Western North American Naturalist 63(1), ©2003, pp. 21–34

BENTHIC INSECT FAUNA OF A CLEAN-WATER STREAM ON UTAH'S COLORADO PLATEAU, USA

C.A. Brammer[1] and J.F. MacDonald[2]

ABSTRACT.—Extensive collecting using a variety of methods was conducted in 1994 and 1995 in association with Pleasant Creek in south central Utah, USA, in an effort to inventory the aquatic insects. Collecting efforts yielded 133 insect taxa from 12 sample sites in 8 study areas from near the headwaters of Pleasant Creek and downstream to where it flows out of Capitol Reef National Park. Applying Protocol III methodology of Plafkin et al. (1989), we determined species assemblages of benthic insects and calculated selected ecological indices based on monthly collections from March through August 1994. Richness, equitability index, and mean diversity index values at all sample sites approached, or were greater than, the generally accepted values for clean-water streams in the mountains of the western United States.

Key words: benthic insects, faunistic inventory, species assemblages, Capitol Reef National Park, Utah.

This study reports on the insect fauna of Pleasant Creek, a perennial stream flowing through Capitol Reef National Park that terminates in the Fremont River in south central Utah, USA. Pleasant Creek is 1 of only 3 streams that flow through Capitol Reef National Park and the only one that appears to have experienced little degradation associated with the activities of humans and livestock.

One objective of our study was to inventory the aquatic insects associated with Pleasant Creek from near its headwaters and downstream to where it flows out of Capitol Reef National Park. Another objective applied at selected sample sites was to determine species assemblages of benthic insects and document dominant taxa.

STUDY STREAM

Pleasant Creek originates on Boulder Mountain in Garfield County, Utah, on an andesite formation known as the Aquarius Plateau, which ranges in altitude from about 3600 m to 3800 m. In wet years flow exists in meadows on top of the Aquarius Plateau and then cascades down a nearly vertical, 100–150 m escarpment. More substantial headwaters begin below the escarpment where several first-order streams join. Pleasant Creek is a first-order stream at the highest study area (2900–2920 m) and a third-order stream at the lowest study area (1630 m) where it flows out of Capitol Reef National Park, approximately 25 km from its source. The stream channel continues for about 5 km until it meets the Fremont River, but this lower reach of Pleasant Creek is dry much of the year due to draw-down for irrigation.

The upper reaches of Pleasant Creek flow through a mixed-coniferous forest, with nearly 100% canopy. The canopy begins to open at an altitude of about 2300 m and decreases steadily down to an altitude of about 2000 m where the stream is completely exposed to direct sunlight, except for limited stretches where steep canyon walls provide partial shade. Starting at an altitude of approximately 2500 m, Pleasant Creek largely is confined within a steep-walled canyon carved into Mesozoic sedimentary strata. Over most of its course, Pleasant Creek ranges from 2 m to 4 m in width and 0.5 m to 1.0 m in depth.

Pleasant Creek has not experienced modifications by humans great enough to alter its permanency or flow regime, except immediately downstream from the east boundary of Capitol Reef National Park. In this downstream stretch, nearly the entire flow is diverted for use by ranchers who acquired water rights in the late 1800s or early 1900s. The only upstream modification occurs approximately 5.5 km below the headwaters and just upstream from Utah State Highway 12. Here, Pleasant Creek

[1]Department of Biology, Utah State University, Logan, UT 84322.
[2]Department of Entomology, Purdue University, West Lafayette, IN 47907.

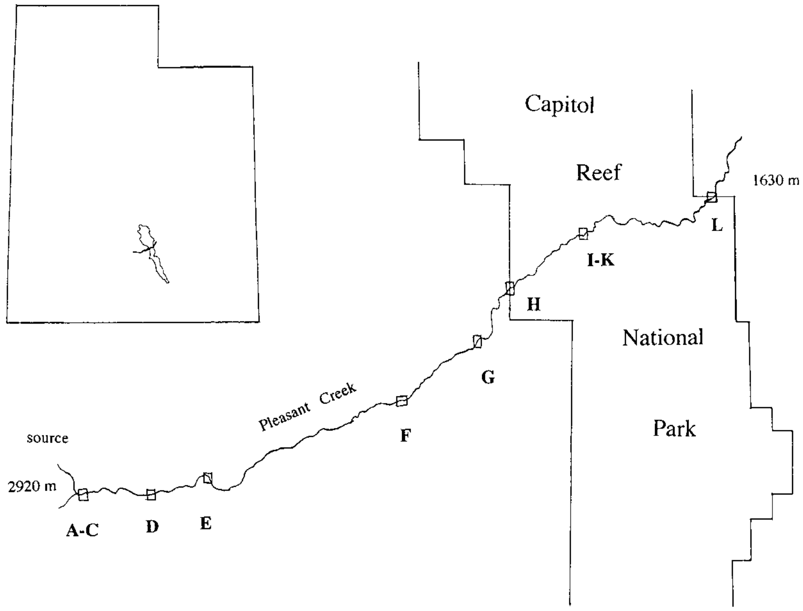

Fig. 1. Locations of 8 study areas and 12 sample sites on Pleasant Creek, Utah, USA.

is diverted into a channel constructed in 1903 and 1904, from which a relatively small volume is directed into a man-made reservoir. Below this diversion the vast majority of Pleasant Creek flow is returned to its original streambed.

Other potentially adverse influences on Pleasant Creek include the harvesting of isolated sections of coniferous forest at higher altitudes and removal of expansive stands of pinyon/juniper forest above the stream channel upstream from Capitol Reef National Park. Cattle constitute another impact, with approximately 300 head being driven up Pleasant Creek early each spring to grazing land on Boulder Mountain and then driven down in late summer. Erosion and siltation have not occurred, however, and riparian vegetation along Pleasant Creek in Capitol Reef National Park has been categorized as "largely unaltered," consisting almost exclusively of native species (Barth and McCullough 1988).

METHODS

We established 8 study areas along a 25-km course of Pleasant Creek, from approximately 3 km below its headwaters on Boulder Mountain to immediately upstream from the east boundary of Capitol Reef National Park (Fig. 1). Each study area is a discrete region of the stream in which we collected insects in the water and adults just above and along the banks. Twelve sample sites were established, each of which, designated by a capital letter, includes an extensive stretch of riffle zone in which we collected benthic insects in accordance with Protocol III sampling of Plafkin et al. (1989; see below). One study area near the headwaters includes 3 sample sites (A–C) but was collected only once, in August 1995, when it was possible to reach this area. Another study area was established in a high-use location within Capitol Reef National Park and includes 3 sample sites (I–K). All other study areas include 1 sample site. Study areas and sample sites with their approximate altitudes (Fig. 2) include the following: A–C (2920–2900 m), D (2820 m), E (2680 m), F (2120 m), G (2000 m), H (1900 m), I–K (1770 m), and L (1630 m). Collections at all sample sites except A–C and D were made at least at approximately monthly intervals from late March through mid-August 1994. A more precise sampling interval for all sites was not possible due to logistics, including long distances between study areas, most of which involved a 4-wheel drive or hiking (A–C, D, F, G, H, and L). Snow at higher altitudes and

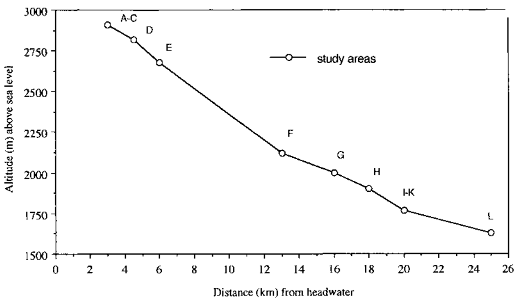

Fig. 2. Locations and approximate altitudes of study areas and sample sites on Pleasant Creek: A–C (2920–2900 m), D (2820 m), E (2680 m), F (2120 m), G (2000 m), H (1900 m), I–K (1770 m), and L (1630 m).

muddy roads at times precluded or delayed access to several study areas in 1994. All sample sites were sampled at least once in August 1995, with sample sites I–K also sampled once in March 1995 and once in June 1995.

Protocol III methodology prescribed by Plafkin et al. (1989) was adopted as the primary sampling procedure in compliance with requests from resource management specialists at Capitol Reef National Park. This approach to collecting benthic insects employs a kick-net constructed of window screen (1-mm^2 mesh) placed within a riffle run, above which approximately 1 m^2 of substrate is displaced by foot. Where possible, substrate consisting primarily of gravel and cobble was selected, but sample sites at higher altitudes involving faster current tended to include eroded substrate consisting mostly of large cobble and small boulders. Based on parameters presented in appendix A-1 of Barbour et al. (1999), sample sites A–C, D, E, and F included approximately 50% boulders/50% cobble; sample sites G–H approximately 30% boulders/60% cobble/10% gravel-sand; and sample sites I–K and L approximately 10% boulders/60% cobble/30% gravel-sand.

Preliminary assessment of collections made during the process of selecting study areas in 1994 suggested that a modification of Protocol III methodology (Plafkin et al. 1989) would result in more uniform sampling with little additional effort. Therefore, instead of a single kick-net sample, we took 3 samples in 3 different portions of a riffle, working upstream. Collected specimens from the 3 kick-net samples were pooled in the field, large debris removed, and specimens placed in a zip-type bag. Each bag was placed in a cold chest for transport to the lab, where live specimens were removed and preserved in 70% ethyl alcohol.

Supplemental collecting also was conducted in each study area following the collection of Protocol III samples. Implemented in an effort to inventory the entire stream, supplementary collecting included displacing the substrate in the following habitats: along sides of the streambed that were partially undercut, in depositional zones, and immediately downstream from large boulders that were displaced by hand. Supplemental collecting also involved using kick-nets of small mesh (0.5 mm^2) in all habitats plus picking specimens off small boulders and driftwood removed from the water.

Malaise traps (available from BioQuip Products, bioquip@aol.com) based on the design of Townes (1962) were positioned across or along Pleasant Creek adjacent to 3 sample sites (D, G, and I) from late March to mid-August 1994. We removed specimens from alcohol reservoirs in the traps at approximately monthly intervals. Adult insects also were collected in 1994 and 1995 by sweeping streamside vegetation and by mouth-aspiration of specimens found on rock surfaces of stream banks and on emergent rocks in Pleasant Creek.

Using North American faunal keys (Baumann et al. 1977, Edmunds et al. 1976, Merritt and Cummins 1996, Stewart and Stark 1993, Wiggins 1977, 1996), we sorted to genus the larvae and adults of nearly all taxa. When possible, specimens were identified to species using regional references and specialized keys. Representative specimens of genera and species were sent to various authorities for verification of identification and nomenclature, all of whom are listed in the acknowledgments. Voucher specimens are deposited in the Purdue University Entomological Research Collection, West Lafayette, Indiana, USA.

Calculations

Subsets of the pooled Protocol III samples were used to obtain an unbiased estimate of the percent composition of taxa in each Protocol III sample, based on a procedure presented by Hilsenhoff (1987). All specimens in a subset were identified to species if possible, with undetermined species within a genus being coded and treated as "operational taxonomic units" (OTUs). The subset process was repeated 3 times for each Protocol III sample and an average value determined for each species and OTU. These values were the basis for determining assemblages and calculating indices.

We calculated richness, Shannon-Wiener diversity index (Shannon and Weaver 1963), and evenness or equitability (Klemm et al. 1990) for each Protocol III sample. These data were selected as measures of the benthic insect fauna of Pleasant Creek to provide baseline data, to provide data for comparisons with similar streams, and to provide data for use in future bioassessment. Richness represents the number of species and OTUs present at a sample site. The Shannon-Wiener diversity index is a method of assembling data into an indicator value which potentially can be used for comparative purposes, although its value has been questioned (e.g., Washington 1984). Evenness or equitability is an indicator of how evenly individuals of different taxa are distributed with respect to numbers of species.

RESULTS AND DISCUSSION

Inventory

The inventory of aquatic insects collected by Protocol III sampling and supplementary collecting in Pleasant Creek totaled 133 OTUs, primarily larvae, with 44 identified to species and the remainder identified to genus, except for certain taxa of Diptera (Table 1). Adults of 52 species were collected in Malaise traps, in streamside vegetation, and from rock surfaces associated with Pleasant Creek, including 21 species of Trichoptera, 15 species of Plecoptera, 6 species of Coleoptera, and 10 species of Diptera (Table 2). We were unable to identify adults of Diptera to species, except for Empididae (determined by JFM). Species identification of Ephemeroptera captured in Malaise traps was not possible because all specimens were subimagos.

Individuals of 123 taxa were captured in Protocol III samples. The 10 taxa not represented in Protocol III samples were larvae captured during supplemental collecting in habitats that included cutbanks and woody debris submerged along the stream bank. Only 3 species collected in Protocol III samples were not captured in supplementary samples: *Bibiocephala* sp., *Allognosta* sp., and *Oligophlebodes* sp.

Relatively few taxa were collected in Protocol III samples at all study areas: *Epeorus longimanus, Ephemerella* sp., *Bezzia* sp., and *Metachela* sp. and/or *Neoplasta* spp. Two species of *Ephemerella, E. infrequens* and *E. inermis,* are known to exist in the region, but larvae could not accurately be separated at the time of our analyses. Larvae of *E. infrequens* generally occur at higher elevations and larvae of *E. inermis* at lower elevations, with the latter being more likely to exist in Pleasant Creek (W.P. McCafferty personal communication). Larvae of *Metachela* and *Neoplasta* now have been differentiated (MacDonald and Harkrider 1999), but this was not possible during analyses of Protocol III samples. Larvae of both genera now are known to occur in all sample sites.

Larvae of 21 taxa were collected at only 1 study area and 7 were collected in a single sample. Those of *Heptagenia elegantula* may represent an incorrect identification as they resemble the more commonly collected larvae of *H. solitaria* (McCafferty et al. 1993). A larva of *Ameletus* sp., tentatively identified as *A. velox*, was captured in an early supplemental sample, but it was not taken in any subsequent collection. Larvae of *Oligophlebodes* sp., *Psychoglypha* sp., *Laccobius* sp., *Nemotelus* sp., and *Tabanus* sp. also were collected only once. Larvae of the remaining 14 taxa collected at 1 study area were taken in more than one Protocol III sample. Those identified as *Alisotrichia* sp. have not been verified, but representatives of this genus have been reported from Utah (Flint 1970). Beetle adults representing 2 genera of Hydrophilidae may have flown in from another aquatic habitat since larvae of these genera were not collected in Pleasant Creek. Other taxa reported from only a single study area, but taken in more than one Protocol III sample, include *Taenionema pallidum, Hydroptila* sp., *Leucotrichia* sp., *Hesperophylax* sp., *Allognosta* sp., *Limonia* sp., *Limonia* cf. *defuncta, Ormosia* sp., *Pedicia* sp., *Bibiocephala* sp., and *Trichoclinocera* sp.

Relative Abundance of Taxa

Combined relative abundance of ordinal level taxa in Protocol III samples in 1994 and 1995 is shown in Figure 3. Larvae of Ephemeroptera accounted for over 40% of individuals at all sample sites. Based on numbers of individuals, Ephemeroptera was the dominant

TABLE 1. Inventory of insects in Pleasant Creek, Utah, based on Protocol III samples (Plafkin et al. 1989) and supplemental collecting in Pleasant Creek. See Methods and Figure 2 for details pertaining to altitudes. x = lavae; * = adults.

Study areas	A–B	C	D	E	F	G	H	I–K	L
Ephemeroptera									
AMELETIDAE									
Ameletus sparsatus	x	x	x	x	x				
Ameletus velox				x					
BAETIDAE									
Acentrella insignificans								x	x
Baetis bicaudatus	x	x	x	x	x	x	x		
Baetis notos								x	x
Baetis tricaudatus					x	x	x	x	x
Fallceon quilleri					x			x	
Pseudocloeon apache								x	x
EPHEMERELLIDAE									
Drunella coloradensis	x	x	x	x					
Drunella doddsi		x	x	x	x				
Drunella grandis					x	x	x	x	
Ephemerella sp.	x	x	x	x	x	x	x	x	x
HEPTAGENIIDAE									
Cinygmula sp.	x	x	x	x	x	x	x		
Epeorus longimanus	x	x	x	x	x	x	x	x	x
Heptagenia elegantula								x	
Heptagenia solitaria							x	x	x
Rhithrogena robustus			x	x					
Rhithrogena sp.					x	x	x	x	x
LEPTOHYPHIDAE									
Tricorythodes minutus							x	x	x
LEPTOPHLEBIIDAE									
Choroterpes inornata							x	x	
Paraleptophlebia debilis				x	x	x	x	x	x
Paraleptophlebia memorialis					x			x	
Paraleptophlebia vaciva					x	x	x	x	
Odonata									
CALOPTERYGIDAE									
Hetaerina americana								x	x
COENAGRIONIDAE									
Argia vivida								x	x
GOMPHIDAE									
Ophiogomphus severus						x	x	x	x
Hemiptera									
NAUCORIDAE									
Ambrysus sp.									x
Cryphocricos sp.							x	x	x
NOTONECTIDAE									
Notonecta sp.					x				
Plecoptera									
CAPNIIDAE									
Capnia sp.					x		x	x	
CHLOROPERLIDAE									
Plumiperla diversa	x	x	x	x					
Suwallia sp.			x	x	x	x	x	x	
Sweltsa sp.	x	x	x	x	x	x	x		
LEUCTRIDAE									
Paraleuctra sp.	x	x	x	x					
Perlomyia sp.			x	x					
NEMOURIDAE									
Amphinemura sp.				x	x	x	x	x	
Malenka sp.	x	x	x						
Prostoia besametsa			x	x					
Zapada haysi	x	x	x	x					
PERLIDAE									
Hesperoperla pacifica					x	x	x	x	

TABLE 1. Continued.

Study areas	A–B	C	D	E	F	G	H	I–K	L
PERLODIDAE									
Isogenoides zionensis						x	x	x	x
Isoperla sp.	x	x	x	x	x	x	x	x	
Megarcys signata	x	x	x	x	x				
PTERONARCYIDAE									
Pteronarcella badia				x	x	x	x	x	x
TAENIOPTERYGIDAE									
Taenionema pallidum			x	x					
Taenionema sp.							x	x	
Trichoptera									
BRACHYCENTRIDAE									
Brachycentrus americanus				x	x	x	x	x	x
Micrasema bactro			x	x	x	x		x	
Micrasema onisca			x	x	x	x	x	x	x
GLOSSOSOMATIDAE									
Glossosoma spp.				x	x				
HELICOPSYCHIDAE									
Helicopsyche sp.								x	x
HYDROPSYCHIDAE									
Arctopsyche sp.			x	x	x				
Ceratopsyche sp.				x	x	x	x	x	x
Hydropsyche sp.								x	x
HYDROPTILIDAE									
Alisotrichia sp.?								x	
Hydroptila sp.								x	
Leucotrichia sp.								x	
Ochrotrichia spp.						x	x	x	x
LEPIDOSTOMATIDAE									
Lepidostoma sp.			x	x	x	x	x	x	
LEPTOCERIDAE									
Triaenodes sp.								x	x
LIMNEPHILIDAE									
Amphicosmoecus canax				x	x	x	x	x	
Chyranda centralis			x	x					
Hesperophylax sp.								x	
Limnephilus sp.		x	x					x	
Onocosmoecus sp.	x						x	x	
Psychoglypha sp.				x					
PHILOPOTAMIDAE									
Dolophilodes sp.			x	x					
RHYACOPHILIDAE									
Rhyacophila angelita	x	x	x	x	x				
Rhyacophila brunnea	x	x	x	x	x	x	x		
Rhyacophila coloradensis			x	x		x			
Rhyacophila harmstoni	x	x	x	x	x	x			
UENOIDAE									
Neothremma sp.	x	x	x	x	x	x	x		
Oligophlebodes sp.					x				
Coleoptera									
DRYOPIDAE									
Helichus striatus						*	*	*	*
DYTISCIDAE									
Agabus sp.								x	*
ELMIDAE									
Cleptelmis ornata					x*	x*			
Heterlimnius corpulentus		x*	x*	x*	x*	x	*	x*	
Microcylloepus pusillus similis							*	*	x*
Narpus concolor					x*	x*	x		
Optioservus quadrimaculatus					x*	x*	x*	x*	x*
HALIPLIDAE									
Peltodytes sp.					*		*		

TABLE 1. Continued.

Study areas	A–B	C	D	E	F	G	H	I–K	L
HYDROPHILIDAE									
Berosus sp.								*	
Hydrobiomorpha sp.					x		x	x	
Hydrobius sp.					*				
Hydrophilus sp.								*	
Laccobius sp.								x	
Diptera									
ATHERICIDAE									
Atherix pachypus							x	x	x
BLEPHARICERIDAE									
Bibiocephala sp.				x					
CERATOPOGONIDAE									
Bezzia sp.	x	x	x	x	x	x	x	x	x
CHIRONOMIDAE									
CHIRONOMINAE									
Chironomini	x						x	x	x
Demicryptochironomus sp.									x
Polypedilum sp.								x	x
Pseudochironomus sp.								x	x
Rheotanytarsus sp.	x	x						x	x
Tanytarsini			x	x	x	x	x	x	
DIAMESINAE									
Diamesinae	x	x		x	x	x	x	x	x
Pagastia sp.			x						
ORTHOCLADIINAE									
Cardiocladius sp.	x	x						x	
Cricotopus sp.								x	
Eukiefferiella sp.		x				x		x	x
Lopescladius sp.								x	x
Orthocladius sp.								x	
Orthocladiinae	x	x	x	x	x	x	x	x	
TANYPODINAE									
Conchapelopia sp.								x	x
Meropelopia sp.				x			x		
Thienemannimyia complex									x
DIXIDAE									
Dixa sp.	x		x					x	
EMPIDIDAE									
Hemerodromia sp.						x	x	x	x
Metachela/Neoplasta spp.		x	x	x	x	x	x	x	x
Oreogeton sp.		x	x	x	x	x	x		
Roederoides sp.								x	
Trichoclinocera sp.								x	
Wiedemannia sp.							x	x	
PSYCHODIDAE									
Pericoma sp.			x	x	x	x			
SIMULIIDAE									
Prosimulium sp.	x	x	x	x	x	x	x	x	
Simulium spp.			x	x	x	x	x	x	x
STRATIOMYIDAE									
Allognosta sp.								x	
Caloparyphus sp.							x	x	
Nemotelus sp.								x	
TABANIDAE									
Tabanus sp.								x	

TABLE 1. Continued.

Study areas	A–B	C	D	E	F	G	H	I–K	L
TIPULIDAE									
Antocha monticola				x	x	x	x	x	x
Dicranota sp.			x	x	x	x	x	x	x
Gonomyia sp.					x			x	
Hesperoconopa sp.					x	x	x		
Hexatoma sp.					x	x	x	x	x
Limnophila sp.	x	x			x	x			
Limonia sp.								x	
Limonia cf. *defuncta*								x	
Ormosia (*Scleroprocta*) sp.					x				
Pedicia sp.					x				
Rhabdomastix cf. *trichophora* group								x	x
Tipula (*Beringotipula*) sp.					x		x	x	
Tipula (*Sinotipula*) cf. *commiscibilis* group		x			x			x	

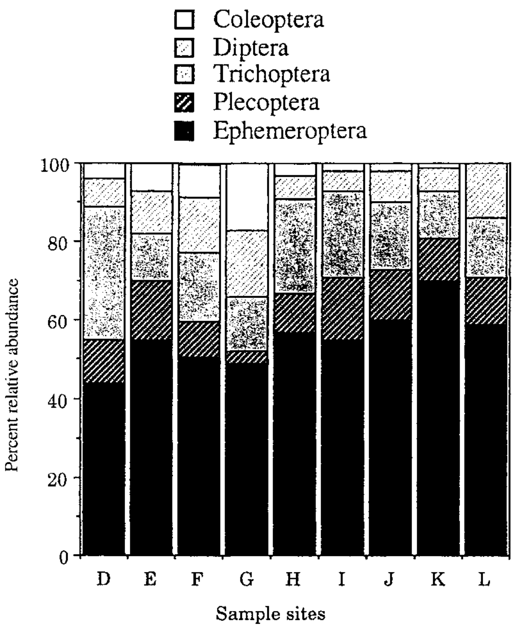

Fig. 3. Relative abundance of insect orders based on Protocol III samples (Plafkin et al. 1989) for 1994 and 1995.

taxon except at sample site D (2820 m) where Trichoptera were nearly as numerous. Larvae of Trichoptera, Plecoptera, or Diptera tended to be the next most abundant at all other sample sites except G (2000 m), where larvae and adults of Coleoptera were nearly as numerous.

A given order in a sample tended to be heavily represented by only one or a few species, one or more of which potentially could serve as indicator taxa at a specific collecting site. The 5 most abundant taxa at each sample site are presented in Tables 3 and 4, but data on the relative percentage of all taxa at all sample sites are available upon request. Only a single collection was possible at sample sites A–C (2920–2900 m), on 10 August 1995, due to travel restrictions in 1994. *Baetis bicaudatus, Cinygmula* sp., *Drunella coloradensis*, and *Neothremma alicia* were abundant at all sample sites.

Richness, Diversity, and Equitability

Protocol III samples provided the basis for calculating richness, diversity, and equitability, with values at all study areas summarized in Tables 5 and 6. It was not possible to conduct an equal number of samples at all study areas due to differences in accessibility and emphasis on more frequent sampling at the 3 sample sites in study area I–K within Capitol Reef National Park. Accordingly, although data on numbers of taxa collected may be indicative of richness, they cannot be used to compare one study area with another. However, total taxa, range in taxa, and mean number of taxa collected per sample suggest relative richness at all sample sites (Fig. 4).

Mean diversity values at all sample sites in 1994 ranged from 2.85 to 3.9 (Table 5). Such values approach or exceed the reference value of 3.0 considered by Wilhm (1970) and Wilhm and Dorris (1968) to be reflective of clean-water streams in the western United States. Even the low end of the range of diversity

TABLE 2. Species collected as adults in Malaise traps, in riparian vegetation, and on rock surfaces associated with Pleasant Creek in 1994 and 1995.

Plecoptera
- CAPNIIDAE
  - *Capnia confusa*
- CHLOROPERLIDAE
  - *Plumiperla diversa*
  - *Suwallia pallidula*
  - *Sweltsa coloradensis*
- LEUCTRIDAE
  - *Perlomyia utahensis*
- NEMOURIDAE
  - *Amphinemura mogollonica*
  - *Malenka coloradensis*
  - *Prostoia besametsa*
  - *Zapada haysi*
- PERLIDAE
  - *Hesperoperla pacifica*
- PERLODIDAE
  - *Isogenoides zionensis*
  - *Isoperla sobria*
  - *Megarcys signata*
- PTERONARCIDAE
  - *Pteronarcella badia*
- TAENIOPTERYGIDAE
  - *Taenionema pallidum*

Trichoptera
- BRACHYCENTRIDAE
  - *Brachycentrus americanus*
  - *Micrasema bactro*
  - *Micrasema onisca*
- GLOSSOSOMATIDAE
  - *Glossosoma ventrale*
  - *Glossosoma verdona*
- HYDROPSYCHIDAE
  - *Ceratopsyche oslari*
  - *Hydrospyche occidentalis*
- HYDROPTILIDAE
  - *Hydroptila rono*
  - *Leuchotrichia pictipes*
  - *Ochrotrichia logana*
  - *Ochrotrichia lometa*
  - *Ochrotrichia stylata*
- LEPIDOSTOMATIDAE
  - *Lepidostoma unicolor*
- LIMNEPHILIDAE
  - *Amphicosmoecus canax*
  - *Chyranda centralis*
- PHILOPOTAMIDAE
  - *Dolophilodes aequalis*
- RHYACOPHILIDAE
  - *Rhyacophila angelita*
  - *Rhyacophila brunnea*
  - *Rhyacophila coloradensis*
  - *Rhyacophila harmstoni*
- UENOIDAE
  - *Neothremma alicia*

Coleoptera
- DRYOPIDAE
  - *Helichus striatus*
- ELMIDAE
  - *Cleptelmis ornata*
  - *Heterlimnius corpulentis*
  - *Microcylloepus pusillus similis*
  - *Narpus concolor*
  - *Optioservus quadrimaculatus*

Diptera
- EMPIDIDAE
  - *Hemerodromia burdicki*
  - *Metachela collusor*
  - *Neoplasta concava*
  - *Neoplasta hansoni*
  - *Neoplasta octoterga*
  - *Neoplasta paramegorchis*
  - *Neoplasta scapularis*
  - *Oreogeton scopifer*
  - *Trichoclinocera dolicheretma*
  - *Wiedemannia undulata*

indices was near or above 3.0 at all sample sites except I–K (see below for a possible explanation). Mean equitability values for all sample sites in 1994 were between 0.52 and 0.77 (Table 5). Such values exceed the value of 0.5 generally considered to be reflective of clean-water streams (Klemm et al. 1990). Mean diversity indices (Fig. 5) and mean equitability values (Fig. 6) are greater at higher altitudes, decrease down to sample site H, remain relatively constant through sample sites I–K, but increase again at sample site L. Higher values at sample site L were not expected because the range of water temperatures was the greatest we measured and the area appeared to be the most heavily impacted by cattle. Higher diversity values at such a site may not be unusual, however, because total community diversity is theoretically greatest where temperature variations tend to be higher (Vannote et al. 1980) and increased organic input from cattle, below the point of detrimental eutrophication, may have facilitated increased richness (Denoncourt and Polk 1975).

As reported above, richness, diversity, and equitability values for all collection dates at individual sample sites were greater than the generally accepted values indicative of a clean-water stream, except for sample sites H and I–K where the range in values was greater than at all other sample sites. Lower values here may have been a consequence of a more dynamic

TABLE 3. Relative percentages of the 5 most abundant taxa in Protocol III samples (Plafkin et al. 1989) for 1994. See Methods and Figure 2 for details on collecting dates and locations of sample sites. Taxa listed at each sample site are arranged based on the sequence of taxa presented in Table 1.

	Early April	Late April	Late May/ early June	Early July	Early August	Mean; *s*
Sample site D						
B. bicaudatus	–	–	13.7	6.7	6.3	8.9; 4.2
D. coloradensis	–	–	3.3	10.7	6.3	6.8; 3.7
Cinygmula sp.	–	–	16.3	20.7	20.0	19.0; 2.4
R. brunnea	–	–	5.3	6.3	9.3	7.0; 2.1
Neothremma sp.	–	–	18.0	23.3	16.0	19.1; 3.8
Sample site E						
B. bicaudatus	7.7	12.0	38.7	5.7	11.3	15.1; 13.5
D. doddsi	7.3	12.7	13.3	13.7	2.7	9.9; 4.8
Cinygmula sp.	2.0	1.7	6.3	46.7	26.0	16.5; 19.6
T. pallidum	25.3	10.7	.3	0	0	7.3; 11.1
Heterlimnius sp.	2.0	4.3	8.7	3.0	8.0	5.2; 3.0
Sample site F						
Ephemerella sp.	8.0	17.3	6.3	0	1.0	6.5; 6.9
Cinygmula sp.	1.3	2.3	30.7	0	0	6.9; 13.4
E. longimanus	0	0	10.3	21.3	10.7	8.5; 8.9
Rhithrogena sp.	30.3	30.0	21.7	20.3	23.0	25.1; 4.7
Ceratopsyche sp.	9.3	3.7	1.7	17.0	5.3	7.4; 6.0
Sample site G						
B. tricaudatus	37.3	16.7	13.7	16.0	26.7	22.1; 9.9
D. grandis	18.3	9.0	14.3	2.7	9.0	10.7; 5.9
Ephemerella sp.	1.0	4.7	2.3	37.3	1.3	9.3; 15.7
Rhithrogena sp.	5.7	24.3	20.0	1.3	.7	10.4; 11.0
O. quadrimaculatus	.7	1.0	5.7	19.3	16.7	8.7; 8.8
Sample site H						
B. tricaudatus	50.7	15.0	18.7	31.3	31.3	29.4; 14.0
Ephemerella sp.	14.3	30.7	36.0	6.0	0	17.4; 15.5
Rhithrogena sp.	8.3	15.3	5.3	.7	.7	6.1; 6.1
I. zionensis	.7	1.3	.7	22.7	13.3	7.7; 9.9
Ceratopsyche sp.	6.7	13.0	8.7	23.3	32.7	16.9; 10.9
Sample site L						
B. tricaudatus	13.3	21.3	9.0	4.0	1.0	9.7; 8.0
Rhithrogena sp.	2.3	9.7	31.3	1.3	2.0	9.3; 12.8
T. minutus	0	0	0	49.0	18.7	13.5; 21.4
I. zionensis	30.3	19.3	.7	6.3	16.0	14.5; 11.5
Hydropsyche sp.	13.7	9.0	1.3	5.0	20.7	9.9; 7.6

streambed consisting of a shallow layer of gravel, cobble, and small boulders overlying bedrock. Periods of increased flow may have affected the establishment of the benthic insect fauna. This was especially true following a flash flood that occurred in these 2 study areas in October 1994. Protocol III sampling was not possible in October and December because kick-netting captured very few or no benthic insects (K. Berghoff personal communication). Protocol III sampling in sample sites I–K in March 1995 (by K. Berghoff) and in June 1995 revealed only partial reestablishment of the benthic insect fauna, and nearly complete reestablishment only having taken place by August 1995.

Two additional results of our study are worth emphasizing. Richness, diversity, and equitability values were lower across all sample sites during midsummer, presumably because much of the benthic insect fauna was represented by terrestrial adults, eggs, or very early larval instars, resulting in reduced number of specimens collected in kick-net samples. On the other hand, results of Protocol III sampling in 1994 (Table 5), 1995 (Table 6), and in follow-up sampling in 1997–1999 (unpublished observations) reveal a high degree of repeatability associated with the method, as suggested by similar richness, diversity, and equitability values at each sample site over these years.

TABLE 4. Relative percentages of the 5 most abundant taxa in Protocol III samples (Plafkin et al. 1989) at study area I-J-K for 1994. See Methods and Figure 2 for details on collecting dates and locations of sites. Taxa listed at each site are arranged based on the sequence of taxa presented in Table 1.

	March	April	May	June	July	August	Mean; *s*
Sample site I							
B. tricaudatus	41.5	13.5	12.5	25.4	9.5	4.0	17.7; 13.6
Ephemerella sp.	18.0	34.2	52.5	36.5	.2	0	23.6; 21.2
Rhithrogena sp.	4.5	5.5	10.2	3.5	5.4	5.7	5.8; 2.3
I. zionensis	7.9	4.2	6.7	11.0	18.0	27.2	12.5; 8.6
Ceratopsyche sp.	9.7	10.2	5.0	5.5	11.7	8.4	8.4; 2.7
Sample site J							
B. tricaudatus	25.4	10.2	12.5	22.5	9.2	2.2	13.7; 8.7
Ephemerella sp.	30.3	42.7	56.6	36.0	.4	0	27.7; 23.0
Rhithrogena sp.	10.2	15.7	13.5	5.5	8.9	8.2	10.3; 3.7
I. zionensis	11.7	4.4	4.5	10.2	28.5	18.4	13.0; 9.2
Ceratopsyche sp.	7.7	13.3	5.2	4.9	10.2	9.2	8.4; 3.2
Sample site K							
B. tricaudatus	47.7	21.4	12.0	19.0	12.3	2.9	19.2; 15.4
Ephemerella sp.	14.2	34.8	34.7	29.0	.5	0	18.9; 16.3
Rhithrogena sp.	12.2	23.4	33.7	22.9	11.2	7.7	18.5; 9.8
I. zionensis	4.0	2.7	2.2	10.2	22.1	25.7	11.2; 10.3
Ceratopsyche sp.	9.0	8.0	3.8	.8	12.3	13.2	7.9; 4.8

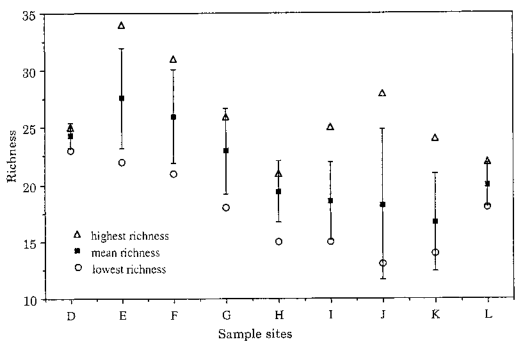

Fig. 4. Richness values with standard deviations based on Protocol III samples (Plafkin et al. 1989) for 1994.

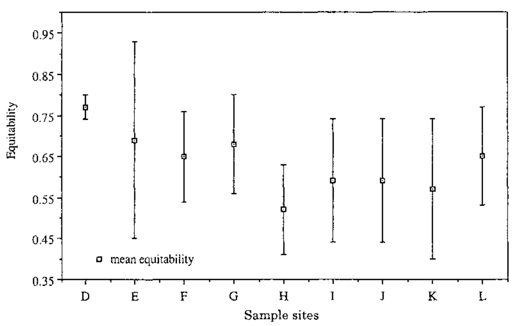

Fig. 6. Equitability index values with standard deviations based on Protocol III samples (Plafkin et al. 1989) for 1994.

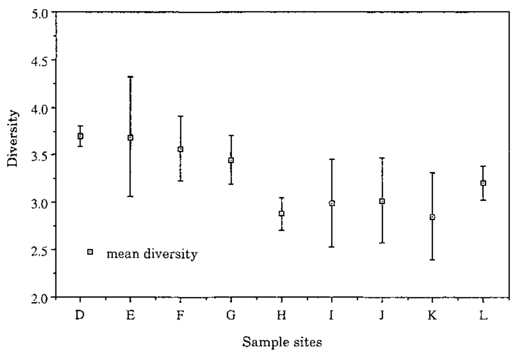

Fig. 5. Diversity index values with standard deviations based on Protocol III samples (Plafkin et al. 1989) for 1994.

CONCLUSIONS

Pleasant Creek supports a diverse benthic insect fauna of at least 133 taxa documented in this study, all represented by larvae with the exception of adults of several beetle species. In addition to the benthic taxa, adults representing 52 species were collected in association with Pleasant Creek in Malaise traps, in streamside vegetation, and on rock surfaces adjacent to or emerging from the stream. The results of our inventory are similar to those reported for other perennial streams of comparable size in the western United States that have not been heavily impacted by humans

TABLE 5. Summary of richness (= number of species and OTUs), diversity index (DI) values, and equitability index (EI) values based on Protocol III samples (Plafkin et al. 1989) for each site in 1994.

Sample sites	A	B	C	D	E	F	G	H	I	J	K	L
No. samples	–	–	–	3	5	5	5	5	12	12	12	5
Richness total	–	–	–	48	46	53	39	39	52	48	47	41
Richness range	–	–	–	23–25	22–34	21–31	18–26	15–21	15–25	13–28	14–24	18–22
Richness mean; *s*	–	–	–	24.3; 1.15	27.6; 4.39	26.0; 4.12	23.0; 3.74	19.4; 2.7	18.58; 3.42	18.25; 6.59	16.7; 4.29	20.0; 1.87
DI range	–	–	–	3.58–3.79	3.01–4.25	3.05–3.96	3.04–3.73	2.61–3.09	2.41–4.01	2.47–3.91	2.33–3.66	2.96–3.45
DI mean; *s*	–	–	–	3.7; .11	3.9; .63	3.57; .34	3.45; .26	2.88; .17	2.99; .47	3.02; .45	2.85; .46	3.21; .18
EI range	–	–	–	.74–.8	.5–.97	.52–.76	.54–.85	.40–.67	.40–.96	.43–.79	.40–1.0	.50–.83
EI mean; *s*	–	–	–	.77; .03	.69; .24	.65; .11	..68; .12	.52; .11	.59; .15	.59; .15	.57; .17	.65; .12

TABLE 6. Summary of richness (= number of species and OTUs), diversity index (DI) values, and equitability index (EI) values based on Protocol III samples (Plafkin et al. 1989) for 1995.

Sample sites	A	B	C	D	E	F	G	H	I	J	K	L
No. samples	1	1	1	1	1	1	1	1	3	3	3	1
Richness total	22	23	22	21	18	27	26	13	29	29	24	16
Richness range	–	–	–	–	–	–	–	–	13–20	14–19	11–15	–
Richness mean; *s*	22	23	22	21	18	27	26	13	16.3; 3.51	16.3; 2.52	12.3; 2.31	16
DI range	–	–	–	–	–	–	–	–	2.48–3.17	2.13–3.08	1.91–2.95	–
DI mean; *s*	3.41	2.87	3.21	3.47	2.97	3.91	3.44	2.26	2.74; .38	2.57; .48	2.27; .59	3.42
EI range	–	–	–	–	–	–	–	–	.44–.62	.35–.63	.36–.67	–
EI mean; *s*	.68	.43	.59	.76	.61	.81	.58	.46	.55; .10	.47; .14	.49; .16	.94

and cattle (e.g., Bruns and Minckley 1980, Gray 1981). The results of our Protocol III sampling and supplemental collections of benthic insects support the conclusion of Barth and McCullough (1988) that Pleasant Creek has not been adversely impacted by human activities or by cattle. Although our study did not directly show it, Pleasant Creek appears to be a good candidate as a reference stream based on relative richness of the benthic insect fauna, apparent absence of adverse impacts, and the protected status of the permanence of its flow through Capitol Reef National Park.

ACKNOWLEDGMENTS

Sandy Borthwick and Kevin Berghoff, former resource management specialists at Capitol Reef National Park, encouraged and facilitated this project. We are especially grateful to Kevin Berghoff for conducting Protocol III sampling in our absence in late 1994 and early 1995. The following individuals assisted in the identification of specimens and provided confirmations: Guenter A. Schuster, Eastern Kentucky University (Trichoptera); Harley P. Brown, University of Oklahoma (Coleoptera: Elmidae and Dryopidae); Richard W. Baumann, Brigham Young University (Plecoptera); Richard Merritt, Michigan State University (Diptera: Simuliidae); John Morse, Clemson University (Trichoptera: Brachycentridae); Peter Adler, Clemson University (Diptera: Simuliidae); Stamford Smith, Central Washington University (Trichoptera: Rhyacophilidae); John Gelhaus, Philadelphia Academy of Sciences (Diptera: Tipulidae); Michael Bolton, United States EPA, Ohio (Diptera: Chironomidae); Steven Harris, Clarion University (Trichoptera: Hydroptilidae); Arwin Provonsha, Purdue University (Odonata); and W.P. McCafferty and Carlos Lugo-Ortiz, Purdue University (Ephemeroptera). Research was supported by the Purdue University Agricultural Experiment Station, with this paper assigned journal number 16576.

LITERATURE CITED

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. 2nd edition. EPA 841-B-99-002. United States Environmental Protection Agency, Washington, DC.

BARTH, R.C., AND E.J. MCCULLOUGH. 1988. Livestock grazing impacts on riparian areas within Capitol Reef National Park. Final report prepared for National Park Service. Soil-Plant Systems, Golden, CO.

BAUMANN, R.W., A.R. GAUFIN, AND R.F. SURDICK. 1977. The stoneflies (Plecoptera) of the Rocky Mountains. Memoirs of the American Entomological Society 31:1–208.

BRUNS, D.A., AND W.L. MINCKLEY. 1980. Distribution and abundance of benthic invertebrates in a Sonoran Desert stream. Journal of Arid Environments 3: 117–131.

DENONCOURT, R.F., AND J. POLK. 1975. A five-year macroinvertebrate study with discussion of biotic and diversity indices as indicators of water quality, Codorus Creek drainage, York County, Pennsylvania. Proceedings of the Pennsylvania Academy of Science 49:113–120.

EDMUNDS, G.F., S.L. JENSEN, AND L. BERNER. 1976. The mayflies of North and Central America. University of Minnesota Press, Minneapolis. 330 pp.

FLINT, O.S. 1970. Studies of neotropical caddisflies, X: *Leucotrichia* and related genera from North and Central America (Trichoptera: Hydroptilidae). Smithsonian Contributions to Zoology 60.

GRAY, L. 1981. Species composition and life histories of aquatic insects in a lowland Sonoran Desert stream. American Midland Naturalist 106:229–242.

HILSENHOFF, W.L. 1987. An improved biotic index of organic stream pollution. Great Lakes Entomologist 20:31–38.

KLEMM, D.J., P.A. LEWIS, F. FULK, AND J.M. LAZORCHAK. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. EPA-600-4-90-030. United States Environmental Protection Agency, Cincinnati, OH.

MACDONALD, J.F., AND J.R. HARKRIDER. 1999. Differentiation of larvae of *Metachela* Coquillett and *Neoplasta* Coquillett (Diptera: Empididae: Hemerodromiinae) based on larval rearing, external morphology, and ribosomal DNA fragment size. Journal of the North American Benthological Society 18:414–419.

MCCAFFERTY, W.P., R.S. DURFEE, AND B.C. KONDRATIEFF. 1993. Colorado mayflies (Ephemeroptera): an annotated inventory. Southwestern Naturalist 38:252–274.

MERRITT, R.W., AND K.W. CUMMINS. 1996. An introduction to the aquatic insects of North America. Kendall-Hunt Publishing Company, Dubuque, IA. 862 pp.

PLAFKIN, J.L., M.T. BARBOUR, K.D. PORTER, S.K. GROSS, AND R.M. HUGHES. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. EPA 440-4-89-001. United States Environmental Protection Agency, Cincinnati, OH.

SHANNON, C.E., AND W. WEAVER. 1963. The mathematical theory of communication. University of Illinois Press, Urbana. 117 pp.

STEWART, K.W., AND B.P. STARK. 1993. Nymphs of North American stonefly genera (Plecoptera). University of North Texas Press, Denton. 460 pp.

TOWNES, H.K. 1962. Design for a Malaise trap. Proceedings of the Entomological Society of Washington 64:253–262.

VANNOTE, R.L., G.W. MINSHALL, K.W. CUMMINS, J.R. SEDELL, AND C.E. CUSHING. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Science 37:130–137.

WASHINGTON, H.G. 1984. Diversity, biotic and similarity indices: a review with special relevance to aquatic ecosystems. Water Resources 18:653–694.

WIGGINS, G.B. 1977. Larvae of the North American caddisfly genera (Trichoptera). University of Toronto Press, Toronto, Ontario, Canada. 401 pp.

______. 1996. Larvae of the North American caddisfly genera (Trichoptera). University of Toronto Press, Toronto, Ontario, Canada. 457 pp.

WILHM, J.L. 1970. Effect of sample size on Shannon's formula. Southwestern Naturalist 14:441–445.

WILHM, J.L., AND T.C. DORRIS. 1968. Biological parameters for water quality criteria. BioScience 18:477–480.

Received 3 July 2001
Accepted 4 February 2002