	
pH	8.4		8.7		8.6	
Dissolved oxygen (% saturation)	111		—		100.9	
Dissolved oxygen (mg/L)	11.1		—		9.5	
Turbidity (NTU)	0.41		0.30		—	
Discharge (cfs)	—		—		0.8	

We found 3 different aquatic macroinvertebrate habitat types along transects in our monitoring site (fig. 11). Rock was the most frequent, at 42.5%, followed by vegetation and algal mats at 26.3% and 12.5%, respectively. Substrate fitting the category "Absence", meaning it lacked habitat that we define as appropriate for aquatic macroinvertebrates, occurred along 17.5% of the site.

Reach level. Channel structure dynamics are represented by particle size distributions in Figure 12, based on modified Wolman pebble counts. The dominant particle size class along HER01 was gravel (3–64 mm) representing 29.2% of particles sampled at the site. Bedrock (>4000 mm) and cobbles (65–250 mm) and were the next most abundant at 20.7% and 14.1%. Thirty-one percent of the particles we attempted to measure were too embedded to pull from the streambed for measurement.

Runs were the dominant GCU along the reach at our monitoring site (fig. 13). Runs were found along 24.4% of the site. Cascades and riffles were the next most abundant GCU, both at 21.2%. Scour pools made up 12.1% of the site followed by dammed pools and glides, both at 9.1%. Chutes were the least abundant, at 3.0%.

Figure 11. Aquatic macroinvertebrate habitat characterization based upon line point intercept data collected along habitat transects from HER01 at Hermit Creek in GRCA, 2009–2011. Some habitat structure types were not observed.

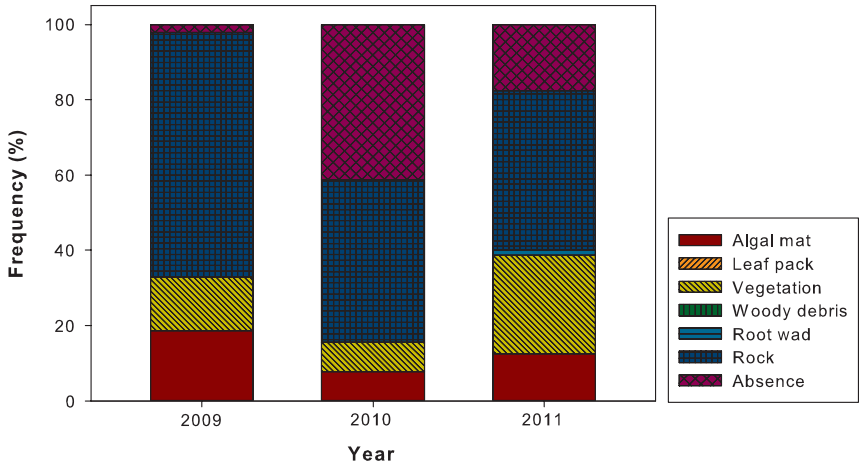


Figure 12. Particle size distribution based on modified Wolman pebble counts (minimum 400 particles), from HER01 at Hermit Creek in GRCA, 2010–2011. Particles that are completely cemented into the stream channel preclude size measurements.

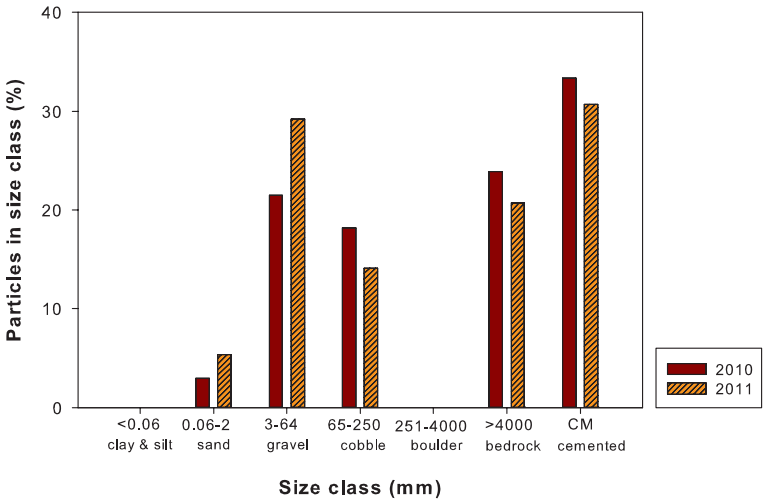
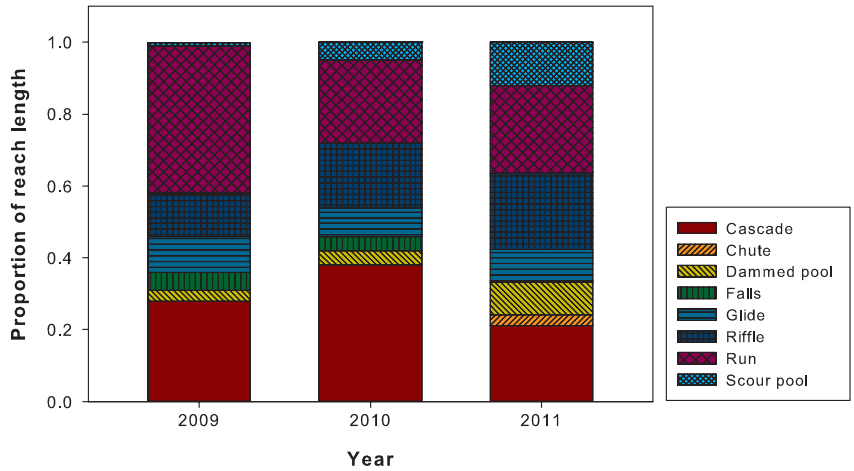


Figure 13. Geomorphic channel unit characterization from HER01 at Hermit Creek in GRCA, 2009–2011



3.3 Hydrologic conditions for Hermit Creek

3.3.1 SCPN hydrologic field data

NPS core 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 water temperature was recorded as 13.3°C. Specific conductivity and pH measured 435 µS/cm and 8.6 units, respectively. Dissolved oxygen measured 100.9% saturation and 9.5 mg/L. Stream discharge at the time of our visit was 0.02 cfs. Turbidity was not taken at Hermit Creek during 2011.

We were not able to collect daily air or water temperature data because of the flood in September of 2011 that destroyed the Hermit Creek above Tonto Trail gaging station.

3.3.2 NADP station precipitation data

Daily precipitation totals were monitored by the National Atmospheric Deposition Program (NADP) at Hopi Point (AZ03) in Grand Canyon National Park (http://nadp.sws.uiuc.edu/sites/siteinfo.asp?net=NTN&id=AZ03). Moisture events were abundant and evenly spread across the entire year (fig. 14). The driest portion of the year was during the early summer months of late May to mid-July.

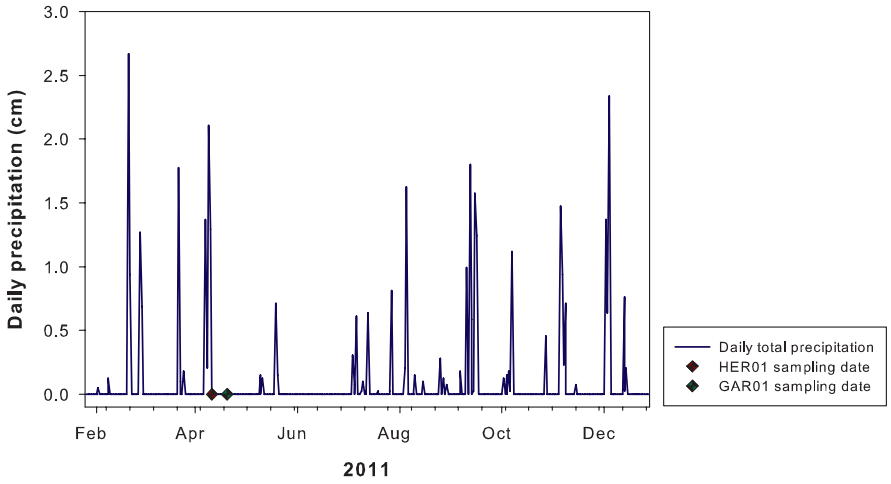


Figure 14. Daily precipitation values for 2011 from the NADP/NTN AZ03 monitoring station at Hopi Point in GRCA. Precipitation data from this station are also applicable to the Garden Creek site (GAR01).

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 from 2010 to 2011. 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. Mean total abundance for quantitative targeted riffle samples averaged 706.80 individuals (fig. 15). Riffle sample abundances ranged from a low of 599 individuals to a high of 770 individuals.

Taxa richness. Total richness averaged 19.20 taxa per riffle (fig. 16). Riffle richness ranged from a low of 17 taxa to a high of 21 taxa. Taxa richness for the qualitative multihabitat sample was 20 taxa.

Diversity. Taxonomic and functional diversity were measured using the Simpson's Diversity Index (fig. 17). Taxonomic diversity averaged 0.74 while functional diversity averaged 0.49.

Stress tolerance. Taxa which are moderately tolerant to disturbance dominated the relative abundance of aquatic macroinvertebrates, averaging 88.07% (fig. 18a). Intolerant individuals averaged 10.37% of the samples and tolerant individuals represented only 1.56% of the samples. Taxa richness by tolerance class followed a similar pattern (fig. 18b). Moderately tolerant taxa accounted for 59.47% of the taxa collected. Intolerant taxa accounted for 28.58% of taxa collected. Only 11.96% 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 31.43% of the taxa collected (fig. 19). Trichoptera accounted for 5.59% of the taxa collected. No plecopterans were collected at this sampling site in 2011. Abundance of all 3 EPT taxa combined accounted for 37.02% of the individuals collected at GAR01.

Table 4. Qualitative metrics for aquatic macroinvertebrate samples collected from GAR01 at Garden Creek in Grand Canyon National Park, Arizona, 2010–2011. Richness-based metrics are expressed as the percentage of taxa in a given order, tolerance or functional feeding group.

Qualitative metric	2010	2011
Taxa richness	28	20
Tolerance group		
Richness of tolerant taxa (%)	7.41	6.25
Richness of moderately tolerant taxa (%)	48.15	56.25
Richness of intolerant taxa (%)	44.44	37.50
Functional group		
Richness of collector-filterers (%)	18.52	18.75
Richness of collector-gatherers (%)	33.33	31.25
Richness of scrapers (%)	11.11	0.00
Richness of shredders (%)	3.70	6.25
Richness of predators (%)	33.33	43.75
Taxonomic group		
Number of EPT taxa	10	5
Richness of EPT taxa (%)	35.71	25.00
Richness of Ephemeroptera (%)	14.29	10.00
Richness of Plecoptera (%)	0.00	0.00
Richness of Trichoptera (%)	21.43	15.00
Richness of noninsect taxa (%)	14.29	30.00
Richness of Chironomid Diptera (%)	10.71	15.00
Richness of non-Chironomid Diptera (%)	25.00	10.00
Richness of Coleoptera (%)	7.14	10.00
Richness of Odonata (%)	7.14	10.00

Figure 15. Total abundance expressed as the mean number of individuals in quantitative targeted riffle samples collected from GAR01 at Hermit Creek in GRCA, 2010–2011

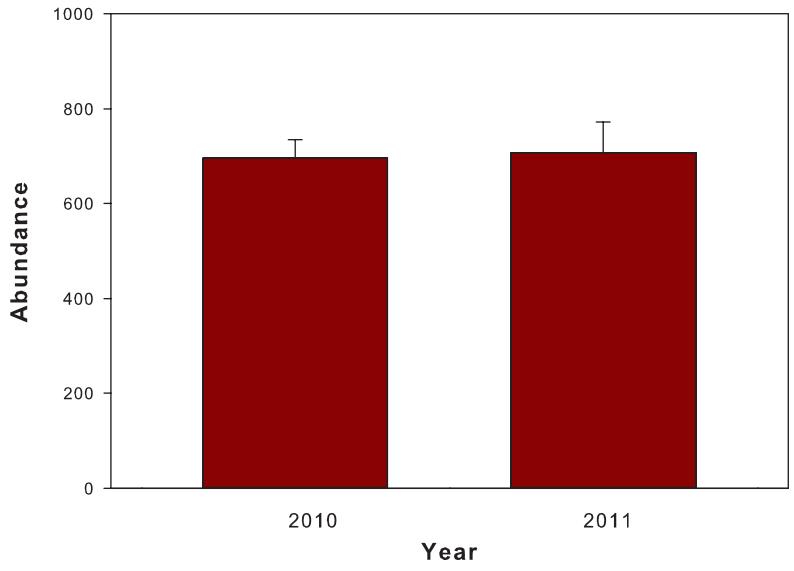


Table 5. Quantitative metrics for aquatic macroinvertebrate samples collected from GAR01 at Garden Creek in Grand Canyon National Park, Arizona, 2010–2011. For a given order, tolerance or functional feeding group, abundance-based metrics are expressed as the percentage of individuals in the group, while richness-based metrics are expressed as the percentage of taxa in the group.

	2010		2011	
Quantitative metric	**Mean**	**SD**	**Mean**	**SD**
Total abundance	696.00	39.40	706.80	64.69
Total richness	23.60	1.82	19.20	1.48
Simpson's Diversity—taxonomic	0.84	0.04	0.74	0.05
Simpson's Diversity—functional group	0.47	0.07	0.49	0.06
Dominant taxa	28.38	9.11	38.10	9.41
Tolerance group				
Relative abundance of tolerant taxa (%)	1.93	0.85	1.56	0.79
Relative abundance of moderately tolerant taxa (%)	68.31	8.27	88.07	6.84
Relative abundance of intolerant taxa (%)	29.76	8.16	10.37	7.31
Richness of tolerant taxa (%)	8.22	3.22	11.96	6.09
Richness of moderately tolerant taxa (%)	56.08	6.10	59.47	6.40
Richness of intolerant taxa (%)	35.69	6.06	28.58	3.92
Functional group				
Relative abundance of collector-filterers (%)	15.25	3.17	31.67	16.55
Relative abundance of collector-gatherers (%)	70.15	6.35	60.61	14.85
Relative abundance of scrapers (%)	8.27	4.88	1.03	0.93
Relative abundance of shredders (%)	0.09	0.13	0.24	0.19
Relative abundance of predators (%)	6.25	2.67	6.45	2.00
Richness of collector-filterers (%)	14.40	4.83	20.07	3.27
Richness of collector-gatherers (%)	35.55	3.48	27.72	5.65
Richness of scrapers (%)	8.51	0.64	8.87	4.86
Richness of shredders (%)	2.62	4.01	5.84	4.44
Richness of predators (%)	38.91	5.79	37.50	8.55
Taxonomic group				
Number of EPT taxa	7.80	1.48	5.40	1.52
Relative abundance of EPT taxa (%)	58.52	4.41	37.02	10.98
Relative abundance of Ephemeroptera (%)	44.49	7.95	31.43	12.28
Relative abundance of Plecoptera (%)	0.00	0.00	0.00	0.00
Relative abundance of Trichoptera (%)	14.03	4.60	5.59	3.14
Relative abundance of noninsect taxa (%)	4.38	1.85	2.77	1.25
Relative abundance of Chironomid Diptera (%)	22.88	2.95	25.70	5.39
Relative abundance of non-Chironomid Diptera (%)	11.86	3.02	27.58	15.49
Relative abundance of Coleoptera (%)	1.63	1.41	4.27	4.79
Relative abundance of Odonata (%)	0.73	0.36	2.66	0.92

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 2010–2011

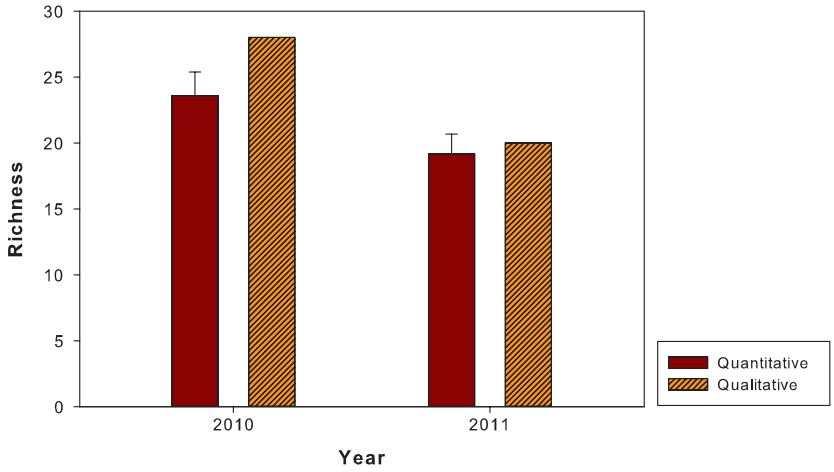


Figure 17. Simpson's Diversity Index for taxonomic and functional diversity in quantitative targeted riffle samples collected from GAR01 at Garden Creek in GRCA, 2010–2011

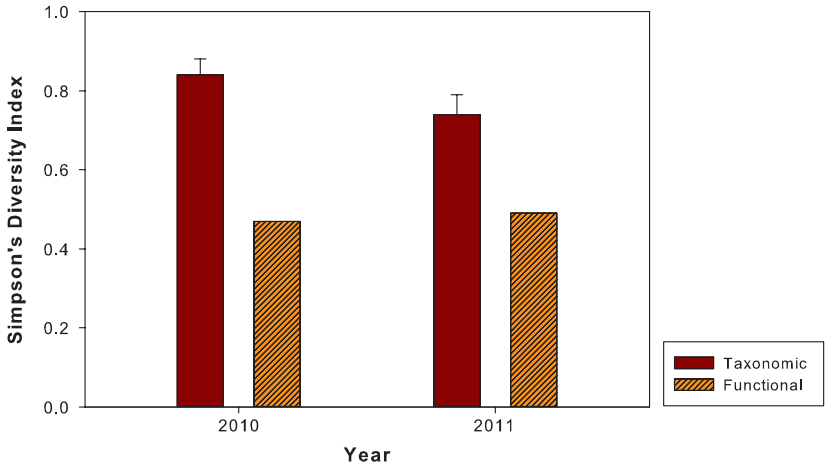
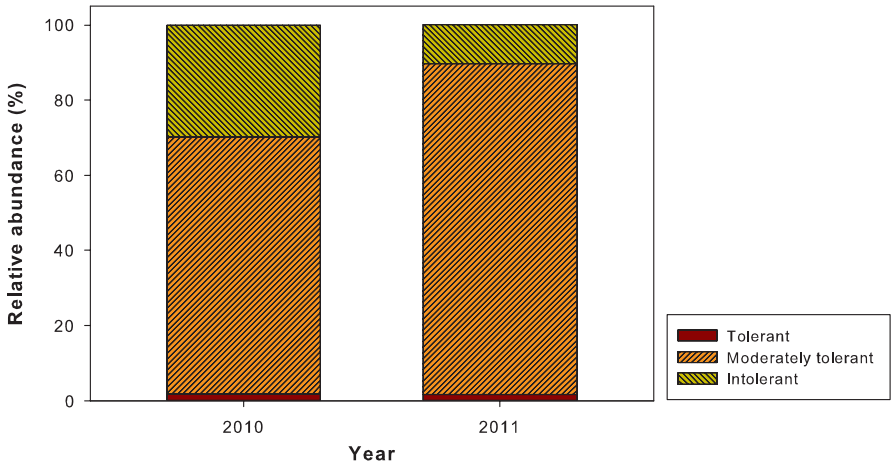


Figure 18a. Mean relative abundance of aquatic macroinvertebrate taxa in quantitative targeted riffle samples collected from GAR01 at Garden Creek in GRCA, 2010–2011, based on their tolerance to perturbation



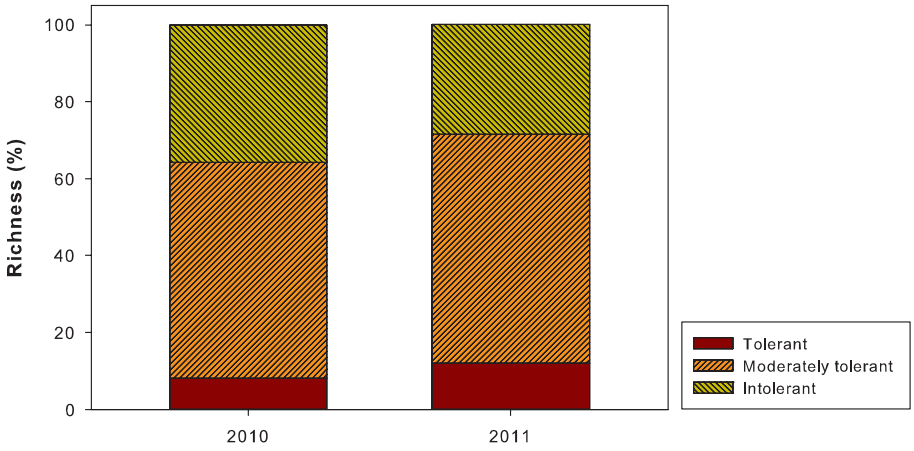


Figure 18b. Mean richness of aquatic macroinvertebrate taxa in quantitative targeted riffle samples collected from GAR01 at Garden Creek in GRCA, 2010–2011, based on their tolerance to perturbation

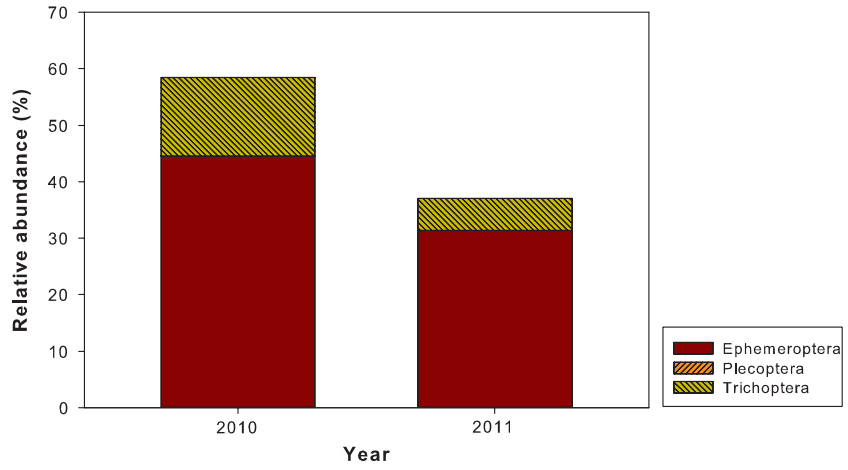


Figure 19. Relative abundance of sensitive EPT orders in quantitative targeted riffle samples from GAR01 at Garden Creek in GRCA, 2010–2011. No Plecoptera were found in these samples.

Aquatic macroinvertebrate orders. Ephemeroptera (31.43%) were the most abundant taxa among all the different orders collected at GAR01 (fig. 20). Non-chironomid dipterans were the second most abundant order, at 27.58%. Chironomids accounted for 25.70% of the taxa. Coleopterans and odonates were low in abundance, at 4.27% and 2.66%, respectively. Organisms belong to the category "Noninsect" accounted for 2.77% of the individuals collected. For GAR01, organisms belonging to "Noninsect" included Trombidiformes, Megoloptera, Basommatophora (snails), as well as the phyla Annelida (segmented worms) and Platyhelminthes (flat worms).

Functional feeding groups. Collector-gatherers were the most abundant of the functional groups collected from GAR01, averaging 60.61% of the individuals collected (fig. 21). Collector-filterers were the second most abundant, at 31.67%. Predators accounted for 6.45% and scrapers 1.03%. Shredders were the least abundant group, at 0.24%.

Figure 20. Relative abundance of individuals by taxonomic order in quantitative targeted riffle samples collected from GAR01 at Garden Creek in GRCA, 2010–2011

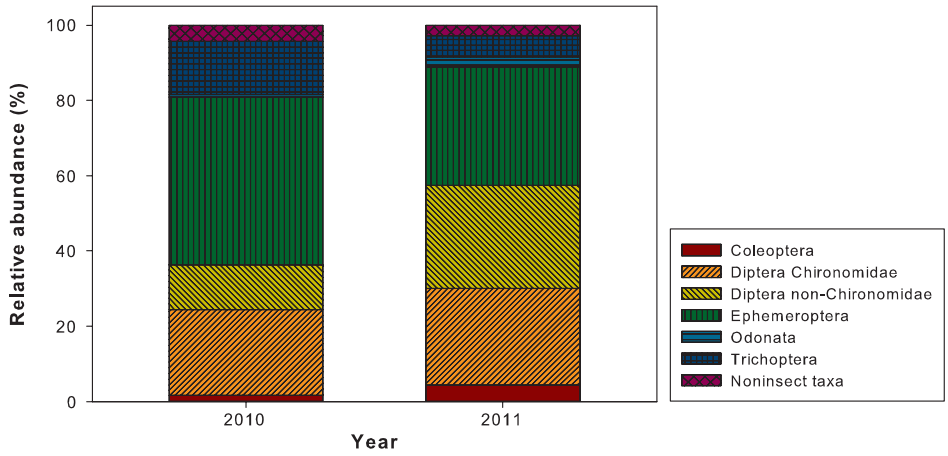
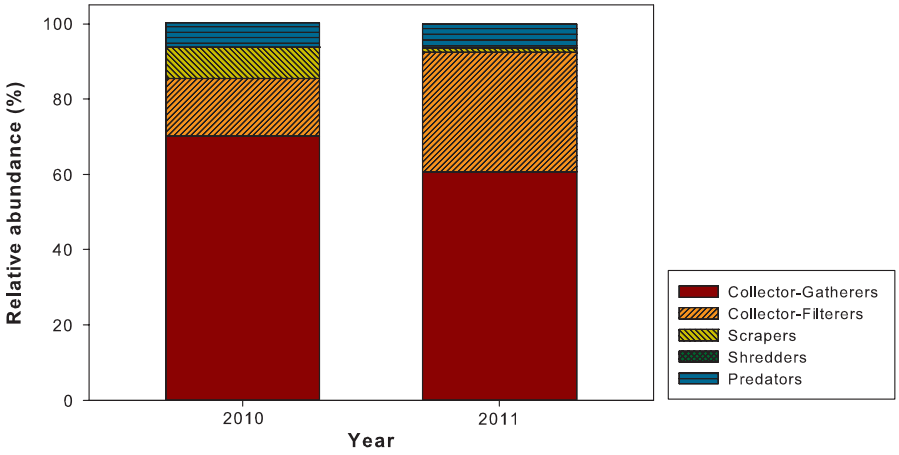


Figure 21. Relative abundance of functional feeding groups in quantitative targeted riffle samples collected from GAR01 at Garden Creek in GRCA, 2010–2011



3.5 Physical habitat characteristics for Garden Creek

This section presents data describing physical habitat characteristics collected at GAR01 during 2011, summarized in Table 6. Additional transect data can be found in Appendix D.

Microhabitat level. Stream flow velocity at the quantitative targeted riffle sites averaged 0.70 m/s and depths averaged 0.16 m (table 6). Embeddedness of particles in the quantitative sampling frame averaged 33.6%.

Transect level. Active channel widths and wetted channel widths at the 11 physical habitat transects averaged 11.0 m and 1.5 m, respectively (table 6). Velocity along the monitoring site averaged 0.40 m/s and depth averaged 0.09 m. Riparian vegetation canopy cover averaged 64.2% across the transects.

Vegetation was the dominant aquatic macroinvertebrate habitat sampled along our monitoring site (fig. 22). Vegetation accounted for 42.3% of the habitats sampled. Root wads were next most abundant, at 34.6%. Rock and woody debris represented 11.5% and 1.3% of the habitats sampled, respectively. Substrate fitting the category "Absence", meaning it lacked habitat that we define as appropriate for aquatic macroinvertebrates, occurred along 10.3% of the site.

Reach level. Gravels were the most abundant particle size found along the monitoring site (fig. 23). Gravels accounted for 41.8% of the particles sampled. Sand was found along 40.5% of the monitoring site. Cobbles were found along 11.8% of the monitoring site. Bedrock accounted for 3.8% of the particles sampled.

Table 6. Physical habitat and hydrologic data from GAR01 at Garden Creek in Grand Canyon National Park, Arizona, 2011. Particle embeddedness and canopy closure measurements are expressed as percentages.

	2010		2011	
Physical habitat metric	**Mean**	**SD**	**Mean**	**SD**
Microhabitat level				
Riffles				
Velocity (m/s)	0.75	0.21	0.70	0.15
Depth (m)	0.13	0.02	0.16	0.04
Embeddedness (%)	34.1	16.0	33.6	10.11
Transect level				
Channel dimensions				
Velocity (m/s)	0.63	0.24	0.40	0.13
Depth (m)	0.08	0.02	0.09	0.04
Wetted channel width (m)	1.3	0.3	1.5	0.5
Active channel width (m)	6.6	2.7	11.0	2.1
Riparian cover				
Canopy closure (%)	70.8	28.7	64.2	34.5
Reach level				
Water quality	**Value**		**Value**	
Temperature (°C)	15.3		15.2	
Specific Conductivity (µS/cm)	—		267	
pH	8.9		8.6	
Dissolved oxygen (% saturation)	—		96.5	
Dissolved oxygen (mg/L)	—		8.5	
Turbidity (NTU)	—		8.3	
Discharge (cfs)	—		2.3	

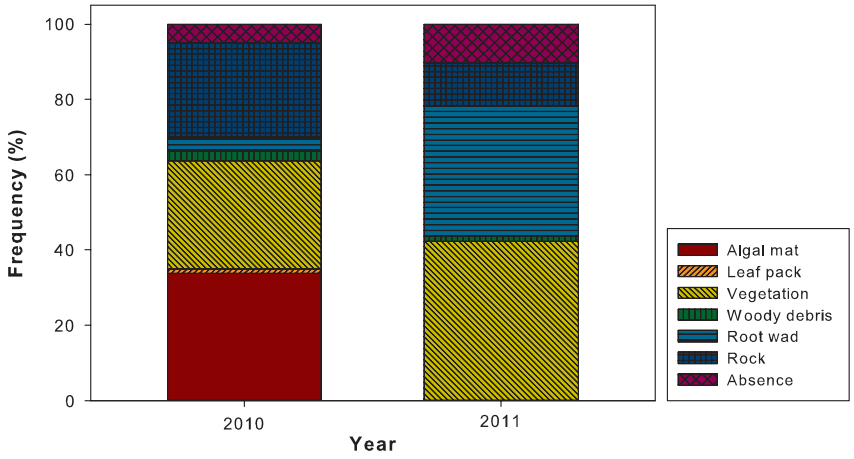


Figure 22. Aquatic macroinvertebrate habitat characterization based upon line point intercept data collected along habitat transects from GAR01 at Garden Creek in GRCA, 2010–2011

Riffles and runs were the most abundant GCUs found along our monitoring site, at 37.0% each (fig. 24). Cascades were found along 15.0% of the site. Scour pools were the least abundant, at 7.0%. No chutes existed along our site in 2011.

Figure 23. Particle size distribution based on modified Wolman pebble counts (minimum 400 particles), from GAR01 at Garden Creek in GRCA, 2010–2011. Particles that are completely cemented into the stream channel preclude size measurements.

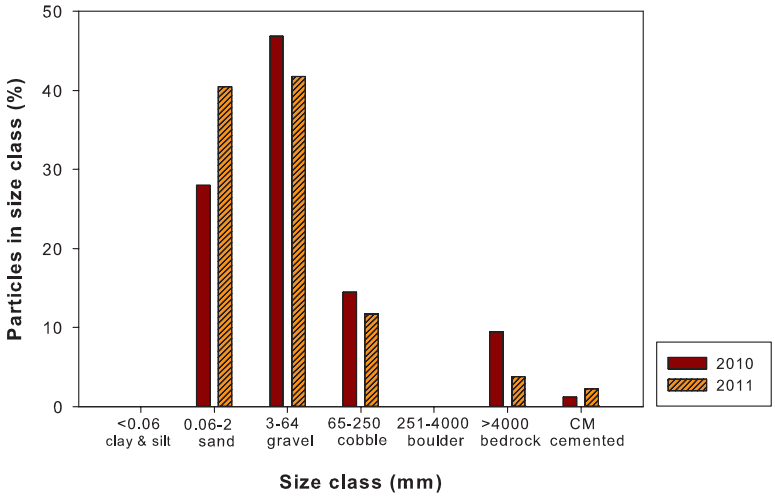
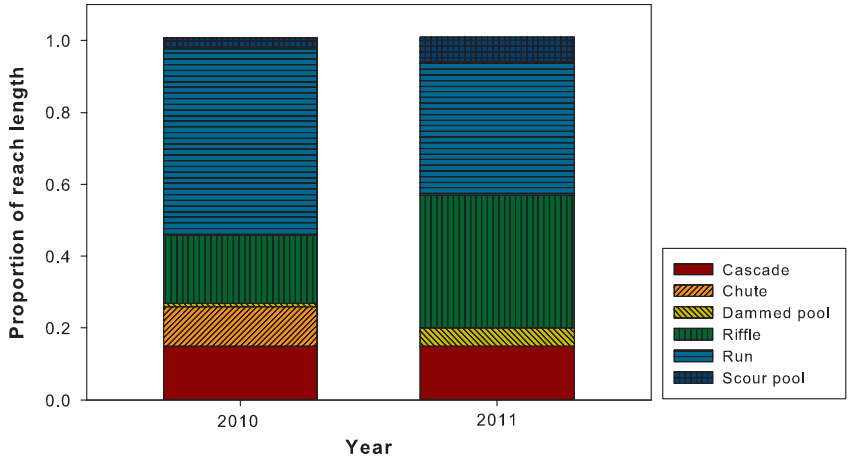


Figure 24. Geomorphic channel unit characterization from GAR01 at Garden Creek in GRCA, 2010–2011



3.6 Hydrologic conditions for Garden Creek

3.6.1 SCPN hydrologic field data

NPS core 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 water temperature was recorded as 15.2°C. Specific conductivity measured 267 µS/cm, and pH was 8.6. Dissolved oxygen measured 96.5% saturation and 8.5 mg/L. Turbidity averaged 8.3 NTU. Stream discharge at the time of our visit was 2.3 cfs.

3.6.2 NADP station precipitation data

Precipitation values associated with Hermit Creek (fig. 14) 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 from 2010 to 2011. 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.

Table 7. Qualitative metrics for aquatic macroinvertebrate samples collected from BRI01 at Bright Angel Creek in Grand Canyon National Park, Arizona, 2010–2011. Richness-based metrics are expressed as the percentage of taxa in a given order, tolerance or functional feeding group.

Qualitative metric	2010	2011
Taxa richness	26	22
Tolerance group		
Richness of tolerant taxa (%)	8.33	9.52
Richness of moderately tolerant taxa (%)	45.83	33.33
Richness of intolerant taxa (%)	45.83	57.14
Functional group		
Richness of collector-filterers (%)	11.54	15.00
Richness of collector-gatherers (%)	34.62	35.00
Richness of scrapers (%)	11.54	15.00
Richness of shredders (%)	0.00	10.00
Richness of predators (%)	42.31	25.00
Taxonomic group		
Number of EPT taxa	8	8
Richness of EPT taxa (%)	30.77	36.36
Richness of Ephemeroptera (%)	15.38	13.64
Richness of Plecoptera (%)	0.00	0.00
Richness of Trichoptera (%)	15.38	22.73
Richness of noninsect taxa (%)	19.23	13.62
Richness of Chironomid Diptera (%)	11.54	13.64
Richness of non-Chironomid Diptera (%)	19.23	27.27
Richness of Coleoptera (%)	7.69	4.55
Richness of Odonata (%)	11.54	4.55

Abundance. Mean total abundance values from quantitative targeted riffle samples at BRI01 averaged 340.80 individuals (fig. 25). Sample abundances ranged from a low of 168 individuals to a high of 721 individuals.

Taxa richness. Total taxonomic richness from quantitative targeted riffle samples at BRI01 averaged 17.40 taxa per sample (fig. 26). Quantitative samples ranged from a low of 14 taxa to a high of 20 taxa. Taxa richness from our qualitative multihabitat sample was 22 taxa.

Diversity. We used the Simpson's Diversity Index to measure both taxonomic and functional diversity of quantitative samples from BRI01 (fig. 27). Taxonomic diversity averaged 0.79. Samples ranged from a low of 0.72 to a high of 0.85. Functional diversity was lower, averaging 0.36. Functional diversity ranged from a low of 0.31 to a high of 0.43.

Stress tolerance. Individuals moderately tolerant to disturbance were the most abundant group at BRI01 in 2011, averaging 74.73% of the sample (fig. 28a). Intolerant individuals accounted for 24.69% of the sample. Few tolerant taxa (0.88%) were collected. Taxa richness of tolerance groups differed from abundances (fig. 28b). Intolerant taxa were the most species rich, averaging 50.85% of the taxa collected. Moderately tolerant taxa were next at 41.58%. Tolerant taxa only accounted for 7.58% of the sample.

EPT taxa. Relative abundance of individuals in sensitive EPT orders was dominated by ephemeropterans (fig. 29). Ephemeropterans accounted for 42.28% of the orders collected from BRI01 in 2011. Relative abundance of trichopterans was 7.21%. Very few plecoperans were collected (0.08%).

Table 8. Quantitative metrics for aquatic macroinvertebrate samples collected from BRI01 at Bright Angel Creek in Grand Canyon National Park, Arizona, 2010–2011. 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		2011	
Quantitative metric	**Mean**	**SD**	**Mean**	**SD**
Total abundance	672.20	69.16	340.80	219.59
Total richness	18.60	3.85	17.40	2.30
Simpson's Diversity—taxonomic	0.78	0.06	0.79	0.05
Simpson's Diversity—functional group	0.50	0.16	0.36	0.06
Dominant taxa	35.42	4.60	35.96	6.41
Tolerance group				
Relative abundance of tolerant taxa (%)	0.31	0.35	0.88	1.01
Relative abundance of moderately tolerant taxa (%)	28.32	13.16	74.73	9.23
Relative abundance of intolerant taxa (%)	71.37	13.07	24.69	9.01
Richness of tolerant taxa (%)	4.11	3.99	7.58	4.71
Richness of moderately tolerant taxa (%)	43.71	3.14	41.58	2.78
Richness of intolerant taxa (%)	52.18	4.99	50.85	2.78
Functional group				
Relative abundance of collector-filterers (%)	13.11	6.59	15.76	5.11
Relative abundance of collector-gatherers (%)	59.39	19.76	77.82	4.78
Relative abundance of scrapers (%)	24.91	20.68	2.07	1.90
Relative abundance of shredders (%)	0.00	0.00	0.04	0.09
Relative abundance of predators (%)	2.59	1.54	4.30	1.91
Richness of collector-filterers (%)	17.69	3.57	19.05	2.73
Richness of collector-gatherers (%)	36.51	1.12	38.72	5.71
Richness of scrapers (%)	20.01	5.30	11.08	4.76
Richness of shredders (%)	0.00	0.00	1.05	2.35
Richness of predators (%)	25.79	7.21	30.09	3.79
Taxonomic group				
Number of EPT taxa	7.40	0.89	6.80	1.48
Relative abundance of EPT taxa (%)	51.99	12.34	49.57	5.78
Relative abundance of Ephemeroptera (%)	35.93	13.04	42.28	3.99
Relative abundance of Plecoptera (%)	0.00	0.00	0.08	0.19
Relative abundance of Trichoptera (%)	16.06	8.74	7.21	3.05
Relative abundance of noninsect taxa (%)	2.86	1.86	7.09	4.20
Relative abundance of Chironomid Diptera (%)	11.25	7.04	24.39	8.20
Relative abundance of non-Chironomid Diptera (%)	21.59	17.72	10.47	3.08
Relative abundance of Coleoptera (%)	11.31	9.56	8.21	3.78
Relative abundance of Odonata (%)	0.99	0.78	0.27	0.31

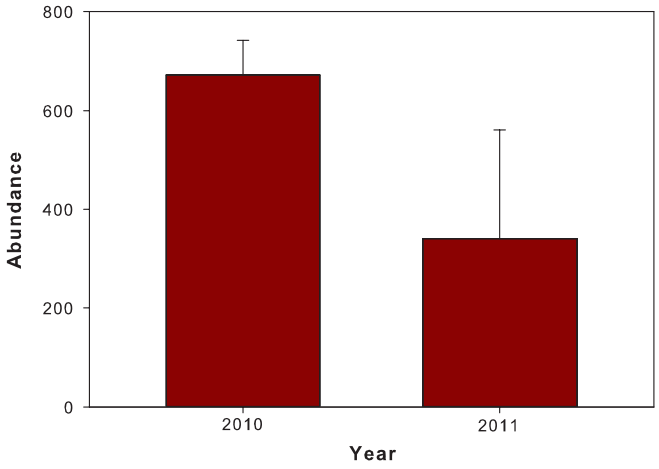


Figure 25. Total abundance expressed as the mean number of individuals in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010–2011

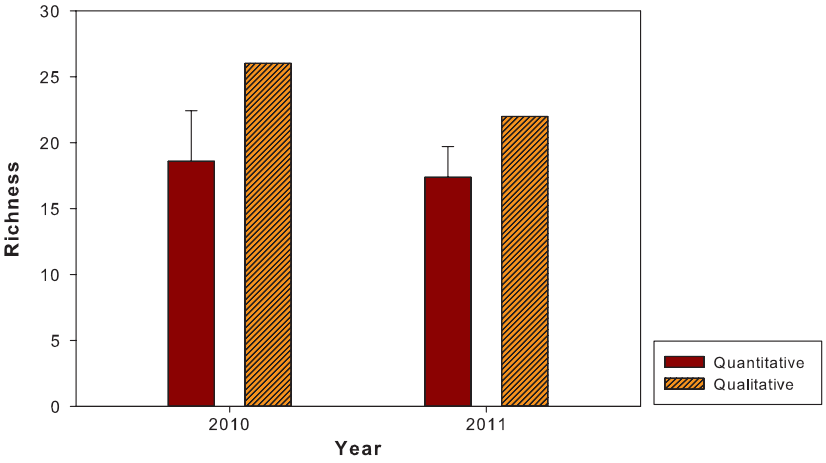


Figure 26. Mean taxa richness in quantitative targeted riffle and total taxa richness in qualitative multihabitat samples collected from BRI01 at Bright Angel Creek in GRCA, 2010–2011

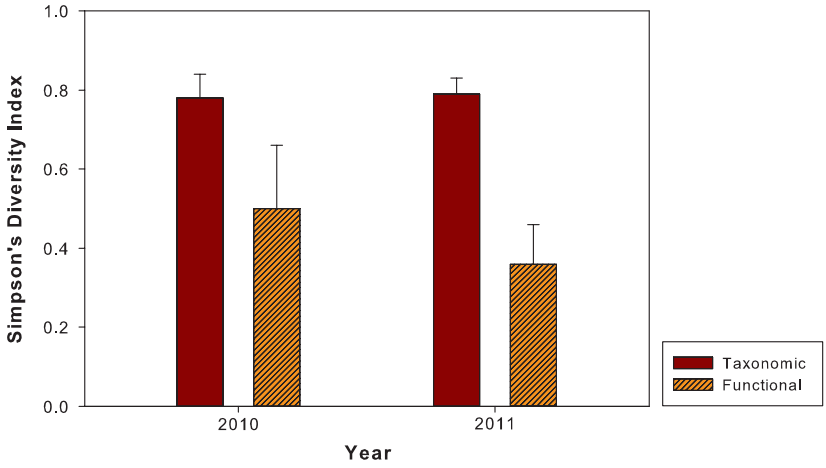


Figure 27. Simpson's Diversity Index for taxonomic and functional diversity in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010–2011

Figure 28a. Mean relative abundance of aquatic macroinvertebrates in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010–2011, based on their tolerance to perturbation

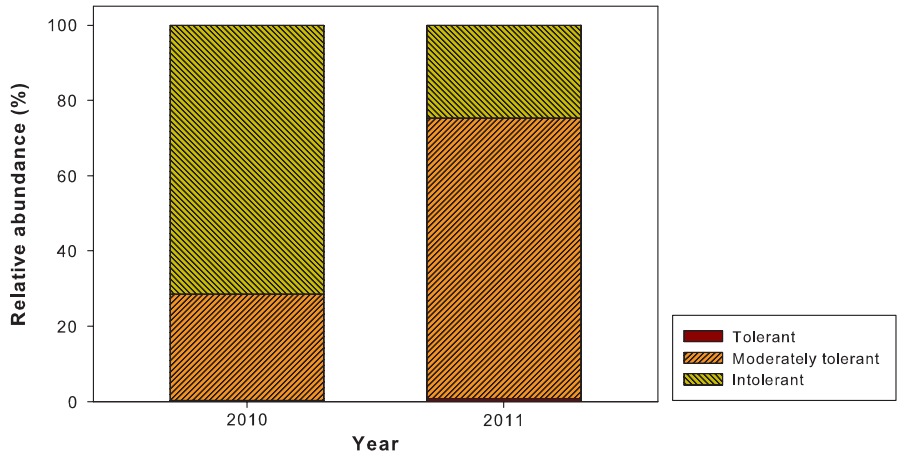


Figure 28b. Mean richness of aquatic macroinvertebrates in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010–2011, based on their tolerance to perturbation

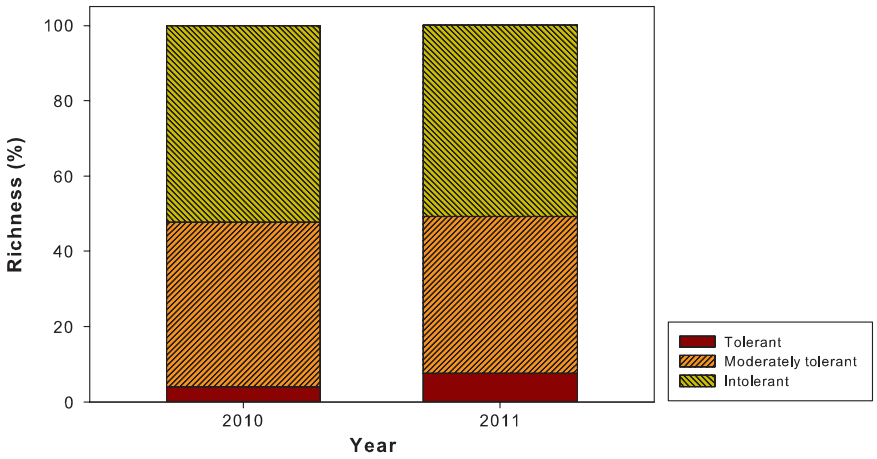
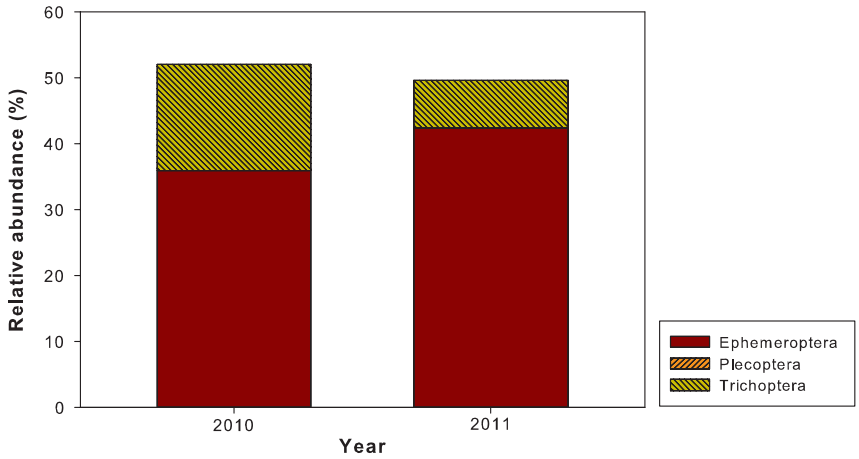


Figure 29. Relative abundance of sensitive EPT orders in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010–2011



Aquatic macroinvertebrate orders. Ephemeropterans were the most abundant group of aquatic macroinvertebrates collected from BRI01, at 42.28% (fig. 30). Chironomids were the next most abundant group, at 24.39%, followed by non-chironomid dipterans (10.47%), coleopterans (8.21%), trichopterans (7.21%), and noninsect taxa (7.09%). Odonates and plecopterans were both found in an abundance of <1.0%.

Functional feeding groups. Collector-gatherers were the most abundant functional feeding group of aquatic macroinvertebrates in our samples (fig. 31). Relative abundance of collector-gatherers was 77.82%. Collector-filterers were the second most abundant, at 15.76%. Predators averaged 4.30% and scrapers averaged 2.07% Shredders were the least abundant, at 0.04%.

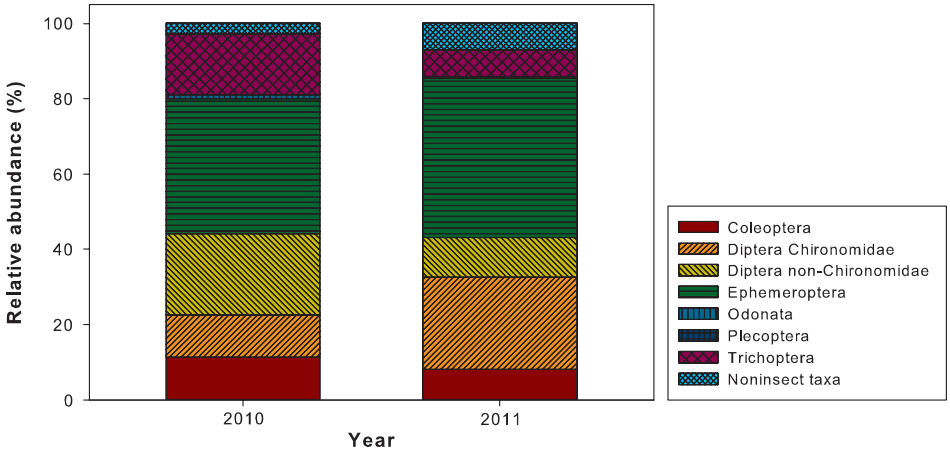


Figure 30. Relative abundance of individuals by taxonomic order in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010–2011

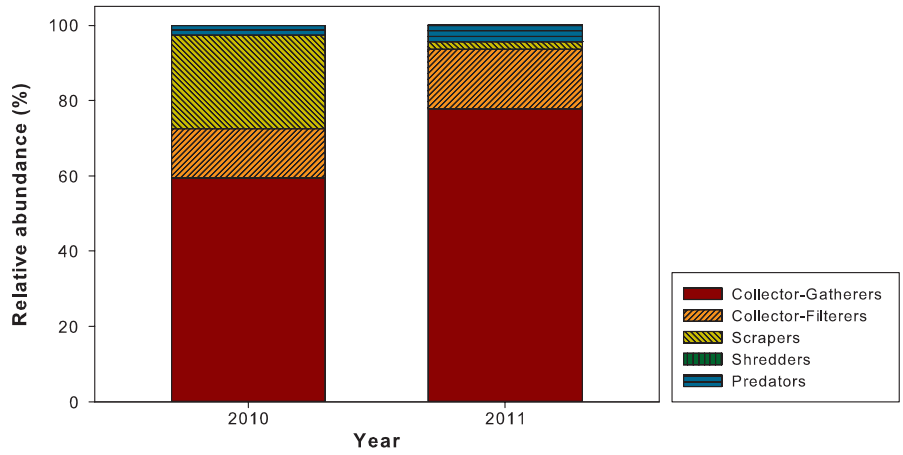


Figure 31. Relative abundance of functional feeding groups in quantitative targeted riffle samples collected from BRI01 at Bright Angel Creek in GRCA, 2010–2011

3.8 Physical habitat characteristics for Bright Angel Creek

Physical habitat characteristics collected at BRI01 during 2011 are summarized in Table 9. Additional transect data can be found in Appendix D.

Microhabitat level. Velocity at the 5 targeted riffle sample locations averaged 0.75 m/s. Depths at these locations averaged 0.24 m. Individual particles were 30.8% embedded, on average (table 9).

Transect level. The average active channel width at the 11 physical habitat transects was 17.7 m. Wetted channel width averaged 5.9 m. Velocity and depth averaged 0.52 m/s and 0.26 m, respectively (table 9).

Rock was the dominant habitat type and was found along 50.0% of the transects (fig. 32). Vegetation was found along 4.1% of the transects. Root wads and algal mats were each found along 1.4% of the transects. Substrate fitting the category "Absence", meaning it lacked habitat that we define as appropriate for aquatic macroinvertebrates, occurred along 43.2% of the site.

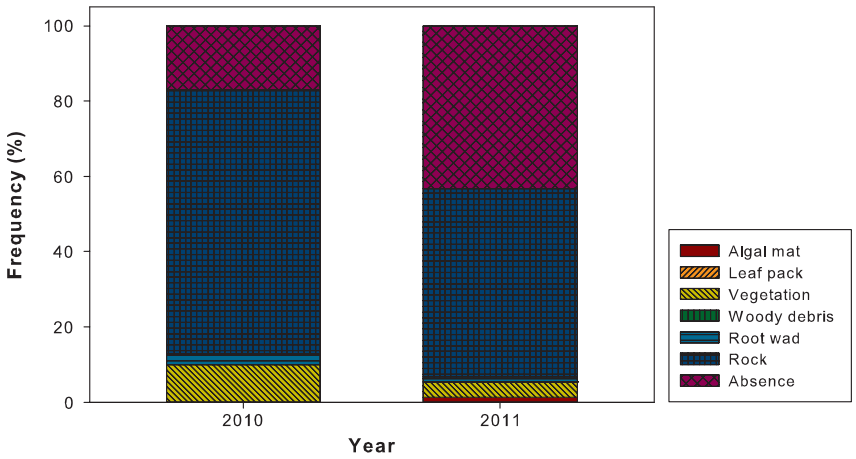
Reach level. Particle size distribution was dominated by gravel, which made up 41.0% of the particles sampled (fig. 33). The next most abundant size class was cobble, which was found along 24.0% of the monitoring site. Sand comprised 9.5% of the particles. Boulders were found at 7.8% of the site. Clay & silt accounted for <1.0% of the particles sampled at the site. Cemented particles, those which we were unable to remove from the stream bottom, accounted for 16.5% of the particles sampled.

Runs were the dominant GCU type found along the monitoring site (fig. 34). Runs made up 29.9% of the site. Riffles were the next most abundant at 28.7%, followed by root wads at 24.6% and scour pools at 6.7%.

Table 9. Physical habitat and hydrologic data from BRI01 at Bright Angel Creek in Grand Canyon National Park, Arizona, 2010–2011. Particle embeddedness and canopy closure measurements are expressed as percentages.

	2010		2011	
Physical habitat metric	**Mean**	**SD**	**Mean**	**SD**
Microhabitat level				
Riffles				
Velocity (m/s)	0.56	0.26	0.75	0.31
Depth (m)	0.15	0.07	0.24	0.06
Embeddedness (%)	23.6	15.3	30.8	14.0
Transect level				
Channel dimensions				
Velocity (m/s)	0.48	0.19	0.52	0.17
Depth (m)	0.22	0.05	0.26	0.08
Wetted channel width (m)	6.9	2.5	5.9	1.7
Active channel width (m)	17.6	5.0	17.7	5.7
Riparian cover				
Canopy closure (%)	11.8	23.9	2.1	7.7
Reach level				
Water quality	**Value**		**Value**	
Temperature (°C)	13.8		13.3	
Specific conductivity (µS/cm)	352		343	
pH	8.6		8.8	
Dissolved oxygen (% saturation)	100.5		99.7	
Dissolved oxygen (mg/L)	9.4		9.4	
Turbidity (NTU)	0.60		2.65	
Discharge (cfs)	21.3		21.7	

Figure 32. Aquatic macroinvertebrate habitat characterization based upon line point intercept data collected along habitat transects from BRI01 at Bright Angel Creek in GRCA, 2010– 2011. Some habitat structures were not observed.



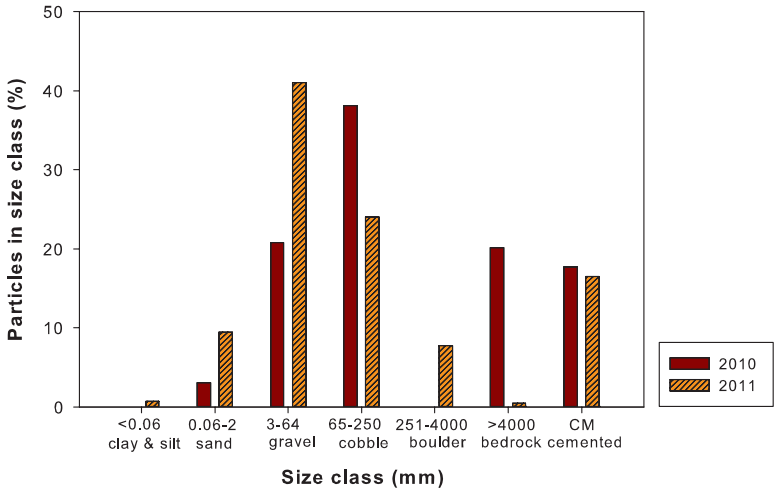


Figure 33. Particle size distribution based on modified pebble counts (minimum 400 particles), from BRI01 at Bright Angel Creek in GRCA, 2010–2011. Particles that are completely cemented into the stream channel preclude size measurements.

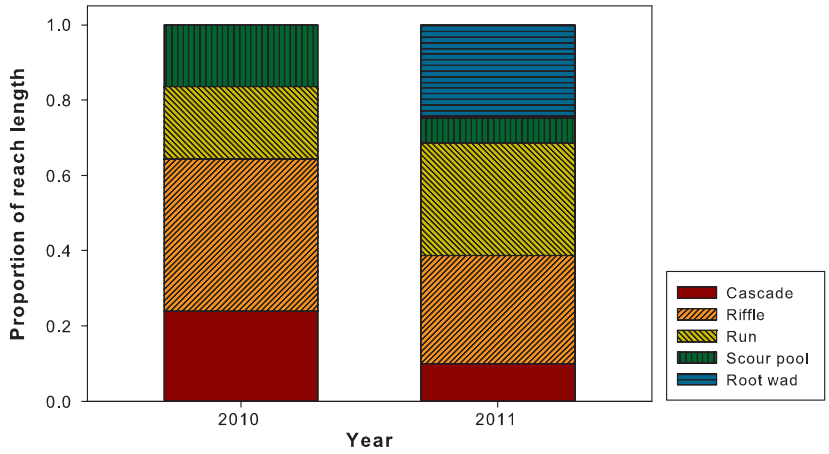


Figure 34. Geomorphic channel unit characterization from BRI01 at Bright Angel Creek in GRCA, 2010–2011

3.9 Hydrologic conditions for Bright Angel Creek

We collected NPS core water quality data at BRI01 (table 9). These data represent measurements at or near midday of the sample date. The noon time water temperature was 13.3°C. Specific conductivity was 343 µS/cm and pH measured 8.8. Dissolved oxygen measured 99.7% saturation and 9.4 mg/L. Turbidity was 2.65 NTU. Stream discharge for the site at the time of our visit was 21.7 cfs.

4 Discussion

This report presents data from SCPN's third year of monitoring aquatic macroinvertebrates and physical habitat at Hermit Creek and the second 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.

On 11 September 2011, a large storm event occurred within Grand Canyon National Park. The storm resulted in heavy rains and flash flooding throughout the park. Hermit and Bright Angel Creeks were both affected by flash flooding. The floods at Hermit Creek occurred months after our sampling date and the data for that stream were not affected by the event. However, the data presented from Bright Angel Creek were collected only 4 weeks after the flood event.

4.1 Aquatic macroinvertebrate communities

Hermit and Garden Creeks continue to provide very large aquatic macroinvertebrate abundance averages. Abundance averages at Bright Angel Creek, however, were halved compared to the 2010 averages, which is most likely the result of the flood event. Many of the richness metrics in 2011for Bright Angel Creek were similar to those from 2010. The largest differences between the 2 years occur in our abundance metrics. However, until we have multiple years of data, we cannot be certain abundance of aquatic macroinvertebrates does not fluctuate largely from year to year in Bright Angel Creek.

4.2 Physical habitat

There were very few differences in physical habitat characteristics among monitoring sites. Garden Creek stream velocity and depth were greater on average at riffle and transects than the other 2 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 monitoring site 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, adds 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 2 sites. At Hermit and Bright Angel Creeks, appropriate macroinvertebrate habitat accounted for 81.3% and 56.9% of the monitoring site, respectively, with rocky habitats dominating. 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, 2 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, 2011

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 3 monitoring sites in Grand Canyon National Park, Arizona, 2011. "NEW" under the site column denotes a new record for this SCPN monitoring site.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Common name	BRI01	GAR01	HER01
Annelida	Clitellata						segmented worms	NEW	x	NEW
Arthropoda	Arachnida	Trombidiformes	Arrenuridae		*Arrenurus* sp.		water mites	NEW	x	
Arthropoda	Arachnida	Trombidiformes	Hygrobatidae				water mites		x	
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		*Lebertia* sp.		water mites			x
Arthropoda	Arachnida	Trombidiformes	Lebertiidae				water mites			NEW
Arthropoda	Arachnida	Trombidiformes	Sperchonidae		*Sperchon* sp.		water mites	x	NEW	x
Arthropoda	Arachnida	Trombidiformes	Sperchonidae				water mites		NEW	NEW
Arthropoda	Arachnida	Trombidiformes	Torrenticolidae		*Torrenticola* sp.		water mites	NEW	NEW	x
Arthropoda	Arachnida	Trombidiformes	Torrenticolidae				water mites			x
Arthropoda	Arachnida	Trombidiformes					water mites	NEW	x	x
Arthropoda	Entognatha	Collembola					springtails	NEW		x
Arthropoda	Insecta	Coleoptera	Dryopidae		*Helichus* sp.		long-toed water beetles		NEW	
Arthropoda	Insecta	Coleoptera	Dryopidae		*Postelichus* sp.		long-toed water beetles			NEW
Arthropoda	Insecta	Coleoptera	Elmidae		*Microcylloepus*	*pusillus*	pusillanimous riffle beetle	x	x	x
Arthropoda	Insecta	Coleoptera	Elmidae				riffle beetles		x	x
Arthropoda	Insecta	Coleoptera	Hydrophilidae				water scavenger beetle		x	
Arthropoda	Insecta	Diptera	Empididae	Hemero-dromiinae	*Hemerodromia* sp.		dance flies			x
Arthropoda	Insecta	Diptera	Empididae		*Neoplasta* sp.		dance flies		x	x
Arthropoda	Insecta	Diptera	Empididae		*Wiedemannia* sp.		dance flies	NEW		
Arthropoda	Insecta	Diptera	Empididae				dance flies	x	x	x
Arthropoda	Insecta	Diptera	Muscidae				house flies		x	x
Arthropoda	Insecta	Diptera	Stratiomyidae		*Caloparyphus* sp.		solider flies			x
Arthropoda	Insecta	Diptera	Stratiomyidae		*Euparyphus* sp.		solider flies		x	x
Arthropoda	Insecta	Diptera	Tabanidae		*Tabanus* sp.		horse and deer flies		x	x
Arthropoda	Insecta	Diptera	Tabanidae				horse and deer flies	x	NEW	
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	*Bezzia* sp.		biting midges			x
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	*Probezzia* sp.		biting midges			x
Arthropoda	Insecta	Diptera	Ceratopogonidae	Dasyheleinae	*Dasyhelea* sp.		biting midges			x
Arthropoda	Insecta	Diptera	Ceratopogonidae				biting midges		x	x
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae			midges	x	x	x

Appendix C (*continued*)

Phylum	Class	Order	Family	SubFamily	Genus	Species	Common name	BRI01	GAR01	HER01
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae			midges	x	x	x
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae			midges	x	x	x
Arthropoda	Insecta	Diptera	Chironomidae				midges	x	x	x
Arthropoda	Insecta	Diptera	Dixidae		*Dixa* sp.		meniscus midges	NEW		x
Arthropoda	Insecta	Diptera	Psychodidae		*Maruina* sp.		moth flies	x		
Arthropoda	Insecta	Diptera	Psychodidae		*Pericoma* sp.		moth flies		x	
Arthropoda	Insecta	Diptera	Simuliidae	Simuliinae	*Simulium*	*piperi*	black flies		NEW	
Arthropoda	Insecta	Diptera	Simuliidae	Simuliinae	*Simulium* sp.		black flies	x	x	x
Arthropoda	Insecta	Diptera	Simuliidae				black flies			x
Arthropoda	Insecta	Diptera	Simuliidae				black flies		x	
Arthropoda	Insecta	Diptera	Tipulidae	Tipulinae	*Tipula* sp.		large crane flies		NEW	
Arthropoda	Insecta	Diptera	Tipulidae				large crane flies	NEW	x	
Arthropoda	Insecta	Diptera					flies	x	x	x
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae		*Paraleptophlebia* sp.		pronggilled mayflies		x	
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae				pronggilled mayflies	x	x	
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Baetis* sp.		small minnow mayflies	x	x	x
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Baetodes* sp.		small minnow mayflies	x		x
Arthropoda	Insecta	Ephemeroptera	Baetidae		*Fallceon*	quilleri	small minnow mayflies	x	x	x
Arthropoda	Insecta	Ephemeroptera	Baetidae				small minnow mayflies	x	x	x
Arthropoda	Insecta	Lepidoptera	Crambidae	Nymphulinae	*Petrophila* sp.		crambid snout moths	x		x
Arthropoda	Insecta	Megaloptera	Corydalidae	Corydalinae	*Corydalus*	*cornutus*	dobsonflies	x	x	x
Arthropoda	Insecta	Odonata	Libellulidae				skimmers			x
Arthropoda	Insecta	Odonata	Calopterygidae		*Hetaerina* sp.		broad-winged damselflies		x	
Arthropoda	Insecta	Odonata	Calopterygidae				broad-winged damselflies		x	
Arthropoda	Insecta	Odonata	Coenagrionidae		*Argia* sp.		narrow-winged damsel-flies	x	x	x
Arthropoda	Insecta	Odonata	Coenagrionidae				narrow-winged damsel-flies	x		x
Arthropoda	Insecta	Odonata	Coenagrionidae				narrow-winged damsel-flies		x	
Arthropoda	Insecta	Odonata					damselflies and drag-onflies			x
Arthropoda	Insecta	Plecoptera	Taeniopterygidae				winter stoneflies	NEW		

Appendix C (*continued*)

Phylum	Class	Order	Family	SubFamily	Genus	Species	Common name	BRI01	GAR01	HER01
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Chloroperlinae			green stoneflies	NEW		
Arthropoda	Insecta	Plecoptera					stoneflies	NEW		
Arthropoda	Insecta	Trichoptera	Brachycentridae		*Micrasema* sp.		humpless casemaker caddisflies		x	
Arthropoda	Insecta	Trichoptera	Helicopsychidae		*Helicopsyche* sp.		snail-case caddisflies	x		
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychinae	*Hydropsyche* sp.		netspinng caddisflies	x	x	x
Arthropoda	Insecta	Trichoptera	Hydropsychidae				netspinng caddisflies	x	x	x
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	*Hydroptila* sp.		microcaddisflies		NEW	x
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	*Leucotrichia* sp.		microcaddisflies	x		
Arthropoda	Insecta	Trichoptera	Hydroptilidae				microcaddisflies	x	x	x
Arthropoda	Insecta	Trichoptera	Lepidostomatidae	Lepidostomatinae	*Lepidostoma* sp.		bizarre caddisflies	NEW		
Arthropoda	Insecta	Trichoptera	Philopotamidae	Chimarrinae	*Chimarra* sp.		fingernet caddisflies	x	x	
Arthropoda	Insecta	Trichoptera	Polycentropodidae	Polycentropodinae	*Polycentropus* sp.		tubemaker caddisflies			NEW
Arthropoda	Insecta	Trichoptera	Psychomyiidae				net tube caddisflies			NEW
Arthropoda	Insecta	Trichoptera	Rhyacophilidae		*Rhyacophila* sp.		green sedges	x		
Arthropoda	Insecta	Trichoptera					caddisflies		x	NEW
Mollusca	Gastropoda	Basommatophora	Planorbidae				snails		NEW	
Mollusca	Gastropoda						snails		NEW	
Nemata							nematodes		NEW	
Platyhelminthes	Turbellaria						flatworms		x	

Appendix D Measured velocity and channel characteristics at 3 monitoring sites in Grand Canyon National Park, Arizona, 2011

	Velocity (m/s)		Depth (m)		Wetted channel width (m)	Active channel width (m)
Transect	Mean	Std Dev	Mean	Std Dev	Value	Value
BRI01						
1	0.17	0.17	0.17	0.11	8.0	30.2
2	0.65	0.50	0.17	0.12	6.9	24.8
3	0.47	0.09	0.32	0.10	3.7	11.1
4	0.44	0.12	0.22	0.07	5.6	13.4
5	0.53	0.50	0.18	0.14	8.0	18.5
6	0.85	0.50	0.33	0.32	8.6	19.3
7	0.61	0.15	0.20	0.10	4.8	11.5
8	0.50	0.54	0.26	0.17	5.1	14.2
9	0.47	0.29	0.39	0.24	4.5	16.3
10	0.50	0.21	0.35	0.05	4.3	18.6
11	0.55	0.58	0.23	0.17	5.8	16.8
GAR01						
1	0.27	0.43	0.10	0.09	1.8	9.4
2	0.62	0.38	0.11	0.02	1.2	8.8
3	0.35	0.43	0.08	0.04	2.0	10.0
4	0.23	0.20	0.09	0.06	2.3	10.3
5	0.40	0.36	0.08	0.04	1.8	14.0
6	0.53	0.49	0.09	0.06	1.2	13.4
7	0.37	0.26	0.07	0.04	1.1	7.5
8	0.53	0.29	0.04	0.03	0.7	10.8
9	0.33	0.16	0.09	0.05	1.1	11.8
10	0.27	0.30	0.18	0.24	1.5	11.3
11	0.47	0.54	0.04	0.04	1.4	13.6
HER01						
1	0.17	0.10	0.06	0.02	2.2	14.1
2	0.11	0.07	0.21	0.05	1.0	12.0
3	0.08	0.03	0.12	0.09	2.2	5.2
4	0.18	0.30	0.09	0.05	1.7	7.1
5	0.08	0.14	0.08	0.04	2.6	7.1
6	0.43	0.21	0.05	0.02	2.0	7.7
7	0.09	0.22	0.17	0.03	1.7	6.1
8	0.03	0.06	0.25	0.12	2.7	8.2
9	—	—	0.02[a]	n/a[a]	5.1	10.5
10	0.25	0.25	0.06	0.04	1.4	12.8
11	0.16	0.25	0.15	0.05	1.3	10.3

[a]Only one reading was possible for depth on this transect, therefore, standard deviation is not applicable.