National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Aquatic Macroinvertebrate and Physical Habitat Monitoring for Tsaile Creek in Canyon de Chelly National Monument

2008 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2010/031

ON THE COVER
Tsaile Creek, Canyon de Chelly National Monument
Photograph by Stacy Stumpf

Aquatic Macroinvertebrate and Physical Habitat Monitoring for Tsaile Creek in Canyon de Chelly National Monument

2008 Summary Report

Natural Resource Technical Report NPS/SCPN/NRDS—2010/031

Stacy E. Stumpf
Stephen A. Monroe

National Park Service
Southern Colorado Plateau Network
Northern Arizona University
P.O. Box 5765
Flagstaff, AZ 86011-5765

February 2010

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and are applicable to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for timely release of basic data sets and data summaries. Care has been taken to ensure the accuracy of raw data values, for which a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

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.

Views, statements, findings, conclusions, recommendations, and data in this report are those of the author(s) and do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Park Service.

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 Lisa Thomas. SCPN staff provided support for the project.

Please cite this publication as:

Stumpf, S. E., and S. A. Monroe. 2010. Aquatic macroinvertebrate and physical habitat monitoring for Tsaile Creek in Canyon de Chelly National Monument: 2008 summary report. Natural Resource Data Series NPS/SCPN/NRDS—2010/031. National Park Service, Fort Collins, Colorado.

NPS 334/101111, February 2010

1 Introduction and Background

The National Park Service Inventory and Monitoring (I&M) 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). Little or no data has been collected describing the aquatic ecology of perennial streams in Canyon de Chelly National Monument (CACH). SCPN selected Tsaile Creek for long-term monitoring of aquatic macroinvertebrates in CACH. Additional monitoring sites on other streams may be added in the future.

In 2008 SCPN implemented aquatic macroinvertebrate monitoring for the first time at one site on Tsaile Creek in CACH. Our sampling site, *Tsaile Creek below Tsaile Dam* (CACHTSA01), is identified in this report as TSA01 (see Appendix A for list of locations, codes, and common names of sampling sites). The site, located approximately 0.95 km downstream from the Tsaile Dam, was selected using Generalized Random-Tesselation Stratified design (fig. 1).

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

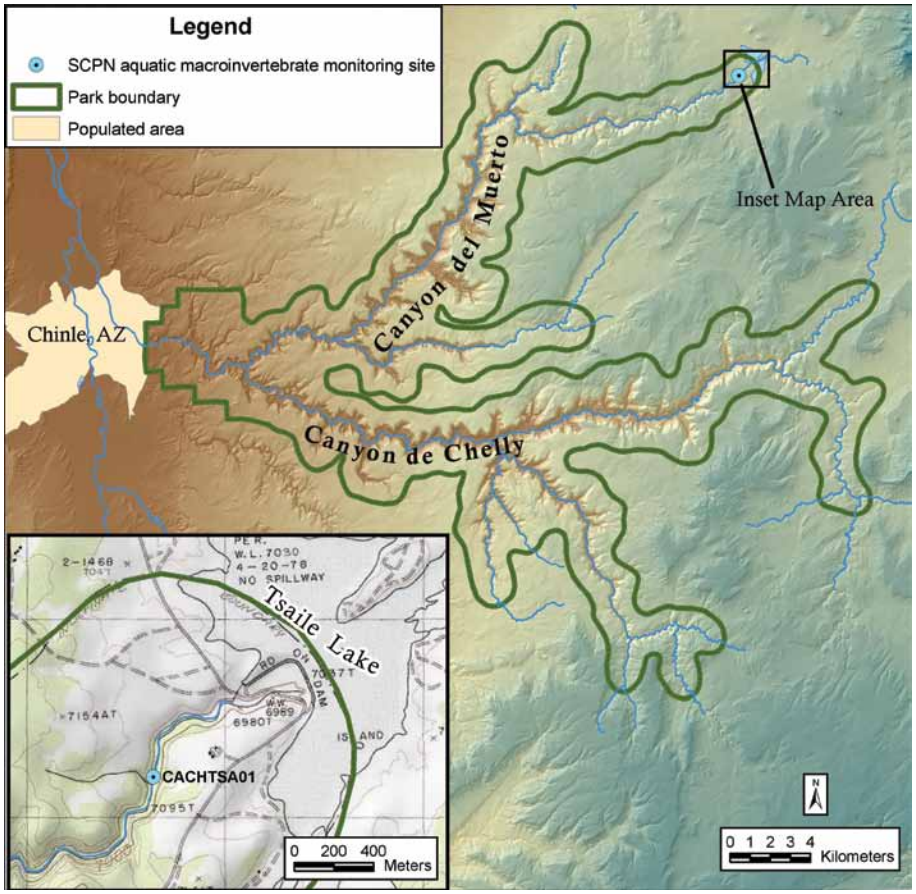


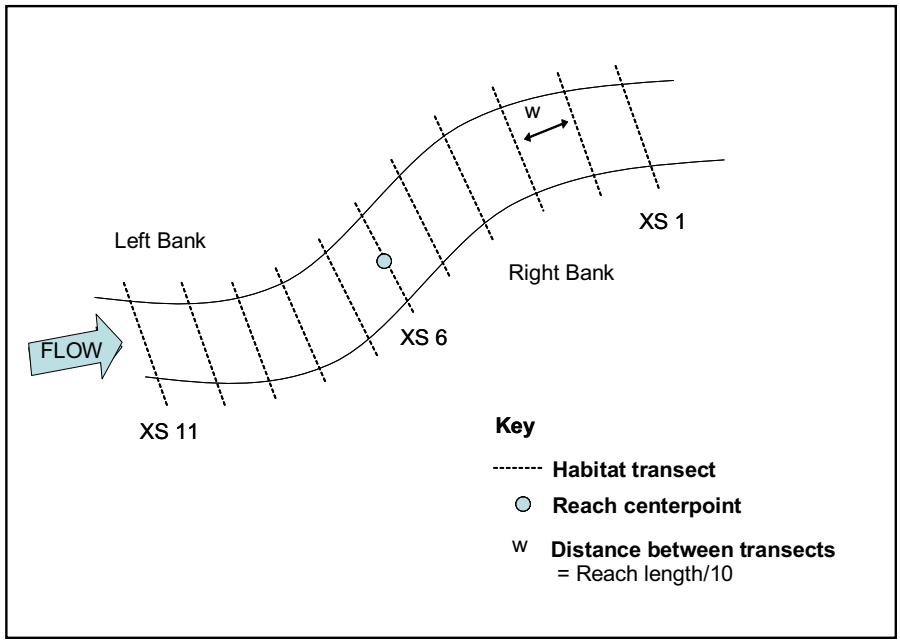
Figure 1. Location map of Tsaile Creek, Canyon de Chelly National Monument. Aquatic macroinvertebrate monitoring site TSA01 is depicted in the figure inset.

Tsaile Creek flows across the western side of the Defiance Plateau, with headwaters in the Chuska Mountains. The watershed is approximately 42,395 ha (104,760 acres) and is located entirely on Navajo Nation lands. Tsaile Dam was constructed in 1963 for irrigation and recreational purposes and forms Tsaile Lake. The lake separates the upper portion and lower portions of the watershed. The approximate boundary of Canyon de Chelly National Monument passes through Tsaile Lake. Tsaile Creek enters Canyon del Muerto in the monument immediately downstream of the dam (NRCS 2000). The Tsaile Creek watershed receives most of its moisture in the spring, as snowmelt from the nearby Chuska Mountains, and in summer, as monsoon rains. Summer monsoons are responsible for approximately 40% of the annual precipitation (Rydout 1983).

In 1996, the Navajo Nation Watershed Prioritization Study identified the Tsaile Creek watershed as a top conservation priority because of the natural and cultural resources that exist there and the need to protect these resources from the many threats that exist (NRCS 1999). For example, the Navajo Nation has concerns about the status and threats to several native species found within the watershed, including the northern leopard frog (*Rana pipens*), speckled dace (*Rhinichthys osculus*), and the federally endangered blueheaded sucker (*Catostomus discobolus*). Puebloan ruins which date as far back as 350 to 1300 AD are found throughout Canyon del Muerto.

Aquatic macroinvertebrates face multiple threats in Tsaile Creek watershed, including flow regulation and invasion by exotic plant and animal species. Water diverted by Tsaile Dam is used for irrigation upstream of the monument, eliminating peak flows and altering the hydrologic regime of Tsaile Creek. Streamflow data for Tsaile Creek below Tsaile Dam is not available, but recent observations indicate that about 4.5 miles of the creek flows perennially between the dam and approximately Middle Trail Canyon. Introductions of invasive species, pose another threat to aquatic life along Tsaile Creek. Two riparian species, salt cedar (*Tamarix ramosissima*) and Russian olive (*Elaeagnus angustifolia*), introduced to control erosion (NRCS 2000), can outcompete and replace native vegetation, as well as deplete groundwater resources. Furthermore, non-native aquatic species in Tsaile Creek, including goldfish (*Carassius auratus*), fathead minnow (*Pimephales promelas*), and virile crayfish (*Orconectes virilis*) (Trammell unpublished report 2008) have the potential to harm the aquatic macroinvertebrate community within Tsaile Creek.

Figure 2. General aquatic-macroinvertebrate sampling reach layout.



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*). In Arizona, macroinvertebrate samples are collected from cold-water perennial sites (above 1,500 m elevation), such as Tsaile Creek, during May–June (ADEQ-WQD 2006). On September 23, 2008, SCPN Water Resources field crew collected aquatic macroinvertebrate samples and physical habitat data from the monitoring site (TSA01), comprised a 150-m reach on Tsaile Creek within Canyon de Chelly National Monument (CACH), Arizona (see fig. 2 for reach layout diagram). This site is located approximately 0.95 km downstream from the Tsaile Dam where the creek flows through a *Poa pratensis, Scirpus* spp., and *Pascopyrum* spp. meadow. Channel substrate in the reach is primarily coarse gravel. A brief description of field methods is provided here, and a detailed description of sampling methods can be found in Brasher et al. (*in review*). We collected two types of aquatic macroinvertebrate samples in the reach.

(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 creek. Using the Slack Sampler, we collected samples from all habitat types within the sampling reach and combined them into one composite qualitative sample. A list of existing habitat types from which qualitative samples were collected can be found in section 3.2 of this report.

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

- For each of the quantitative targeted riffle microhabitats, we measured depth, velocity, particle size, and particle embeddedness.
- For each of the 11 transects (see fig. 2), 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 each 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 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. 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

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). 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.

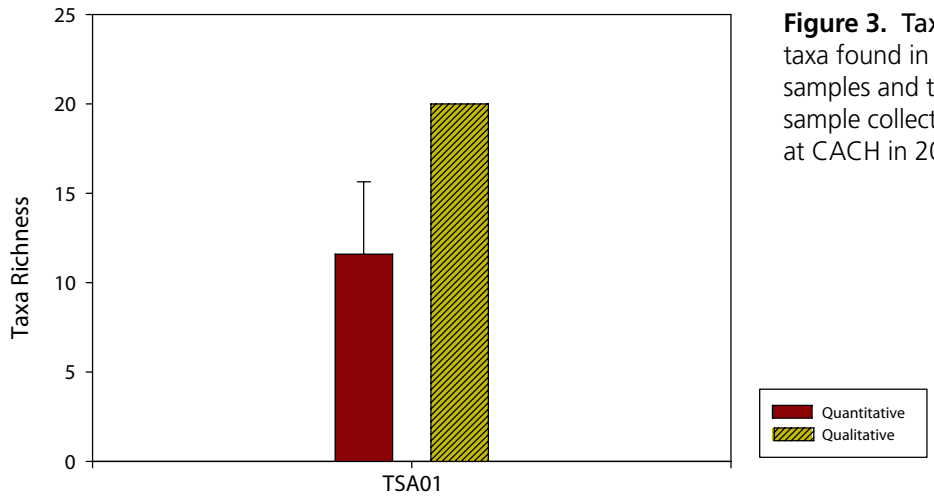


Figure 3. Taxa richness. Mean number of taxa found in quantitative targeted habitat samples and the qualitative multihabitat sample collected from TSA01 in Tsaile Creek at CACH in 2008.

Table 1. Summary of macroinvertebrate metrics based on samples collected from the monitoring site (TSA01) on Tsaile Creek during 2008. Richness-based metrics are expressed as the number of different taxa in a particular sample. Abundance-based metrics are expressed as the number of individuals in a sample. The mean was reported for the five replicate targeted riffle habitat samples

Qualitative Multihabitat		Quantitative Targeted Riffle Habitat	Mean	SD
Taxa richness	20.00	Total abundance	311.80	229.80
Richness of tolerant taxa (%)	26.32	Taxa richness	11.60	4.04
Richness of filterer-collectors (%)	15.79	Simpson's Diversity - Taxonomic	0.51	0.09
Richness of scrapers (%)	10.53	Simpson's Diversity - Functional Group	0.22	0.09
Number of EPT taxa	3.00	Dominant taxa	63.83	12.8
Richness of EPT taxa (%)	15.00	Relative abundance tolerant taxa	27.78	12.83
Richness of Ephmeroptera (%)	5.00	Richness tolerant taxa (%)	36.88	7.86
Richness of Plecoptera (%)	0.00	Relative abundance Filterer-collector	2.10	1.73
Richness of Trichoptera (%)	10.00	Richness Filterer-collector (%)	10.98	7.44
Richness of non-insect taxa (%)	25.00	Relative abundance of Scrapers	2.29	1.56
Richness of Chironomids (%)	15.00	Number of EPT taxa	1.80	1.48
		Relative abundance of EPT taxa	1.21	1.27
		Relative abundance of Ephmeroptera	0.36	0.45
		Relative abundance of Plecoptera	0.00	0.00
		Relative abundance of Trichoptera	0.86	1.38
		Relative abundance of non-insect taxa	24.96	15.85
		Relative abundance of Chironomids	69.64	16.35

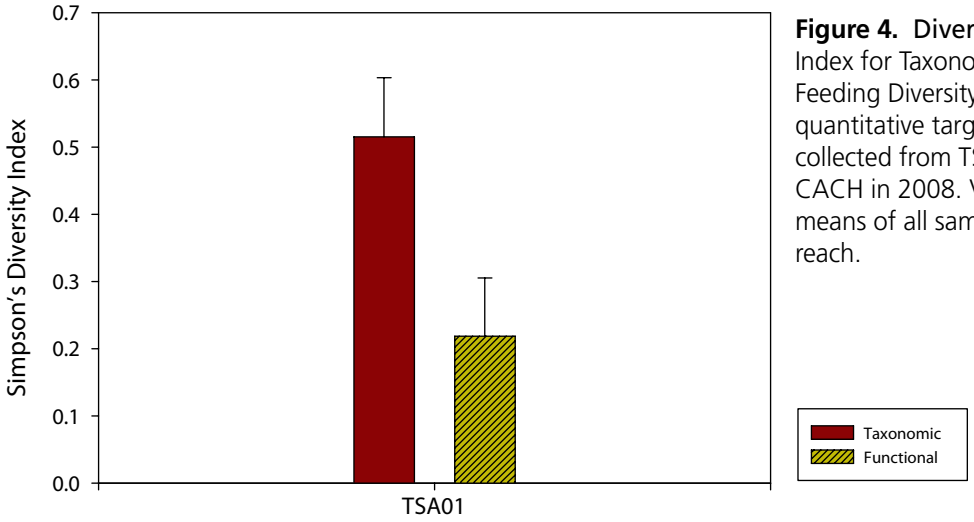


Figure 4. Diversity. Simpson's Diversity Index for Taxonomic (red) and Functional Feeding Diversity (green) calculated for quantitative targeted habitat samples collected from TSA01 in Tsaile Creek at CACH in 2008. Values expressed are means of all samples collected from the reach.

3 Results

3.1 Summary of Aquatic Macroinvertebrate Community Data

Table 1 presents data describing aquatic macroinvertebrate communities from samples collected in 2008 at the TSA01 sampling reach on Tsaile Creek in Canyon de Chelly National Monument. A summary of metrics describing these data can be found in Appendix C. All tables and figures listed in this section refer to data collected from quantitative targeted riffle habitat unless otherwise noted.

Abundance. Mean abundance was relatively high at 311.80 individuals per quantitative targeted riffle habitat.

Richness. Taxa richness was higher in the qualitative sample than in the quantitative samples. Taxa richness for the qualitative sample was 20.00 taxa. Mean taxa richness for our quantitative samples was 11.60 (fig. 3).

Diversity. Taxonomic diversity as calculated by the Simpson's Diversity Index was 0.51, and functional diversity was considerably lower at 0.22 (fig. 4).

Tolerant taxa. Twenty-seven percent of the individuals collected were classified as tolerant, and tolerant taxa made up 37% of all taxa collected. Moderately tolerant taxa were the most abundant (72 %) and taxa rich (54%) of any tolerance classification. We collected very few intolerant individuals (0.45%) and richness for intolerant taxa was (8.68%) (fig. 5).

EPT taxa. Relative abundance of EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa was extremely low—1.2% of the individuals collected in the sample. Ephemeroptera (mayflies) made up 0.36% and Trichoptera made up 0.86%. No Plecopterans (stoneflies) were present in the sample (fig. 6).

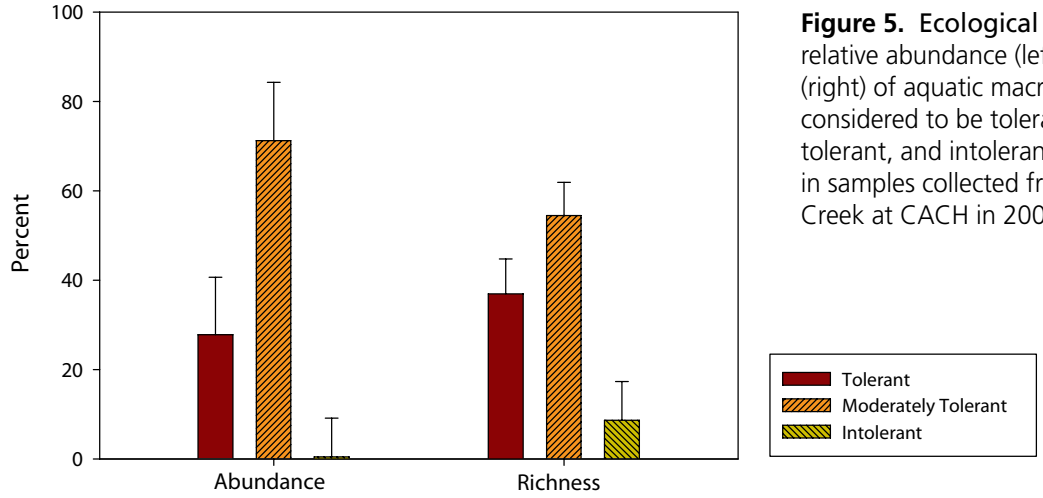


Figure 5. Ecological tolerance. Mean relative abundance (left) and richness (right) of aquatic macroinvertebrate taxa considered to be tolerant, moderately tolerant, and intolerant to perturbation in samples collected from TSA01 in Tsaile Creek at CACH in 2008.

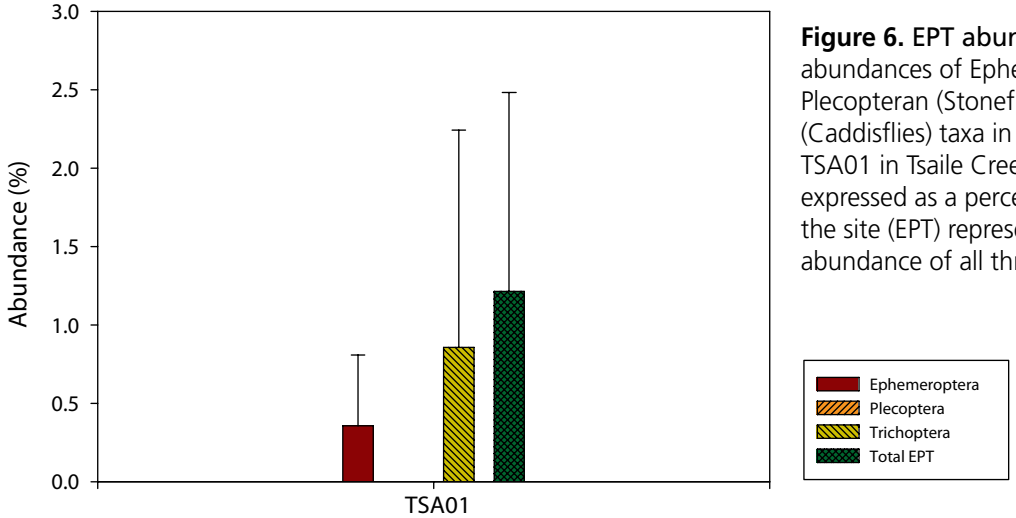


Figure 6. EPT abundance. Relative abundances of Ephemeropteran (Mayflies), Plecopteran (Stoneflies), and Trichopteran (Caddisflies) taxa in samples collected from TSA01 in Tsaile Creek at CACH in 2008, expressed as a percentage. The last bar for the site (EPT) represents the total relative abundance of all three orders.

Aquatic macroinvertebrate orders. Chironomids (midges) were the largest order (60%) of taxa in samples collected from Tsaile Creek in 2008. Odonates (dragonflies/damselflies) and non-Chironomid dipterans (flies) were the second largest groups, each making up 2% of the sampled taxa. Trichopterans (caddisflies) comprised one percent of the taxa, and Coleopterans (beetles) and Ephemeroptera both comprised less than one percent of the taxa collected. Thirty-four percent of the taxa collected belonged to orders outside of these major macroinvertebrate groups. The majority of these belonged to the orders Basommatophora and Amphipoda (fig. 7).

Functional feeding groups. Organisms belonging to the collector functional groups (gatherers and filter feeders) dominated the samples we collected from TSA01, comprising 90% of the functional taxa collected. Predators made up 28%, scrapers 11% and shredders 4% of the samples collected (fig. 8).

3.2 Summary of Physical Habitat Characteristics

Physical habitat data collected at one site (TSA01) on Tsaile Creek in Canyon de Chelly National Monument in 2008 are presented in Table 3. 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. Aquatic macroinvertebrate habitat cover represents point data (5 points/transect) across the entire reach. Reach characterization data represent the proportion of the reach characterized by that particular geomorphic channel unit (GCU).

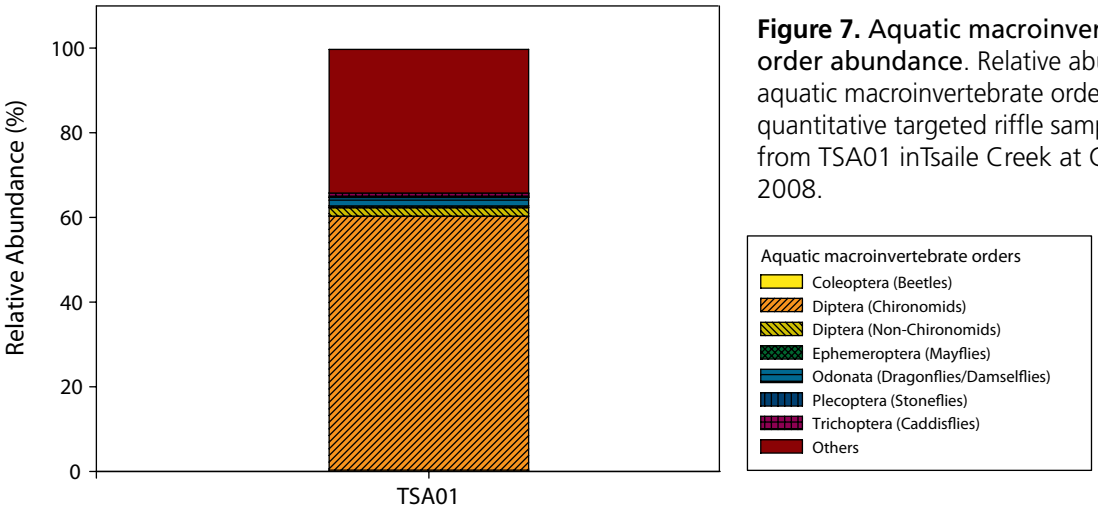


Figure 7. Aquatic macroinvertebrate order abundance. Relative abundance of aquatic macroinvertebrate orders found in quantitative targeted riffle samples collected from TSA01 inTsaile Creek at CACH in 2008.

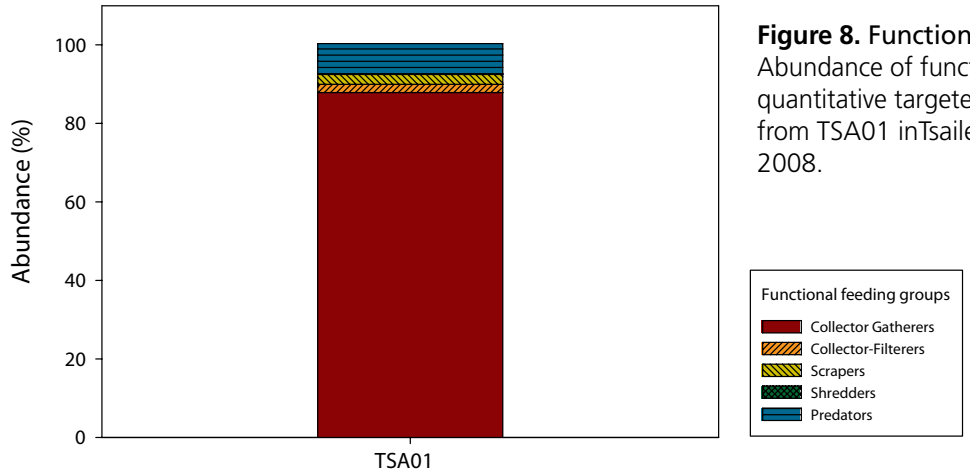


Figure 8. Functional group abundance. Abundance of functional feeding groups in quantitative targeted riffle samples collected from TSA01 inTsaile Creek at CACH in 2008.

Transect level. Mean velocity along each transect (channel dimension) and at each riffle (microhabitat) averaged 0.0 m/s. The active channel width was nearly double the wetted channel width along our sampling reach. Very little riparian cover (9.12%) existed along the sampling reach (table 3).

Channel structure dynamics are represented by particle-size distributions in Figure 9. Based on modified Wolman pebble counts, fine sediments were the dominant particle-size class in the sampling reach. Fine gravels in the 4-8 mm and 8-16 mm were the next most abundant size classes represented. No particles larger than cobble (64-128 mm) were present at our sampling reach.

Reach level. We found only two types of aquatic macroinvertebrate habitat structures along our sampling reach–44% of the reach was composed of vegetation and 42% was composed of rock. The remaining 14% of the reach lacked habitat suitable for aquatic macroinvertebrates ("No habitat" in fig. 10).

Four geomorphic channel units (GCU) occurred in our sampling reach in Tsaile Creek. Runs dominated the GCUs, making up 76% of the entire reach. Riffles were the next largest category of GCU at 17%, followed by dammed pools (5%) and scour pools (2%). For a complete description of GCUs see Brasher et al. (*in review*).

Table 2. Summary of physical habitat transect data for TSA01 in Tsaile Creek at CACH in 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 noon on the day of the sampling event.

	Mean	SD
Microhabitat level		
Riffles		
Velocity (m/s)	0.00	0.09
Depth (m)	0.07	0.02
Particle size (mm)	8.76	0.89
Embeddedness	10.44	7.57
Transect level		
Channel dimensions		
Velocity (m/s)	0.00	0.02
Depth (m)	0.18	0.10
Wetted channel (m)	2.73	1.16
Active channel (m)	5.58	1.23
Riparian cover		
Canopy closure	1.05	2.01
Reach level		
Water Quality		
Temperature (°C)	12.9	–
Specific conductivity (µS/cm)*	362	–
pH	8.2	–
Dissolved oxygen (% saturation)	108.7	–
Turbidity (NTU)**	19.9	–

* Microsiemens per cm
** Nephelometric Turbidity Units

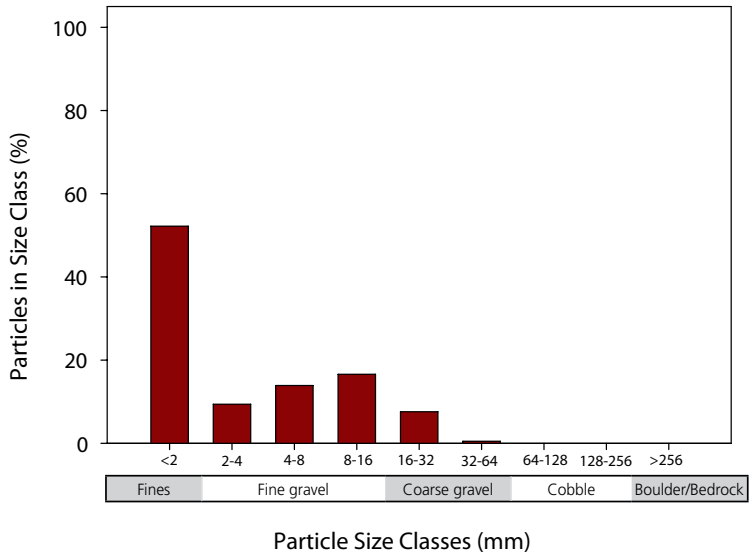


Figure 9. Channel surface substrate particle size distribution. Particle size distribution, based on the modified Wolman pebble counts, for the aquatic macroinvertebrate sampling reach at TSA01 in Tsaile Creek at CACH in 2008.

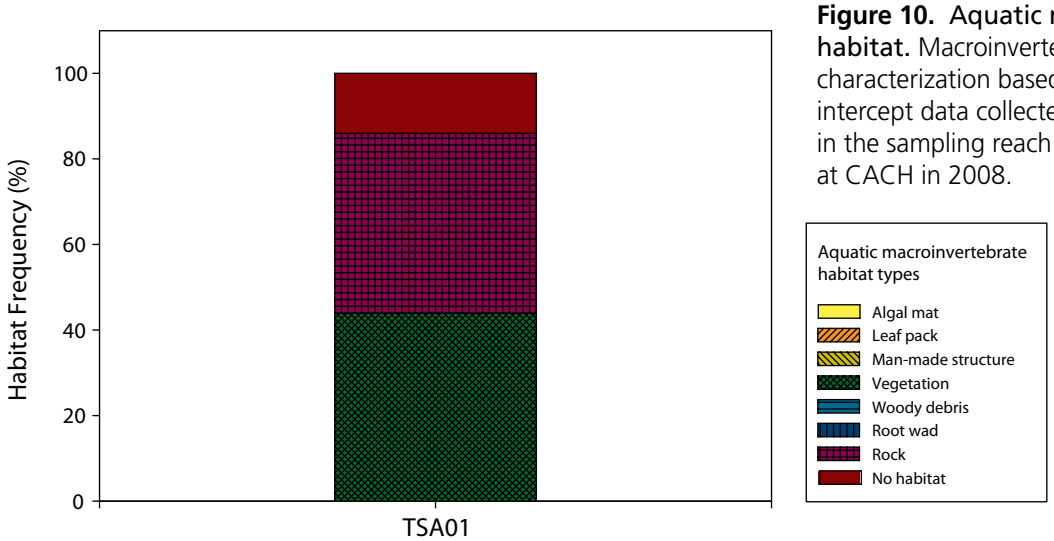


Figure 10. Aquatic macroinvertebrate habitat. Macroinvertebrate habitat characterization based upon line point intercept data collected from habitat transects in the sampling reach at TSA01 in Tsaile Creek at CACH in 2008.

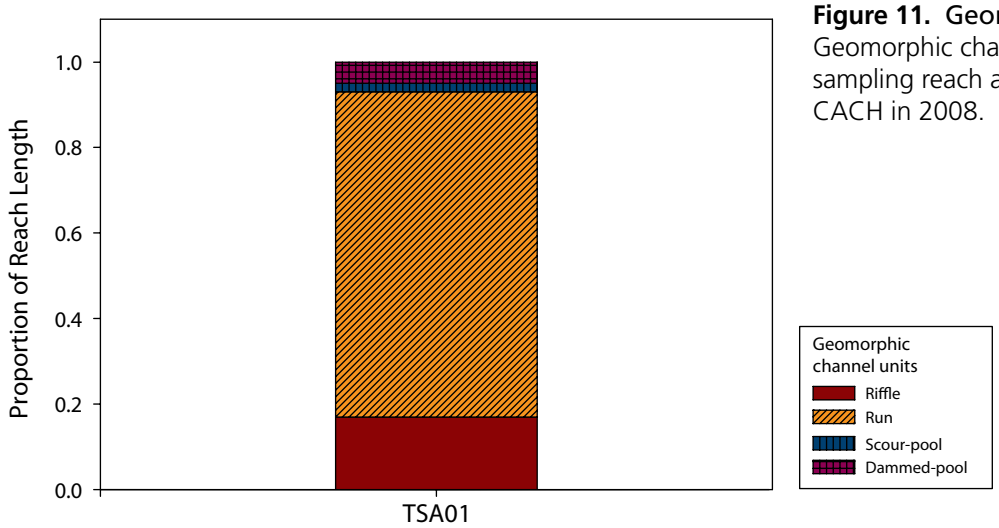


Figure 11. Geomorphic channel units. Geomorphic channel unit characterization of sampling reach at TSA01 in Tsaile Creek at CACH in 2008.

4 Discussion

Data included in this report represent SCPN's first year of monitoring aquatic macroinvertebrates and physical habitat at Tsaile Creek in Canyon de Chelly National Monument, Arizona.These data suggest that overall abundance of aquatic macroinvertebrates is relatively high and diversity is relatively low compared to other sites sampled by SCPN. Mean abundance for all quantitative samples was high, but the large standard deviation suggests that the mean was not representative of all samples.

Diversity at both the taxonomic and functional levels was low (table 1). Possible explanations for the low levels are the presence of non-native crayfish or the altered hydrologic regime. Crayfish have been shown to greatly reduce diversity and abundance of aquatic macroinvertebrate communities (Stenroth & Nyström 2003; Usio and Towsend 2004). In addition, crayfish are polytrophic, feeding at multiple trophic levels which may affect aquatic macroinvertebrates, not only through direct predation but by reducing available food resources as well.

Ecological tolerance describes how well a taxon tolerates disturbance. Aquatic macroinvertebrate taxa can be assigned tolerance values based on their ability to withstand pollution or environmental degradation. 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. We found very few taxa that were intolerant to disturbance in our samples from Tsaile Creek (fig. 5). These data suggest that the system may be undergoing some form of disturbance or stress.

The data in this report should be viewed as a snapshot of conditions existing within the aquatic community at the time of our visit. When sufficient data are available, SCPN plans to produce an interpretive report including trend analysis of macroinvertebrate metrics and physical habitat data for Tsaile Creek.

5 Literature Cited

Arizona Department of Environmental Quality, Water Quality Division (ADEQ-WQD). 2006. Biocriteria program, quality assurance program plan, revision E. 30 pp.

Barbour, M.T., J. Gerritsen, B. D.Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish 2d ed.: U.S. Environmental Protection Agency, Office of Water, Washington, D.C., EPA 841-B-99-002.

Brasher, A. M. D., C. M. Albano, M. L. Freeman, and R. N. Close. *In review*. Aquatic macroinvertebrate monitoring protocol for the Southern and Northern Colorado Plateau Networks of the National Park Service. Prepared for the Southern and Northern Colorado Plateau Networks. 213 pp.

Brasher, A. M. D., C. M. Albano, R. N. Close, and Q. H. Cannon. 2006. Pilot protocol implementation: report on macroinvertebrate communities and habitat characteristics in national parks of the Colorado Plateau. Prepared for the Southern and Northern Colorado Plateau Networks. 155 pp.

Griffith, M. B., B. H. Hill, F. H. McCormick, P. R. Kaufmann, A. T. Herlihy, and A. R. Selle. 2005. Comparative application of indices of biotic integrity, based on periphyton, macroinvertebrates, and fish, to southern Rocky Mountain streams. Ecological Indicators 5:117–136.

Natural Resources Conservation Service. 1996. Natural resources plan for Canyon del Muerto/ Tsaile Creek watershed (2nd draft). United States Department of Agriculture, Window Rock and Phoenix, Arizona.

Natural Resources Conservation Service. 2000. Natural resources plan Canyon del Muero/Tsaile Creek watershed. United States Department of Agriculture, Window Rock and Phoenix, Arizona.

Rydout, G. B. 1983. A statement on the operation of the Canyon de Chelly-del Muerto watershed with reference to recent geomorphological change in Canyon de Chelly National Monument, AZ. National Park Service Report. Chinle, Arizona.

Stenroth P., and P. Nyström. 2003. Exotic crayfish in a brown water stream: effects on juvenile trout, invertebrates and algae. Freshwater Biology 48: 466-477.

Thomas, L., M. Hendrie (ed.), C. Lauver, S. Monroe, N. Tancreto, S. Garman, and M. Miller. 2006. Vital signs monitoring plan for the Southern Colorado Plateau Network. Natural Resource Technical Report NPS/SCPN/NRR-2006/002. National Park Service, Omaha, Nebraska.

Trammel, M. 2008. Fish and water quality sampling in Canyon de Chelly NM. National Park Service Unpublished Report, Denver, Colorado.

Usio, N., and C. R. Townsend. 2004. Roles of crayfish: consequences of predation and bioturbation for stream invertebrates. *Ecology* **85**: 807-822.

Vieira, N. K. M, W. H. Clements, L. S. Guevara, and B. F. Jacobs. 2004. Resistance and resilience of stream insect communities to repeated hydrologic disturbances after a wildfire. Freshwater Biology 49:1243-1259.

Appendix A. Monitoring site codes, names, and location information for Canyon de Chelly National Monument

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)
CACHTSA01	*Tsaile Creek below Tsaile Dam*	TSA01	660576	4015393	2125

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 aquatic 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.
	Hydroptilidae+ Hydropsychidae:	Percent of Trichopteran individuals in Hydroptilidae plus Hydropsychidae (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 TSA01 in Tsaile Creek at CACH in 2008

Phylum	Class	Order	Suborder	Family	Genus	species	Common Names
Annelida	Clitellata						segmented worms
Arthropoda	Insecta	Coleoptera		Curculionidae			snout and bark beetles
Arthropoda	Insecta	Coleoptera	Adephaga	Dytiscidae			predacious diving beetles
Arthropoda	Insecta	Coleoptera	Adephaga	Dytiscidae	*Agabus*		predacious diving beetles
Arthropoda	Insecta	Diptera		Ceratopogonidae	*Probezzia*		biting midges
Arthropoda	Insecta	Diptera		Culicidae	*Anopheles*		mosquitoes
Arthropoda	Insecta	Diptera	Brachycera	Stratiomyidae	*Caloparyphus*		soldier flies
Arthropoda	Insecta	Diptera	Nematocera	Chironomidae			midges
Arthropoda	Insecta	Diptera	Nematocera	Dixidae	*Dixa*		meniscus midges
Arthropoda	Insecta	Diptera	Nematocera	Simuliidae	*Simulium*		black flies
Arthropoda	Insecta	Diptera	Nematocera	Simuliidae	*Simulium*	*tuberosum group*	black flies
Arthropoda	Insecta	Diptera	Nematocera	Tipulidae			crane flies
Arthropoda	Insecta	Ephemeroptera	Pisciforma	Baetidae	*Callibaetis*		small minnow mayflies
Arthropoda	Insecta	Ephemeroptera	Pisciforma	Baetidae	*Fallceon*	*quilleri*	small minnow mayflies
Arthropoda	Insecta	Hemiptera	Heteroptera	Corixidae			water boatmen
Arthropoda	Insecta	Hemiptera	Heteroptera	Corixidae	*Sigara*		water boatmen
Arthropoda	Insecta	Hemiptera	Heteroptera	Gerridae			water striders
Arthropoda	Insecta	Odonata	Anisoptera	Aeshnidae			darners
Arthropoda	Insecta	Odonata	Zygoptera	Coenagrionidae			narrow-winged damselflies
Arthropoda	Insecta	Odonata	Zygoptera	Coenagrionidae	*Argia*		narrow-winged damselflies
Arthropoda	Insecta	Trichoptera		Hydropsychidae	*Cheumatopsyche*		netspinning caddisflies
Arthropoda	Insecta	Trichoptera		Hydroptilidae			purse case maker caddisfly
Arthropoda	Insecta	Trichoptera		Limnephilidae			northern caddisflies
Arthropoda	Malacostraca	Amphipoda	Gammaridea	Hyalellidae	*Hyalella*		gammarid amphipods
Arthropoda	Malacostraca	Decapoda	Pleocyemata	Cambaridae			crayfish
Mollusca	Bivalvia	Veneroida		Lymnaeidae	*Lymnaea*		great pond snails
Mollusca	Bivalvia	Veneroida		Physidae	*Physa*		bladder snails
Mollusca	Gastropoda	Basommatophora		Physidae	*Physa*		bladder snails
Mollusca	Gastropoda	Basommatophora		Pisidiidae	*Pisidium*		bladder snails
Mollusca	Gastropoda	Basommatophora		Planorbidae	*Gyraulus*		ramshorn snails

Appendix D. Physical habitat data collected from TSA01 in Tsaile Creek at CACH in 2008

	Velocity (m/s)		Depth (m)		Wetted channel (m)	Active channel (m)
Transect	**Mean**	**SD**	**Mean**	**SD**		
1	0.01	0.01	0.18	0.08	1.90	5.50
2	<0.01	<0.01	0.13	0.06	3.30	4.80
3	0.01	0.01	0.12	0.04	1.80	5.60
4	<0.01	<0.01	0.26	0.15	4.85	6.10
5	-0.05	0.11	0.09	0.02	1.58	8.18
6	0.01	0.02	0.11	0.02	1.41	6.76
7	<0.01	<0.01	0.08	0.05	2.01	4.97
8	-0.02	0.06	0.18	0.05	2.96	3.79
9	0.02	0.04	0.36	0.22	3.92	5.50
10	<0.01	0.01	0.33	0.08	3.55	4.60

Microhabitat	Velocity (m/s)	Depth (m)
1	-0.09	0.05
2	0.12	0.08
3	-0.10	0.09
4	0.004	0.06
5	0.07	0.07