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Aquatic Macroinvertebrate and Physical Habitat Monitoring for the Mancos River in Mesa Verde National Park

2008 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2010/033

ON THE COVER
Aquatic macroinvertebrate sampling on the Mancos River in Mesa Verde National Park
Photograph by Stacy Stumpf

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Natural Resource Technical Report NPS/SCPN/NRDS—2010/033

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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.

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 hydrologist Stephen Monroe (stephen_monroe@nps.gov). Stacy Stumpf is the Water Resources Crew Leader for the project. The 2008 crew consisted additionally of Ellen Soles, and Allison Snyder. SCPN staff provided support for the project.

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1 Introduction and Background

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

There is little information available on the condition of Mancos River aquatic ecosystems in Mesa Verde NP. T-Walk sampling in the early 2000s suggested the river was in poor condition (Colyer 2005). In 2007 the SCPN implemented aquatic macroinvertebrate monitoring at two sites on the Mancos River in Mesa Verde National Park (MEVE) (Stumpf and Monroe 2009):

*Mancos River at Gauge (***MEVEMAN01**), identified in this report as MAN01 (see Appendix A for list of locations, codes, and common names of monitoring sites), was first sampled in 2005 and 2006 by the USGS for a pilot study to develop and test aquatic macroinvertebrate monitoring protocols (Brasher et al. 2006). The site was co-located with a network water quality monitoring site and a USGS streamflow gauging station (USGS 09370600 in fig. 1). The dominant riparian vegetation at MAN01 is cottonwood (*Populus spp.*), coyote willow (*Salix exigua*), and silver buffaloberry (*Shepherdia argentea*).

*Mancos River above Downstream Park Boundary (***MEVEMAN02)**, identified in this report as MAN02 was sampled for the first time in 2007. The site was selected using Generalized Random-Tessellation Stratified design and is located on a large meander bend downstream from MAN01. The vegetation community is composed primarily of coyote willow, juniper (*Juniperus monosperma)*, rabbitbrush (*Chrysothamnus spp.*) and narrowleaf cottonwood (*Populus angustifolia*).

Both sites were resampled in 2008.

The purpose of this report is to (a) document monitoring activities that occurred in 2008, (b) summarize data that were collected, and (c) place these data in the context of the aquatic habitat, biological condition, and management actions within the park through time

2 Methods

2.1 Field Methods

Most of the states on the Colorado Plateau have established index periods for collecting macroinvertebrate samples (Brasher et al. *in review*). The State of Colorado recommends collecting aquatic-macroinvertebrate samples during baseflow conditions, which typically occur in late summer/fall for mountain streams (CDPHE 2003). On September 16 -17, 2008, SCPN Water Resources field crew collected aquatic macroinvertebrate samples and physical habitat data at two monitoring sites—MAN01 and MAN02—on the Mancos River in Mesa Verde National Park (MEVE), Colorado. Each site consists of a 150-m reach, divided into 11 transects spaced 15 meters apart (see fig. 2 for reach layout diagram). A detailed description of sampling methods can be found in Brasher et al. (*in review*).

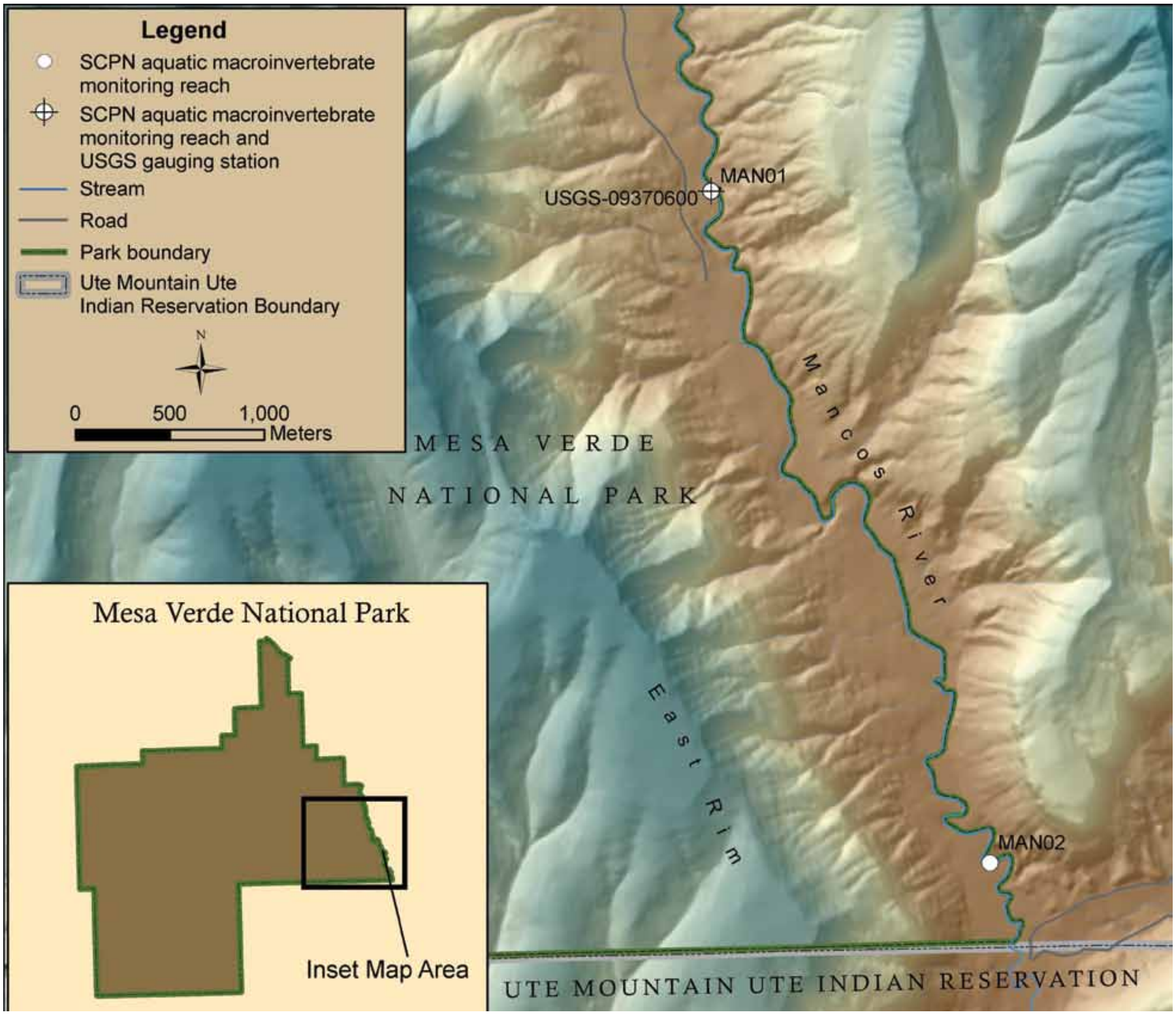


Figure 1. Map of Mancos River, Mesa Verde National Park, Colorado, with the location of two monitoring sites, MAN01 and MAN02.

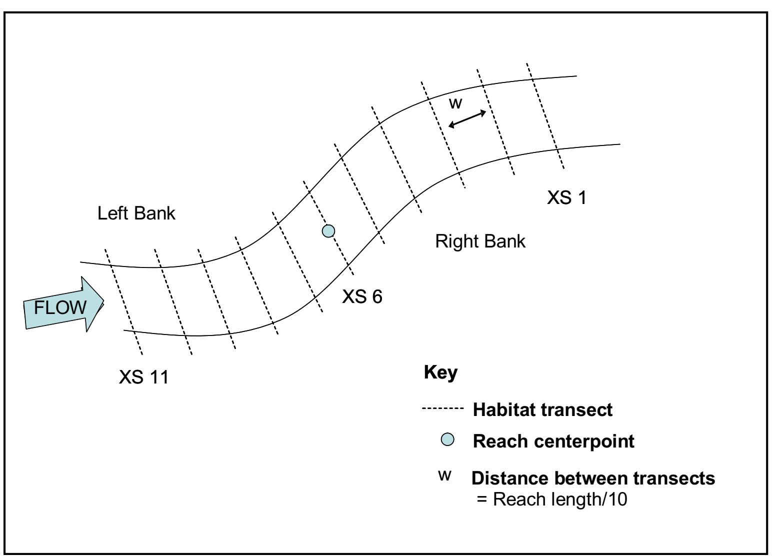


Figure 2. General aquatic-macroinvertebrate sampling reach layout.

Two types of aquatic macroinvertebrate samples were collected at each site:

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

In addition to the quantitative and qualitative macroinvertebrate samples, we collected physical habitat data at three spatial scales: microhabitat, transect, and reach.

- For each of the targeted riffle microhabitats, we measured depth, velocity, particle size, and particle embeddedness.
- For each of the 11 transects we
  - measured wetted and active channel widths
  - measured water depth, velocity, and canopy closure at multiple points along each transect
  - observed and recorded the presence or absence, and types of macroinvertebrate habitats. Macroinvertebrate habitat cover represents point data (5 points/transect) across the entire reach
  - measured geomorphic channel units (GCU) at multiple points along each transect
  - measured the size of 40-50 randomly-selected particles using a modified Wolman pebble count
- For the entire reach, we
  - identified and measured the length of GCUs. Reach characterization data represents the proportion of the reach characterized by that particular GCU
  - identified the dominant vegetation and land cover
  - recorded descriptions of flow conditions
  - recorded weather conditions
  - observed and recorded evidence of anthropogenic or natural disturbances
  - measured NPS core water quality parameters of temperature, specific conductivity, pH, dissolved oxygen, and turbidity

2.2 Laboratory Methods

Macroinvertebrate samples were sent to be sorted and identified at the Utah State University National Aquatic Monitoring Center's Bug Lab, a Bureau of Land Management laboratory based in Logan, Utah. Samples were sorted under a dissecting scope at 10× 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. Ten percent of the identified samples were re-identified by a second certified taxonomist to ensure data quality.

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

2.3 Data Analysis

For this report, we summarized 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). Also, they 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 Summary of Aquatic Macroinvertebrate Community Data

Table 1 presents data describing aquatic macroinvertebrate communities from samples collected at MAN01 and MAN02 during 2007 and 2008. For all tables and figures listed in this section, sampling reach results are presented in left to right order corresponding to upstream to downstream positioning along the stream (fig. 1). Figures presented in this section refer to data collected from quantitative samples, unless otherwise noted.

Abundance. For 2008, overall mean abundance was greatest in samples collected from MAN01. In addition, mean abundance increased nearly sixfold from 2007 to 2008 in samples taken from MAN01 . Mean abundance from samples collected at MAN02 nearly doubled from 2007 to 2008. (fig. 3).

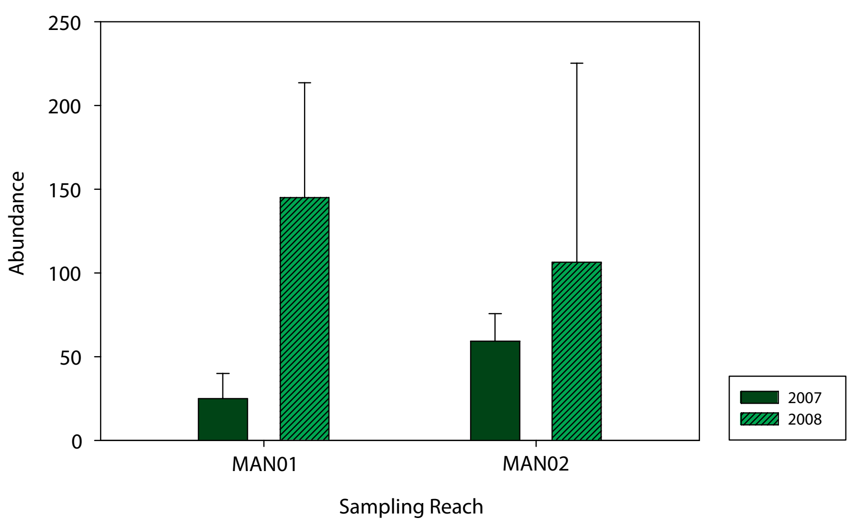


Figure 3. Total abundance. Mean total abundance expressed as the mean number of individuals per sample collected from sampling reaches in the Mancos River at MEVE in 2007 and 2008.

Table 1. Aquatic macroinvertebrate metrics for two sampling reaches (MAN01 and MAN02) in the Mancos River at Mesa Verde National Park in 2007 and 2008. Richness-based metrics are expressed as the percentage of taxa in a given order or functional feeding group. Abundance-based metrics are expressed as the percentage of individuals in a given order or functional feeding group.

Qualitative Samples	MAN01		MAN02	
	2007	2008	2007	2008
Richness - tolerant taxa (%)	16.67	15.00	11.11	11.11
Richness - filterer-collectors (%)	16.67	19.05	20.00	15.79
Richness - scrapers (%)	0.00	9.52	0.00	5.26
Number of EPT taxa	7.00	7.00	4.00	6.00
Richness - EPT taxa (%)	36.84	31.82	40.00	30.00
Richness - Ephmeroptera (%)	21.05	18.18	30.00	15.00
Richness - Plecoptera (%)	0.00	4.55	0.00	5.00
Richness - Trichoptera (%)	15.79	9.09	10.00	10.00
Richness - non-insect taxa (%)	21.05	27.27	20.00	15.00
Richness - Chironomids (%)	10.53	13.64	10.00	15.00

Quantitative Samples	MAN01				MAN02			
	2007		2008		2007		2008	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total abundance	31.20	18.66	145.00	68.52	74.00	20.48	106.40	118.73
Taxa richness	5.20	0.84	8.80	2.77	6.60	1.34	8.20	3.03
Simpson's Diversity - Taxonomic	0.66	0.06	0.51	0.16	0.60	0.06	0.63	0.12
Simpson's Diversity - Functional Group	0.38	0.07	0.36	0.11	0.50	0.40	0.48	0.13
Relative abundance - tolerant taxa	0.00	0.00	0.27	0.60	0.25	0.56	0.00	0.00
Percent richness - tolerant taxa	0.00	0.00	3.33	7.45	2.86	6.39	0.00	0.00
Relative abundance - filterer-collector	27.61	25.19	76.88	8.45	32.95	7.82	49.46	28.85
Percent richness - filterer-collector	31.33	12.38	33.35	7.49	31.33	6.39	31.36	13.41
Relative abundance - scrapers	0.00	0.00	0.24	0.36	0.45	1.02	0.80	1.40
Number of EPT taxa	3.00	0.71	4.40	0.89	3.40	0.89	4.80	1.64
Relative abundance - EPT taxa	73.51	16.87	89.52	3.86	73.37	12.52	88.81	3.28
Relative abundance - Ephemeroptera	59.43	18.82	12.76	6.57	59.04	8.10	38.99	26.53
Relative abundance - Plecoptera	0.00	0.00	1.99	2.10	3.00	2.17	5.23	4.58
Relative abundance - Trichoptera	14.08	4.69	74.77	8.82	11.33	7.95	44.60	28.79
Relative abundance - non-insect taxa	3.93	4.27	1.23	0.95	1.43	0.90	1.40	2.32
Relative abundance - Chironomids	9.04	7.45	6.53	2.99	3.13	2.57	1.98	1.82

Taxa Richness. The number of taxa in qualitative multihabitat samples increased at both sampling reaches in 2008 (Appendix C presents a list of the taxa collected). However, MAN02 showed the greatest increase in the number of taxa present in qualitative samples, doubling in number from 2007 to 2008 (fig. 4).

Diversity. Taxonomic diversity, was slightly higher in samples collected from MAN02 than in samples collected at MAN01 in 2008. We found that, from 2007 to 2008, diversity decreased slightly at MAN02, and by 24% at MAN01 (fig. 5).

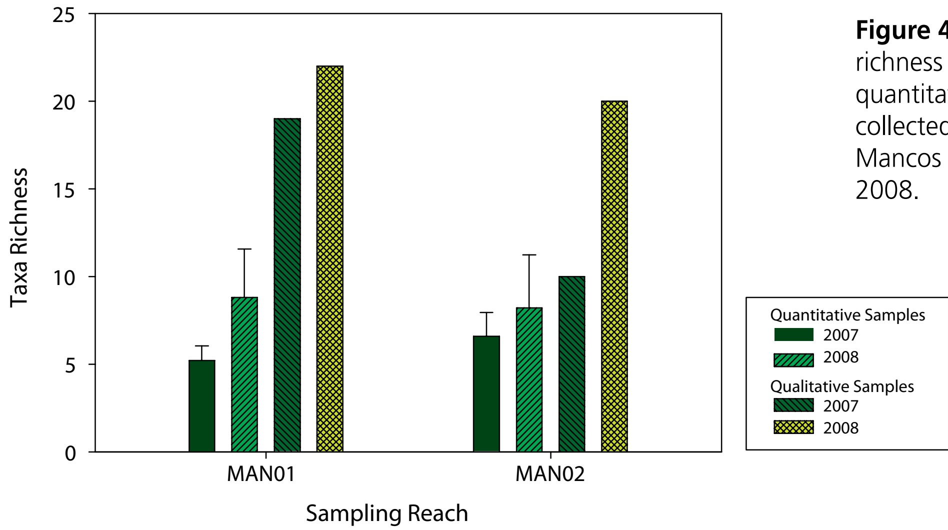


Figure 4. Taxa richness. Mean taxa richness in qualitative multihabitat and quantitative targeted riffle samples collected from sampling reaches in the Mancos River at MEVE in 2007 and 2008.

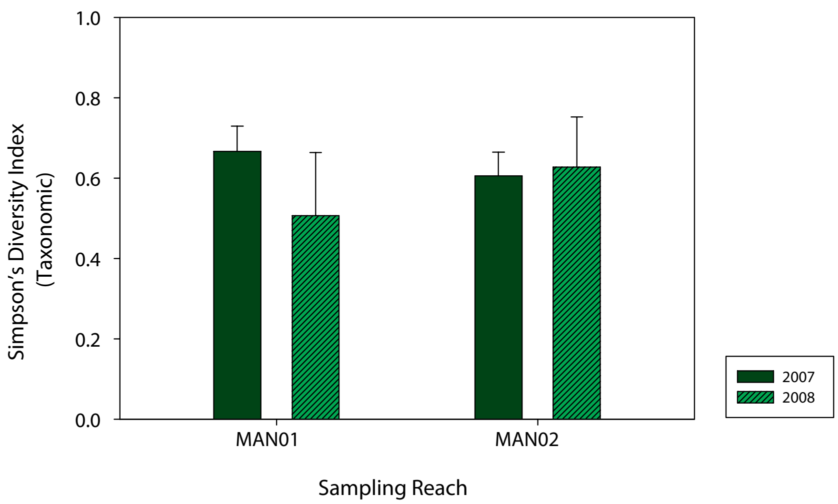
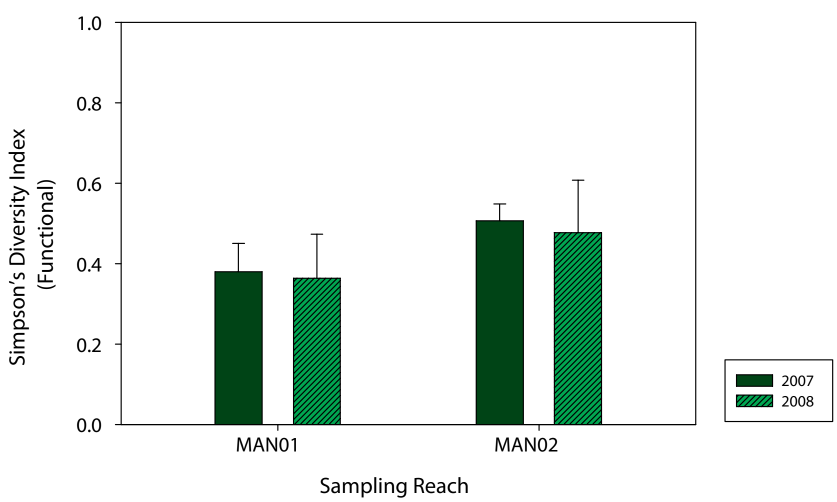
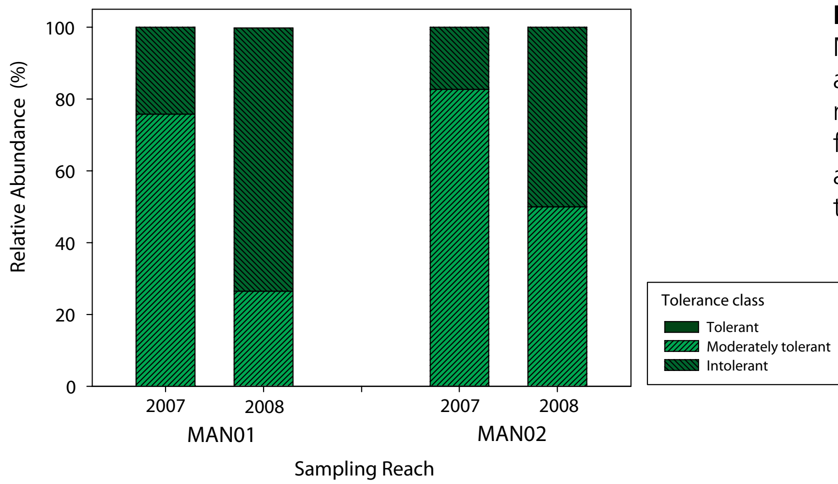


Figure 5. **Diversity.** Simpson's Diversity Index for taxonomic (upper chart) and functional diversity (lower chart) in samples collected from sampling reaches in the Mancos River at MEVE in 2007 and 2008. Values expressed are means of all samples collected from each reach.





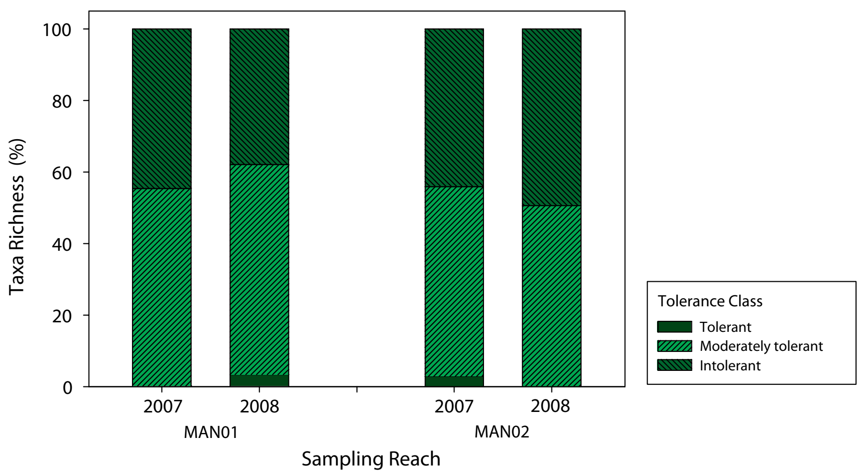


Figure 6. Ecological tolerance. Mean relative abundance (upper chart) and richness (lower chart) of aquatic macroinvertebrate taxa in samples collected from sampling reaches in the Mancos River at MEVE in 2007 and 2008, based on their tolerance to perturbation.

Tolerant taxa. Very few tolerant taxa were found at MEVE during either sampling year. Tolerant taxa abundance was low across all samples collected—0.25 individuals/sample were found at MAN02 in 2007 and 0.27 from MAN01 in 2008. No tolerant taxa were found in samples from MAN01 in 2007 or MAN02 in 2008. Samples collected in 2008 from MAN01 show that intolerant individuals were the most abundant and moderately tolerant taxa were the most species rich for that reach. Relative abundance and richness for samples from MAN02 were split evenly between moderately tolerant and intolerant individuals. Richness of moderately tolerant and intolerant species did not differ greatly among samples collected from MAN02 in 2007 (0.27%) (fig. 6).

EPT Taxa. The number of individuals representing EPT taxa, (Orders Ephemeroptera, Plecoptera, and Trichoptera), declined significantly between 2007 and 2008 in both sampling reaches. Relative abundance of organisms representing EPT taxa increased by roughly 20% at both sampling reaches in 2008 (table 1). Ephemeroptera was the most abundant of the EPT taxa in samples from both reaches in 2007, with an average of 59 individuals at MAN01, and 59 individuals at MAN02. In 2008 Trichopteran species dominated the EPT taxa with an average of 75 individuals per sample at MAN01, and an average of 45 individuals per sample at MAN02, up from 14 and 8 individuals respectively. In 2008 abundance of Plecopteran species remained low with 2 individuals per sample

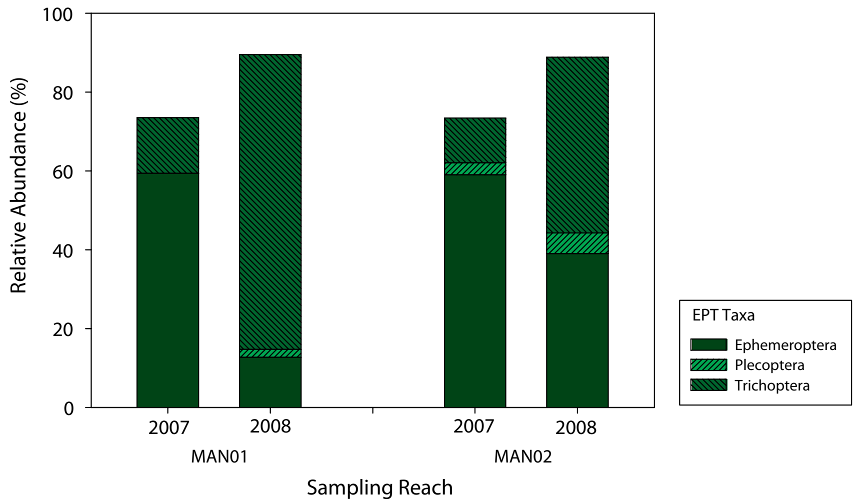


Figure 7. EPT abundance. Relative abundance of Ephemeropteran (mayflies), Plecopteran (stoneflies), and Trichopteran (caddisfly) taxa in samples collected from sampling reaches in the Mancos River at MEVE in 2007 and 2008.

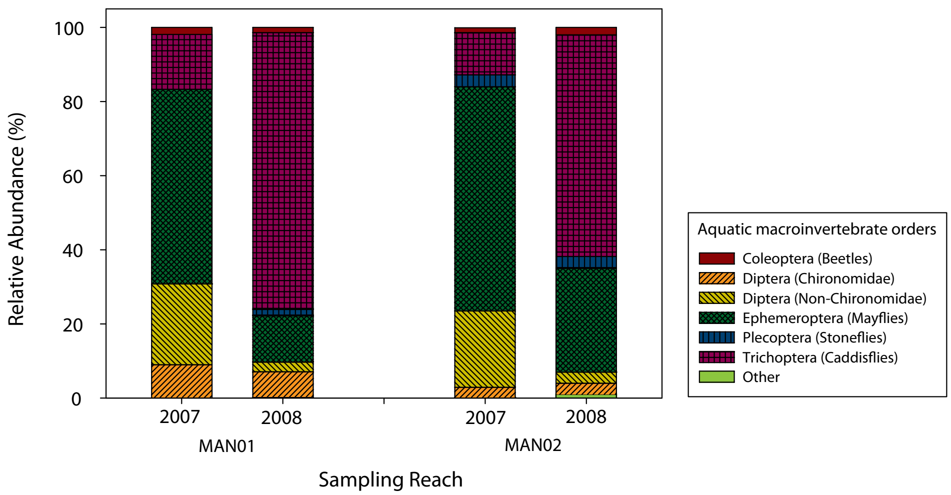


Figure 8. **Aquatic macroinvertebrate order abundance.** Relative abundance of individuals by taxonomic order in quantitative targeted riffle samples collected from sampling reaches in the Mancos River at MEVE in 2007 and 2008.

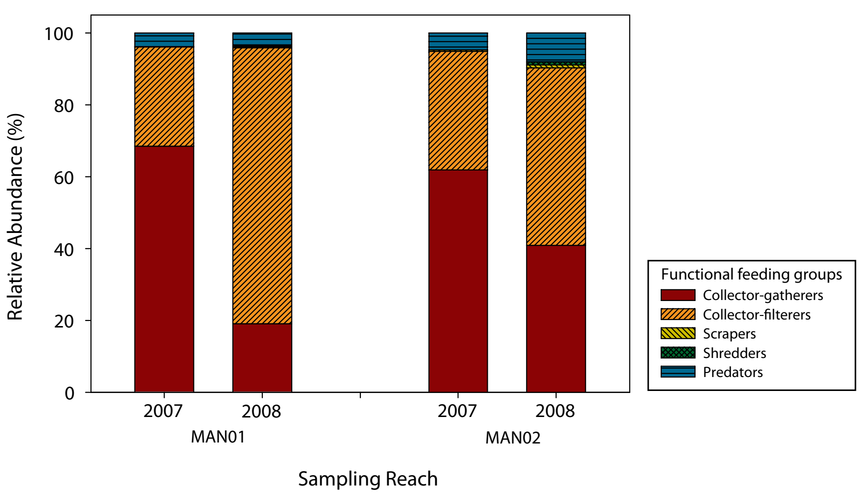


Figure 9. **Functional group abundance.** Relative abundance of functional feeding groups in quantitative targeted riffle samples collected from sampling reaches in the Mancos River at MEVE in 2007 and 2008.

collected from MAN01 and 5.individuals per sample from MAN02 (fig. 7).

Aquatic macroinvertebrate orders. Trichoptera was the most abundant order in samples from either reach in 2008, making up 75% of the taxa collected from MAN01 and 60% of the taxa collected from MAN02. Ephemeroptera was the next most abundant order collected, representing 13% of the individuals found in MAN01 and 28% of the individuals from MAN02. Several orders, including Coleopterans, Plecopterans, and Odonates, not found in samples from either site in 2007, were found in low abundances at both sampling reaches in 2008 (fig. 8).

Functional feeding groups. In 2008 Collector-filterers dominated functional group abundance at both sampling reaches, making up nearly 77% of the individuals at MAN01 and nearly 50% of the individuals at MAN02. Predators were the second most abundant functional group, comprising 25% of the samples collected from MAN01, and 27% of the samples from MAN02. Scrapers, found only in samples from MAN02 in 2007, doubled in abundance in samples from that same reach in 2008. Shredders, which were not present in any samples collected in 2007, were found at both sampling reaches in 2008. Shredders and scrapers combined to make up 7% of the taxa collected from MAN01 and 10% of the taxa from MAN02 (Figure 9).

3.2 Summary of Physical Habitat Characteristics

Physical habitat data collected at MAN01 and MAN02 during 2007 and 2008 are presented in Table 2, and additional transect and microhabitat data can be found in Appendix D. Particle size distribution data are presented as the proportion of particles counted across each transect per reach. Macroinvertebrate habitat was described from point data collected along all transects (5 points/transect). Reaches are described as the proportion of the reach characterized by a particular geomorphic channel unit (GCU).

Transect. Physical habitat data show that mean velocity along our sampling reaches decreased from 2007 to 2008 by 28% at MAN01 and by 29% at MAN02.

The channel surface substrate of both sampling reaches was dominated by particles in the fine gravels particle size class, which accounted for 76.5% of the substrate sampled from MAN01 and 86.0 % of the substrate sampled from MAN02 (fig. 10). The size class with the largest increase between sampling years across both reaches was the fines class, which increased by 24% at MAN01 and 55% at MAN02.

In 2008, aquatic macroinvertebrate habitat in both sampling reaches was dominated by rock , which comprised 57% of the available habitat in MAN01 and 74% of MAN02. However, rock along MAN01 decreased by 34% between 2007 and 2008. In 2008, vegetation habitat, which was not found along either sampling reach in 2007, comprised 24% of the habitat structures for the MAN01 reach and 13% for MAN02 (fig.11).

Reach. We found that riffles and runs were the dominant geomorphic channel units (GCUs) in both of the sites we sampled, comprising 88% at MAN01 and 98% at MAN02. Cascades were absent from MAN01 during both 2007 and 2008, and from MAN02 in 2007. However, cascades made up 2% of MAN02 in 2008. Falls occurred in 3% of MAN01 reaches in 2008 (fig. 12).

Of the water quality parameters measured, the greatest differences between sampling reaches occurred in specific conductivity, which was greater for MAN02 by 48 μS/cm, and turbidity, which was also greater at MAN 02 by 4.77 NTU (table 2).

Table 2. Summary of physical habitat transect data for the Mancos River in MEVE for 2007 and 2008. Wetted and active channel measurements are expressed as widths. Particle embeddedness and canopy closure measurements are expressed as percentages. Water quality measurements were made at or near 12:00 noon on the day of the sampling event. NC - data was not collected

Physical Habitat Metric	MAN01				MAN02			
	2007		2008		2007		2008	
Microhabitat level	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Riffles								
Velocity (m/s)	0.69	0.27	0.63	0.13	0.91	0.20	0.39	0.12
Depth (m)	0.18	0.07	0.13	0.04	0.15	0.05	0.06	0.01
Particle Size (mm)	9.08	1.56	9.85	1.23	9.19	1.48	9.26	2.82
Embeddedness (%)	19.20	9.04	31.60	5.64	28.00	12.88	27.60	8.50
Transect level								
Channel dimensions								
Velocity (m/s)	0.68	0.23	0.50	0.23	0.63	0.19	0.45	0.19
Depth (m)	0.30	0.10	0.30	0.15	0.31	0.10	0.25	0.07
Wetted Channel (m)	5.71	2.11	5.56	1.82	6.37	2.35	5.41	0.93
Active Channel (m)	7.49	2.16	9.36	3.32	10.28	4.19	9.98	2.57
Riparian cover								
Canopy Closure (%)	9.05	12.88	19.33	25.81	10.05	18.68	22.98	33.42
Reach level								
Water quality	**Value**		**Value**		**Value**		**Value**	
Temperature (°C)	10.8	—	17.5	—	11.2	n/a	16.9	—
Specific Conductivity (µS/cm)*	NC	—	945	—	NC	n/a	993	—
pH	NC	—	8.5	—	NC	n/a	8.5	—
Dissolved Oxygen (% saturation)	NC	—	106.0	—	NC	n/a	104.9	—
Turbidity (NTU)**	NC	—	12.1	—	NC	n/a	16.8	—
Discharge (cfs)	46.0	—	19.0	—	41.0	n/a	19.0	—

* Microsiemens per cm
** Nephelometric Turbidity Units

3.3 Antecedent Conditions

Streamflow data were collected by the USGS at the gauging station *Mancos River at Anitas Flat, Mesa Verde National Park, CO* (09370600) (USGS 2009). A comparison of hydrographs for 2007 and 2008 shows that in 2008 water availability in the Mancos River was greater during the spring and early summer months but was less from October to December (fig. 13). The annual mean discharge was 20.5 cfs greater in 2008 (53.9 cfs) than it was in 2007 (33.4 cfs).

Climate data were collected at the town of Mancos, Colorado, approximately 12.5 km upstream of the gauging station along the Mancos River; and at the Mesa Verde National Park headquarters, approximately 14 km southeast of the gauging station on an escarpment above the river (WRCC 2009). Period of record for average precipitation is from 1948-2008. Precipitation was above average

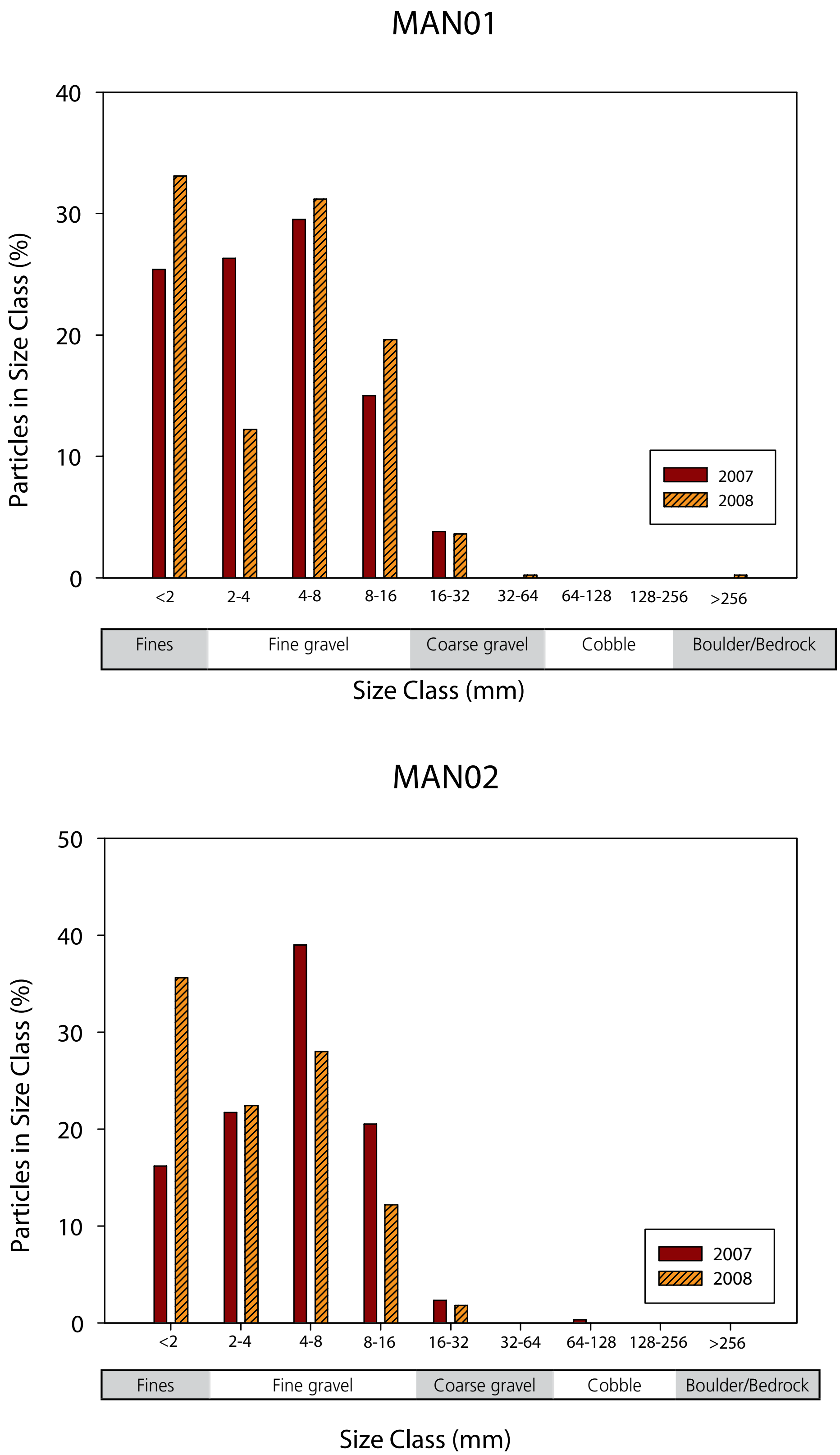


Figure 10. Channel surface substrate particle size distribution. Particle size distribution, based on modified Wolman pebble counts, for macroinvertebrate sampling reaches (MAN01 - top graph; MAN02 - bottom graph) in the Mancos River at MEVE, 2008.

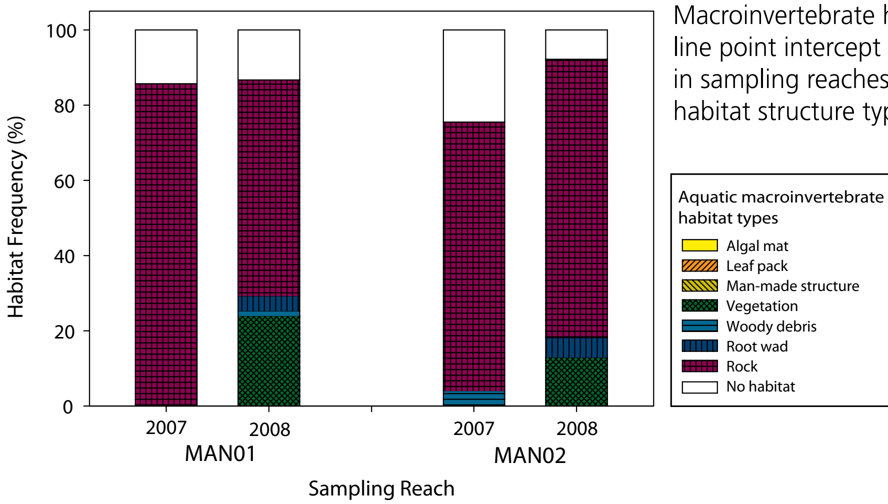


Figure 11. Aquatic macroinvertebrate habitat. Macroinvertebrate habitat characterization based upon line point intercept data collected from habitat transects in sampling reaches in the Mancos River at MEVE. Some habitat structure types were not observed.

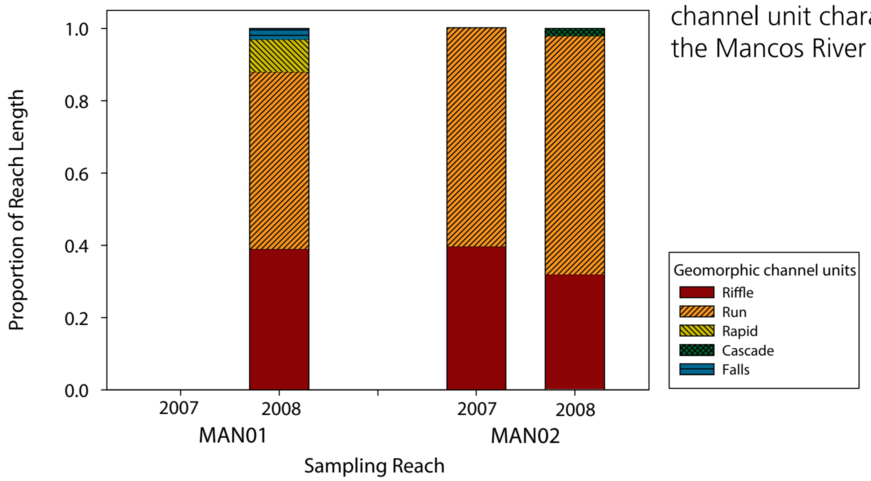


Figure 12. Geomorphic channel units. Geomorphic channel unit characterization of sampling reaches in the Mancos River at MEVE in 2007 and 2008.

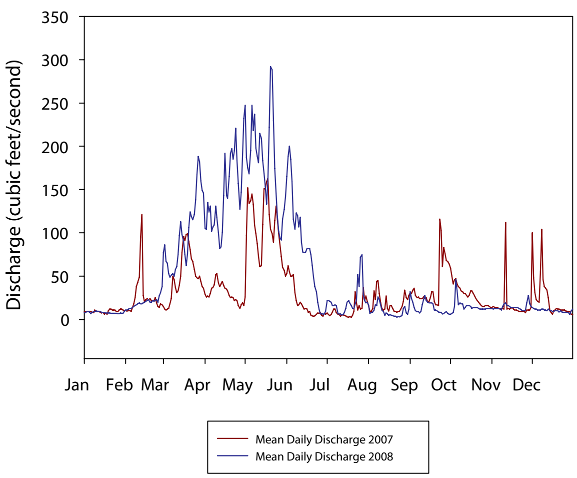


Figure 13. Mancos River Streamflow, 2008. Hydrographs from the streamflow gauging station *Mancos River at Anitas Flat, Mesa Verde National Park, CO (09370600)* showing mean daily discharge for 2007 and 2008.

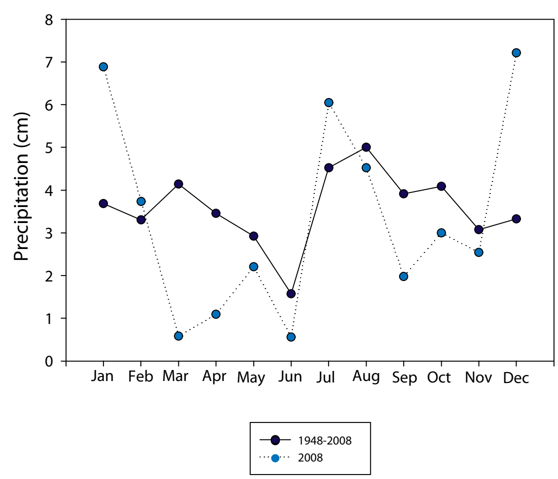


Figure 14. Mean monthly precipitation (cm) for Mancos, Colorado in 2008, and from 1948-2008 (WRCC 2009).

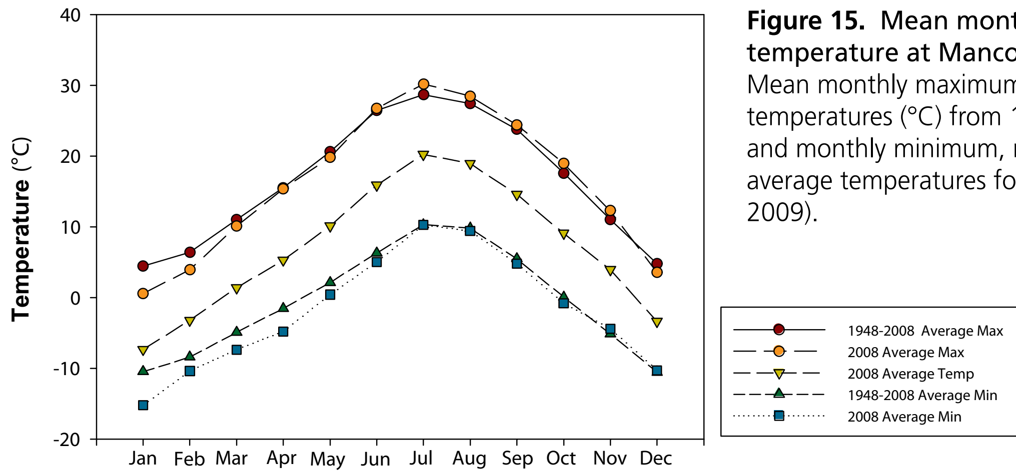


Figure 15. Mean monthly temperature at Mancos, Colorado. Mean monthly maximum and minimum temperatures (°C) from 1948-2008; and monthly minimum, maximum, and average temperatures for 2008 (WRCC 2009).

for January and February, but was below average for the remainder of the year, with the exceptions of July and December during the early monsoon and winter seasons (fig. 14)). Average minimum temperatures were lower than average for the first 6 months of 2008 and average maximum temperatures were higher than average from June to November (fig. 15).

4 Discussion

This report presents data from SCPN's second year of monitoring aquatic macroinvertebrates and physical habitat at the Mancos River in Mesa Verde National Park, Colorado. We stress that the differences between sampling years and locations are not to be interpreted as an ecologically significant trend, as trends cannot be determined by two years of sampling data. Differences may be attributed to multiple factors, including ecological variability and sampling error. Differences in physical habitat metrics, such as geomorphic channel units, canopy closure, and particle embeddedness may be a result of observer bias. SCPN attempts to minimize such error by thoroughly training crew members in the proper field techniques prior to each sampling season.

4.1 Aquatic Macroinvertebrate Communities

Several metrics suggest that more favorable conditions existed for aquatic macroinvertebrates during our sampling event in 2008 compared to 2007. The greatest increases in our quantitative targeted riffle samples occurred in total abundance and relative abundance of EPT taxa at both sampling reaches during 2008.

4.2 Ecological Tolerance

Ecological tolerance describes how well a taxon tolerates disturbance. For aquatic macroinvertebrate taxa, ecological tolerance relates to their ability to withstand pollution or environmental degradation in their environment. Taxa that are considered to be intolerant are expected to decline quickly as water quality degrades. Conversely, tolerant taxa would be expected to persist during times of degraded water quality. Less than 1% of the individuals collected from MAN01 were representative of tolerant taxa, and we found very few or no tolerant taxa in samples collected from MAN02 (fig. 6). Intolerant individuals dominated samples collected from MAN01, while the abundances of intolerant and moderately tolerant individuals were roughly the same in samples collected from MAN02. These data suggest that water quality may be better at MAN01 than at the downstream reach, MAN02. Water quality data collected at our two sampling reaches support this. Specifically, turbidity and specific conductivity is greater for MAN02 than for MAN01. Both turbidity, the concentration of particles suspended in the water column, and specific conductivity, the total dissolved solids and salinity in the water, negatively impact macroinvertebrate communities (Brasher et al. *in review*). This could also explain why taxa richness and abundances were higher at MAN01. Additionally, ecological tolerance data also suggest that any future disturbance to the system has the potential to impact the aquatic community by causing declines in both diversity and abundances of macroinvertebrate taxa, especially along the upper sampling reach.

4.3 Physical Habitat Diversity

Physical habitat data from transects showed that both reaches were relatively homogeneous. Vegetation and woody debris increased from 2007 to 2008 along both reaches, indicating greater habitat availability in 2008 than 2007. Conversely, mean velocity, and depth decreased at both reaches between 2007 and 2008. This finding may be explained by the difference in the timing of our sampling events in 2007 and 2008. Discharge on the Mancos River declined significantly during our 2008 sampling event compared to our 2007 event (table 2). Overall, streamflow, as measured by mean daily discharge, increased in 2008 compared to 2007, suggesting that, over the course of the calendar year, more water was available in the Mancos during 2008 (fig. 13).

The channel surface substrate particle size did not differ greatly between sampling reaches in 2008. We did see an increase in finer size grains at both sampling reaches from 2007 to 2008. Unlike our previous sampling effort in 2007, microhabitat data suggests that embeddedness is largely the same for the two sampling reaches. These findings differ from those of Stacey (2007), and Joyal and Anderson (2008), who found an increase in particle embeddedness in a downstream direction, which they attributed to the sediment inflows from nearby tributaries. However, mean particle embeddedness at the microhabitat level decreased greatly at both sampling reaches in 2008. While we have only two years of data, if this trend continues into future sampling years, it may suggest that targeted riffles at both sampling reaches are becoming less embedded, thus improving their potential as macroinvertebrate habitat.

Homogeneity in habitat throughout the two sampling reaches may explain the relatively low taxa richness detected through both quantitative and qualitative sampling. Although taxonomic diversity is relatively high (fig. 5), dominant taxa data suggests that abundances are weighted towards the most dominant taxa found in quantitative samples (table 1).

4.4 Other Factors Affecting the Aquatic Community

Many factors may be negatively affecting aquatic community structure in the Mancos River, including natural disturbances, such as fire, pollution from agricultural sources, and management activities related to land use, rehabilitation, and protection. In 2000 the Bircher fire burned several thousand acres on the eastern escarpment of Mesa Verde, within the Mancos River watershed. The fire caused increased sediment loads in the river (Stacey 2007), and aquatic macroinvertebrate and native fish populations were severely reduced. Upstream of the park boundary, the Mancos River flows through agricultural land where it is diverted for irrigation and is potentially subject to anthropogenic inputs of nutrients and pesticides, which could further depress the aquatic community (Colyer 2005).

Park resource managers have been active within the Mancos River watershed. In 2003, the Colorado Division of Wildlife and Mesa Verde National Park began a cooperative effort to reintroduce the native roundtail chub (*Gila robusta*) in the Mancos River. The Colorado Division of Wildlife provided 1,000 round tail chub fingerlings to Mesa Verde National Park to release, and another several thousand of these fishes were provided to the Ute Mountain Tribe for release below the park boundary.

Local ranchers had grazed cattle within the park until 1998. While grazing has not been permitted in the park for ten years, trespass livestock have been noted during sampling visits. Mesa Verde National Park removed cattle and horses from the Mancos River canyon and repaired fences at the north and south boundaries to prevent further entry of domestic livestock. Any of these factors, or a combination of them may be contributing to the poor condition of the macroinvertebrate community at the park.

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Appendix A Monitoring site codes, names and location information for Mesa Verde National Park

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

Site Code	Common Name	Report Name	UTM X	UTM Y	Elevation (m)
MEVEMAN01	*Mancos River at Gauge*	MAN01	734371	4125939	1933
MEVEMAN02	*Mancos River above Down-stream Park Boundary*	MAN02	735878	4122566	1882

Appendix B Selected aquatic macroinvertebrate metrics*

Metric type	Metric	Definition
Abundance	Total abundance	Total number of individuals.
Richness	Taxa richness	Total number of taxa (measures the overall diversity of macroinvertebrates in a sample).
Diversity	Simpson's diversity	A measure of the variety of taxa that takes into account the relative abundance of each taxon. $D_S = 1-[(\Sigma n(n-1))/(N(N-1))]$
Tolerance	Dominant taxa	Measures the dominance of the most abundant taxa. Typically calculated as dominant 2, 3, 4, or 5 taxa.
	Relative abundance for tolerant taxa	Percent of individuals considered to be tolerant to perturbation.
	Percent richness for tolerant taxa	Percent of taxa considered to be tolerant to perturbation.
Functional-feeding	Relative abundance filtering-collectors	Percent of individuals that filter fine particulate organic matter from the water column.
	Percent richness filtering-collectors	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 finer substrates).
	Percent richness burrowers	Percent of taxa that move between substrate particles (typically finer 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.
	Relative abundance of Hydroptilidae or Hydropsychidae within Trichoptera	Percent of Trichopteran individuals belonging to Hydroptilidae or Hydropsychidae families (ratio of tolerant caddisfly abundance to total caddisfly abundance).
	Relative abundance non-insect taxa	Percent of individuals that are not insects.
	Relative abundance Chironomidae	Percent of individuals that are midges.

* from Brasher et al. (*in review*)

Appendix C Aquatic macroinvertebrate taxa collected from the Mancos River at MEVE in 2008

Phylum	Class	Order	Suborder	Family	Genus	Species	Common Name
Annelida	Clitellata						segmented worms
Arthropoda	Arachnida	Trombidiformes	Prostigmata	Sperchonidae	*Sperchon*		water mites
Arthropoda	Insecta	Coleoptera	Polyphaga	Dryopidae	*Helichus*		long-toed water beetle
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Microcylloepus*	***pusillus***	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Optioservus*		riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Optioservus*	***divergens/pecosensis***	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Optioservus*	***quadrimaculatus***	riffle beetles
Arthropoda	Insecta	Diptera		Ceratopogonidae	*Probezzia*		biting midges
Arthropoda	Insecta	Diptera	Nematocera	Chironomidae			midges
Arthropoda	Insecta	Diptera	Nematocera	Simuliidae	*Simulium*		black flies
Arthropoda	Insecta	Diptera	Nematocera	Simuliidae	*Simulium*		black flies
Arthropoda	Insecta	Diptera	Nematocera	Simuliidae	*Simulium*	***tuberosum group***	lack flies
Arthropoda	Insecta	Diptera	Nematocera	Tipulidae	*Hexatoma*		crane flies
Arthropoda	Insecta	Diptera	Nematocera	Tipulidae	*Tipula*		crane flies
Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Leptohyphidae	*Tricorythodes*		mayfly spinner
Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Leptophlebiidae			pronggilled mayflies
Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Leptophlebiidae	*Paraleptophlebia*		pronggilled mayflies
Arthropoda	Insecta	Ephemeroptera	Pisciforma	Baetidae	*Baetis*		small minnow mayflies
Arthropoda	Insecta	Ephemeroptera	Setisura	Heptageniidae			stream mayflies
Arthropoda	Insecta	Hemiptera	Heteroptera	Veliidae	*Rhagovelia*		broad-shouldered water striders
Arthropoda	Insecta	Odonata	Anisoptera	Gomphidae			clubtail dragonflies
Arthropoda	Insecta	Odonata	Zygoptera	Coenagrionidae			narrow-winged damselflies
Arthropoda	Insecta	Plecoptera					stonflies
Arthropoda	Insecta	Plecoptera	Systellognatha	Chloroperlidae	*Sweltsa*		green stoneflies
Arthropoda	Insecta	Plecoptera	Systellognatha	Perlidae	*Doroneuria*	***theodora***	common stoneflies
Arthropoda	Insecta	Plecoptera	Systellognatha	Perlodidae			perlodid stoneflies
Arthropoda	Insecta	Plecoptera	Systellognatha	Perlodidae	*Skwala*	***americana***	perlodid stoneflies
Arthropoda	Insecta	Trichoptera		Hydropsychidae			netspinning caddisflies
Arthropoda	Insecta	Trichoptera		Hydropsychidae	*Cheumatopsyche*		netspinning caddisflies
Arthropoda	Insecta	Trichoptera		Hydropsychidae	*Hydropsyche*		netspinning caddisflies
Arthropoda	Malacostraca	Amphipoda	Gammaridea	Hyalellidae	*Hyalella*		gammarid amphipods
Arthropoda	Malacostraca	Decapoda	Pleocyemata	Cambaridae			crayfish
Arthropoda	Malacostraca	Decapoda	Pleocyemata	Cambaridae	*Orconectes*	*virilis*	virile crayfish
Mollusca	Bivalvia	Veneroida		Pisidiidae	*Pisidium*		peaclams

Appendix D Physical habitat data collected from the Mancos River at MEVE in 2008

Appendix D-1 Physical habitat data collected at the transect level in the Mancos River in Mesa Verde National Park during 2008.

Transect	Velocity (m/s)		Depth (m)		Wetted channel (m)	Active channel (m)
MAN01	**Mean**	**SD**	**Mean**	**SD**		
1	0.65	0.16	0.17	0.04	6.22	9.80
2	0.34	0.26	0.12	0.06	8.56	10.85
3	0.52	0.15	0.26	0.20	7.20	10.40
4	0.34	0.09	0.18	0.06	7.49	8.57
5	0.30	0.17	0.32	0.10	6.39	8.88
6	0.65	0.38	0.16	0.06	4.43	6.23
7	0.44	0.50	0.41	0.14	3.20	5.08
8	0.91	0.41	0.30	0.11	3.35	5.49
9	0.79	0.45	0.52	0.07	4.20	17.00
10	0.18	0.37	0.58	0.19	3.95	9.15
11	0.35	0.13	0.23	0.08	6.15	11.52
MAN02	**Mean**	**SD**	**Mean**	**SD**		
1	0.38	0.05	0.28	0.05	5.13	8.32
2	0.25	0.15	0.36	0.11	5.02	7.90
3	0.85	0.15	0.19	0.04	4.51	9.53
4	0.29	0.19	0.37	0.11	5.02	8.62
5	0.66	0.08	0.26	0.10	4.00	10.15
6	0.66	0.61	0.15	0.09	6.52	13.70
7	0.38	0.52	0.30	0.13	6.30	16.07
8	0.35	0.20	0.24	0.09	5.52	9.10
9	0.45	0.36	0.20	0.10	4.67	8.62
10	0.40	0.13	0.16	0.04	7.03	9.61
11	0.30	0.06	0.30	0.07	5.84	8.16

Appendix D-2 Microhabitat data collected at targeted riffle quantitative sampling reaches

Microhabitat	Velocity (m/s)	Depth (m)	Microhabitat	Velocity (m/s)	Depth (m)
MAN01			**MAN02**		
1	0.71	0.10	1	0.53	0.07
2	0.42	0.13	2	0.45	0.06
3	0.75	0.21	3	0.43	0.07
4	0.69	0.12	4	0.31	0.04
5	0.61	0.11	5	0.22	0.05