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Aquatic Macroinvertebrate Monitoring Protocol for the Southern Colorado Plateau Network

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ON THE COVER

Bandelier National Monument
Photo Courtesy Southern Colorado Plateau Network

Aquatic Macroinvertebrate Monitoring Protocol for the Southern Colorado Plateau Network

Natural Resource Technical Report NPS/SCPN/NRR—2011/460

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Acronyms

ANOSIM	Analysis of Similarities
ANOVA	Analysis of Variance
CV	Coefficients of Variation
DCA	Detrended Correspondence Analysis
DEQ	Department of Environmental Quality
EPA	U.S. Environmental Protection Agency
EMAP	Ecological Monitoring and Assessment Program
EPT	Ephemeroptera, Plecoptera, and Trichoptera
GRTS	Generalized Random-Tessellation Stratified
I&M	Inventory and Monitoring
IBI	Index of Biotic Integrity
NAU	Northern Arizona University
NAWQA	National Water-Quality Assessment Program
NCPN	Northern Colorado Plateau Network
NMDS	Non-metric Multi-Dimensional Scaling
NPS	National Park Service
NRDT	Natural Resources Database Template
QA/QC	Quality Assurance/Quality Control
RIVPACS	River Invertebrate Prediction and Classification System
SCPN	Southern Colorado Plateau Network
SIMPER	Analysis of Similarity Percentages
SOP	Standard Operating Procedure
USGS	U.S. Geological Survey

Acronyms for Southern Colorado Plateau Network Park Units

Park	Abbreviation	State	Hectares
Aztec Ruins National Monument	AZRU	NM	130
Bandelier National Monument	BAND	NM	13,367
Canyon De Chelly National Monument	CACH	AZ	37,448
Chaco Culture National Historical Park	CHCU	NM	13,929
El Malpais National Monument	ELMA	NM	47,352
El Morro National Monument	ELMO	NM	420
Glen Canyon National Recreation Area	GLCA	AZ/UT	505,909
Grand Canyon National Park	GRCA	AZ	488,551
Hubbell Trading Post National Historic Site	HUTR	AZ	65
Mesa Verde National Park	MEVE	CO	21,546
Navajo National Monument	NAVA	AZ	243
Petrified Forest National Park	PEFO	AZ	37,852**
Petroglyph National Monument	PETR	NM	2,923
Rainbow Bridge National Monument	RABR	UT	66
Salinas Pueblo Missions National Monument	SAPU	NM	432
Sunset Crater Volcano National Monument	SUCR	AZ	1,230
Walnut Canyon National Monument	WACA	AZ	1,465
Wupatki National Monument	WUPA	AZ	14,388
Yucca House National Monument	YUHO	CO	13

**Recently approved boundary addition to Petrified Forest NP will bring the total area to 88,439 ha pending additional funding.

Executive Summary

Aquatic macroinvertebrate communities and their associated physical habitat were identified for long-term monitoring as one of 10 core vital signs for the Southern Colorado Plateau Network (SCPN) of the National Park Service. Because aquatic macroinvertebrates are sensitive to environmental change, monitoring them can detect chemical, physical and biological impacts to aquatic ecosystems, as well as their cumulative effects. This protocol narrative and 14 associated Standard Operating Procedures (SOPs) detail the rationale and methods to monitor this vital sign, including (1) background and objectives (2) sampling design (3) field methods (4) data management, analysis and reporting, and (5) personnel and operation requirements. Appendices provide supplemental information identifying specific monitoring sites, describing aquatic macroinvertebrate sampling techniques used by other agencies on the Colorado Plateau, outlining a yearly task list, selecting a qualified contract laboratory for aquatic macroinvertebrate identification, detailing use of the database, providing example data analysis and annual reports, and showing examples of the physical habitat structures and geomorphic channel units targeted in the protocol.

SCPN and the Northern Colorado Plateau Network collaboratively funded protocol development work through an Interagency Agreement with the U.S. Geological Survey. The methods are modified from protocols developed by the U.S. Geological Survey *National Water-Quality Assessment* (NAWQA) *Program*, and the U.S. Environmental Protection Agency *Environmental Monitoring and Assessment Program* (EMAP).

Monitoring of this vital sign will occur annually at Bandelier National Monument, Canyon de Chelly National Monument, Glen Canyon National Recreation Area, Grand Canyon National Park, and Mesa Verde National Park. Sites are established either in association with existing water quality monitoring locations (active stream gauges, historical or ongoing water quality data available) or by using a Generalized Random-Tessellation Stratified design to spatially allocate sample units within the established sampling frame.

As detailed in the SOPs, aquatic macroinvertebrate species composition and abundance data are collected using both quantitative and qualitative methods from within a 150 m reach at each of monitoring sites. Physical habitat characteristics (including stream depth and velocity, particle size class and embeddedness, channel width, canopy closure and NPS core water quality parameters) are variously measured at the reach level, the transect level (7–11 transects/reach) and at the microhabitat level (5 riffles/reach). Data entry, analysis, and archiving are completed at the end of each field season, and project summary reports are produced annually. Trend reports will be developed at five year intervals.

1 Background and objectives

1.1 Introduction

The Aquatic Macroinvertebrate Monitoring Protocol for the National Park Service's (NPS) Southern Colorado Plateau Network (SCPN) includes a narrative and 14 Standard Operating Procedures (SOPs). The protocol narrative describes the rationale for monitoring aquatic macroinvertebrates and associated physical habitat characteristics, establishes specific monitoring objectives, and provides an overview of the monitoring efforts. The SOPs provide detailed descriptions of all activities related to aquatic macroinvertebrate and stream habitat monitoring.

1.2 Background

The Southern Colorado Plateau Network is comprised of 19 national park units, encompassing a wide range of aquatic ecosystems, including lotic systems (seeps, springs; perennial, ephemeral, and intermittent streams; big rivers) and lentic systems (ponds, lakes and tinajas). The monitoring methods outlined in this protocol are applicable to a continuum of wadeable aquatic environments, ranging in size from small headwater streams to mid-sized perennial rivers. Intermittent and ephemeral streams are included because of their (1) dominance in the regional landscape, (2) importance to ecosystem dynamics of the larger extra-regional rivers, and (3) key functional role in watersheds of the arid southwest. Reference to streams throughout this protocol refers to wadeable perennial, intermittent, and ephemeral streams.

Aquatic macroinvertebrates are centrally important in aquatic systems because they perform functional roles as detritivores, herbivores, predators, competitors, and prey. In addition to their ties to the biotic environment, they are sensitive to changes in the physical and chemical environment (Scott et al. 2005). The response of aquatic macroinvertebrates to environmental change can be rapid and provides an excellent means for examining temporal and spatial variation in aquatic ecosystem quality. Because of their utility as an integrated indicator of water quality and the condition of aquatic ecosystems (Allan 1995, Karr and Chu 1999), aquatic macroinvertebrates have been identified as high-priority vital signs for aquatic ecosystems in the SCPN (Thomas et al. 2006).

Because aquatic macroinvertebrates are potentially sensitive indicators of environmental change, monitoring aquatic macroinvertebrates enables detection of important degradational changes or processes that may be occurring in network parks, from site-specific to regional scales. This protocol describes specific methods for monitoring key vital signs associated with SCPN aquatic ecosystems and pertains specifically to aquatic macroinvertebrates and the associated physical habitat characteristics in the reach where they are collected. To attain increased interpretive value, aquatic macroinvertebrate monitoring will be conducted in conjunction with evaluation of water quality characteristics and riparian ecosystem function and condition whenever feasible.

To successfully detect the ecological effects of anthropogenic stressors, a monitoring program must provide information that enables interpretation of trends in resource condition against the backdrop of intrinsic variation. In this case, conceptual models were developed to portray how natural drivers (e.g., climate or natural fires) and anthropogenic stressors (e.g., recreational use, grazing, human-caused fires, and streamflow alteration) affect aquatic and riparian ecosystem structure and functioning on the Colorado Plateau (Scott et al. 2005). With data collected following this protocol, SCPN will be able to provide park managers with information describing the status and long-term trends of aquatic resources, and to identify associations between

aquatic macroinvertebrate communities and habitat. These data will provide park managers with information which can serve as a guide for evaluating the effectiveness of management actions aimed at protecting or restoring aquatic ecosystems. Because aquatic macroinvertebrates are indicative of a stream's ecological condition, changes in these communities through time will provide an indication of changes in ecosystem health.

1.3 Rationale for monitoring aquatic macroinvertebrates to indicate watershed quality

Aquatic macroinvertebrates have been used extensively to assess the status and trends of aquatic life in rivers (Rosenberg and Resh 1993). Aquatic macroinvertebrates play a vital role in aquatic and riparian systems, as they are a key component of organic-material processing and nutrient cycling (Scott et al. 2005). They can be a food source for fish, amphibians, reptiles, turtles, and birds, and they also play an important role as consumers of algae, macrophytes, and detritus (Steinman 1996, McCafferty 1998). Because aquatic macroinvertebrates integrate (over time and space) the effects of land and water use in the watershed, they are excellent indicators of both long-term changes (such as siltation) and short-term events (such as point-source pollution) (Maret et al. 2001). Monitoring the status of aquatic macroinvertebrate assemblages complements physical and chemical water quality assessment methods, and provides a more complete evaluation of watershed condition (Karr 1991).

Aquatic macroinvertebrates offer many advantages for monitoring watershed condition (adapted from Rosenberg and Resh 1993): (1) they are ubiquitous and consequently can be affected by environmental perturbation in a variety of aquatic systems and habitats, (2) the large number of species offers a wide spectrum of responses to environmental stressors, as different species require different habitat and water conditions, (3) their basic sedentary nature allows effective spatial analyses of pollutants or disturbance effects, and (4) they have relatively long life cycles, which allows elucidation of temporal changes caused by perturbation. Recent efforts have focused on the development of indicator species, diversity indices, and multivariate techniques that link aquatic macroinvertebrate communities and habitat conditions.

Aquatic macroinvertebrate community structure has been shown to be a useful indicator of aquatic ecosystem quality, and aquatic macroinvertebrates have been used for biomonitoring since the early 1900s (Cairns and Pratt 1993). Methods for collecting aquatic macroinvertebrates and conducting physical habitat assessments are well established. The most notable federal programs collecting aquatic macroinvertebrate data are the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program (Fitzpatrick et al. 1998) and the U.S. Environmental Protection Agency (EPA) Ecological Monitoring and Assessment Program (EMAP) (Lazorchak et al. 1998, Peck et al. 2006). Arizona, Colorado, New Mexico and Utah, the four states on the Colorado Plateau, all utilize aquatic macroinvertebrates in their water quality monitoring program (see appendix B for a summary of these monitoring efforts).

1.4 Previous studies of aquatic macroinvertebrates in national parks on the Colorado Plateau

Aquatic macroinvertebrates have been the focus of a number of studies conducted within SCPN and Northern Colorado Plateau Network (NCPN) parks (see Scott et al. 2005). Although these park-specific studies have provided valuable data, such as aquatic macroinvertebrate species lists, rarely have they looked at physical habitat characteristics, and few have been conducted over long periods of time (with the exception of studies in a number of NCPN parks; Schelz 2001). No study has examined aquatic or riparian resources at the network scale. Furthermore, previous

studies have focused little or no effort on using established multimetric and multivariate techniques to assess aquatic macroinvertebrate assemblages.

A number of surveys have examined the general taxonomy of aquatic macroinvertebrate species across the Colorado Plateau (e.g., Moulton et al. 1994, Moulton and Stewart 1997, Wiersema et al. 2004). Other studies have examined aquatic macroinvertebrate response to a single variable in areas with known disturbance, such as mining (Peterson et al. 2002, Griffith et al. 2005), dams (Benenati et al. 2000, Shannon et al. 2001), drought (Canton et al. 1984, Dahm et al. 2003), and fire (MacRury and Clements 2002, MacRury 2002, Vieira et al. 2004). Studies on algal response to damming have also provided limited aquatic macroinvertebrate inventories in the area around Glen Canyon Dam (Shannon et al. 1996, Benenati et al. 2000, Shannon et al. 2001).

Aquatic macroinvertebrate community structure has been described for a number of perennial streams in national parks across the Colorado Plateau, including tributaries of the Colorado River in Grand Canyon National Park (Oberlin 1999), the Escalante River and tributaries in Grand Staircase-Escalante National Monument (Vinson 2002), Capulin and Frijoles creeks at Bandelier National Monument (Pippin and Pippin 1980, 1981), the Fremont River, Pleasant Creek, and Sulphur Creek at Capitol Reef National Park (Kirby and McAllister 2000, Brammer and MacDonald 2003), the Virgin River and tributaries at Zion National Park (Workman 1980, Shakarjian and Stanford 1998, Boyle and Strand 2003), the Green and Colorado rivers (Haden et al. 2003) and Salt Creek at Canyonlands National Park (Banta 2002).

In addition to data from studies of perennial stream systems within the parks, baseline aquatic macroinvertebrate data are available for ephemeral systems in several national parks across the Colorado Plateau (Haefner and Lindahl 1988, 1991, Berghoff 1995, Baron et al. 1998, Graham 2001, Vinson 2002). Aquatic macroinvertebrates were included in a recent inventory of selected springs, seeps, and hanging gardens in NCPN and SCPN parks (Springer et al. 2006), and aquatic macroinvertebrate communities have been documented in seeps, springs, hanging gardens, ponds, pools, and emergent wetlands in Zion National Park (Woodbury 1933), Grand Canyon National Park (Sorensen and Kubly 1997), Chaco Culture National Historical Park (Freehling and Johnson 2002), and in tinajas at Capitol Reef National Park (Haefner and Lindahl 1988).

1.5 Measurable objectives

We can evaluate responses to natural drivers and anthropogenic stressors at four spatial scales: individual (organism), population, community, and ecosystem (fig. 1). Individual organisms will display physiological responses (e.g., oxygen consumption, feeding rates), morphological responses (e.g., anatomical deformities, growth rates), and behavioral responses (e.g., migration, prey vulnerability) to both natural drivers and anthropogenic stressors. At the population level, abundance, distribution, and age structure may be affected. At the community level, species diversity, abundance, or functional roles may shift. At the ecosystem level, nutrient dynamics, spatial structure, and patterns of succession may be altered (see Scott et al. 2005 for a discussion of ecosystem-level processes of riparian and aquatic systems of the Colorado Plateau). Metrics and indices have been developed to describe aquatic macroinvertebrates at the population and community levels and can be used in statistical analyses to assess status and trends in aquatic macroinvertebrate community structure.

The process of developing objectives for aquatic macroinvertebrate monitoring began with the selection of SCPN vital signs (Thomas et al. 2006). Vital signs are physical, chemical, or biological elements and processes of park ecosystems that have

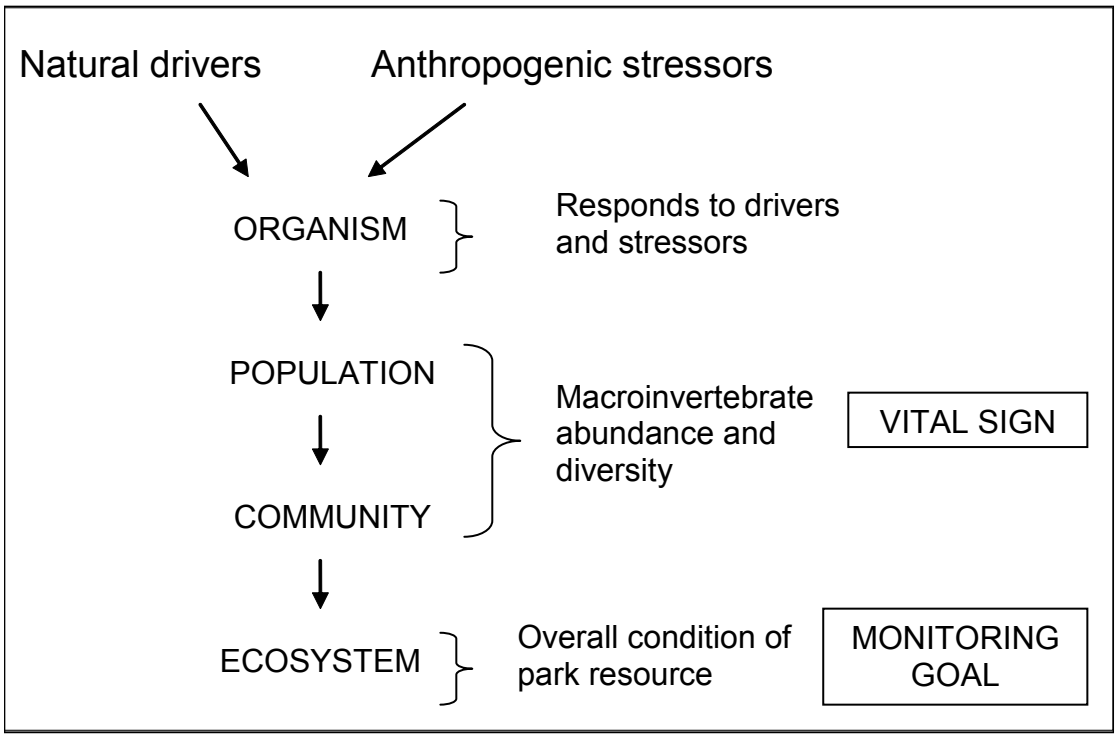

Figure 1. Responses to natural drivers and anthropogenic stressors occur at various spatial scales.

been selected to represent (1) the overall health or condition of park resources, (2) known or hypothesized effects of stressors, or (3) elements that have important human values. The SCPN parks have identified three vital signs pertaining to aquatic ecosystems:

- aquatic macroinvertebrate communities in streams
- stream and spring water quality
- spring ecosystems

This protocol is designed to facilitate monitoring of aquatic ecosystems in the SCPN, using aquatic macroinvertebrates as indicators of overall aquatic-ecosystem integrity, focusing specifically on species abundance and diversity of aquatic macroinvertebrates (Thomas et al. 2006). The specific objectives of aquatic macroinvertebrate monitoring for SCPN parks are to determine, in selected perennial streams or stream reaches, the status and trends in (a) the composition and abundance of aquatic macroinvertebrate assemblages, and (b) the distribution and condition of aquatic macroinvertebrate habitats (Thomas et al. 2006).

This protocol is designed to guide long-term monitoring of aquatic macroinvertebrate communities of streams found in SCPN parks. The network also identified riparian vital signs (channel morphology, stream flow and depth to groundwater, and riparian vegetation) that are relevant to aquatic ecosystems. The context and ecological significance of these vital signs are further explained in Scott et al. (2005). Wherever feasible, monitoring of aquatic macroinvertebrates should be conducted in conjunction with monitoring of water quality characteristics and riparian communities, allowing for an integrated evaluation of watershed status.

1.6 Relationship to national and state monitoring efforts

In developing this protocol, it was important to select methods and procedures that were comparable to those used by various state and federal agencies that also collect data on aquatic organisms in streams across the Colorado Plateau. Therefore, this protocol incorporated methods modified from the two most widely used protocols for sampling aquatic macroinvertebrates and associated habitat characteristics—those used by the

USGS NAWQA Program (see Cuffney et al. 1993 and Moulton et al. 2002 for aquatic macroinvertebrate protocols and Fitzpatrick et al. 1998 for habitat protocols), and those used by the EPA EMAP (Peck et al. 2006). NAWQA and EMAP use similar techniques for aquatic macroinvertebrate sampling and reach-habitat characterization. The main methodological differences between the two programs are (1) site selection methodology, with NAWQA using a targeted approach and EMAP using a random probabilistic design, and (2) scale of description, with NAWQA using a spatially hierarchical approach for describing environmental settings and evaluating stream habitat that includes four spatial scales: basin, segment, reach, and microhabitat (Frissell et al. 1986), and EMAP primarily collecting reach-scale habitat information.

The states of Arizona, Colorado, New Mexico, and Utah use, or are in the process of implementing, modified versions of the NAWQA and EMAP approaches (appendix A). It will be important to continue to interact with representatives of the four state agencies to maintain a consistent sampling methodology across the Colorado Plateau. Specific details and sampling procedures for this protocol are provided in SOP #4, SOP #5, SOP #6 and SOP #7.

2 Sampling design

The SCPN's goal is to efficiently sample aquatic macroinvertebrate communities within designated streams through time. This section identifies the target populations for monitoring and describes the spatial design for selecting sampling sites, the revisit design (i.e., how frequently sites are sampled), and the timing of sampling.

The SCPN selected specific streams for aquatic macroinvertebrate monitoring because of the presence of near-pristine water quality conditions, or the existence of known impairments or potential threats to stream water quality. Reasonable access time was an additional consideration. The SCPN will monitor aquatic macroinvertebrates in Bandelier National Monument, Canyon de Chelly National Monument, Glen Canyon National Recreation Area , Grand Canyon National Park, and Mesa Verde National Park.

2.1 Rationale for selected sampling designs

We are using two sampling designs to monitor aquatic macroinvertebrate communities in SCPN parks: (1) sampling at established water quality sites and (2) linear-based probabilistic sampling. The majority of our aquatic macroinvertebrate monitoring sites are index sites, co-located with water quality monitoring sites. The major goal of linear-based probabilistic sampling is to provide unbiased, defensible inferences from sample observations to target populations. To ensure that the inferences are valid, we are using a probability-based design that draws random, spatially-balanced samples. Co-location allows us to evaluate changes among multiple vital signs at the same locations within streams and to determine and interpret system-wide condition and trends.

2.2 Site selection

Perennial wadeable streams within SCPN parks are the focus of aquatic macroinvertebrate monitoring (appendix B). Because of the high variability in biotic and abiotic components of stream ecosystems across network parks, the focus of our sampling strategy is on individual streams and their related tributaries within a park. This allows us to make valid inferences within individual streams, but not among or across streams, when using probability-based sampling.

Index monitoring sites are established near active streamflow gauges, at sites with a history of water quality data, or at sites intended to address park-specific water quality concerns. Co-location of aquatic macroinvertebrate and water quality monitoring at these sites enhances our ability to comprehensively evaluate stream conditions and allows for direct association of aquatic macroinvertebrate communities with water quality conditions.

For streams where sites are selected with the linear-based sampling design, we are using the Generalized Random-Tessellation Stratified (GRTS) design (Stevens and Olsen 2004) to spatially allocate sample units within the sampling frame. (See SOP #3 for details of applying a linear GRTS design.) The sampling frame is composed of targeted individual streams or perennial stream segments. Every point within the sampling frame has an equal chance of being selected. Sites are selected from this population using equal probabilities with no stratification. In general, six potential sampling sites (with an oversample of six sites) are generated for each frame, with the intention of establishing one to three monitoring sites. Each monitoring site consists of a stream reach 150 meters long. The sites are evaluated sequentially in the field before final selection.

2.3 Sampling frequency and replication

Sampling for aquatic macroinvertebrates occurs once every year at each site. One qualitative and five quantitative samples are collected during each sampling event. Qualitative samples are collected from all

available habitat types within each reach to provide a comprehensive species list. Riffle habitats are targeted for collection of quantitative samples. At each riffle, quantitative samples are collected within a known sampling area, providing estimates of organism abundances. Quantitative samples allow for comparisons among sites and over time. Replication of the quantitative samples provides information on measures of central tendency and sample variability and is useful for statistically determining trends or change over time.

2.4 Timing of sample collection

Most of the states on the Colorado Plateau have established index periods for collecting aquatic macroinvertebrate samples (table1). In general, and as appropriate, index periods for aquatic macroinvertebrate sample collection by the SCPN should coincide with the relevant state's index period to ensure compatibility of monitoring samples. The timing of the index periods varies among the state agencies. In Arizona, aquatic macroinvertebrate samples are collected from warm-water perennial sites (below 1,500 m elevation) from April through May, and in cold-water perennial sites (above 1,500 m elevation) from May through June (ADEQ-WQD 2005). In Utah, aquatic macroinvertebrate samples are collected from perennial streams from September to October (UDEQ-DWQ 2006). This index period was developed based primarily on high-altitude sites in the northern portion of the state. The SCPN will sample low-elevation streams in Utah (GLCA) according to the Arizona index period for warm-water perennial sites. This decision is based on elevation, proximity to the Arizona-Utah state border, and a historic weather pattern of high-intensity storms in late summer and fall.

The state of Colorado recommends collecting aquatic macroinvertebrate samples during baseflow conditions, which typically occur in late summer/fall for mountain streams and from April through May for plains streams, but does not provide a recommendation for xeric streams (Colorado Department of Public Health and Environment 2003). Xeric streams in Colorado that are above 1,500 m elevation are faunistically similar to mountain streams (Paul et al. 2005), and therefore should be sampled during the late summer/early fall. In New Mexico, the sampling window is from August to mid-November (NMED-SWQB 2007). NAWQA has historically collected samples from perennial streams in the four states during late summer and early fall. EMAP has collected samples during the state-designated index periods.

Table 1. Index periods for sampling aquatic macroinvertebrates in perennial streams in the four states on the Colorado Plateau and in the Southern Colorado Plateau Network

State	State index period	SCPN index period
Arizona	April–May (streams <1,500 m elevation), May–June (streams >1,500 m elevation)	April–May (streams <1,500 m elevation), May–June (streams >1,500 m elevation)
Colorado	Late summer/fall (mountain/xeric) streams	September–October
New Mexico	August–mid-November	September–October
Utah	September–October	April–May (streams <1,500 m elevation), May–June (streams >1,500 m elevation)

3 Field methods

3.1 Overview of sampling procedures

At each monitoring site, aquatic macroinvertebrate samples and supporting information describing physical habitat and water quality are collected within a designated length of stream called the 'reach', which represents a relatively homogenous set of physical, chemical and biological features. Upon arrival at the sampling site, the lead technician observes stream conditions and if these are suitable, sampling proceeds. Core water quality parameters (temperature, pH, specific conductance, and dissolved oxygen) are logged at 15-minute intervals for the entire sampling period, using a multi-parameter sonde. If possible, the sonde should be left in the stream overnight to collect data over a 24-hour period. Air and water temperatures should be recorded and turbidity samples should be collected as close to noon as possible for comparability over time. Air and water temperature data are to be collected at 15-minute intervals throughout the year using recording thermistors deployed at most sampling sites. Two types of aquatic macroinvertebrate samples are collected from the reach: (1) quantitative samples are collected from five different riffles within the reach, and (2) a composite qualitative sample is collected from all available habitats within the reach. After aquatic macroinvertebrate samples have been collected, supporting physical habitat information is collected at the reach, transect, and microhabitat scales. A description of field activities for sampling aquatic macroinvertebrates and conducting a habitat assessment is provided in Table 2, and a yearly project task list is described in Appendix C. Some of the tasks described require only one or

Table 2. Field activities for aquatic macroinvertebrate and physical habitat sampling

Activities	Relevant SOP	Crew members	Estimated time
1. Reach set up			
A. Locate sampling site (based on previously established site such as a water quality or riparian monitoring site, or as indicated by random selection) using a GPS unit, the topographic map, and reach description.	3	1	15 min
B. Determine start and end points of sampling reach and mark with flagging tape.	3	2	15 min
C. Walk length of reach (avoid unnecessarily disturbing substrate in stream). Use measuring tape or rangefinder to determine exact location of each transect and mark each with surveyor's flag. Lead technician selects each of the five targeted quantitative riffle sampling areas and marks each with surveyor's flag.	3	2	20–45 min
2. Calibrate multi-parameter sonde and begin collection of core water quality parameters upon arrival at sampling site.	7	1	30 min
3. Quantitative aquatic macroinvertebrate sampling and microhabitat measurements	4	2	2 hours
4. Qualitative aquatic macroinvertebrate sampling	5	1–2	30 min
5. Reach and transect habitat measurements	6	3	3–4 hours
6. Measure discharge, record air and water temperatures, collect turbidity sample, download temperature sensors, take site photos, and note general reach/weather information for the site.	6,7	1	30 min
7. Wrap up	4,5,6,7		
A. Complete water quality data collection. Save water quality data file.	7	1	10 min
B. Check all datasheets and sample labels for completeness.	-	1	10 min
C. Remove flagging along reach.	-	1	15 min
TOTAL TIME			7–9 hours

two crew members. Therefore, if a crew of three persons is available, some of the tasks can be accomplished simultaneously. Total estimated time for collecting aquatic macroinvertebrate samples and physical habitat data at one site is 7–9 hours.

3.2 Sampling procedures and sample processing

3.2.1 Sampling reach

Wadeable streams included in the SCPN aquatic macroinvertebrate monitoring program are all relatively narrow and consequently, the reach length for all SCPN aquatic macroinvertebrate monitoring sites is 150 meters. The field crew should ensure that geomorphic features representative of the stream, such as riffles, runs, and pools, are present within the reach. Once the reach location has been determined, all transect locations are flagged and marked. All flagging should be removed after each sampling event. Refer to SOP #3 for reach establishment instructions.

3.2.2 Quantitative aquatic macroinvertebrate sampling

Quantitative samples are collected from five different riffles within the 150 m reach. When using a Slack sampler (a modified surber sampler developed by Keith Slack, USGS, Menlo Park, CA), the sampling area is the 0.25 m^2 area immediately upstream of the sampler. Replicate quantitative samples provide estimates of organism abundances and permit comparison among sites and over time. SOP #4 discusses quantitative aquatic macroinvertebrate sampling.

3.2.3 Qualitative aquatic macroinvertebrate sampling

Qualitative samples, collected from all available habitat types within a reach, enable development of a comprehensive species list for each site. Timed qualitative samples (i.e., samples collected during a standard amount of time) can be used for semi-quantitative, relative species abundances, which allow for comparisons between sites and over time. SOP #5 describes qualitative aquatic macroinvertebrate sampling.

3.2.4 Sample preparation and shipping samples to the lab

Following collection, samples are transferred from the sampler to wide-mouthed plastic jars and preserved with ethanol. They are then prepared for shipment to the identification laboratory. All samples should be labeled on both the outside and inside of the jar and then securely packed for shipment. Shipping samples to the contract laboratory also requires filling out the appropriate paperwork. SOP #8 discusses the steps required for sample processing.

3.2.5 Physical habitat assessment

Physical habitat characteristics are measured at microhabitat, transect, and reach scales (see SOP #6). Measurements of microhabitat characteristics, including stream depth, stream velocity, particle size and embeddedness, are taken at the locations where quantitative aquatic macroinvertebrate samples have been collected (see SOP #4). Transect measurements (fig. 2) are made at 7 to 11 transects, and include riparian canopy closure, wetted channel width, water depth, flow velocity, geomorphic channel unit, habitat structure, and solar radiation. Reach-scale measurements include the length and type of geomorphic channel units present (e.g., riffle, run, pool), pebble counts, and riparian land use (anthropogenic alterations and disturbances). Additional reach-scale variables that may be used in data analyses include discharge and NPS core water quality parameters (see SOP #7).

3.3 End-of-season procedures

Post-season procedures fall into four categories: (1) care of equipment, (2) data management, (3) summarizing of field notes or trip reports, and (4) reporting on scientific collecting activities. These procedures are detailed in SOP #9.

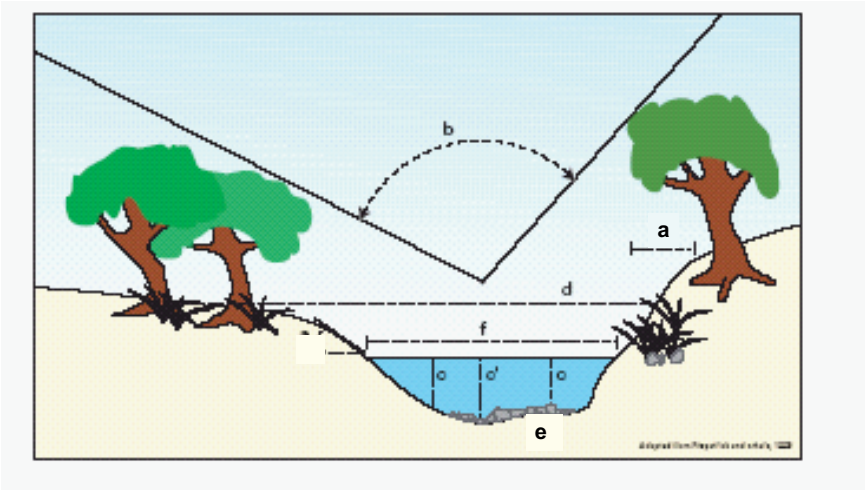

Figure 2. Diagram of selected habitat measurements made at each transect. (a) riparian canopy closure, (b) solar radiation, (c) stream depth, (d) active channel width, (e) substrate size, and (f) wetted channel width.

3.4 Aquatic macroinvertebrate sample storage and reference collections

The primary purpose of aquatic macroinvertebrate monitoring is to describe the current status and track changes in aquatic macroinvertebrate communities as an indicator of the condition of stream ecosystems. Documenting aquatic macroinvertebrate species occurrence is a secondary use of the resulting data. Quantitative and qualitative aquatic macroinvertebrate samples will be maintained by the contract aquatic laboratory for an extended period of time (at least five years) in order to provide for repeat subsampling should any data questions arise. Identified samples will be stored in four-dram glass vials, filled with 70% ethanol, and sealed with polycone caps.

The contract laboratory will also prepare a project reference collection for the SCPN, consisting of a few representative specimens of each taxon. The reference collection will be stored in properly labeled vials filled with 70% ethanol. The collection will be stored in the SCPN dry lab, located at Northern Arizona University, until an appropriate permanent repository is identified and arranged. Network staff will provide park curators with the information necessary to accession the reference collection into the NPS Automated National Catalog System (ANCS+).

4 Laboratory processing of aquatic macroinvertebrate samples

To ensure accurate and reliable identification of specimens and consistency with the level of identification used in other state and federal monitoring programs, aquatic macroinvertebrates must be identified to genus or species when possible (with the exception of chironomids, which will be identified to subfamily) at an established laboratory with stringent quality assurance/quality control procedures. Appendix D provides laboratory standards and guidelines for selecting a contract laboratory, and information on the required level of taxonomic resolution. Table 3 provides a summary of the minimum standards for laboratory subsampling, sorting, identification, and quality assurance/quality control procedures.

Four laboratories currently used for aquatic macroinvertebrate identification by state and federal agencies within the Colorado Plateau are (1) the U.S. Geological Survey National Water Quality Laboratory, Denver CO (processing, taxonomy, and QA/QC described in Moulton et al. 2000); (2) EcoAnalysts, Moscow, ID (detailed methods and QA/QC at www.ecoanalysts.com); (3) the Bureau of Land Management/Utah State University National Aquatic Monitoring Center, Logan, UT (detailed methods and QA/QC at www.usu.edu/buglab/); and (4) Rhithron Associates,Inc., Missoula, MT (information at www.rhithron.com).

Aquatic macroinvertebrate identification will be performed by one of these four laboratories, or by a similarly well-established and qualified laboratory, through agreements or contracts initiated by SCPN. To increase efficiency and minimize variability that may be introduced through differences in laboratory methods, it is highly preferable to consistently use the same laboratory for sample identification over the long term. Sample sorting and identification costs will vary among labs and over time and must be negotiated with individual laboratories. Factors that will influence the cost include turnaround time, level of taxonomic resolution required, subsample size, type of preservative used, mesh size of the collection net and sieve apparatus used in the field, sample area, type of habitat sampled, and geographic region where the sample was collected.

Table 3. Minimum standards for handling of aquatic macroinvertebrate samples by contract laboratory

Procedure	Standard
Subsampling	500 fixed-count method.
Sorting	Minimum of 7x magnification.
Identification	All taxa must be identified to genus (see table D-2, appendix D for exceptions).
QA/QC (Sorting)	Minimum of 10% of samples will be re-examined.
QA/QC (Identification)	Minimum of 10% of samples will be rechecked for correct identification by a second taxonomist. Laboratory must keep a reference collection, and all identifications must be verified by a second taxonomist.
Turnaround time	Maximum time = 4–6 months.

5 Data management

Data management requirements for monitoring protocols include procedures to collect, enter, document, archive, and distribute data. The project manager and lead technician will ensure the integrity and security of the data during a given field season by adhering to standard operating procedures. Additional details are provided in the network data management plans.

5.1 Data management overview

Project information management may be best understood as an ongoing process, as shown in Figure 3. Yearly data management tasks are shown in Appendix C. Each stage in the data management process is explained in detail below.

5.2 Pre-season preparations

5.2.1 Project workspace

A section of the network file server is reserved for the project, and permissions are established so that project staff members have access to files within this workspace (see SOP #10). Automated back-up procedures run on a daily schedule.

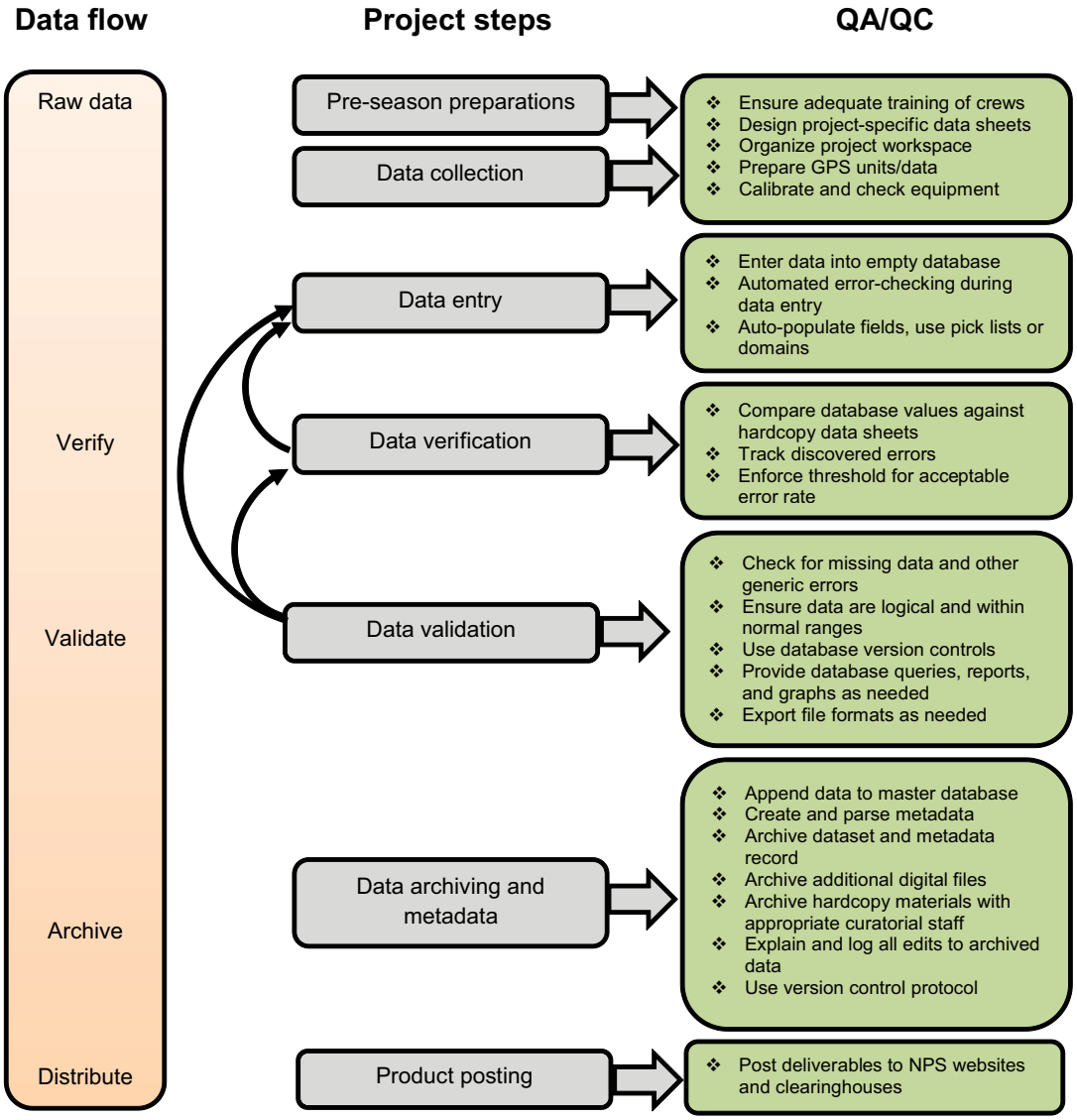

Figure 3. Schematic diagram of the overall data management procedures to be carried out during the project stages associated with the typical data flow

5.2.2 GPS preparation

The GIS specialist and lead technician work together to ensure that GPS units are loaded with target coordinates as well as any navigational waypoints, routes, tracks and backdrop maps. The GIS specialist prints out maps for use by the field crews and works with the field crews to identify what features on paper maps and GPS units will be the most useful (map scale, roads, waypoints, aerial photos, etc.). GPS units may be less reliable than paper maps at sites in steep canyons.

5.3 Data collection

5.3.1 Field measurements

Specific methods have been developed for acquiring aquatic macroinvertebrate, physical habitat, and water quality data (SOP #3–#7). Before leaving a sampling reach, the lead technician is responsible for ensuring that all forms have been filled out completely and that the information on each datasheet is correct and legible. Upon returning from each field trip, datasheets will be scanned to PDFs. If changes are made to paper datasheets, they should be re-scanned. The lead technician is responsible for safekeeping and organization of the datasheets until data entry and verification procedures have been completed, at which point the datasheets are stored in the network office.

5.3.2 GPS data procedures

Point data collected with GPS units are loaded into the site locations geodatabase. The lead technician periodically reviews the location data to make sure that any errors or inconsistencies are corrected.

5.4 Digital image procedures

The field crew downloads digital images from cameras at the end of each field trip and stores them in the project workspace (see SOP #10). Data images are linked to the project database. Other images are entered into the network image database. (See the SCPN Data Management Plan, [Tancreto and Hendrie 2006], for more details.)

5.5 Contract laboratory data

Data returned from the contract laboratory in digital format are stored in the project workspace (see SOP #10) and are also uploaded to the database (see SOP #11). Data are processed using the Invertebrate Data Analysis System (IDAS) (see SOP #13). Results from IDAS are output in MS Excel and are stored in the project workspace.

5.6 Data entry, verification, and validation

5.6.1 Data entry

Aquatic macroinvertebrate monitoring data are managed through the SCPN aquatic macroinvertebrate database, a relational database based on the NPS Inventory and Monitoring Program's Natural Resources Database Template (NRDT) (http://science.nature.nps.gov/im/apps/template/index.cfm). The database was designed following the NRDT's hierarchical data table organization (see appendix E). The database is divided into two components: one for entering, editing, and error checking data for the current season (the "working database"), and another that contains the complete set of certified data for the monitoring project (the "master project database").

During the field season, the project crew is provided with a copy of a working database into which they enter and edit data for the current season (refer to SOP #11). The lead technician is responsible for ensuring that multiple copies of the database are not created, with edits inadvertently occurring in multiple database files. As soon as possible following each field trip, the aquatic macroinvertebrate data recorded on the paper forms are entered into this database. Data entry should be completed by the person who collected the data or someone who is familiar with the project and data. The primary goal of data entry is to transcribe the data from paper and photographic records into the computer with 100% accuracy. Aquatic macroinvertebrate data are received in

digital format from the contract lab and can be imported directly into the database using an import tool. This should be done as soon as possible after the data are received. The lead technician is responsible for ensuring that data are entered completely and properly into the database.

It is recommended that backups be done every time new data are entered. This ensures that the initial data entry starting point can be recovered should irreversible errors or problems occur during the data entry session.

Any time a revision of protocols requires a revision to the database, a complete copy of the database is made and stored in an archive directory.

5.6.2 Data verification

The aquatic macroinvertebrate database application incorporates Quality Assurance/Quality Control (QA/QC) strategies to enforce data quality. The database design and the allowable value ranges assigned to individual fields within the data tables help to minimize the potential for data entry errors and/or the transcription of erroneously recorded data.

SOP #11 describes the steps that the project manager, lead technician, and data management staff will take to ensure that the data records within a given season's dataset are verified (i.e., database values are compared against hard-copy datasheets). The overall goal is to check 10% of records, correct and track any errors discovered, and enforce a threshold for an acceptable error rate. If, among the records checked, more than 10% are found to contain errors, then all of the records within that season's dataset will be reviewed. The GIS specialist will verify the geospatial component of the aquatic macroinvertebrate database each field season (Tancreto and Hendrie 2006).

Record reviewing tools are built into the aquatic macroinvertebrate database (see SOP #11). Documented error rates are noted in the dataset metadata, along with details about any all-record review, in the event the 10% error threshold is exceeded, and the resulting actions (e.g., percent of records corrected, nature of the errors, and any necessary re-entry of data).

5.6.3 Data validation and certification

The water resources and data management staff collectively validate (i.e., ensure that the data make sense) a given season's dataset. Some validation methods have been incorporated into the aquatic macroinvertebrate database (see SOP #12). Other, more specific, validation routines are worked out with the project manager and lead technician, and incorporated into the database as appropriate. Data management staff work closely with the water resources staff to provide any needed database queries, reports, graphs, or export file formats to assist with this overall validation.

Once validated, the data manager reviews the dataset and, if necessary, requests revisions or corrections. Once approved, the dataset is considered certified and the data manager will upload the dataset to the master project database.

5.7 Data archival procedures

5.7.1 Metadata

Metadata can be defined as structured information about the content, quality, condition, and other characteristics of a given dataset. Additionally, metadata provide the means to catalog and search among datasets, thus making them available to a broad range of potential data users. Metadata for all protocol monitoring data will conform to Federal Geographic Data Committee standards.

Metadata are created annually for tabular data. Specific procedures for creating, parsing, and posting the metadata record are provided in Tancreto and Hendrie (2006). Final metadata records are posted to the online NPS Integrated Resource Management Applications (IRMA) (https://irma.nps.gov). All metadata for spatial data posted to IRMA automatically become available on the NPS Data Clearinghouse

website (http://www.nps.gov/gis/data_info/), which satisfies the requirements of Executive Order 12906 (http://www.archives.gov/federal-register/executive-orders/pdf/12906.pdf).

5.7.2 Storage

Secure data archiving is essential for protecting data files from corruption (see Chapter 11 of the SCPN Data Management Plan in Tancreto and Hendrie 2006). Once the master project dataset and metadata are certified, the data manager will place a copy of the dataset and the metadata record into the appropriate folder within the archive directory on the network server. These archived files will be stored in read-only format. Any subsequent changes made to this database must be documented in an edit log and in the metadata. In addition to archiving the database copy in its native format, all tables will be archived in a comma-delimited ASCII format that is platform-independent by using the Access_to_ascii.mdb utility developed by the NPS Central Alaska Network.

Additional digital files to be archived include all digital photos and raw laboratory spreadsheets associated with that field season, and any digital files associated with data analysis products and project reporting.

All digital materials are stored in the network office and can be made available to park curators upon request. Hard-copy materials (e.g., datasheets, field notebooks, photo prints, and reports) are currently stored in the network office but will be moved to an NPS-approved repository for permanent storage.

5.8 Data maintenance

Any editing of archived data must be documented in the edit log and accompanied by an explanation that includes pre- and post-edit data descriptions (Tessler and Gregson 1997). Datasheets can be reconciled to the database through the use of the edit log.

5.8.1 Version control

Prior to any major changes of a dataset, a copy is stored with the appropriate version number to allow for tracking changes over time. Each additional version is assigned a sequentially higher number. Frequent users of the data are notified of the updates and provided with a copy of the most recently archived version.

5.8.2 Product posting

Full metadata records are available through IRMA. Records for reports and other publications are created in the Data Store section (https://irma.nps.gov/App/Reference/Create) of IRMA. Digital report files, in PDF format, are then uploaded and linked to the IRMA record. Species observations are extracted from the database and entered into the NPSpecies section of IRMA, which is the NPS database and application for maintaining park-specific species lists and observation data (https://irma.nps.gov/App/Species/ManageSpeciesLists). Water quality data are uploaded to NPSTORET annually.

The requestor should contact the data manager to fulfill any data requests. Only certified datasets should be shared outside NPS. See Tancreto and Hendrie (2006) for more details.

6 Data analyses and reporting

6.1 Metrics commonly used to evaluate aquatic macroinvertebrate communities

Metric calculation can be used in conjunction with other aquatic macroinvertebrate community analyses to identify significant trends or changes in various measures of aquatic macroinvertebrate community composition and structure. Techniques include evaluating individual metrics, calculating indices, and developing predictive models related to aquatic macroinvertebrate community structure and functioning. Multivariate and trend analysis techniques can also be used to assess status and trends of aquatic macroinvertebrate communities and how these relate to habitat characteristics and changes over time. Federal and state agencies are currently using a number of different approaches to analyze these kinds of data for streams across the Colorado Plateau. The selection of the most appropriate analytical techniques for the Colorado Plateau should continually be evaluated as more data are collected. Detailed examples and a review of the commonly used methods for evaluating aquatic macroinvertebrate communities are provided in Karr (1991), Barbour et al. (1999), Karr and Chu (1999), Maret et al. (2001), Moulton et al. (2002), and Ostermiller and Hawkins (2004).

Metrics are used to summarize key community characteristics that can provide information on environmental and biological conditions. A metric is an enumeration representing an assemblage (community), characteristic, or combination of characteristics that change in a predictable way with increased human influence or changes to system drivers. Biological metrics are used to relate specific measures of assemblage structure, composition, and functional attributes to a minimally disturbed system. An individual metric can describe a specific community attribute or be combined with other metrics into an index that provides a more comprehensive summary of the community. Hundreds of aquatic macroinvertebrate metrics and indices have been developed for water quality assessment purposes (see Cuffney 1993 and Barbour et al. 1999 for some examples). Some of these vary across different geographic areas and in response to different stressors. Developing reliable metrics and indices for specific geographic regions and for particular environmental stressors remains an active area of research. Many commonly used metrics and indices were developed in the eastern United States and may not be appropriate for use in streams of the Colorado Plateau.

Initial recommendations for metrics potentially most useful for summarizing SCPN aquatic macroinvertebrate monitoring data are based on metrics commonly used in state and national programs. The metrics listed in Table 4 provide a starting point and should be re-evaluated using additional data collected during the long-term monitoring program. These metrics were selected because they are generally considered to be sensitive, reliable indicators of water quality and/or stream health. In addition, they represent a range of ecological characteristics, thus providing a comprehensive assessment of multiple aspects of community structure. Refinement of a specific set of metrics and indices most appropriate for summarizing aquatic macroinvertebrates from streams in SCPN will be an ongoing process as monitoring data are collected. More detailed information about various metrics is available in SOP #13.

Aquatic macroinvertebrate metrics are grouped into five major classes: (1) abundance/richness/diversity, (2) tolerance, (3) functional-feeding, (4) functional-habitat, and (5) composition.

In the *abundance/richness/diversity* class, total abundance is the number of individuals, and taxa richness is the number of different taxa. In addition to calculating these for the sample as a whole,

Table 4. Suggested aquatic macroinvertebrate metrics

Metric type	Metric	Definition
Abundance/Richness/ Diversity	Total abundance	Total number of individuals.
	Taxa richness	Total number of taxa (measures the overall variety of aquatic macroinvertebrates in a sample).
	Simpson's diversity	A measure of the variety of taxa that takes into account the relative abundance of each taxon. $D = \sum(n_i(n_i -1)/N(N-1))$
Tolerance	Dominant taxa	Measures the dominance of the most abundant taxa. Typically calculated as dominant 2, 3, 4, or 5 taxa.
	Relative abundance tolerant taxa	Percent of individuals considered to be sensitive to perturbation.
	Percent richness of tolerant taxa	Percent of taxa considered to be sensitive to perturbation.
Functional-Feeding	Relative abundance collector-filterers	Percent of individuals that filter fine particulate organic matter from the water column.
	Percent richness collector-filterers	Percent of taxa that filter fine particulate matter from the water column.
	Relative abundance scrapers	Percent of individuals that scrape or graze upon periphyton.
Functional-Habit	Relative abundance burrowers	Percent of individuals that move between substrate particles (typically fine substrates).
	Percent richness burrowers	Percent of taxa that move between substrate particles (typically fine substrates).
	Relative abundance clingers	Percent of individuals that have fixed retreats or adaptations for attachment to surfaces in flowing water.
	Percent richness clingers	Percent of taxa that have fixed retreats or adaptations for attachment to surfaces in flowing water.
Composition	Number of EPT taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).
	Relative abundance EPT	Percent of individuals in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).
	Relative abundance Ephemeroptera	Percent of individuals that are mayflies.
	Relative abundance Plecoptera	Percent of individuals that are stoneflies (for streams >1,500 m in elevation).
	Relative abundance Trichoptera	Percent of individuals that are caddisflies.
	Hydroptilidae+ Hydropsychidae/Trichoptera	Percent of trichopteran individuals in Hydroptilidae plus Hydropsychidae (ratio of tolerant caddisfly abundance to total caddisfly abundance).
	Relative abundance noninsect taxa	Percent of individuals that are not insects.
	Relative abundance Chironomidae	Percent of individuals that are midges.

most metrics can be calculated either as abundance (number of individuals), richness (number of different taxa), percent abundance, or percent richness. Percent abundance and percent richness provide a relative comparison to the rest of the sample. An alternative calculation of richness is Margalef's index which compensates for differences in sample size among different sampling events. Numerous diversity indices have been developed. Diversity indices reduce the structure of a community to a numeric value by mathematically describing how abundance is distributed among taxa in a sample (Cuffney 2003). Simpson's diversity is one commonly used diversity index. Other suggested diversity indices include the Shannon-Weiner diversity index and Shannon's evenness index.

Tolerance and dominance indices are used to evaluate the relative tolerance of a community to various perturbations. Tolerance values have been assigned to different taxa based on EPA standards.

Tolerance metrics include dominant taxa, relative abundance tolerant taxa, and percent richness tolerant taxa. Dominance indices are related to diversity indices—they measure how strongly community structure is dominated by abundant taxa.

The *functional-feeding* metrics suggested in this protocol are relative abundance collector-filterers, percent richness collector-filterers, and relative abundance scrapers. The functional-habit metrics describe aquatic macroinvertebrate behavior and include relative abundance burrowers, percent richness burrowers, relative abundance clingers, and percent richness clingers. The recommended tabular sources for functional classifications are Barbour et al. (1999) and Poff et al. (2006). Barbour et al. (1999) includes classifications limited to tolerance, feeding, and habit, and these classifications have been widely used for analyzing state, EMAP, and NAWQA data. Poff et al. (2006) provide a more recent source of functional classifications, and incorporate a wide variety of trait classifications, including morphological, ecological, life history, and mobility/dispersal characteristics for 311 genera and 78 families of lotic insects.

Community composition metrics describe the number of taxa or the relative abundance of particular orders or families of interest. For example, insects in the orders Ephemeroptera, Plecoptera and Trichoptera (EPT taxa) are generally intolerant of pollution, sedimentation and other forms of aquatic habitat degradation. See Table 4 for a complete list of community composition metrics.

The use of multimetric indices in bioassessments is often advocated because several different metrics, each measuring a different component of the assemblage, are believed to provide a more robust and succinct assessment of ecological integrity (Karr 1991, Southerland and Stribling 1995, Gibson et al. 1996, Barbour et al. 1999). A comprehensive suite of metrics typically includes metrics representing species composition, richness, diversity, tolerance, and feeding and habit guilds. The Western EMAP program and the Arizona DEQ have developed multimetric indices to be used for bioassessment in portions of the Colorado Plateau. However, additional work is needed for developing multimetric indices specifically for this region.

An approach often used to summarize the overall condition of a biological community is to develop a multimetric Index of Biotic Integrity (IBI). The IBI uses metrics describing multiple aspects of community composition, such as functional composition (based on trophic or habit guilds), taxonomic composition, species richness and diversity, and pollution tolerance to generate scores that indicate the biological integrity of a given site relative to a minimally disturbed reference site for the stream, locale, or region. Data collected during long-term monitoring may aid efforts to develop a Colorado Plateau-specific IBI, or IBIs that are appropriate for different ecoregions within the Colorado Plateau.

Predictive models, such as RIVPACS (River InVertebrate Prediction and Classification System), are commonly used for bioassessments when reference and impacted sites are available for comparison. A RIVPACS model can be used to compare an observed score (O) to the expected score (E) at a reference site, providing an estimate of the degree of impact on the test site (Ostermiller and Hawkins 2004). The four states are currently developing predictive models that include the Colorado Plateau. RIVPACS models require a large number of sites (20–30 minimum), so it is unlikely that the networks will be able to develop independent models. However, data collected as part of SCPN monitoring efforts could be used for RIVPACs modeling through coordination with associated state and federal agencies. Many of the network sites will provide information on reference conditions, which may prove valuable in the development of models.

6.2 Expected associations between aquatic macroinvertebrate communities and changes in water quality or physical habitat

Changes to water quality and physical habitat on the Colorado Plateau are caused by myriad natural and anthropogenic events that occur in the upland watershed (e.g., fire, mining, grazing, roads, and recreational use), riparian areas (e.g., invasive species, grazing, recreational use), and within streams themselves (e.g., flow alteration). These changes ultimately influence aquatic community structure and function. The linkages and degradational pathways between these landscape-scale disturbances and aquatic communities are identified and explained in detail in Scott et al. (2005). Some of the hypothesized physical and chemical stressors that may directly influence aquatic macroinvertebrates on the Colorado Plateau are shown in Table 5, along with potential responses of selected metrics to these factors. These metrics may be effective in detecting impacts of specific stressors of interest and may supplement the suite of recommended metrics.

An illustration of how landscape-scale disturbances may lead to the degradation of aquatic communities in a stream, and the expected response of aquatic macroinvertebrate community metrics, is provided in Figure 4. In this hypothetical

Table 5. Examples of how selected aquatic macroinvertebrate metrics might respond to various potential stressors

Stressors	Metric	Expected Response	Observed on Colorado Plateau or in near proximity	Observed in other regions
Reduced stream-flow	Percent Ephemeroptera and Plecoptera	Decrease		Rader and Belish 1999, Growns and Growns 2001
	Abundance/Richness	Decrease		Ladle and Bass 1981, McIntosh et al. 2002, Rader and Belish 1999, Growns and Growns 2001
Erosion (scouring events)	Abundance	Decrease	Grimm and Fisher 1989, Vieira et al. 2004	
Sedimentation	Percent clingers and/or number of clinger taxa	Decrease		Rabeni et al. 2005
	Trichoptera richness	Decrease	Blinn and Ruiter 2006	
	Percent collector-filterers	Decrease	Spindler 2004	Grubbs and Taylor 2004
	Percent scrapers and/or number of scraper taxa	Decrease	Spindler 2004	
	Percent EPT and/or number of EPT taxa	Decrease		Angradi 1999
	Richness/Diversity	Decrease		Cline et al. 1982, Lemly 1982, Nuttall 1973, Wright and Berrie 1987
Declining water quality	Percent tolerant	Decrease		Hilsenhoff 1988
Salinity	Diversity	Decrease	Oberlin et al. 1999	
	Hydroptilidae+ Hydropsychidae: Trichoptera	Increase	Blinn and Ruiter 2006	
Pesticides	Richness/Diversity	Decrease		Thiere and Schulz 2004
Metals	Percent Ephemeroptera	Decrease		Clements 1994, Kiffney and Clements 1994
	Richness/Diversity	Decrease		Clements 1994, Kiffney and Clements 1994

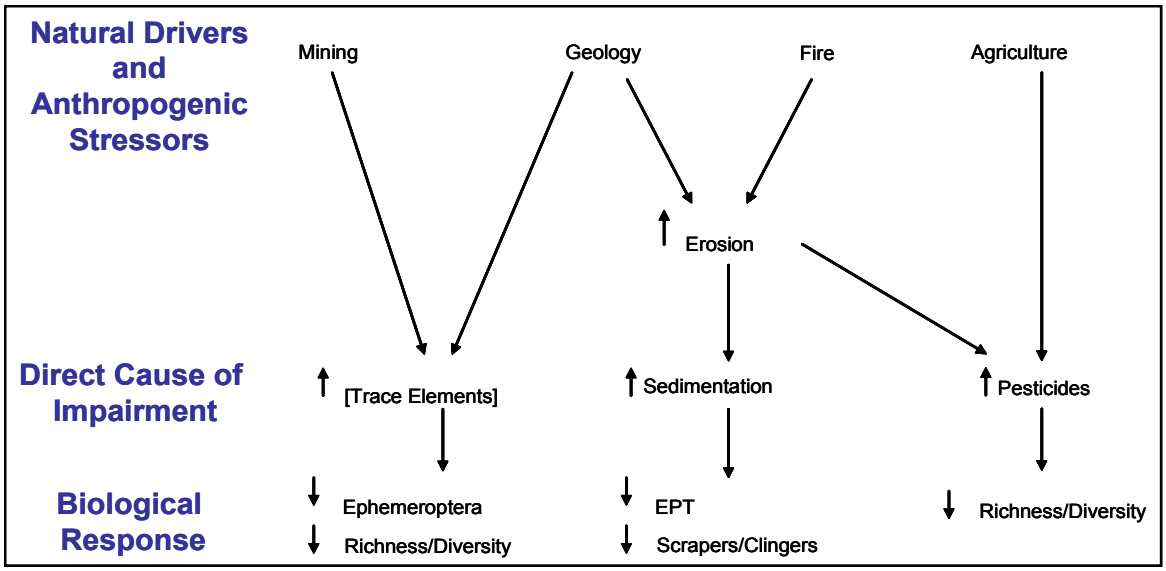

Figure 4. Examples of how a degradational pathway may lead to biological impairment. Hypothetical biological responses are indicated as changes in selected aquatic macroinvertebrate community metrics.

example, a fire occurred in the upland watershed of this hypothetical stream, leading to increased surface runoff and erosion. Present-day and historical agricultural activities have contaminated floodplain sediments with pesticides. The increased erosion caused by the fire has introduced large amounts of contaminated sediments into the stream. Physical measurements of embeddedness and substrate composition (pebble counts) quantify these physical effects in the stream. As typically occurs, more than one stressor is currently causing impairment in this system. In addition to the actual increase in sedimentation, pesticides have been carried into the stream during the erosional process. An additional natural driver in this system is the geological setting, which, combined with the anthropogenic stressor of mining, has resulted in elevated concentrations of some trace elements. Fire, land use, and natural factors have led to degradation of habitat and water quality through sedimentation and elevated pesticide and trace element concentrations. In turn, this has led to a depauperate aquatic community with decreases in sensitive species such as Ephemeroptera and EPT, and decreases in the metrics of richness and diversity. Increased sediment is also predicted to lead to a decrease in the functional metrics of scrapers and clingers.

6.3 Data analysis

The primary focus guiding the statistical approach to data analysis is to estimate parameters and conduct trend analyses, including testing hypotheses to determine if changes have occurred. We apply this approach in three main areas: (1) determining status and trends for single metrics and indices of the aquatic macroinvertebrate community, (2) determining status and trends in faunal composition and structure at the community level, and (3) determining associations between aquatic macroinvertebrates and their habitats.

A useful first step in data analysis is to conduct exploratory analyses designed to elucidate underlying trends in the data and their distributions. This includes visual analysis by graphing parameter means and variances over time, and by displaying box-whisker plots to evaluate distributions. Another early step in data analysis is to conduct tests for normality and homogeneity of variances. For tests requiring normal distributions, data that fail the normality test will be transformed (e.g., using $a\sqrt{(x + 1)}$ or $\log (x +1)$ transformation). Transformed data that fail normality tests will be compared using nonparametric methods, such as Kruskal-Wallis ANOVA (Analysis of Variance) on ranks.

6.3.1 Testing for temporal change

Testing for temporal change of individual "indicator" taxa is easier than defining trends in species composition (Philippi et al. 1998), especially if examining the trends of every species observed is required. One approach is to use the analysis of dissimilarity among replicate samples to examine trends through time. Progressive change in species composition (trends) can be determined as the dissimilarity between two samples increases with their temporal separation (Philippi et al. 1998). The simplest approach to evaluating progressive change examines change from a specified baseline condition. Nonparametric tests, including Spearman's rank correlation and Kendall's tau correlation (Kendall and Gibbons 1990), can be used to determine the correlation or rank correlation between time and dissimilarity with the baseline condition. Additional analyses include computing the correlation between each date and dissimilarity, using each date as the baseline to which previous and subsequent dates are compared, and calculating the correlation between dissimilarity in species composition and differences in times, using all pairs of samples (Philippi et al. 1998). To test the power of these correlations, the Mantel test of the association between the two distance matrices (Manly 1991) or an analysis of similarities (ANOSIM; Clarke and Warwick 1994) can be performed.

6.3.2 Determining trends in metrics

As previously described, numerous metrics and indices of aquatic macroinvertebrate data are useful for assessing the faunal community and determining the condition of the aquatic ecosystem. Initially, we will determine the trends associated with the metrics presented in Table 4. Other metrics and indices will also be investigated for their utility to provide additional trend information that is independent of the set of recommended metrics and for their ability to help describe the status of the aquatic macroinvertebrate community. Correlation analyses will be conducted among the suite of metrics and indices to determine a set of variables that individually describes independent components, but collectively covers the complexity of community composition, structure, and function. The variability (and usefulness) of the metrics and indices will be examined during the first several years of monitoring by calculating the coefficients of variation (CV) by reach and by stream. No established criteria exist for determining a threshold at which to consider a metric as highly variable, but as a starting point, metrics with greater than 50% CV may be eliminated from further analysis.

For detecting trends in the aquatic macroinvertebrate metrics and indices within a reach or a stream, we will use least-squares regression and ANOVA (or Kruskal-Wallis ANOVA on ranks) to test for significant differences across sampling periods. A potential drawback in using ANOVA is that the method works best for detecting gains or losses in species richness as opposed to cases where species are replaced (Halse et al. 2002). If no significant trends in species richness are detected with ANOVA, questions concerning other changes in aquatic macroinvertebrate composition, structure, and function will be addressed by analyzing trends of other metric types, including those shown in Table 5. Species composition will also be investigated using multivariate analysis techniques, including ordination methods (see below).

6.3.3 Analysis of multivariate aquatic macroinvertebrate community measures

Several authors have described a general approach for multivariate hypothesis testing (Clarke and Green 1988, Clarke 1993, Anderson 2001) that includes these steps: (1) choosing an appropriate distance measure to serve as the basis of analysis (e.g., Bray-Curtis or Euclidean); (2) performing ordination to visualize patterns of resemblance among observations based on their community composition; and (3) conducting a multivariate nonparametric test to detect differences

among groups, or directional change. While ordination is not essential in terms of conducting the statistical test, it provides a visual representation by reducing the dimensionality of the data (Anderson 2001)

6.3.4 Multivariate trends analyses

Numerous multivariate analysis techniques may be used to assess trends in aquatic macroinvertebrate community composition and structure. Many of these techniques are ordination methods, designed to represent multivariate data structures in low-dimensional space. Typically, low-dimensional space reduces the noise associated with multivariate data, and ideally represents interpretable environmental gradients or trends. Thus, ordination methods are useful for detecting and summarizing underlying trends. We discuss several commonly used methods here.

Ordination methods are operations performed on the community data matrix. For aquatic macroinvertebrates, these matrices include species abundances for each reach by sampling period, and species abundances for individual streams (using average reach data) by sampling period. Ordination techniques arrange the samples in terms of their similarity of species composition or associated environmental gradients (see next section). Ordination analyses generate diagrams in which each point corresponds to an individual sample at a reach or stream, and the distances between the points approximate the degree of similarity between the samples (i.e., the closer the points, the greater the similarity). For example, two reaches with exactly the same species composition and abundance would occupy the same point or position in ordination space. Trends in aquatic macroinvertebrate communities within a sampled reach or stream can be examined using several techniques that analyze these relative distances in ordination space.

Polar ordination involves the calculation of Bray-Curtis distances (Bray and Curtis 1957), and is a technique commonly used to assess trends in faunal composition for each pair of samples from consecutive years. This is a measure of dissimilarity, with values ranging from 0 (identical samples) to 1 (complete dissimilarity). This method is well-suited for species abundance data because it is usually applied only to species that are abundant (i.e., it ignores species that have no abundances for any sampling period) and are likely to change over time. The Bray-Curtis index has been shown to have high within-site and within-season coherence when used to assess aquatic macroinvertebrates (Lorenz and Clarke 2006). ANOVA is used to test for differences in compositional similarity between years by reach and by stream. Regression analysis is used to further examine relationships among community persistence (using Bray-Curtis distances) and key habitat variables (e.g., habitat complexity, substrate, channel-reach features). Additionally, the Bray-Curtis values serve as inputs for conducting further multivariate analysis (see nonmetric multidimensional scaling, below). Studies that used Bray-Curtis distances for examining compositional stability in aquatic macroinvertebrate communities include Scarsbrook (2002), Brown et al. (2006), and Milner et al. (2006).

For qualitative compositional (i.e., presence/absence) data, faunal-community persistence (e.g., Milner et al. 2006) can be examined using Jaccard's similarity coefficients (where J values range from 0, no similarity/low persistence to 1, identical/high persistence). Index calculations can be limited to only those taxa that are found in at least two consecutive seasons, or, alternatively, can include all taxa in order to examine the importance of rare species. ANOVA is used to test for differences in compositional similarity between years, by reach, and by stream. Regression analysis is used to further examine the relationships between community persistence (using Jaccard's similarity coefficients) and key habitat variables (e.g., habitat complexity, substrate, channel-reach features).

Trends in aquatic macroinvertebrate

community composition and structure can also be examined using Nonmetric Multi-Dimensional Scaling (NMDS). NMDS calculates a set of metric coordinates for samples using the rankings of distances between species. The Bray-Curtis similarity coefficients (and other indices, including Morisita's and Jaccard's index) can be used as inputs to NMDS ordinations. A stress coefficient is computed, which measures the mismatch between a new ranked ordination and the original Bray-Curtis distances. Successive, iterative ordinations are conducted until the "stress" appears to reach a minimum. NMDS is an appropriate technique for biotic data, which are typically nonlinear, because it makes no assumptions about the underlying data structure.

Temporal variations in aquatic macroinvertebrate communities within a stream can be analyzed in NMDS ordination space to compare the time trajectories, synchronicity, and magnitude of change among reaches (e.g., Brown et al. 2006), and to examine responses to disturbances at the reach or stream level (e.g., Kreutzweiser et al. 2005). Similar streamwide responses among reaches may indicate system-level changes (e.g., reduced stream flow), whereas large changes within a single reach may suggest a localized disturbance or a significant change in habitat.

Two techniques can be employed to determine which taxa contribute the most to the patterns observed in NMDS ordination space. These include constructing bubble plots (Clarke and Warwick 1994) and conducting an analysis of similarity percentages (or SIMPER). Kreutzweiser et al. (2005) used bubble plots to detect taxa in aquatic macroinvertebrate samples from reference and disturbed (logged) sites that exhibited distinct patterns in ordination space. Quinn et al. (2000) used SIMPER and Bray-Curtis distances to determine which aquatic macroinvertebrate taxa contributed most to the similarity (or dissimilarity) among a group of wetlands in southeastern Australia.

If ordination results indicate major trends, we can test for significant differences in aquatic macroinvertebrate communities within or among reaches with multivariate analysis of similarities (ANOSIM) (Clarke and Warwick 1994). ANOSIM is a nonparametric permutation procedure that can be applied to a similarity matrix (e.g., Bray-Curtis). Pairwise ANOSIM comparisons are summarized into an R-statistic that is a relative measure of dissimilarity of samples; higher R-values indicate greater dissimilarity (Clarke and Warwick 1994). A randomization process (e.g., Monte Carlo) can be used to assess the probabilities of gaining particular R values, and thus derive a significance level for testing purposes.

See Appendix F for a demonstration of several multivariate analysis methods of examining and testing for temporal change using aquatic macroinvertebrate abundance data.

6.3.5 Aquatic macroinvertebrate community-habitat relationships

To help interpret observed aquatic macroinvertebrate community trends, it will be useful to first determine the response patterns of aquatic macroinvertebrates to environmental gradients and habitat variables. To do this, we can use correlation and regression analysis to relate key habitat measures with aquatic macroinvertebrate community variables. Correlation analysis is used to identify the community-habitat variables that are most closely related and of highest interest. Pearson's correlation (or Spearman's rank correlation as a nonparametric method) can be used to determine the strength of the relationship. To determine which habitat or community variables best characterize differences in sampling periods among habitats, ANOVA (e.g., Nakano and Nakamura 2006) and Tukey's multiple comparison technique can be used. The comparable nonparametric

tests include Kruskal-Wallis ANOVA on ranks, and Dunn's multiple comparison technique.

Regression methods can be used to further analyze relationships between a response variable (e.g., taxa richness) and one or more explanatory variables (e.g, % canopy closure). Stepwise multiple regression is useful for identifying significant relationships between individual community measures and numerous physical and chemical variables (e.g., Clements et al. 2000), and for identifying hydrological indicators of community variation (Wood et al. 2000).

Ordination techniques that arrange species abundance data or habitat variables in terms of their similarity can also be used, but selecting an appropriate method depends upon the study objectives and the underlying data structure. Some methods (e.g., PCA, or principal components analysis) assume a linear data structure and are often appropriate for abiotic data. Biotic data, however, are usually nonlinear and therefore correspondence analysis (CA) is commonly used in ecological studies. Ordination methods that use indirect gradient analysis are appropriate for SCPN aquatic macroinvertebrate data because sampling units are not formally partitioned along an environmental gradient. We will employ two commonly used methods of indirect gradient analysis: detrended correspondence analysis (DCA) and NMDS. One difference between these methods is that DCA is based on an underlying, unimodal model for species distributions. NMDS does not assume an underlying data structure, and thus may be a good choice when factors determining species composition are unknown. Scarsbrook (2002) analyzed environmental data and invertebrate species abundance data separately using NMDS, and identified the variables most strongly correlated to the first NMDS axis using Spearman's rank correlation. Nakano and Nakamura (2006) used DCA to identify important environmental gradients in the composition of macroinvertebrates from three variable reaches on a river in Japan.

6.4 Reporting

Two types of reports will be prepared based on data collected and analyzed in this protocol: annual reports and trend reports. Annual reports of aquatic macroinvertebrate monitoring results will be prepared each year. The primary purposes of annual reports for specific monitoring projects are to (1) summarize annual data and document monitoring activities for the year (2) describe current conditions of the resources sampled, and (3) provide data back to park managers in a timely way to increase data utility and improve communication within and among SCPN parks. The details of summarizing data for annual reports are provided in SOP #13; an example report is presented in Appendix G. Trend reports will be prepared approximately every five years and will provide comprehensive statistical analyses of long-term data. The main objectives of trend reports are to (1) report patterns and trends in condition of resources being monitored, (2) report new characteristics of resources and correlations among related vital signs, (3) report the degree of change that can be detected by the current level of sampling, and (4) provide interpretation of monitoring data in a park, multi-park, and regional context.

7 Personnel requirements and training

7.1 Roles and responsibilities

The SCPN program manager is responsible for the overall management and supervision of the network monitoring program. Serving in the role of project manager, the SCPN hydrologist/aquatic ecologist is responsible for the overall management and supervision of aquatic macroinvertebrate monitoring and will work with the program manager to coordinate the involvement of other network staff (table 6). The SCPN is accomplishing the field work associated with this protocol through a cooperative agreement with Northern Arizona University (NAU). The SCPN water resources field crew, consisting of 3–5 individuals, will conduct monitoring associated with this protocol and the Integrated Riparian, Water Quality, and Springs Ecosystem monitoring protocols. The crew will be led by an NPS Science Technician (GS-9) with considerable field experience. The crew will also include one to three additional technicians and interns. These will be either NPS or NAU field

Table 6. Positions and key roles and responsibilities for implementing aquatic macroinvertebrate monitoring in the Southern Colorado Plateau Network

Position	Roles and responsibilities
Program manager	The program manager is responsible for the overall management and supervision of the program. Duties include developing the process for selecting indicators, overseeing the development and testing of monitoring protocols, hiring and supervising network staff, managing the implementation of monitoring projects, and ensuring that resulting data are appropriately analyzed, reported, and made available for park planning and management.
Project manager	The project manager is the network hydrologist/aquatic ecologist, who is responsible for implementing the aquatic macroinvertebrate monitoring project. Duties include working collaboratively with park staff to understand management issues and information needs, hiring and training field staff, obtaining all necessary research permits, and completing scheduled data analysis, reporting, and integration/interpretation of monitoring results. The project manager works closely with the data manager and the water resources lead technician to ensure that high-quality standards are achieved and maintained in the collection, processing, and analysis of aquatic macroinvertebrate data. The project manager will serve as the point of contact concerning data content and will work to establish partnerships with state and federal agencies and others involved in aquatic macroinvertebrate monitoring.
Data manager	The data manager is responsible for the information and data stewardship of the aquatic macroinvertebrate monitoring project. The data manager designs databases, writes the data management plan and protocols, and works with the project manager and network staff to ensure that datasets are fully documented, validated, and certified. The data manager, in collaboration with the project manager and water resources lead technician, develops data entry forms and other database features as part of quality assurance, and automates report generation. The project manager and data manager share the responsibility of preparing data for analysis. The data manager populates NPS service-wide databases, maintains digital document libraries, and maintains the network website.
GIS specialist	The GIS specialist is responsible for managing the spatial data and providing GIS support to the aquatic macroinvertebrate monitoring project. Duties include managing, documenting and distributing spatial data resulting from the monitoring project, and maintaining a library of relevant park spatial data.
Quantitative ecologist	The quantitative ecologist works with the program manager and project manager to develop spatial and temporal sampling designs for the project, develop sound statistical approaches to analyzing monitoring data, and provide analytic support to the project.
Water resources field lead technician	The water resources field lead technician (biological science technician) is responsible for overseeing the field crew and will supervise field data collection and pre- and post-season activities, including data entry, verification, and routine data summary. Duties include scheduling sampling trips and making logistical field trip arrangements, ensuring that data collection procedures and standards are maintained on a day-to-day basis, overseeing sample preparation and shipping, and writing data summary reports.
Water resources field crew members	In addition to the lead technician, the field crew will usually consist of two (and possibly up to four) crew members with responsibilities for field data collection and laboratory processing of samples, equipment maintenance, ordering supplies, and data entry and verification.

technicians, ideally with field experience in a complementary subject area.

7.2 Field crew qualifications

Competent, well-trained, and detail-oriented observers are essential for collecting credible, high-quality data in long-term monitoring efforts. All field crew members should have good organizational skills and the ability to perform detailed data collection procedures. A background in the physical or biological sciences is desirable for all crew positions and mandatory for the research specialist positions. The lead technician must be knowledgeable in the fields of aquatic and riparian ecology, have a strong background in monitoring techniques, and be an effective leader and teacher of field skills. Because many of the aquatic macroinvertebrate monitoring sites are located in remote wilderness settings, crew members should be physically fit and experienced with backcountry hiking and camping. More detailed qualifications are provided in SOP #2.

7.3 Field crew training

Prior to the field season, all field crew members should read and become familiar with the monitoring protocol. Training is an essential component of pre-season preparation and is crucial for collection of credible data. Because year-to-year consistency in implementing the protocol will ultimately determine the quality of the monitoring data and affect the likelihood of detecting trends in aquatic ecosystem condition, the need for high-quality training cannot be overemphasized. At minimum, one or two crew members should receive formal training in aquatic macroinvertebrate sampling methods. This could be accomplished by contracting with an aquatic ecologist familiar with the methods used in this protocol or by sending crew members to training offered by NAWQA, EMAP, or one of the state agencies. The lead technician will then train other crew members and hold field practice sessions to develop individual skill levels. SOP #2 provides details on hiring and training field crews.

8 Operation requirements

8.1 Annual workload and field schedule

The SCPN water resources field crew is responsible for field data collection, sample processing, data entry and verification, and for helping to prepare routine data summaries relating to four of the network's monitoring projects. Approximately 25% of the crew's time will be dedicated to the aquatic macroinvertebrate monitoring project. Preparation for the field season must begin well in advance of the pre-season training session. Appendix C provides a yearly project task list that identifies each task by project stage, indicates who is responsible, and establishes the timing for its execution.

Aquatic macroinvertebrate samples will be collected once each year from streams in SCPN parks. Sampling will occur during the spring or fall index periods (April–May or September–November) and should be scheduled to begin as soon as possible each April following snowmelt runoff, and each September after summer rains have ended. If flood events or other problems interrupt the sampling schedule, sampling will be re-scheduled during the same year, if possible. At a minimum, two people will be required to complete the field portion of the protocol; however, a three-person field crew is much more efficient and should be used whenever possible. SCPN parks are widely dispersed and most sampling sites are in remote areas, therefore completing the field work will require a minimum of two field days (including travel). We estimate that we can sample between 12 and 18 aquatic macroinvertebrate sites per year.

Aquatic macroinvertebrate samples will be processed in the field if sufficient time is available, or in the laboratory immediately following the field season. Tasks, including sorting, sub-sampling, and taxonomic identification, will be completed by a qualified contract laboratory (see appendix D for guidelines and standards for selecting a qualified laboratory). Laboratory processing should require approximately four to six months. The contract laboratory will provide taxonomic data in a format compatible with network databases. Field crews will enter data into the appropriate database throughout the field season and should be able to complete data entry within one or two weeks after completing their last sampling event of the spring and fall sampling season. Detailed data entry instructions are provided in SOP #11.

The project manager will oversee preparation of annual summary reports and periodic trend reports of monitoring results, as well as represent the SCPN at a variety of local, regional, and national aquatic ecology, water quality, and related forums. Several network staff members, including the GIS specialist and the data manager, will also support the aquatic macroinvertebrate monitoring project (see Section 7, *Personnel Requirements and Training*, for details).

8.2 Facility and equipment needs

The SCPN aquatic macroinvertebrate monitoring project will be based out of the SCPN program office on the NAU campus in Flagstaff, AZ, where a small laboratory facility, offices, and equipment storage space are available. The SCPN will acquire and maintain all equipment required to implement this monitoring protocol. A complete list of field equipment needs can be found in SOP #1. There will be an ongoing need for equipment maintenance and/or replacement due to normal wear and tear. Most required equipment will be specific to the aquatic macroinvertebrate monitoring program; however, some equipment will also be used for the water quality, integrated riparian, and springs monitoring projects.

Travel accommodations for field staff will include park housing when available, use of vehicle-accessible campgrounds in or near parks, or overnight camping at remote, primitive locations.

8.3 Budget considerations

Estimated costs for conducting aquatic macroinvertebrate monitoring in SPCN parks are shown in Table 7. Start-up field equipment costs were approximately $5,000. After the first year, we anticipate that field equipment replacement and supplies will cost less. Laboratory processing of aquatic macroinvertebrate samples by a qualified laboratory will vary depending upon the number of sites sampled and the laboratory used.

8.4 Procedures for making / implementing changes to the protocol

Revisions to the protocol narrative and SOPs will be inevitable over time. Explicit documentation of these changes is critical for proper acquisition, processing, interpretation, and analysis of aquatic macroinvertebrate data. Procedures for changing the protocol narrative and related SOPs are documented in SOP #14. The protocol narrative and all SOPs are labeled with version numbers and included in a revision history log. Changes to either document type are to be accompanied by changes in version numbers. Version numbers and dates, the changes, reasons for the changes, and the author of the changes are to be recorded in the revision history log. The updated version numbers must be recorded in the aquatic macroinvertebrate monitoring master version table and provided to the data manager for proper updating of the master version table database.

Table 7. SCPN aquatic macroinvertebrate monitoring project budget

Budget item	Annual cost ($)
NPS water resources field lead technician (GS-9) (25%)	21,000–25,000
NAU water resources field crew (25%)	12,000–16,500
Equipment and supplies	2,000–3,000
Travel	3,000–5,000
Laboratory	20,000–23,000
Total	**58,000–72,500**

Literature cited

Allan, J. D. 1995. Stream ecology: Structure and functioning of running waters. London, Chapman and Hall.

Anderson, M. J. 2001. A new method for non-parametric multivariate analysis of variance. Austral Ecology 26:32–46.

Angradi, T. R. 1999. Fine sediment and macroinvertebrate assemblages in Appalachian streams: A field experiment with biomonitoring applications. Journal of the North American Benthological Society 18:49–66.

Arizona Department of Environmental Quality, Water Quality Division (ADEQ-WQD). 2005. Narrative biocriteria standard implementation procedures for perennial streams.

——. 2006. Biocriteria program, quality assurance program plan, revision E.

ASTM International, 2003, D6855-03 Standard test method for determination of turbidity below 5 NTU in static mode: ASTM International, Annual Book of Standards, Water and Environmental Technology, 2003, vol. 11.01, West Conshohocken, Pennsylvania, [http://www.astm.org/cgibin/SoftCart.exe/DATABASE.CART/REDLINE_PAGES/D6855.htm?L+mystore+flap7535+1094151215]

Banta, A. J. 2002. Middle Salt Creek Canyon access plan. Canyonlands National Park environmental assessment.

Barbour, M.T., and J. Gerritsen. 1996. Subsampling of benthic samples: A defense of the fixed-count method. Journal of the North American Benthological Society 15:386-391.

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

Baron, J. S., T. LaFrancois, and B. C. Kondratieff. 1998. Chemical and biological characteristics of desert rock pools in intermittent streams of Capitol Reef National Park, Utah. Great Basin Naturalist 58:250–284.

Benenati, E. P., J. P. Shannon, D. W. Blinn, K. P. Wilson, and S. J. Hueftle. 2000. Reservoir-river linkages: Lake Powell and the Colorado River, Arizona. Journal of the North American Benthological Society 19:742–755.

Berghoff, K. 1995. Capitol Reef National Park tinaja wetland survey. Capitol Reef National Park Summary Report, Resource Management and Science Division.

Blinn, D. W., and D. E. Ruiter. 2006. Tolerance values of stream caddisflies (Trichoptera) in the lower Colorado River basin, USA. Southwestern Naturalist 51(3):326–337.

Boyle, T. P., and M. J. Strand. 2003. Macroinvertebrate community structure and related environmental variables in two forks of the Virgin River, Utah. Western North American Naturalist 63(2):155–166.

Brammer, C. A., and J. F. MacDonald. 2003. Benthic insect fauna of a clean-water stream on Utah's Colorado Plateau, USA. Western North American Naturalist 63:21–34.

Bray, J. R., and J. T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs 27:325–349.

Brown, L. E., A. M. Milner, and D. M. Hannah. 2006. Stability and persistence of alpine stream macroinvertebrate communities and the role of physicochemical habitat variables. Hydrobiologia 560:159–173.

Cairns, J. and J. R. Pratt. 1993. A history of biological monitoring using benthic macroinvertebrates. In D. M. Rosenberg, and V. H. Resh, eds., Freshwater biomonitoring and benthic macroinvertebrates: New York:

Chapman and Hall.

Canton, S. P., L. D. Cline, R. A. Short, and J. V. Ward. 1984. The macroinvertebrates and fish of a Colorado stream during a period of fluctuating discharge. Freshwater Biology 14:311–316.

Clarke, K. R., and R. H. Green. 1988. Statistical design and analysis for a 'biological effects' study. Marine Ecology Progress Series 46:213–226.

Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18:117–143.

Clarke, K. R., and R. M. Warwick. 1994. Change in marine communities: An approach to statistical analysis and interpretation. Bournemouth, U.K.: Bourne Press.

Clarke, K. R. and R. N. Gorley. 2006. PRIMER v6: User manual/Tutorial. PRIMER-E: Plymouth, UK.

Clements, W. H. 1994. Benthic community responses to heavy metals in the Upper Arkansas River Basin, Colorado. Journal of the North American Benthological Society. 13:30–44.

Clements, W. H., D. M. Carlisle, J. M. Lazorchak, and P. C. Johnson. 2000. Heavy metals structure benthic communities in Colorado mountain streams. Ecological Applications 10:626–638.

Cline, L. D., R. A. Short, and J. V. Ward. 1982. The influence of highway construction on the macroinvertebrates and epilithic algae of a high mountain stream. Hydrobiologia 96:149–159.

Colorado Department of Public Health and Environment (CDPHE). 2003. Standard operating procedures for collecting and preserving benthic macroinvertebrate samples.

Colorado Department of Public Health and Environment. 2005. Sampling, Analysis and Assessment Plan (SAAP) for the Collection and Preservation of Benthic Macroinvertebrates – FY 2005.

Cuffney, T. F., 2003. User's manual for the National Water-Quality Assessment Program invertebrate data analysis system (IDAS) software, Version 3. U.S. Geological Survey Open-File Report 03-172.

Cuffney, T. F., M. E. Gurtz, and M. R. Meador. 1993. Methods for collecting benthic invertebrate samples as part of the National Water-Quality Assessment Program. U.S. Geological Survey Open-File Report 93-406. http://water.usgs.gov/nawqa/protocols/bioprotocols.html.

Dahm, C. N., M. A. Baker, D. I. Moore, and J. R. Thibault. 2003. Coupled biogeochemical and hydrological responses of streams and rivers to drought. Freshwater Biology 48:1219–1231.

Dinger, E. C. 2006. Aquatic conservation biology in arid ecosystems. PhD Dissertation. Northern Arizona University, Arizona, USA.

Fitzpatrick, F. A., I. R. Waite, P. J. D'Arconte, M. R. Meador, M. A. Maupin, and M. E. Gurtz. 1998. Revised methods for characterizing stream habitat in the National Water-Quality Assessment Program. U.S. Geological Survey Open-File Report 98-4052. http://water.usgs.gov/nawqa/protocols/bioprotocols.html.

Freehling, M., and K. Johnson. 2002. Inventory of aquatic invertebrates, Chaco Culture National Historical Park, New Mexico Natural Heritage Program. 24.549901.

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification: Viewing streams in a watershed context. Environmental Management 10:199–214.

Gibson, G. A., M. T. Barbour, J. B. Stribling, J. Gerritsen, and J. R. Karr. 1996. Biological criteria: Technical guidance for streams and rivers. EPA/822-B-94-001. Washington, D.C.: U.S. Environmental Protection Agency, Office of Science and Technology.

Graham, T. B. 2001. Survey of ephemeral pool invertebrates at Wupatki National Monument: An evaluation of the significance of constructed impoundments as habitat. Final report for Wupatki National Monument. WUPA-310.

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.

Grimm, N. B., and S. G. Fisher. 1989. Stability of periphyton and macroinvertebrates to disturbance by flash floods in a desert stream. Journal of the North American Benthological Society 8:293–307.

Growns, I. O., and J. E. Growns. 2001. Ecological effects of flow regulation on macroinvertebrate and periphytic diatom assemblages in the Hawkesbury-Nepean River, Australia. Regulated Rivers-Research & Management 17:275–293.

Grubbs, S. A., and J. M. Taylor. 2004. The influence of flow-impounded river regulation of the distribution of riverine macroinvertebrates of Mammoth Caves National Park, Kentucky, U.S.A. Hydrobiologia 520:19–28.

Haden, G. A., J. P. Shannon, K. P. Wilson, and D. W. Blinn. 2003. Benthic community structure of the Green and Colorado Rivers through Canyonlands National Park, Utah, USA. Southwestern Naturalist 48:23–35.

Haefner, J. W., and A. M. Lindahl. 1988. The ecology of small pools in Capitol Reef National Park, Utah. Final Report for Phase I of USDI/NPS Contract No. PX-1350-7-0259.

Haefner, J. W., and A. M. Lindahl. 1991. The ecology of small pools in Capitol Reef National Park, UT: Phase II. Final Report for Phase II of USDI/NPS Contract No. PX-1350-8-0187.

Halse, S. A., D. J. Cale, E. J. Jasinska, and R. J. Shiel. 2002. Monitoring change in aquatic invertebrate biodiversity: Sample size, faunal elements and analytical methods. Aquatic Ecology 36:395–410.

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family level biotic index. Journal of the North American Benthological Society 7:65–68.

Hynes, H. B. N. 1970. The ecology of running waters. University of Toronto Press.

Irwin, R. J. 2008. Draft Part B lite QA/QC Review Checklist for Aquatic Vital Sign Monitoring Protocols and SOPs, National Park Service, Water Resources Division. Fort Collins, Colorado, distributed on Internet only at: http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/PartBLite.pdf

Karr, J. R. 1991. Biological integrity: A long-neglected aspect of water resource management. Ecological Applications 1:66–84.

Karr, J. R., and E. W. Chu. 1999. Restoring life in running waters: Better biological monitoring. Washington, D.C.: Island Press.

Kaufmann, P. R. and E. G. Robinson. 1998. Physical habitat characterization. Pp. 77-118 in J.M. Lazorchak, D.J. Klemm and D.V. Peck, eds., Environmental Monitoring and Assessment Program – Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams. EPA/620/R-94/004F. Office of Research and Development, US EPA, Washington, DC.

Kendall, M., and J. D. Gibbons. 1990. Rank correlation methods. Fifth edition. New York: Oxford University Press.

Kiffney, P. M., and W. H. Clements. 1994. Effects of heavy metals on a Rocky Mountain stream macroinvertebrate assemblage in experimental streams. Journal of the North American Benthological Society 13:511–523.

Kirby, J. M., and J. McAllister. 2000. Fish and benthic macroinvertebrate survey of the Fremont River and selected sites on Pleasant Creek and Sulphur Creek within the boundaries of Capitol Reef National Park. National Park Service.

Kreutzweiser, D. P., S. S. Capell, and K. P. Good. 2005. Macroinvertebrate community responses to selection logging in riparian and upland areas of headwater catchments in a northern hardwood forest. Journal of the North American Benthological Society 24:208–222.

Ladle, M., and J. A. Bass. 1981. The ecology of a small chalk stream and its responses to drying during drought conditions. Archiv Fur Hydrobiologie 90:448–466.

Lazorchak, J. M., D. J. Klemm, and D. V. Peck, eds. 1998. Environmental monitoring and assessment program-surface waters: Field operations and methods for measuring the ecological conditions of streams. EPA/620/R-94/004F. U.S. Environmental Protection Agency, Washington D.C.

Lemly, A. D. 1982. Modification of benthic insect communities in polluted streams: Combined effects of sedimentation and nutrient enrichment. Hydrobiologia 87:229–245.

Lorenz, A., and R. T. Clarke. 2006. Sample coherence: A field study approach to assess similarity of macroinvertebrate samples. Hydrobiologia 566:461–476.

MacRury, N. 2002. Impacts of wildfire on benthic invertebrates in burned streams: A multiple-scale approach to measuring community and population responses. PhD dissertation, Colorado State University, Fort Collins, Colorado.

MacRury, N., and W. Clements. 2002. Ecological, hydrological, and geo-chemical effects of fire on canyon watersheds in Bandelier National Monument, New Mexico: Final technical report. Southwestern Parks and Monument Association. 48.585314.

Manly, B. F. J. 1991. Randomization and Monte Carlo methods in biology. London: Chapman and Hall.

Maret, T. M., D. E MacCoy, K. D. Skinner, S. E. Moore, and I. O'Dell. 2001. Evaluation of macroinvertebrate assemblages in Idaho rivers using multimetric and multivariate techniques, 1996–1998. U.S. Geological Survey Water-Resources Investigations Report 2001-4145.

McCafferty, W. P. 1998. Aquatic entomology: The fishermen's and ecologists' illustrated guide to insects and their relatives. Sudbury, Mass.: Jones and Bartlett Publishers.

McIntosh, M. D., M. E. Benbow, and A. J. Burky. 2002. Effects of stream diversion on riffle macroinvertebrate communities in a Maui, Hawaii, stream. River Research and Applications 18:569–581.

Merritt, R.W. and K.W. Cummins (editors). 1996. An introduction to the aquatic insects of North America, 3rd ed. Kendall/Hunt Publishing Company, Dubuque, Iowa.

Milner, A. M., S. C. Conn, and L. E. Brown. 2006. Persistence and stability of macroinvertebrate communities in streams of Denali National Park, Alaska: Implications for biological monitoring. Freshwater Biology 51:373–387.

Monroe, S. A., and C. A. Bliss. (In preparation). Water Quality Monitoring Protocol for the Southern Colorado

Plateau Network. National Park Service, Fort Collins, Colorado.

Moulton, S. R. II, K. W. Stewart, and K. L. Young. 1994. New records, distribution and taxonomic status of some Northern Arizona caddisflies (Trichoptera). Entomological News 105:164–174.

Moulton, S. R. II, and K. W. Stewart. 1997. A new species and first record of the caddisfly genus Cnodocentron Schmid (Trichoptera: Xiphocentronidae) north of Mexico. Proceedings of the 8th International Symposium on Trichoptera, 343–347.

Moulton, S. R., II, J. L. Carter, S. A. Grotheer, T. F. Cuffney, and T. M. Short. 2000. Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Processing, taxonomy, and quality control of benthic macroinvertebrate samples. U.S. Geological Survey Open-File Report 00-212.

Moulton, S. R., II, J. G. Kennen, R. M. Goldstein, and J. A. Hambrook. 2002. Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water Quality Assessment Program. U.S. Geological Survey Open-File Report 02-150. http://water.usgs.gov/nawqa/protocols/bioprotocols.html.

Muldavin, E., A. Kennedy, C. Jackson, P. Neville, T. Neville, K. Schulz, and M. Reid. 2011. Vegetation classificationand map: Bandelier National Monument. Natural Resource Technical Report NPS/SCPN/NRTR—2011/438. National Park Service, Fort Collins, Colorado.

Nakano, D., and F. Nakamura. 2006. Responses of macroinvertebrate communities to river restoration in a channelized segment of the Shibetsu River, northern Japan. River Research and Applications 22:681–689.

New Mexico Environment Department, Surface Water Quality Bureau (NMED-SWQB). 2007. The 2007 NMED/SWQB Standard Operating Procedures for Data Collection. http://www.nmenv.state.nm.us/swqb/sop/SWQB-MASStandardOperatingProcedures.pdf.

Nuttall, P. M. 1972. The effects of sand deposition upon the macroinvertebrate fauna of the River Camel, Cornwall. Freshwater Biology 2:181–186.

Oberlin G. E., J. P. Shannon, and D. W. Blinn. 1999. Watershed influence on the macroinvertebrate fauna of ten major tributaries of the Colorado River through Grand Canyon, Arizona. Southwestern Naturalist 44:17–30.

Ostermiller, J. D., and C. P. Hawkins. 2004. Effects of sampling error on bioassessments of stream ecosystems: Application to RIVPACS-type models. Journal of the North American Benthological Society 23:363–382.

Paul, M. J., J. Gerritsen, C. Hawkins, and E. Leppo. 2005. Development of biological assessment tools for Colorado. Draft report. Colorado Department of Public Health and Environment,Water Quality Control Division –Monitoring Unit, Denver, Colorado.

Peck, D. V., A. T. Herlihy, B. H. Hill, R. M. Hughes, P. R. Kaufmann, D. J. Klemm, J. M. Lazorchak, F. H. McCormick, S. A. Peterson, P. L. Ringold, T. Magee, and M. Cappaert. 2006. Environmental Monitoring and Assessment Program-Surface Waters Western Pilot Study: Field Operations Manual for Wadeable Streams. EPA/620/R-06/003. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. http://www.epa.gov/wed/pages/publications/authored/EPA620R-06003EMAPSWFieldOperationsManualPeck.pdf.

Peterson, M. J., J. G. Smith, G. R. Southworth, M. G. Ryon, and G. K. Eddlemon. 2002. Trace element contamination in benthic macroinvertebrates from a small stream near a uranium mill tailings site. Environmental Monitoring and Assessment 74:193–208.

Philippi, T. E., P. M. Dixon, and B. E. Taylor. 1998. Detecting trends in species composition. Ecological Applications 8:300–308.

Pippin, W. F., and B. D. Pippin. 1980. Aquatic invertebrates of Rito de los Frijoles, Bandelier National Monument, New Mexico, National Park Service. 17.10633.

Pippin, W. F. and B. D. Pippin. 1981. Aquatic invertebrates from Capulin Creek, Bandelier National Monument, New Mexico, National Park Service. 15.10631.

Poff, N. L., J. D. Olden, N. K. M. Vieira, D. S. Finn, M. P. Simmons, and B. C. Kondratieff. 2006. Functional trait niches of North American lotic insects: trait-based ecological applications in light of phylogenetic relationships. Journal of the North American Benthological Society 25:730–755.

Quinn, G. P., T. J. Hillman, and R. Cook. 2000. The response of macroinvertebrates to inundation in floodplain wetlands: A possible effect of river regulation? Regulated Rivers: Research and Management 16:469–477.

Rabeni C. F., K. E. Doisy, and L. D. Zweig. 2005. Stream invertebrate community functional responses to deposited sediment. Aquatic Sciences 67:395–402.

Rader, R. B., and T. A. Belish. 1999. Influence of mild to severe flow alterations on invertebrates in three mountain streams. Regulated Rivers: Research and Management 15:353–363.

Rantz, S.E., and others, 1982. Measurement and computation of streamflow: Volume 1, measurement of stage and discharge. U.S. Geological Survey Water-Supply Paper 2175.

Rosenberg, D. M., and V. H. Resh. 1993. Introduction to freshwater biomonitoring and benthic macroinvertebrates, in D. M. Rosenberg and V. H. Resh, eds., Freshwater biomonitoring and benthic macroinvertebrates. New York: Chapman and Hall, 1–9.

Scarsbrook, M. R. 2002. Persistence and stability of lotic invertebrate communities in New Zealand. Freshwater Biology 47:417–431.

Schelz, C. D. 2001. Long-term riparian monitoring in Salt Creek in Canyonlands National Park. Annual report, Southeast Utah Group. Biologist files, Southeast Utah Group headquarters, Moab, Utah.

Scott, M. L., A. M. D. Brasher, A. M. Caires, E. W. Reynolds, and M. E. Miller. 2005. The structure and functioning of riparian and aquatic ecosystems of the Colorado Plateau: Conceptual models to inform monitoring. Report to the Southern and Northern Colorado Plateau Networks.

Shakarjian, M. J., and J. A. Stanford. 1998. Effects of trampling by hikers on zoobenthos of the North Fork of the Virgin River, Zion National Park, Utah. National Park Service Open File Report 145-97.

Shannon, J. P., D. W. Blinn, P. L. Benenati, and K. P. Wilson. 1996. Organic drift in a regulated desert river. Canadian Journal of Fisheries and Aquatic Sciences 53:1360–1369.

Shannon, J. P., D. W. Blinn, T. McKinney, E. P. Benenati, K. P. Wilson, and C. O'Brien. 2001. Aquatic food base response to the 1996 test flood below Glen Canyon Dam, Colorado River, Arizona. Ecological Applications 11:672–685.

Sharrow, D., D. Thoma, K. Wynn, and M. Beer. 2007. Water quality vital signs monitoring protocol for park units in the Northern Colorado Plateau Network. Version 1.00. National Park Service. Available at: http://science.nature.nps.gov/im/monitor/protocoldb.cfm

Sorensen, J. A., and D. M. Kubly. 1997. Investigations of the endangered Kanab ambersnail: Monitoring, genetic studies, and habitat evaluation in Grand Canyon and Northern Arizona. Arizona Game and Fish Department Technical Report 122.

Southerland, M. T., and J. B. Stribling. 1995. Status of biological criteria development and implementation. Pages 79–94 in W. Davis and T. Simon, eds., Biological assessment and criteria: Tools for water resources planning and decision making. Chelsea, Mi.: Lewis Publishers, Inc.

Spindler, P. 2004. Stream channel morphology and benthic macroinvertebrate community associations in the San Pedro River and Verde River Basins of Arizona, 1999–2002. Arizona Department of Environmental Quality. Open File Report 04-01.

Springer A., L. E. Stevens, R. Harms. 2006. Inventory and classification of selected National Park Service springs on the Colorado Plateau. Report to the Southern and Northern Colorado Plateau Networks.

Steinman, A. D. 1996. Effects of grazers on freshwater benthic algae. Pages 341–373 in R. J. Stevenson, M. L. Bothwell, and R. L. Lowe, eds., Algal ecology: Freshwater benthic ecosystems. San Diego, Calif.: Academic Press.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262–278.

Tessler, S., and J. Gregson. 1997. Draft data management protocol. NPS I&M Program. http://www1.nrintra.nps.gov/im/dmproto/joe40001.htm. Last accessed August 9, 2006.

Thiere, G., and R. Schulz. 2004. Runoff-related agricultural impact in relation to macroinvertebrate communities of the Lourens River, South Africa. Water Research 38:3092–3102.

Thomas, K. A., M. L. McTeague, L. Ogden, M. L. Floyd, K. Schulz, B. Friesen, T. Fancher, R. Waltermire, and A. Cully. 2009. Vegetation classifi cation and distribution mapping report. Mesa Verde National Park. Natural Resource Report NPS/SCPN/NRR—2009/112. NationalPark Service, Fort Collins, Colorado.

Thomas, K. A., M. L. McTeague, L. Ogden, K. Schulz, T. Fancher, R. Waltermire, and A. Cully. 2010. Vegetation-classification and distribution mapping report: Canyon de Chelly National Monument. National Resource Technical Report NPS/SCPN/NRTR—2010/306. National Park Service, Fort Collins, Colorado.

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, Fort Collins, Colorado.

United States Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9, available online at http://pubs.water.usgs.gov/twri9A.

Utah Department of Environmental Quality, Division of Water Quality (UDEQ-DWQ). 2006. Monitoring manual. http://www.waterquality.utah.gov/Monitoring/2007_DWQ_Monitoring_plan.pdf.

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.

Vinson, M. R., and C. P. Hawkins. 1996. Effects of sampling area and subsampling procedure on comparison of taxa richness among streams. Journal of the North American Benthological Society 15:392-399.

Vinson, M. R. 2002. Aquatic ecosystems and invertebrates of the Grand Staircase-Escalante National Monument. Annual report of activities for 2001.

Wiersema, N. A., C. R. Nelson, and K. F. Kuehnl. 2004. A new small minnow mayfly (Ephemeroptera: Baetidae) from Utah, U.S.A. Entomological News 115:139–145.

Wood, P. J., M. D. Agnew, and G. E. Petts. 2000. Flow variations and macroinvertebrate community responses in a small groundwater-dominated stream in south-east England. Hydrological Processes 14:3133–3147.

Woodbury, A. M. 1933. Biotic relationships of Zion Canyon, Utah with special reference to succession. Ecological Monographs 3:147–245.

Workman, G. W. 1980. An aquatic survey of the North Fork of the Virgin River and two of its tributaries in Zion National Park, Utah. Survey Report Order No. PX 1590-0-0106.

Wright, J. F., and A. D. Berrie. 1987. Ecological effects of groundwater pumping and a natural drought on the upper reaches of a chalk stream. Regulated Rivers: Research and Management 1:145–160.

Glossary

Abandoned Channel - empty channel, with no surface water connection to main channel.

Abundance - the number of individuals in a sample.

Active Channel – the width of the channel at normal winter high flows. Active channel can often be determined by an absence of perennial vegetation on banks with soil and the presence of "scrubbed" clean rock surfaces on banks.

Algae - aquatic, eukaryotic one-celled or multicellular autotrophic plants without stems, roots, and leaves.

Algal Mat - an assemblage of algae visible to the naked human eye.

Anthropogenic - human caused.

Aquatic Ecosystem - an ecological community located in a body of water, either freshwater or marine.

Assemblage - an association of interacting populations of organisms in a given waterbody.

Backwater - standing water that is disconnected from the main channel during low flow.

Bankfull Width - the distance across a stream channel perpendicular to the flow between two points where the channel intersects with the encompassing plateau, regardless of whether there is actually water in the channel. Compare to Wetted Channel Width.

Basin - the entire geographical area drained by a river and its tributaries.

Behavioral Response - an observable reaction in an organism's activity.

Benthic - living on the bottom of a body of water.

Biotic Environment - all the organisms of a community and their interactions with each other.

Cascade - turbulent series of short falls and small scour basins; prominent feature of high gradient bedrock and cascade reaches.

Chironomid - of the family Chironomidae; small two winged flies that lack piercing mouthparts, or their larvae. Commonly known as "Midges."

Chute - Narrow, high-gradient slots in bedrock containing fast moving water.

Coarse-grained substrates - stream substrates (>2 mm widest dimension) composed primarily of gravels, cobbles, and boulders.

Colorado Plateau - is a physiographic region roughly centered on the Four Corners region of the southwestern United States characterized by a semi-arid environment.

Community - an association of organisms having mutual relationships among themselves and to their environment.

Community Structure - organization of a biological community based on numbers of individuals within different taxonomic groups and the proportion of each taxonomic

group to the community.

Competitor - an organism which demands simultaneously with another organism or organisms limited environmental resources.

Composite Sample - a mixture of multiple macroinvertebrate specimens collected from different points within the same reach.

Crayfish - an small lobster-like freshwater aquatic macroinvertebrate of the phylum Arthropoda, class Crustacea.

Dammed Pool - Impoundment of water formed by an obstruction (e.g., debris, beaver dam, landslide).

Depth - at any given point in a stream the distance from the surface of the water to the substrate.

Detritovore - an organism that feeds on fresh to partly decomposed dead organic matter.

Dissolved Oxygen - the amount of free oxygen dissolved in water.

Distribution - the spatial organization of a population.

Eddy - Scouring action or flow reversal behind a flow obstruction; often formed along the edge of the channel.

Edgewater - a point where the surface of the water in a stream meets the surface of the channel that contains the water. For example, each transect has two edgewater points, a River Left Edgewater and a River Right Edgewater.

Elutriate - to separate the lighter or finer particles of a sample by agitating the sample in water and then decanting the water along with the finer particles into a sieve.

Embeddedness - the degree to which gravel-sized and larger particles are surrounded or enclosed by finer-sized particles.

Emergent Wetland - an area usually saturated by water and characterized by plants rooted underwater projecting foliage above the water surface.

Ephemeral Stream - a lotic system that has flowing water only after precipitation events.

Exuviae - the moulted exoskeleton of an invertebrate.

Falls - vertical drop of water spanning a flow obstruction; commonly found in bedrock, cascade, and step-pool stream reaches.

Faunistically Richest Community (FRC) - those habitats within the reach of a stream most likely to yield abundant and diverse biota. In the case of macroinvertebrates, typically cobble-sized substrate located in a swift riffle.

Fine-grained substrates - stream substrates (< 2 mm widest dimension) composed primarily of silt and sand.

Geomorphic channel units - fluvial geomorphic descriptors of channel shape and stream velocity. Pools, riffles, and runs are three types of geomorphic channel units considered for National Water-Quality Assessment (NAWQA) Program habitat sampling.

Glide - non-turbulent, fast-moving water; found in bedrock, cascade, step-pool, and pool-riffle reaches.

Gradient - a measure of the steepness of a stream channel calculated by change elevation/ change distance.

Grazer - an animal that feeds on growing grass or other herbage on the ground.

Habitat - the place occupied by an organism, population, or community.

Hanging Garden - a place where vegetation is present on the vertical face of the ground.

Headwater - the source or upper reaches of a stream.

Herbivore - an animal that eats only plants.

Index - an integrative expression of site condition across multiple metrics.

Indicator Species - a species whose status provides information about the overall state of its ecosystem.

Insolation - solar radiation that contacts the earth's surface.

Intermittent Stream - a stream that flows seasonally or occasionally, sometimes alternating between surface and subterranean flow paths throughout its course. Typical sources include snowmelt or springs.

Invertebrates - animals that do not have backbones, such as worms, clams, crustaceans, and insects.

Leaf Pack - any significant accumulation of leaf detritus.

Lentic - related to or living in still water.

Life Cycle - the series of different states that comprise the growth and development of an organism.

Lotic - related to or living in moving water.

Macroinvertebrate - an organism without a backbone that is visible to the naked human eye.

Macrophyte - any plant that is visible to the unaided human eye.

Metric - a calculated term or enumeration representing some aspect of biological assemblage, function, or other measurable aspect and is a characteristic of the biota that changes in some predictable way with increased human influence. A multimetric approach involves combinations of metrics to provide an integrative assessment of the status of aquatic resources.

Microhabitat - small area with physical and ecological characteristics that distinguish it from its immediate surrounding area.

Monitoring - the process of continually checking or observing a system.

Morphological Response - reaction in an organism's form or structure.

Multimetric - relating to analytical techniques which use several measurable characteristics of a biological assemblage.

Multivariate - statistical, mathematical, or graphical consideration of multiple variables simultaneously.

Native - referring to a species which has lived and co-evolved naturally in its geographical environment.

Non-Native - referring to a species which is invasive or has been introduced into its environment by humans.

Nutrient Cycling - the continuous process through an ecosystem of minerals, compounds, or elements that promote biological growth or development.

Perennial - of or relating to a freshwater system in which water is typically present at all times during a given year.

Periphyton - algae attached to substrate.

pH - the measure of the activity of hydrogen ions in a solution, and thus of the solution's acidity or alkalinity.

Physiological Response - reactions in an organism's function.

Plunge Pool - scoured pool caused by vertical fall; common to steeper bedrock, cascade, and step-pool reaches.

Point Source Pollutant - a chemical that can be traced back to a single source.

Pollutant - an undesired contaminant.

Pond - a still body of water shallow enough for plants to grow.

Pool - a part of a stream with relatively lower velocity and commonly with water deeper than surrounding areas.

Population - all the organisms of a specific group within a habitat, community, or system.

Potholes - an erosion-caused depression that collects rainwater.

Predator - an animal that eats only other animals.

Prey - an animal that is hunted for food.

Process - in the context of sampling, the sorting of live macroinvertebrate specimens from incidental debris such as pebbles, and leaves.

Qualitative multihabitat - a series of different habitats identified in a reach from which discrete collections of algae or invertebrates are taken and later combined to for a composite sample.

Rapid - a section of a stream characterized by swift current and persistent surface turbulence in which the waves exceed equilibrium and collapse upstream on themselves. Moderate gradient, deep, longitudinally planar turbulent flow; prominent feature of plane-bed streams.

Reach - a length of stream (typically 150–300 m for aquatic sampling in streams) that is chosen to represent a uniform set of physical, chemical, and biological conditions within a segment. It is the principal sampling unit for collecting physical, chemical, and biological data.

Recovery - the re-establishment of a community after a disturbance event.

Richest-targeted habitat - a targeted habitat (usually a riffle or woody snag where the taxonomically richest algal or invertebrate community is theoretically located) identified in a reach from which discrete collections of algae or invertebrates are taken and later combined to form a composite sample.

Richness - the number of different taxa in a sample.

Riffle - a shallow part of the stream where water flows swiftly over completely or partially submerged obstructions to produce surface agitation. Most common type of turbulent flow in lower gradient alluvial channels; found in plane bed and pool-riffle reaches.

Riparian Ecosystem - a community of organisms located in the interface zone between aquatic and upland terrestrial ecosystems.

Riparian Canopy Closure - how much foliage is present in the area over a stream channel. Measured with a spherical densiometer.

River Left - the left bank of a stream as determined from the vantage point of an observer facing downstream.

River Right - the right bank of a stream as determined from the vantage point of an observer facing downstream.

RIVPAC - river invertebrate prediction and classification system.

Run - non-turbulent, fast-moving water in lower gradient alluvial channels; typically deeper than riffles or glides.

Scouring Event - in streams, an occurrence such as a flood that causes extreme erosion and displacement of the substrate and biota.

Scour Pool - depression in stream bed formed by scouring action.

Sedentary - of or relating to an organism that does not migrate or move far from its breeding ground.

Seep - a place where groundwater oozes to the surface slower than a spring.

Siltation - the deposition of finely divided soil and rock particles upon the bottom of stream and river beds.

Solar Path-Finder - a device used to measure the amount and concentration of annual sunlight received by any point on the surface of a stream.

Spatial Scale - a particular unit of area over which distribution is analyzed. For example, microhabitat, habitat, reach, stream, watershed.

Species Diversity - the number and variety of species found in a given area.

Specific Conductivity - a standardized measure of electrical conductivity used as a measure of the ionic activity and content of water, particularly for concentrations of total dissolved solids and salinity.

Spring - a point where an aquifer meets the ground at a rate faster than a seep.

Stressor - internal or external stimuli that produce a reaction in an organism.

Substrate - the material that constitutes the bed of a stream channel.

Substrate Type - the categories of material that are usually located on a river bed: silt, sand, pebble, gravel, cobble, boulder, bedrock.

Succession - the gradual and orderly process of change in an ecosystem brought about by the progressive replacement of one community by another until a stable climax is established.

Taxon - any organism or group of organisms of the same taxonomic rank; for example, members of an order, family, genus, or species.

Terrestrial- living on or in or growing from land

Thalweg - that part of a stream channel in which the current flows fastest.

Tinaja - Spanish for large earthen jar. See "Water Pocket" or "Pothole."

Transect - a measurement of a stream within across the stream channel and perpendicular to the flow of current.

Trench - standing water found in tightly constrained bedrock reaches.

Tributary - a stream that flows into a larger stream.

Trophic Composition - the structure of a community based on the functional feeding habits of its constituent populations.

Turbidity - a measure of particles suspended in water.

Univariate - statistical, mathematical, or graphical comparison of two units using only one variable.

Velocity - the rate at which the current is flowing past any given point in a stream.

Watershed - an area of land which drains to the same low point.

Water Pocket - a erosion-caused rainwater-collecting depression in resistant rock.

Wetted Channel Width - the distance across a stream channel where there is actually water present, i.e., from left water's edge to right water's edge.

Woody Debris - any stem or trunk of diameter greater than 0.5cm actually in contact with the water. Measurement consists of diameter of the debris at its largest point and the length of the debris actually in contact with the water.

Standard Operating Procedures

The 14 standard operating procedures (SOPs) included here provide details on all activities necessary to conduct aquatic-macroinvertebrate sampling and associated physical habitat characterization for the Southern Colorado Plateau Network of the National Park Service.

Figure 5a. Collecting a quantitative macroinvertebrate sample in Hermit Creek, Grand Canyon National Park. Photo courtesy of NPS.

Figure 5b. Measuring stream flow velocity in Black Rock Canyon Creek. Photo courtesy of NPS.

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Standard Operating Procedure #1: Preparing for the Field Season

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) describes pre-season procedures for monitoring aquatic macroinvertebrates and habitat characteristics in SCPN parks. The procedures described here are primarily the responsibility of the lead technician, who should be familiar with the monitoring protocol narrative before initiating this and subsequent SOPs. Included in SOP #1 are a description of general preparations, field season scheduling considerations, and a list of necessary supplies and equipment for sampling. A yearly project task list is provided in Appendix C. The procedures described here should begin no later than three months prior to the field season.

1 General preparations and review

- **Review monitoring narrative and all SOPs.** The lead technician should be thoroughly familiar with the objectives described in the SCPN aquatic macroinvertebrate monitoring protocol. He or she should also have a solid working knowledge of the conceptual models that summarize existing knowledge and hypotheses concerning the structure and functioning of riparian and aquatic ecosystems of the Colorado Plateau (Scott et al. 2005).
- **Identify season-specific plans.** The lead technician should discuss specific sampling goals, including scheduling and crew member responsibilities, with the program manager and project manager. Goals for the upcoming season and a realistic timeline to meet the goals should be established. Finally, the lead technician should review notes from previous seasons and be familiar with any unique conditions (i.e., hazardous routes, missing markers) that were encountered during that season.
- **Prepare the field folders.** The lead technician should be familiar with the field folder for each site and should check each folder to make sure that all of the listed items are included (table 1-1).

Table 1-1. List of field equipment and supplies

Field office	Quantity per site
site description	1
topographic site map	1
site coordinates	for each reach at site
road log	1
trail log	1
all necessary permits (research, backcountry, and camping)	site dependent
equipment list	1
park contact information	1
emergency contact information	1
photographs	site specific
copies of previous years field notes and year end summary	1
waterproof pens	2
pencils	2
replacement lead	1 container
field datasheets on waterproof paper	enough for an entire reach
clipboards	1
SCPN Aquatic Macroinvertebrate Protocol	1
Reach layout	
flagging tape	1
Macroinvertebrate sample collection	
Slack Sampler (0.5 m width) 500µm mesh	1
collapsible plastic bucket	1
forceps	1/crew member
re-sealable plastic bags	1 box
hand rake	1
scrub brush	1
squirt bottle	1
wide mouth plastic sample bottles (500 & 1000 mL)	7-500mL and 4-1000mL per reach
ethanol	4 L/reach
sample labels	10-rite in the rain 10 regular/reach
electrical tape	1
clear packing tape	1
scissors	1
Personal and group safety	
first aid kit	1
insect repellant	1
alcohol based hand wash	1
Habitat characterization	
small Phillips screwdriver	1
spare Pendant	1
dessicant packet	1

Habitat characterization (*continued*)	Quantity per site
attachment cord	1
scrub pad	
50 m measuring tape	2
current meter	1
wading rod	1
metric ruler	2
modified concave spherical densiometer	1
chaining pins	2
thermometer	1
temperature sensor downloader	1
spare temperature sensor	1
multi-parameter water quality sonde	1
turbidity meter	1
back-up water quality meter	1
buffer solutions for ph (ph 7 & 10)	1 liter each
conductivity standards (1413, 84)	1 liter each
di water	1 liter
amber sample bottles (250 ml)	2/reach
Basic field supplies	
digital camera	1
GPS	1
extra batteries for all equipment	TBD
tool set	1
hand lens	1
compass	1
climbing rope	1
watch	1
nylon cable ties	10
Personal gear	
rain gear	1
sunhat	1
sandals (or other water shoes)	1 pair
hiking boots	1 pair
waders	1 pair
neoprene gloves	1 pair
drinking water	1
water filter	1
sunscreen	1
sunglasses	1
emergency food supply	1 day supply

- **Obtain permits.** The lead technician should work with the SCPN program manager to obtain all necessary permits. These include Scientific Research and Collecting Permits as well as backcountry hiking and camping permits. Scientific Research and Collecting Permits should be obtained for each park using the National Park Service Research Permit and Reporting System website, http://science.nature.nps.gov/research. These permits require that a sub-section on sample collection and maintaining a reference collection be completed for all aquatic macroinvertebrate sample sites. Backcountry hiking and camping permits or specific permission must be obtained for each park where samples will be collected. This should be done through park backcountry offices, park resource managers, law enforcement rangers, or other designated park staff.
- **Prepare supplies and equipment.** All of the necessary field equipment and supplies for the season should be inventoried and inspected. Equipment should be checked to ensure that it is in optimum working condition. In addition to sampling equipment, additional items that should be available include field guides, datasheets, field notebooks, GPS units, maps, preservatives, camping gear, and safety equipment. For a complete list of supplies and equipment, (see table 1-1) and associated data collection SOPs (SOPs #3–#7).
  - Prior to the beginning of the field season, conduct an inventory of sampling jars, preservative, and shipping supplies (see SOPs #4-#8), and order new supplies, if necessary, to ensure that there are enough to last through the entire field season. Each field season a new set of datasheets will need to be photocopied onto waterproof paper and sample labels created for each sample (one that can be attached to the outside of the jar and one on waterproof paper for inside the sampling jar).
  - Equipment and supplies should be grouped together in containers according to sampling activity, and each container should have an attached checklist of all of the necessary supplies.
  - All field equipment should be available and organized at least one month before field work is scheduled to begin. All equipment should also be examined for functionality and completeness before field work begins. For example, sampling nets should be clean and free of tears, and a sufficient supply of replacement batteries and pencils should be available.
- **Ensure that the lead technician has the necessary certifications for shipping containers filled with ethanol.** The IATA/ICAO/DOT Hazardous Materials Shipping training is required every three years for anyone who either receives or ships any hazardous material. Training courses are provided by the Office of Regulatory Compliance at Northern Arizona University.
- **Confirm site locations.** Prior to the field season, the lead technician should become familiar with the locations of all sampling sites and should ensure that the location coordinates of all sampling sites are correct and available for uploading to GPS units. A printout of all sampling location coordinates should be included in the field folder as a back-up reference for crew members. Topographic maps created from the program TOPO that contain sampling locations marked on them should also be included in the field folder. Access points of difficult to reach areas should be marked on the maps, and if possible, the coordinates of these points should be saved in the GPS units. Road or trail logs, in addition to site descriptions and contact information for landowners, park managers, etc. should be maintained in the field folder.

2 Scheduling field work

Sampling for aquatic macroinvertebrates will be conducted during established sampling windows (typically in the spring or fall for the Colorado Plateau), depending on the

specific site. A tentative schedule should be constructed for the entire field season, taking into account all logistical considerations. This sampling schedule should provide an initial plan for the entire season but allow flexibility for unforeseen circumstances. Potential reasons for schedule changes include weather (spring run-off and snow melt dates, monsoon rainstorms), road conditions, backcountry permits, travel time between sites, and other, sometimes unpredictable, accessibility issues. The number and distribution of sites being sampled and number of field crew members will also determine the schedule.

Standard Operating Procedure #2: Hiring and Training Field Personnel

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) describes the steps for hiring and training seasonal field personnel to collect data for the SCPN aquatic macroinvertebrate monitoring. The steps described here are integral to the monitoring effort because inter-observer variability can potentially reduce the quality of the data or obscure otherwise detectable trends.

1 Hiring field personnel

The SCPN water resources field crew will consist of three to five individuals with responsibilities for conducting monitoring associated with this protocol and with the Integrated Riparian, Water Quality, and Spring Ecosystems Monitoring Protocols. SCPN operational plans call for accomplishing field work using a combination of NPS Hydrologic or Biological Technicians and technicians hired through a cooperative agreement with Northern Arizona University (NAU). The crew will be led by a NPS technician (term GS-9) with considerable field experience in hydrology, aquatic and/or riparian ecology. At minimum, the field crew will also include one NPS hydrologic or biological technician and two temporary NAU positions. The NAU positions will be 1) a Senior Research Specialist (GS-7 equivalent), ideally with field experience in a complementary subject area (e.g., if the lead technician has a background in aquatic and riparian ecology, the Senior Research Specialist would preferably have training in water quality and hydrology), and 2) a Research Specialist (GS-5 equivalent). Additional technicians and interns may be hired as necessary. See Table 2-1 for detailed descriptions of the NAU water resources field crew positions.

Time commitments on the part of the lead technician are estimated to be 50% for

Table 2-1. Water resources crew positions

Senior Research Specialist

Minimum qualifications:

- Master's degree in biology, ecology, geology, or environmental sciences AND 3 years of related research experience; OR
- Bachelor's degree in biology, ecology, geology, or environmental sciences AND 4 years or related research experience, OR
- Any equivalent combination of experience, training, and/or education

Desired qualifications:

- Two years of specialized experience as a biological or hydrological technician with duties similar to those of this position
- Two years related research or ecological experience or master's degree in biology, ecology, geology, or environmental sciences
- Field experience working in remote backcountry settings and harsh field conditions

Knowledge, skills and abilities:

- Knowledge in the following subject areas as related to aquatic and riparian ecosystems of the Colorado Plateau: aquatic macroinvertebrates, water quality, hydrology, geomorphology, and riparian vegetation
- Knowledge and experience with the methods, procedures, and techniques for collecting of physical, biological, and water quality data
- Ability to lead a field crew to accomplish inventory and monitoring objectives
- Ability to recognize, record, and adapt to unusual conditions or data encountered in the normal course of work
- Skills conducting field research in ecological, biological, or environmental topics
- Ability to perform detailed data collection, data organization and record keeping duties
- Ability to communicate information in a clear and concise manner, in order to develop reports and communicate results of data collection
- Ability to work with a wide variety of people from federal, state, and tribal land management agencies, educational and research institutions, and non-profit organizations
- Skill and ability to work in remote backcountry settings with little supervision

Research Specialist

Minimum qualifications:

- Bachelor's degree in biology, ecology, geology, or environmental sciences AND two years related research or experience; OR
- Six years research or work experience in biology, ecology, geology, or environmental sciences; OR
- Any equivalent combination of experience, training, and/or education

Desired qualifications:

- Two years of specialized experience as a biological or hydrological technician with duties similar to those of this position
- Two years related research or ecological experience or master's degree in biology, ecology, geology, or environmental sciences
- Field experience working in remote backcountry settings and harsh field conditions

Knowledge, skills and abilities:

- Knowledge in the following subject areas as related to aquatic and riparian ecosystems of the Colorado Plateau: aquatic macroinvertebrates, water quality, hydrology, geomorphology, and riparian vegetation
- Knowledge and experience with the methods, procedures, and techniques for collecting of physical, biological, and water quality data
- Skills conducting field research in ecological, biological, or environmental topics
- Ability to perform detailed data collection, data organization and record keeping duties
- Ability to communicate information in a clear and concise manner, in order to develop reports and communicate results of data collection
- Ability to work with a wide variety of people from federal, state, and tribal land management agencies, educational and research institutions, and non-profit organizations
- Skill and ability to work in remote backcountry settings with little supervision

fieldwork, 30% for data management, data analysis and reporting, and 20% for scheduling and coordination of field staff. Field staff should expect to be conducting field work 75% of the time, with approximately 25% of their time spent in the office to transfer and manage field data and to organize and maintain field equipment.

2 Technical training

Water resources field crew must participate in technical training that encompasses the following:

- **Familiarity with sampling methods**. Field technicians must be familiar with the Aquatic Macroinvertebrate Monitoring Protocol for the Southern Colorado Plateau Network of the National Park Service, particularly with all sampling methods related to collecting aquatic macroinvertebrates and measuring habitat characteristics (outlined in SOPs #4-#6).
- **Preparedness for field conditions**. Field work in SCPN parks often occurs in remote locations and can be extremely physically demanding. All field crew members should be prepared for difficult field conditions. Fieldwork in the Colorado Plateau requires physical capacity for backpacking to remote field sites and long days of hiking in rugged, steep terrain, which may also include quick-sand, abrupt drop-offs, or dense stands of tamarisk. Technicians must be comfortable working in and around water and should be able to swim. Field crews may remain in the field for long periods of time, experiencing extreme and highly variable weather. The remote nature of this work requires the ability to function as a member of a crew and to independently exercise excellent judgment in difficult situations. Crew members should have prior experience working and camping in backcountry situations. Wilderness First Aid and CPR are recommended.
- **Formal training in macroinvertebrate sampling procedures**. An important component of pre-season preparation is adequate training of the field crew (see "Crew Workshop" below). This could be accomplished by the project manager or by bringing in an individual with a high level of experience with sampling methods similar to those described in the SCPN Aquatic Macroinvertebrate Monitoring Protocol. Alternatively, crew members could be sent to training on aquatic macroinvertebrate sampling procedures offered by NAWQA, EMAP, or one of the states.
- **Briefing on park procedures**. SCPN field crews should be familiar with the rules, regulations and guidelines of individual park units. An important aspect of maintaining good working relationships with park staff is to ensure that all crew members adhere to permit requirements, backcountry hiking and camping guidelines, check-in requirements, and emergency procedures for each park where they will be working.

3 Crew workshop

Prior to the field season a crew workshop should be held. The purpose of this workshop is to provide the field crew with technical training and to ensure that all crew members are familiar with the methods described in this protocol. The workshop (which could be offered at one of the SCPN parks) should be mandatory for all new and returning field technicians. The workshop should emphasize the need for the use of consistent and comparable sampling methods and data handling. The main components of the training workshop should be:

- review of the protocol
- review of proper use of all sampling equipment
- review of all sampling techniques

- review of data entry procedures on data forms
- review of sample preparation, labeling, and shipping
- review of computer data entry and qa/qc procedures
- review of low-impact camping practices and discussion of inherent dangers of camping/working in the parks of the Colorado Plateau; discussion of general safety procedures

Standard Operating Procedure #3: Site Selection and Documentation

Version 1.00

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This standard operating procedure (SOP) describes the methods for establishing aquatic macroinvertebrate monitoring reaches including selecting, laying-out, and marking monitoring reaches at the time of the initial site visit and procedures for subsequent visits once a monitoring reach has been established

1 Selecting sites to sample

SCPN is using two sampling designs to monitor aquatic-macroinvertebrate communities at streams in network parks: (1) sampling at established water-quality sites, and (2) linear-based probabilistic sampling. Index sites may be selected on streams where SCPN water quality monitoring sites exist (BAND, GLCA, GRCA, and MEVE), or a site is present where considerable historic aquatic macroinvertebrate data exists. For streams where potential index sites do not exist, aquatic macroinvertebrate monitoring sites are selected with a linear-based sampling design. For these sites we are using the Generalized Random-Tessellation Stratified (GRTS) design (Stevens and Olsen 2004) to spatially allocate sample units within the sampling frame. The source GIS data layer used to create the sampling frame is the 1:24,000 National Hydrography Dataset (NHD), developed by USGS and EPA. Using the R statistical computing program and the survey design package, scripts are developed and executed to derive a spatially balanced sample. Modified NHD geodatasets serve as the input sampling frame to run the scripts and the GRTS design. Individual sampling frames for aquatic macroinvertebrate monitoring have been developed for streams in two SCPN parks (CACH and MEVE) to date. The digital coverage includes flowline geodatasets that designate the centerlines of streams. To establish the frame for each targeted stream system, the NHD flowlines were initially clipped to the park boundaries. Then the endpoints of the stream were determined by

evaluating ancillary data including aerial photos, digital elevation models, and NHD stream type attributes (i.e., perennial, intermittent, or ephemeral).

2 Initial visit

Prior to the initial site visit the field crew will be provided with UTM coordinates of potential aquatic macroinvertebrate monitoring sites by Network staff. The UTM coordinates are the center point for the selected sampling site. For index sites a single point will be provided. For aquatic macroinvertebrate monitoring sites selected with the linear-based sampling design, a ranked list of potential points will be provided. The field crew will navigate to the point using a GPS unit, topographic maps, aerial photographs, or written directions if available.

2.1 Site and reach selection

An aquatic macroinvertebrate site encompasses a length of stream two kilometers long, centered on the provided UTM coordinates. When the aquatic macroinvertebrate monitoring site is co-located with an SCPN water quality monitoring site, we will utilize the same UTM coordinates for both sites. Within each aquatic macroinvertebrate monitoring site we will collect samples and physical habitat measurements from a sampling reach centered on the UTM coordinates and with a minimum length of 150 meters and a maximum length of 300 meters. Selection of sampling reach is based on habitat suitability (see section below, *Reach selection and rejection criteria*) and can move within the site from sampling event to sampling event.

At the time of site establishment the lead technician will determine if a suitable sampling reach is present at the site center coordinates. If this reach is unsuitable, the reach may be slid upstream or downstream so that one of the ends of the reach is located on the center point. If a suitable reach is not present within this length of stream, a sampling reach may be selected within 1 km upstream or downstream of the UTM location, provided that there are no outside influences that may alter water quality conditions relative to the initial site location and that all other reach selection and rejection criteria are met. If a suitable reach is not present within 1 km of the UTM location, a new site should be selected for aquatic macroinvertebrate monitoring. If a site is rejected, reasons for this decision should be documented.

<u>Reach selection and rejection criteria</u>
The aquatic macroinvertebrate monitoring reach should capture the full sequence of geomorphic channel units present in the stream segment. The selected reach should include aquatic habitat conditions representative of the stream or stream type. The reach should be consistent in slope and valley confinement throughout and should not contain groundwater or tributary inflows or manmade structures (e.g., bridges, impoundments, or culverts), as these represent outside influences that may change the physical, chemical, or biological conditions in the reach. If artificial structures are present at a site, the reach should be located upstream of these features if possible. The selected reach should include at least one, and preferably two, complete sets of geomorphic channel units (pools, riffles, runs). The site should be rejected for macroinvertebrate sampling under the following circumstances:

- There is a point of surface or groundwater inflow from springs or tributaries within the reach.
- The reach contains, or is directly downstream of, an impoundment, culvert, or other manmade structure that may influence physical habitat and/or water chemistry in the

stream reach.

- The stream is at baseflow and the reach is not safely wadeable.
- The stream is at baseflow and the reach is too deep or shallow for sampling equipment to be used effectively to collect samples or measure habitat (i.e., the stream is deeper than the height of the quantitative macroinvertebrate sampling apparatus at the potential sampling locations).
- The stream is at baseflow and the reach does not contain at least 5 suitable riffles for collection of quantitative macroinvertebrate samples. Bedrock and depositional areas that lack coarse substrate are unsuitable for macroinvertebrate sampling.

2.2 Reach layout

Total reach length should be a minimum of 150 m and no longer than 300 m. Each reach includes seven to eleven transects (fig. 3-1). Transects should be numbered in increasing order from downstream to upstream. Left and right banks are designated as though facing downstream.

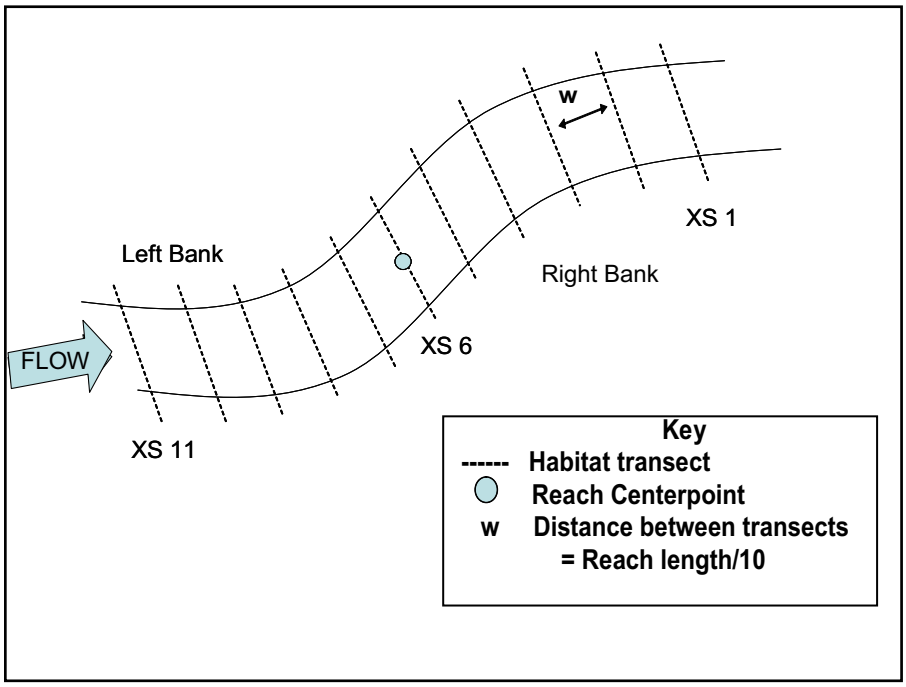

Figure 3-1. Reach layout example using 11 transects

Transects are distributed equally through the reach. For example in a 150 m reach, if 11 transects are used, transect spacing is 1/10th the reach length, or 15 m. Lay out the reach beginning at the center transect and work downstream to the lower end of the reach, then work upstream to the upper end. Distance between transects should be measured along the thalweg or near the center of the channel if the thalweg is not distinct. All transects should be oriented perpendicular to flow. To the extent that it is possible, avoid walking in the channel or causing disturbance to the substrate and macroinvertebrates when laying out the reach.

For larger rivers begin by taking 5–10 measurements of the wetted channel width using a field tape or range finder. Multiply the average wetted width from your measurements by 30 to get the recommended reach length. For example at a 300 m reach, if 11 transects

are used, transect spacing is 1/10th the reach length, or 30 m. Lay out the reach beginning at the center transect and work downstream to the lower end of the reach, then work upstream to the upper end. Distance between transects should be measured along the thalweg or near the center of the channel if the thalweg is not distinct. All transects should be oriented perpendicular to flow. To the extent that it is possible, avoid walking in the channel or causing disturbance to the substrate and macroinvertebrates when laying out the reach.

2.3 Reach marking

2.3.1 Center point

The center point of aquatic macroinvertebrate monitoring reaches co-located with water quality monitoring sites should be documented using multiple methods. The reach centerpoint coordinates should be stored in SCPN databases, the site folder, the field folder, a handheld GPS unit (e.g., Garmin GPSMap 76cx), marked on a topographic map, and documented with notes and photos. The use of handheld GPS units may not be effective at sites located in confined canyons where it is difficult to obtain adequate satellite coverage.

2.3.2 Transects

Transect locations should be determined by measuring upstream and downstream from the centerpoint of the reach. Transects should be marked with flagging upon each site visit. Transect numbers should increase from downstream to upstream, with the transect number written on each flag. All flagging should be removed from the site after sampling has been completed.

2.3.3 Establish a unique name for each reach

Site name. This is a descriptive name that is used to identify each reach. The name of the stream should be first, followed by a unique descriptive identifier, usually a local place or feature (e.g. Capulin Creek at Base Camp Gauging Station). If available, existing names should be used. Usage must remain constant over time.

2.3.4 Establish a unique site code for each site

Site code. This a unique identifier that is assigned to each aquatic macroinvertebrate monitoring site using the format "PARK XXX-XX" (e.g., BANDCAP01). First enter the four digit park alpha code (see list of Park Acronyms), then a three letter stream identifier code, and last a two digit number. The site code should be recorded on every side of every field form. Usage must remain constant over time.

3 Revisit

3.1 Reach selection

Upon arrival at a previously established aquatic macroinvertebrate monitoring site, use UTM coordinates, the field note description, and a topographic map to locate the sampling site. The site must be evaluated to ensure that the present conditions are still suitable for sampling using the criteria listed above in Section 2.1 (*Reach selection and rejection criteria*). It is not necessary to sample the same 150 m reach at a site during each revisit. After selecting a sampling reach, walk the length of the reach (avoid unnecessarily disturbing substrate in stream), determining the start and end points and marking these with flagging tape. If the present conditions are unsuitable within the previously established reach, the reach may be moved and re-established under the constraints outlined in Section 2.1 (*Site and reach selection*) and 2.2 (*Reach layout*) of this SOP. If the reach is moved, the lead technician and network staff will determine which of the

sampling reaches will be most appropriate for long term monitoring.

Criteria for rejecting a reach

Streams should never be sampled during or immediately following a flood event. The time for a system to "recover" following a flood event will vary, and the lead technician should determine whether or not the stream should be sampled by assessing the overall condition of the stream. Some indicators of unsuitable sampling conditions include: the stream is flowing at bankfull or greater; the majority of the reach is not safely wadeable; there has been a prolonged period of heavy rains; or the stream is abnormally turbid. If any of these conditions exist, do not sample the stream that day. Information describing the timing and magnitude of floods can be obtained from NPS staff, other local authorities, or from local streamflow gauging stations when available. Indicators of recent flooding include debris lines, damp soil on the floodplain, or evidence of fresh scour or deposition in the channel.

After a large or prolonged rainfall event, decisions about when to sample should be made by the project manager and lead technician and will be based on expected weather patterns, streamflow information, and previous experience. A recommended time period to wait to sample following a flood is four weeks, provided that this time period does not extend beyond the index period for sampling the site.

Some things to consider when determining how long to wait to sample after a flood include:

- Magnitude of the flood and the degree of scouring or deposition that has occurred.
- Proximity to recolonization sources. Nearby streams or undisturbed tributaries may provide a source for recolonization and will decrease recovery time.
- Time of year. Late in the season adult dispersal may be limited, and thus recolonization potential would be low.
- Historical flow regime and adaptations of resident species to flood disturbance events. In streams with frequent flooding events, species may be adapted to this type of disturbance and recovery time will be shorter than for a stream where flood events do not occur regularly.

If flood events or other problems interrupt the sampling schedule, sampling will be rescheduled during the same year, if possible. If riffles are no longer present in the reach following a flood, only a qualitative sample should be collected (see SOP #5).

4 Site documentation

4.1 Site folders

Site folders are designed to be a repository for all documentation and information relevant to a particular sampling site. Site folders should include information that is pertinent to all vital signs being monitored at that site. Site folders may include, but are not limited to the following items:

- annual reports- a collection of all of SCPN's annual reports for all vital signs monitoring
- published data- all relevant published papers (literature and NPS reports) specific to the watershed should be housed in the site folder
- field folders- site descriptions that provide all information relevant to field work at the sampling location

- SCPN data- summaries of data collected by SCPN field crews that may not be relevant to trip or annual reports (e.g., species lists, water quality core parameter datasets, etc.)
- soils maps
- geologic maps
- vegetation maps
- flow description
- flood history
- historic hydrologic data
- land use history
- aerial maps
- current management of area- permit quotas, prescribed burn plans, exotic plant removal plans, fish stocking plans, restoration projects, etc.
- climate stations-climate summaries of historic data and monitoring years

4.2 Field folders (site description)

Field folders are documents that contain all relevant information summarized for a particular sampling site. The field folder is designed to provide all access information, contact information, and describe work being conducted on site. The field folder is a working set of documents that contain all the information needed to sample at field sites. The field folder should be taken along on each sampling trip. Duplicates of all information included in the field folder should be maintained in a site folder kept in SCPN offices.

Contents of the field folder are listed below:

- site access- road log and trail description
- contacts- names and phone numbers of park contacts and local landowners (where relevant)
- land ownership- Who owns the land at the site and the land that must be crossed to reach the site? Where are vehicles to be parked while sampling?
- safety & communications- names and phone numbers for emergency contacts, local first responders, hospitals and SAR teams. This section should also describe in detail all backcountry procedures for the park.
- camping- brief description of camping/housing available on site as well as the park contacts used to arrange accommodations
- history- should include important disturbance history, land use history, and SCPN history at the site
- sampling locations- UTM's and elevations for all sampling reaches located at a site
- issues of concern- flow modifications, diversions, upstream disturbance which may affect the data collected
- current recreational usage- How frequently is the area impacted by visitor use?

- maps- list of usgs 7.5 min. quad maps, backcountry trail maps, and topo generated maps depicting the sampling sites
- instrumentation- a description of all long-term instrumentation deployed at the site. This section should include a detailed description of where to locate the instruments.
- site photos- photos showing sampling reach midpoints, locations, as well as instrumentation locations

4.3 Trip reports

The lead technician must write a trip report following each site visit (figs. 3-2a and 3-2b). Trip reports should include detailed notes describing all work completed during the sampling event. Templates for these reports can be found on the common drive. Trip reports should include the following:

- park name
- stream name, reach name, and site code
- sampling dates of all locations
- description, and travel time
- campsite locations
- general observations, such as weather or road conditions
- any discrepancies that may affect the data
- potential hazards
- unique or noteworthy events beneficial to future visits
- advice for future survey crews
- sampling crew members
- sampling time
- vital signs monitored on trip
- location of photos and other trip related files on the common-drive

Trip Report			
Parks:		**SCPN vital sign:**	
Crew members:			
Purpose of trip:			
Stream/Spring names:			
Site names:			
Note: NAU employees should provide a copy of the following section to the NAU contact along with their travel form.			
Date of departure:		Time of departure:	
Date of return:		Time of return:	
Mode of travel (car, boat…):			
Travel route (roads, trails, time estimates):			
Lodging (List each day separately)			
Date	**Type of accommodations (e.g. camping, hotel)**	**State**	**County**

General observations/Unique and noteworthy events:

Any discrepancies that may affect the data:

Fig. 3-2a. Front side of SCPN *Trip Report* form

Photos (file name/location):

Data files (file name/location):

Day by day activity summary:

Materials or actions needed next site visit:

Report by:

Date of report:

Fig. 3-2b. Back side of SCPN *Trip Report* form

Standard Operating Procedure #4: Quantitative Aquatic Macroinvertebrate Sampling

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) describes quantitative sampling methods for aquatic macroinvertebrates and collection of supporting microhabitat information at the quantitative sampling locations. Field technicians should be provided a copy of this SOP before the season, and all methods described here should be covered in the pre-season training and workshop. The sampling methods used in this protocol are compatible with NAWQA (Moulton et al. 2002) and EMAP (Peck et al. 2006, Section 10) protocols for sampling macroinvertebrates. The invertebrate collection methods described here are intended to be comparable to the protocols being used by the New Mexico, Arizona, Utah, and Colorado agencies. See Appendix A for a summary of the sampling protocols for each state.

1 Preparing to sample

Quantitative aquatic macroinvertebrate sampling consists of five replicate samples distributed in riffle habitat throughout the reach. Microhabitat measures of substrate size, substrate embeddedness, water depth, and velocity are collected for each replicate.

1.1 Determine specific locations for quantitative samples

While identifying and marking the sampling reach, observe the channel and identify all available sampling habitats. Quantitative samples are collected from targeted riffles because this habitat is consistently rich in fauna. Choose five quantitative sampling locations that are consistent in substrate type, current velocity, depth, and debris accumulation. Each riffle sampled should be a minimum size of 0.25 m^2.Water depth at the selected sampling locations should not exceed the height of the net. If baseflow at the stream is consistently deeper than the height of the net, the site should be rejected.

Locations that are in depositional areas or are normally outside of the main channel should be avoided when choosing quantitative sampling locations. Quantitative sampling locations will be reselected each site visit.

2 Quantitative sample collection in riffle habitat

Quantitative sampling should be the first activity conducted and completed before there are any disturbances to the stream channel (i.e., before habitat measurements). When collecting both quantitative and qualitative samples at a monitoring site, collect quantitative samples first. Use a Slack sampler with a 500 μm mesh. A scrub brush, sorting bucket, a 500 μm mesh sieve, and forceps are needed for sampling. A hand rake may also be used to disturb the substrate. Each sample location consists of the 0.25 m^2 area immediately upstream from (inside the frame of) the Slack sampler. The total area that will be sampled is 1.25 m^2 per reach. The sampling begins at the bottom of the determined reach and proceeds upstream. Collect the sample and measure microhabitat in each riffle location before proceeding to the next location.

(1) Position the net perpendicular to the direction of stream flow and firmly against the stream bottom on the substrate (fig. 4-1). There should be as little space as possible between the stream bottom and the frame of the net. The stream depth should not exceed the height of net. If the stream depth exceeds the height of the net, an alternate sampling location must be selected.

(2) Collect each quantitative sample for a period of 2 to 5 minutes. For small streams or streams with smaller sized substrate, use a shorter sample time. For large streams or streams with larger substrate use a longer time. Use a consistent time for all replicate samples collected during a site visit.

(3) The sampling area for a quantitative sample is the 0.25 m^2 area that is contained within the square frame of the Slack sampler. Check large debris (for example, large cobble and woody debris) for attached organisms. Remove the organisms by hand-picking, rinsing, or gently scrubbing the particle surface in front of the net, and allow the current to carry the detached organisms into the net. Using a scrub brush, gently scrub the rocks to remove any adhering organisms. After a rock is scrubbed, check for any additional organisms. If a substrate particle is more than halfway inside the sampling area, organisms attached to the particle are included in the sample. If the substrate particle is more than halfway outside the sampling area, the organisms should not be included in the sample. If possible, place the rock outside of the sampling area once scrubbing is complete. Some substrate particles may be too large to move. Under this circumstance, the surface may be scrubbed thoroughly so that all adhering organisms flow into the net.

(4) As you remove and clean rocks in the sampling area, record the size and estimate the embeddedness of five representative particles (see instructions in the microhabitat measurement section of this SOP). Record these numbers on the datasheet.

(5) Once scrubbing is complete, thoroughly disturb the substrate (starting upstream and working towards the net) within the sampling area defined by the frame of the sampler. A hand rake or scrub brush can be used to disturb the substrate and any large rocks or wood in the sampling area. Try to allow the current to carry the organisms into the net and to avoid collecting excessive amounts of sand and pebbles.

(6) When sampling is complete, lift the net out of the water in a slight forward direction to ensure that none of the sample is lost.

(7) Rinse the sample to the bottom of the net by splashing water on the outside of the net.

(8) Transfer the sample into a bucket. Check for any organisms that are still attached to the net and place them into the bucket or the sample jar using forceps.

(9) Complete microhabitat measurements of water depth and velocity (see methods described in next section of this SOP and in SOP #7).

(10) Process the sample according to SOP #8.

(11) Collect and process four more samples in the same way.

Figure 4-1. Collecting a quantitative macroinvertebrate sample using a Slack Sampler. Photo courtesy of NPS.

2.1 Microhabitat measurements at quantitative sampling locations

At each quantitative sampling location point measurements of water depth, velocity, particle size, and particle embeddedness are collected. Complete microhabitat measurements in each riffle location after collecting a quantitative sample and before proceeding to the next location.

2.1.1 Embeddedness

Embeddedness is the degree to which gravel-sized and larger particles are surrounded or enclosed by finer-sized particles (fig. 4-2). It is a real representation of the volume of fine sediments surrounding coarser particles relative to the height of the rock. As embeddedness increases, interstitial spaces between particles become reduced, thus limiting available habitat space for macroinvertebrates.

Determine embeddedness by examining five substrate particles at each of the five

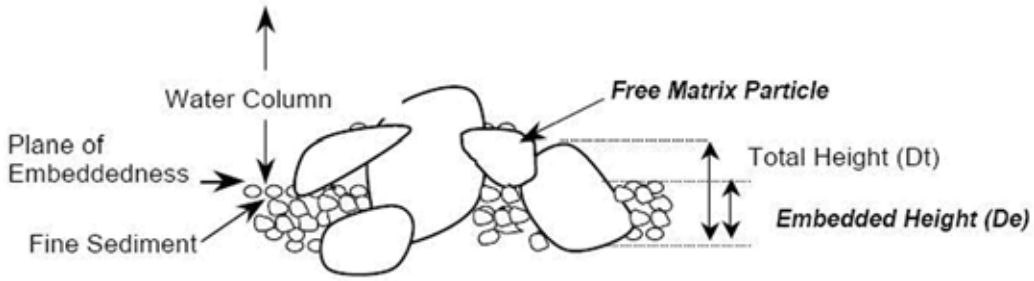

Figure 4-2. Embeddedness diagram (adapted from Sylte and Fischenich 2002)

sampling locations. These five particles should represent the range and distribution of particle embeddedness that occurs at the sampling location. Estimate embeddedness by determining the percentage of the surface area of the larger-sized particles (by visual estimation) covered by fine sediment. Note the percentage (to the nearest 5 percent) of each particle's surface area that was buried in sediment by the extent of discoloration (surface stains, markings and algal coatings) of the particle surface. Homogenous substrates composed of fine particles (sand, silt, clay, muck) are considered 100 percent embedded, while bedrock and hardpan are considered zero percent embedded (Kaufmann and Robison 1998, Peck et al. 2006, Section 7).

2.1.2 Particle size

Particle size is an important determinant of macroinvertebrate distributions. Substrate size is determined by measuring the b-axis diameter of five substrate particles in each targeted riffle (fig. 4-3). Select the particles from a grid-based pattern centered on the sampling net. Sampled particles should be spaced at least the length of the longest diameter of the average size particle in the sample grid to avoid serial correlation. These particles should represent the range and distribution of particle sizes from which macroinvertebrates were collected. The b-axis is the intermediate plane that is perpendicular to the longest (a-axis) and shortest (c-axis) axes of the particle (Gordon et al.,1992). Measure the b-axis using a ruler or a template.

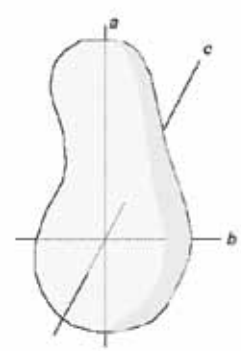

Figure 4-3. Measure the particle along the b-axis (adapted from Yuzyk and Winkler 1991).

2.1.3 Depth

The water depth is recorded in the center of the sampling area at each sampling location. Determine the depth by measuring the distance between the water surface and the bed substrate using a metric wading rod.

2.1.4 Velocity

The velocity in the center of the sampling area at each sampling location is measured using a flow meter and a wading rod to record the 40-second average water-column velocity in meters per second. Set the flow meter at 60-percent depth when the depth is less than one meter. Set the flow meter to collect data for 40 seconds to determine an average velocity for this period (see SOP #7 for detailed instructions for measuring velocity).

3 Completing the Aquatic Macroinvertebrate Sampling Datasheet

Fill out the *Quantitative aquatic macroinvertebrate sample* section of the data sheet (fig. 4-4) completely. (Instructions for filling out the *Qualitative aquatic macroinvertebrate sample* section are in SOP #5.)

Southern Colorado Plateau Network
Aquatic Macroinvertebrate Monitoring

Protocol Version 2011

Aquatic Macroinvertebrate Sampling Datasheet

Park code:_____ Site name:_____Site code: _____

Quantitative aquatic macroinvertebrate sample

Date (YYYYMonDD):_____ Start time:_____ End time:_____

Observer(s):_____ Recorder(s):_____ MST or MDT (circle one)

Notes:

Microhabitat measurements	Collect 5 samples at each sample location. Estimate % embeddedness and measure B (intermediate) axis. Sampled particles should be separated by at least the length of the D_{max} particle size. Tally particle sizes below after collection.											
Sample location number	**Particle embeddedness (%)**					**Particle size classes (mm)**					**Depth (m)**	**Velocity (m/sec)**
1												
2												
3												
4												
5												

Particle sizes						
<0.06 mm, not visible, smooth	<0.06 mm, not visible, gritty	>0.06–2 mm	>2–64 mm	>64–250 mm	>250–4000 mm	≥4000 mm

Qualitative aquatic macroinvertebrate sample

Date (YYYYMonDD):_____ Start time:_____ End time:_____

Collector of sample: _____ Recorder:_____

Habitat types sampled (Check all that apply)														
	Substrate type*													
	Bedrock		Boulder		Cobble		Gravel		Sand/silt		Leaf pack		Undercut bank	
Depth**	D	S	D	S	D	S	D	S	D	S	D	S	D	S
Velocity***														
Fast														
Moderate														
Slow														
	Woody debris		Vegetation		Algal mat		Channel margin		Backwater		Root wad			
Fast														
Moderate														
Slow														

*Substrate types: bedrock, >4 m; boulder, >0.25–4 m; cobble, >0.064–0.25 mm; gravel, >2–64 mm; sand /silt, >0.06–2 mm
**D = deep (net height or deeper); S = shallow (shallower than net height)
***Fast , ≥0.3 m/s; moderate, 0.05–<0.3 m/s; slow, <0.05 m/s

Figure 4-4. ***Aquatic Macroinvertebrate Sampling Datasheet***

- **Park code.** Record the park acronym.
- **Site name.** Record the site name (e.g., Capulin Creek at Base Camp Gauging Station).
- **Site code.** Record the site code (e.g., BANDCAP01).
- **Date.** Record the date in the format YYYYMonDD (e.g., 2008Jan01).
- **Start time.** Use military format, e.g., 1300 or 0845.
- **End time.** Use military format, e.g., 1300 or 0845.
- **Observer** and **Recorder.** Record the initials of crew member serving as observer and crew member serving as recorder.
- **Notes.** Record notes on any conditions that may affect quantitative sampling, such as available substrates, water turbidity, etc.
- **Microhabitat measurements at quantitative sampling locations.**
    - **Particle embeddedness.** Record the embeddedness for each of five particles on the datasheet.
    - **Particle size classes.** Record the length of the b-axis of five substrate particles on the datasheet.
    - **Water depth.** Record the measured depth on the datasheet.
    - **Velocity.** Record the type of flowmeter and the measured velocity on the datasheet.

Standard Operating Procedure #5: Qualitative Aquatic Macroinvertebrate Sampling

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) describes qualitative sampling methods for aquatic macroinvertebrates. Field technicians should be provided a copy of this SOP before the season, and all methods described here should be covered in the pre-season training and workshop. The sampling methods used in this protocol are consistent with NAWQA (Moulton et al. 2002) and EMAP (Peck et al. 2006, Section 10) protocols and are very similar to the methods of the Colorado Department of Public Health and Environment (CDPHE) for macroinvertebrate collection (Colorado Department of Public Health and Environment 2005). The invertebrate collection methods described here are also comparable to the protocols being used by the New Mexico, Arizona, and Utah agencies. See Appendix A for a summary of the sampling protocols for each state.

1 Determine sampling areas

Qualitative macroinvertebrate samples are collected from all types of available habitats along the reach. The goal is to collect macroinvertebrates from all possible combinations of substrates (rocks, woody debris, algal mats, emergent vegetation, etc.) and flow (depth and velocity) conditions that exist in the reach. The datasheet (refer to datasheet in SOP #4) provides guidance for identifying habitats that should be sampled for macroinvertebrates. Prior to sampling, estimate the approximate area of each type of habitat within the reach so that they can be sampled proportionately.

2 Sample collection

Macroinvertebrate sampling should be conducted before disturbing the stream channel (i.e., before physical habitat measurements). When collecting both quantitative and qualitative samples, quantitative samples should be collected first. For qualitative samples,

begin at the downstream end of the reach and work upstream. Use a Slack Sampler with a 500 μm mesh net (see fig. 5-1). A scrub brush, sorting bucket, a metal 500 μm mesh sieve, and forceps are also needed for sampling. A hand rake may also be used to disturb the substrate. Sampling consists of a timed composite sample between 20 to 30 minutes. The lead technician will make this decision based on stream size, ease of movement through the stream reach, and the amount of suitable habitat within the reach.

(1) **Start at the downstream end of the reach**. Working in an upstream direction, collect samples at each habitat location. Use the field form as a guide to identify habitat types present in the reach, and check off habitats as they are sampled.

(2) **Sample each habitat for approximately 30–60 seconds by kicking, scrubbing, jabbing, dipping, or sweeping the substrate into the net**. Typical habitats include riffles, pools, runs, edge water, back waters, root mats, leaf packs, woody snags, bedrock outcrops, and emergent vegetation (see appendix H for examples). When the sampling net is too large to efficiently sample a habitat, a handnet may be used. Macroinvertebrates may also be handpicked from substrate when necessary. At each habitat sampled, estimate water depth and flow velocity.

(3) **When moving to the next habitat, lift the net out of the water in a slightly forward direction to ensure that none of the sample is lost**.

(4) **Repeat the sampling procedure at each habitat location.** Habitats should be sampled proportionately in relation to their availability along the reach.

(5) **After all of the habitats have been sampled, splash water on the outside of the net several times to wash the sample to the end of the net.** Rinse the sample to the bottom of the net by splashing water on the outside of the net.

(6) **Transfer the sample into a bucket for field preparation.** Check for any organisms that are still attached to the net and place them into the bucket or the sample jar using forceps.

(7) **Process the sample according to SOP #8.**

Figure 5-1. Collecting a qualitative aquatic macroinvertebrate sample. Photo courtesy of NPS.

3 Completing the qualitative portion of the *Aquatic Macroinvertebrate Sampling Datasheet*

Record the following information on the datasheet (see figure 5-2 on next page):

- **Date.** Record the date in the format YYYYMonDD (e.g. 2008Jan01).
- **Start time.** Use military format, e.g., 1300 or 0845.
- **End time.** Use military format, e.g., 1300 or 0845.
- **Collector of sample** and **Recorder**. Person collecting qualitative sample. Note the name of the person collecting the sample and the person recording.
- **Habitat types sampled.** Check all combinations of habitat type, water depth, and flow velocity that are sampled.

Southern Colorado Plateau Network
Aquatic Macroinvertebrate Monitoring

Protocol Version 2011

Aquatic Macroinvertebrate Sampling Datasheet

Park code:_____ Site name:_____Site code: _____

Quantitative aquatic macroinvertebrate sample

Date (YYYYMonDD):_____ Start time:_____ End time:_____

Observer(s):_____ Recorder(s):_____ MST or MDT (circle one)

Notes:

Microhabitat measurements	Collect 5 samples at each sample location. Estimate % embeddedness and measure B (intermediate) axis. Sampled particles should be separated by at least the length of the D_{max} particle size. Tally particle sizes below after collection.											
Sample location number	**Particle embeddedness (%)**					**Particle size classes (mm)**					**Depth (m)**	**Velocity (m/sec)**
1												
2												
3												
4												
5												

Particle sizes						
<0.06 mm, not visible, smooth	<0.06 mm, not visible, gritty	>0.06–2 mm	>2–64 mm	>64–250 mm	>250–4000 mm	≥4000 mm

Qualitative aquatic macroinvertebrate sample

Date (YYYYMonDD):_____ Start time:_____ End time:_____

Collector of sample: _____ Recorder:_____

Habitat types sampled (Check all that apply)														
	Substrate type*													
	Bedrock		Boulder		Cobble		Gravel		Sand/silt		Leaf pack		Undercut bank	
Depth**	D	S	D	S	D	S	D	S	D	S	D	S	D	S
Velocity***														
Fast														
Moderate														
Slow														
	Woody debris		Vegetation		Algal mat		Channel margin		Backwater		Root wad			
Fast														
Moderate														
Slow														

*Substrate types: bedrock, >4 m; boulder, >0.25–4 m; cobble, >0.064–0.25 mm; gravel, >2–64 mm; sand /silt, >0.06–2 mm
**D = deep (net height or deeper); S = shallow (shallower than net height)
***Fast , ≥0.3 m/s; moderate, 0.05–<0.3 m/s; slow, <0.05 m/s

Figure 5-2. ***Aquatic Macroinvertebrate Sampling Datasheet***

Standard Operating Procedure #6: Physical Habitat Characterization

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) describes sampling methods for measuring reach, transect, and point habitat characteristics. Field technicians should be provided a copy of this SOP before the season, and all methods described here should be covered in the pre-season training and workshop. This protocol is consistent with previously established habitat assessment techniques used by the national NAWQA and EMAP programs, and users can refer to those documents for additional information. See Fitzpatrick et al. 1998 for NAWQA protocols (http://water.usgs.gov/nawqa/protocols/bioprotocols.html) and Section 7 in Peck et al. (2006) for EMAP protocols (http://www.epa.gov/wed/pages/publications/authored/EPA620R-06003EMAPSWFieldOperationsManualPeck.pdf).

The reach is the primary unit for sampling macroinvertebrates and physical habitat. The reach should capture the full sequence of geomorphic channel units present in the stream segment. Total reach length should be a minimum of 150 m and no longer than 300 m. If possible, all physical habitat measurements should be made at each site on the same day that the macroinvertebrate samples are collected. Within each reach, 7 to 11 equally spaced transects will be established perpendicular to the direction of flow. Physical measurements of bank and riparian features and instream characteristics will be made at each transect (see Fitzpatrick et al. 1998, Kaufmann and Robison1998, and Barbour et al. 1999 for additional discussion of reach and transect measurements).

1 Reach characterization

1.1 Reach characterization datasheet

Record the following information on the *Reach Characterization Datasheet* (fig. 6-1) for each site visit.

Southern Colorado Plateau Network
Aquatic Macroinvertebrate Monitoring

Protocol Version 2011

Reach Characterization Datasheet

Park code:_____ Site name:_____Date (YYYYMonDD):_____

Site code: _____ Observer(s):_____Recorder:_____

Physical description of reach **Disturbance/development**		
Instream (circle all that apply)	Adjacent (circle all that apply)	Describe spatial extent, time frame and details of disturbance/development
diversion dam other flow modification road crossing other anthropogenic recent flooding beaver activity	road trail campsite livestock grazing recent fire vegetation trampling plant removal beaver activity	

Geomorphic channel units Starting from endpoint (circle one): upstream downstream

	Type *	Length (m)		Type *	Length (m)		Type*	Length (m)
1			16			31		
2			17			32		
3			18			33		
4			19			34		
5			20			35		
6			21			36		
7			22			37		
8			23			38		
9			24			39		
10			25			40		
11			26			41		
12			27			42		
13			28			43		
14			29			44		
15			30			45		

*Geomorphic channel unit type codes: riffle (RF); run (RU); rapid (RD); cascade (CA); falls (FA); scour pool (SP); dammed pool (DP); eddy (ED); backwater (BW); glide (GL); exposed rock or bar (EX); chute (CH)

Longitudinal pebble count Starting from endpoint (circle one): upstream downstream

Size class	**Size range (mm)**	**Total number in class**
Clay	<0.06 Not visible, smooth texture	
Silt	<0.06 Not visible, gritty texture	
Sand	>0.06–2	
Gravel	>2–64	
Cobble	>64–250	
Boulder	>250–4000	
Bedrock	>4000	
Embedded	all	

Figure 6-1. ***Reach Characterization Datasheet***

General information

- **Park code**. Record the park acronym.
- **Site name**. Record the site name (e.g., Capulin Creek at Base Camp Gauging Station).
- **Date**. Record the date in the format YYYYMonDD (e.g., 2008Jan01).
- **Site code**. Record the site code (e.g., BANDCAP01).
- **Observer.** Record the initials of the crew member conducting observations.
- **Recorder**. Record the initials of the crew member recording data.

Physical description

- **Disturbance/development**. Indicate the types of disturbance and/or development found in the reach and on immediately adjacent land. In the space alloted, describe the spatial extent of the disturbance/development, the time period when it occurred (if evident), and any relevant details.
- **Geomorphic channel units** (GCUs). Measure and record the length and type of all geomorphic channel units (see appendix I for channel unit descriptions) along the length of the reach. Note on the field sheet whether you started at the upstream or downstream end of the reach. *This is typically the last step (to avoid unnecessarily disturbing the reach) in physical habitat characterization.*
- **Longitudinal pebble count.** Stream channel surface particles are sampled longitudinally along the entire reach using a spatially integrated sampling scheme. This approach produces a reach-averaged, bed-material size (Bunte and Abt 2001). Conduct the pebble count at the same time as you measure the GCUs. Count a minimum of 400 particles in each reach to ensure that an accurate assessment of particle size distribution is obtained (Bunte and Abt 2001). A pebble count is done as follows:
    - Collect samples at one pace (approximately 0.3 m) intervals.
    - At each sample point, aim your finger down vertically and pick up the first pebble that you touch. If the particle is smaller than 0.2 mm, record a value of "Fine". The difference between sand and silt can be determined by rubbing the sample between the forefinger and thumb. Sand will feel gritty and silt will feel smooth. Note if the sample is sand or silt. Particles greater than 2 m should be recorded as "Boulder".
    - To reduce sampling bias, look across and not down at the channel bottom when retrieving each particle.
    - As you retrieve each particle, measure the b-axis diameter of the particle with a ruler or template (fig. 6-2). The b-axis is the intermediate axis, which is perpendicular to the longest (a-axis) axis of the particle. The b-axis may be determined by visualizing which axis of the rock would limit passage through a sieve.
    - In streams <2 m wide collect samples along the center of the channel. In stream >2 m wide, collect samples following a systematic zigzag course (Bunte and Abt 2001).
    - Record your measurements on the back of the *Reach Characterization Datasheet*.

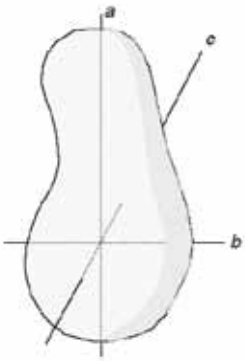

Figure 6-2. Particle axes diagram (adapted from Yuzyk and Winkler 1991). Measure the particle along the b-axis.

1.2 Reach-level vegetation datasheet

Through the NPS Inventory and Monitoring Program, vegetation maps will be completed for all units with significant natural resources using the standards of the U.S. National Vegetation Classification (NVC). Describing the riparian vegetation of each reach within the NVC system will link riparian reaches to each park's current vegetation map and also provide site-specific field validation of map accuracy. Fill out the following fields on the *Reach-Level Vegetation Datasheet* (fig. 6-3). Relevant vegetation map classes for aquatic macroinvertebrate monitoring in Bandelier NM (Muldavin et al. 2011), Canyon de Chelly NM (Thomas et al. 2010) and Mesa Verde NP (Thomas et al. 2009) are listed in Table 6-1.

- General information**.** Fill in the fields as described for the *Reach Characterization Datasheet* above.
- **Dominant physiognomic class.** Physiognomy describes the external or overall appearance of vegetation and is the result of the growth forms of the dominant plants along with structural characteristics such as plant height, stratification into layers, and horizontal spacing of plants. Check the dominant physiognomic class for the reach. If a second physiognomic class is co-dominant for the reach, note it in the comments section (10).
- **Riparian cover by vegetation map class**. Using a list of riparian map classes drawn from the most recent park vegetation map, record cover by vegetation map class for the riparian area adjacent to the reach. Record any discrepancies concerning dominant species or physiognomy in the comments section. This attribute can be omitted for parks without a recent vegetation map.
- **Canopy cover and dominant species by vegetation stratum**. Vegetation strata are described to convey both the vertical distribution of overall cover and the predominant growth forms and to help place associations within the NVC hierarchy. For each stratum, record a canopy cover class for the riparian areas adjacent to the reach and list the dominant species (in order of dominance).
- **Comments**. Record any reach-specific comments.

*Note on completing section 1.2, the *Reach-Level Vegetation Datasheet*. For estimating *Riparian cover by map class*, assume that all riparian areas fall into one map class or another, so that cover values will sum to 100%. However, this is not the case for estimating *Canopy cover and dominant species by vegetation stratum*. In sparsely vegetated riparian areas, total canopy cover for all strata might sum to less than 25%, while it could exceed 100% in densely vegetated areas. Estimate this measure as the vertical projection of live canopy cover for each stratum.

1.3 Photo documentation

Reach documentation photos should be taken on the same day that samples are collected. Record the location and frame numbers of all photos taken during the reach visit. Photos should be taken in upstream and downstream directions at the lower end, centroid, and upper end of the reach. Additional photos should record an overview of the entire reach, when possible, and reference markers for the reach centroid. Record any additional photos taken, such as photos of disturbances, species present, etc.

2 Transect characterization

Complete a transect characterization datasheet (fig. 6-4) for each individual transect along the reach.

Southern Colorado Plateau Network
Aquatic Macroinvertebrate Monitoring

Protocol Version 2011

Reach-Level Vegetation Datasheet

Park code:_____ Site name:_____Date (YYYYMonDD):_____

Site code: _____ Observer(s):_____Recorder:_____

Reach-level vegetation description			
Dominant physiognomic class (check the dominant class for each reach)			
	Forest	60–100% tree canopy cover	canopy height > 5 m
	Woodland	25–60% tree canopy cover	canopy height > 5 m
	Sparse woodland	10–25% tree canopy cover	canopy height > 5 m
	Shrubland	shrub canopy cover 25–100%	canopy height of 0.5 to 5 m
	Sparse shrubland	shrub canopy cover 10–25%	canopy height of 0.5 to 5 m
	Dwarf shrubland	shrub canopy cover 25–100%	canopy height < 0.5 m
	Sparse dwarf shrubland	shrub canopy cover 10–25%	canopy height < 0.5 m
	Herbaceous	herbaceous canopy cover 10–100%	
	Sparsely vegetated	vascular vegetation canopy cover <10%	

Riparian cover by map class	
Map class	**Cover class** (area of reach covered by map class)

Cover range	<1%	1–5%	5–10%	10–25%	25–50%	50–75%	>75%
Cover class	1	2	3	4	5	6	7

Canopy cover and dominant species by vegetation stratum		
	Canopy cover class	**Dominant species**
Tree		
Shrub		
Herbaceous		
Comments		

Figure 6-3. ***Reach-Level Vegetation Datasheet***

Table 6-1. Vegetation map classes for aquatic macroinvertebrate monitoring in Bandelier NM, Mesa Verde NP, and Canyon de Chelly NM

Park	Vegetation map class	Description
BAND—Level 2 Map Units	White Fir - Douglas Fir/Fendler's Meadow-rue Mesic-Wet Forest	These forests are typically found in upper Canon de los Frijoles. The overstory is dominated by white fir, with Douglas fir often codominant. Other pine species can occur as subdominants. There are scattered shrubs and subshrubs with common juniper and gooseberry the most common. The herbaceous under-story is dense and diverse. Common species include Fendler's meadowrue, Virginia strawberry, stickywilly and spruce-fir fleabane. This class also includes the blue spruce/Virginia strawberry forest type, which is characterized by an overstory canopy dominated by blue spruce, and a rich and diverse herbaceous layer with Virginia strawberry well represented to dominant.
	White Fir - Boxelder - Thinleaf Alder Mixed Montane Riparian Forest	This riparian forest has a dense canopy, characterized by a mix of both coniferous and broadleaf deciduous trees. Generally white fir is dominant, often with Douglas fir or ponderosa pine, and there is a subcanopy of box elder and/or Arizona alder. Common shrubs are thinleaf alder, water birch and Gambel's oak. The herbaceous layer is diverse and may include facultative and obligate wetland species such as smooth horse-tail, spreading dogbane, and Fendler's waterleaf.
	Boxelder - Alder - Narrowleaf Cottonwood Montane Riparian Forest	This riparian forest type occurs at mid to lower elevations and has a relatively dense canopy dominated by broadleaf tree species: box elder, narrowleaf cottonwood, or Arizona alder. Frequent small trees and tall shrubs include Goodding's willow, thinleaf alder, and water birch at upper elevations, and common chokecherry, bluestem willow, New Mexico olive, and coyote willow at lower elevations. The herbaceous layer is rich and diverse and may include facultative and obligate wetland species such as smooth horsetail, common spikerush, and hairy willowherb.
	Ponderosa Pine - Broadleaf Mixed Montane Riparian Forest	This type occurs at mid to lower elevations along perennial stream reaches or where there is near surface ground water. It is characterized by a mix of ponderosa pine and broadleaf deciduous trees (box elder or narrowleaf cottonwood). Small trees and tall shrubs include thinleaf alder, water birch, Gambel's oak, common chokecherry and New Mexico olive. The herbaceous layer is rich and diverse and may include facultative and obligate wetland species such as smooth horsetail, common spikerush, and stinging nettle. Ponderosa pine often occupies the outer portion of the zone, with bands of broadleaved trees along the stream edge.
	Sandbar Willow[a] Riparian Shrubland	These riparian willow shrublands occur typically along the river bars of the Rio Grande in White Rock Canyon. They are generally dominated by coyote willow with herbaceous understories that range from sparse to abundant, dominated by facultative wetland species such as clustered field sedge, Indian-hemp, and smooth horsetail. This type also includes stands with open canopies of either peachleaf willow or Rio Grande cottonwood and shrubby understories of coyote willow or boxelder.
	Tamarisk[b] - Sandbar Willow[a] Riparian Shrubland	This riparian shrubland occurs along the river bars of the Rio Grande in White Rock Canyon. It is dominated by tamarisk and/or Russian olive with coyote willow often codominant. Understories are variable and may include a mix of facultative wetland species such as clustered field sedge, Indianhemp, western goldenrod and smooth horsetail.
	Other (specify)	
GRCA—to be determined;	*Vegetation mapping project in progress.*	

Table 6-1. (*continued*)

Park	Vegetation map class	Description
MEVE—Base Map Classes	Lanceleaf Cottonwood Riparian Woodland	This riparian woodland occurs on flat, alluvial terraces and is dominated by a fairly open canopy of lance-leaf and/or Freemont's cottonwood with an understory of introduced perennial grasses, most commonly smooth brome. The shrub layer is absent, or represented by scattered individuals.
	Narrowleaf Cottonwood - Rocky Mountain Juniper Woodland	This semi-riparian woodland occurs on terraces with level slopes adjacent to the stream channel. The canopy is dominated by narrowleaf or lanceleaf cottonwood with Rocky Mountain juniper present as a codominant or scattered member of the canopy. Native shrubs, such as coyote willow, may occur. The herbaceous layer typically includes exotic perennial species such as sweetclover and smooth brome, as well as native upland and riparian species.
	Coyote Willow[a]/ Mesic Forb Shrubland	This shrubland type typically occurs on silty clay flats adjacent to the main stream channel. It is characterized by an open to dense tall-shrub canopy dominated by coyote willow. The herbaceous layer is highly variable.
	Other (specify)	
CACH—Base Map Classes	Douglas Fir / Rio Grande Cottonwood Forest	This forest type generally occurs in the transition zone of cool side canyons Douglas fir forest and lower level riparian areas. The canopy is dominated by Colorado pinyon, with smaller quantities of Douglas fir and Rio Grande cottonwood as well as ponderosa pine and Rocky Mountain juniper. The shrub layer is sparse and dominated by rubber rabbitbrush and skunkbush.
	Boxelder/(Big Sagebrush/Net-leaf Hack-berry) Woodland	This woodland occurs on intermittent streambeds. The canopy is open, and dominated by boxelder, with lesser amounts of Russian olive, Colorado pinyon and Utah juniper. The shrub layer is variable, typically dense, and includes big sagebrush. It may be two layered, with big sagebrush dominating the tall shrub layer, and Wood's rose and snakeweed common in the short shrub layer. The herbaceous layer is dense and diverse.
	Russian Olive Woodland	This woodland type is characterized by relatively dense canopy of Russian olive, salt cedar may be a sub-dominant, but must have less cover than Russian olive. There may be scattered individuals of Rio Grande cottonwood. The shrub layer is generally sparse, and often dominated by coyote willow. The herbaceous layer is variable, with a mix of exotic and native forbs and grasses.
	Rio Grande Cottonwood / Russian Olive Semi-Natural Woodland	This type occurs on abandoned floodplain terraces of low gradient rivers and streams with a history of intense livestock grazing. The canopy is dominated by Rio Grande cottonwood. Typically these are mature trees forming a high, dense canopy. Russian olive is present, but is subdominant, comprising much less total cover. Other species, such a junipers or boxelder, may be present as scattered individuals. The understory consists of mainly upland species, although relict riparian species, such as coyote willow, may be present.
	Saltcedar[b] Temporarily Flooded Shrubland	This is a broadly defined tall shrubland formed by dense thickets of salt cedar. May include native tree and shrub species, such as Rio Grande cottonwood or coyote willow, as subdominants. The short shrub and herbaceous layer are varied.
	Mixed Riparian Herbaceous	This type is found next to surface water in upper and lower canyons, and is usually subject to intermittent flooding. A dense herbaceous layer, particularly of weedy species, characterizes these areas. Trees are present infrequently, and provide less than 25% cover. The shrub layer is variable, with snakeweed, gray rabbitbrush, and four-wing saltbush common, but typically providing less than 25% cover.
	Other (specify)	

[a]The common names sandbar and coyote willow were used by different authors for *Salix exigua*.

[b]The common names tamarisk and saltcedar were used by different authors for *Tamarix* spp.

Southern Colorado Plateau Network
Aquatic Macroinvertebrate Monitoring

Protocol Version 2011

Transect Datasheet

Park code:_____ Site name:_____Date (YYYYMonDD):_____

Site code: _____ Observer(s):_____Recorder:_____

Transect number: ____of ____ Start time: _____ End time: _____ -MST or MDT (circle one)

Geomorphic channel unit dominant in transect (circle one):

riffle (RF) run (RU) rapid (RD) cascade (CA) falls (FA) scour pool (SP) dammed pool (DP)

eddy (ED) backwater (BW) glide (GL) exposed rock or bar (EX) chute (CH)

Wetted channel width (m):_____ Active channel width (m): _____

Transect point measurements (Be sure to take structure and GCU data for edges)

Point	Tape reading (m)	Depth (m)	Velocity (m/s)	Habitat structure*								GCU code (see above)
LEW				AM	LP	MS	VG	WD	RT	RK	NONE	
1				AM	LP	MS	VG	WD	RT	RK	NONE	
2				AM	LP	MS	VG	WD	RT	RK	NONE	
3				AM	LP	MS	VG	WD	RT	RK	NONE	
4				AM	LP	MS	VG	WD	RT	RK	NONE	
5				AM	LP	MS	VG	WD	RT	RK	NONE	
REW				AM	LP	MS	VG	WD	RT	RK	NONE	

***Habitat structure codes**: algal mat (AM), leaf pack (LP), manmade structure (MS), vegetation (VG), woody debris (WD) root wad (RT), cobble/boulder-sized rocks (RK)

Woody debris:
All debris crossing transect >5 cm diameter and <1 m length; and 20 pieces of fine (<5 cm diameter)

Check here if none: ☐

Length (cm)	Diameter (cm)	Length (cm)	Diameter (cm)

Riparian canopy closure
(# intersections):
If stream is <1 m wide, measure only at center of channel. Measure at channel center and both edges of water if stream is >1 m wide.

Facing	Right bank	Center	Left bank
Upstream			
Left bank			
Downstream			
Right bank			

Solar Pathfinder **Site latitude:** _____

Sunrise: D _____ J _____ N _____ F _____ O _____ M _____ S _____ A _____ A _____ M _____ J _____ J _____

Sunset: D _____ J _____ N _____ F _____ O _____ M _____ S _____ A _____ A _____ M _____ J _____ J _____

Figure 6-4. ***Transect Datasheet***

- **Park code**. Record the park acronym.
- **Site name**. Record the site name (e.g., Capulin Creek at Base Camp Gauging Station).
- **Date**. Record the date in the format YYYYMonDD (e.g., 2008Jan01).
- **Site code**. Record the site code (e.g., BANDCAP01).
- **Observer**. Record the initials of the crew member conducting observations
- **Recorder.** Record the initials of the crew member recording data.
- **Transect number**. Record the sequential number of each transect and the total number of transects in the reach. Transect #1 is always located furthest downstream.
- **Start time**. Use military format, e.g., 1300 or 0845. Indicate MST or MDT
- **End time**. Use military format, e.g., 1300 or 0845. Indicate MST or MDT
- **Geomorphic channel unit.** Circle the dominant geomorphic channel unit (i.e., run, riffle, glide, pool, etc.) for the transect (see appendix I for examples).
- **Wetted channel width**. Record the distance between the left and right edges of the water.
- **Active channel width**. Record the distance between the left and right streamward boundaries of riparian vegetation.
- **Transect point measurements**. Stretch a metric tagline or measuring tape from the left bank to the right bank, perpendicular to the direction of flow, and secure each end to the ground using a chaining pin or stake. Depth, velocity, habitat structure, and geomorphic channel unit (GCU) type are recorded at each of five equidistant points along the transect. To determine the distance between transect points, subtract the left edge of water (LEW) from the right edge of water (REW), and divide by six.
    - **Tape reading.** The point (meters) along the measuring tape where the transect point is located.
    - **Depth.** Record the depth (meters) of the stream at each transect point using a top-setting wading rod. The depth is determined by measuring the distance between the water surface and the bed substrate. If the transect point falls on an exposed bar or boulder, the depth is zero.
    - **Velocity.** Measure the velocity (meters/second) at the sampling location using a current meter and a top-setting wading rod to record the 40-second average water-column velocity (see SOP #7 for current meter use instructions). Record the manufacturer and model of current meter used on the datasheet. Velocity is recorded at 60-percent depth when the depth is less than one meter. If the transect point falls on an exposed bar or boulder, the velocity is zero.
    - **Habitat structure.** Record the presence or absence of structures that may provide habitat for macroinvertebrates at the water's edge and at each transect point. Habitat structures may include overhanging or emergent vegetation, woody debris, algal mats, large rocks, leaf packs, or manmade structures that provide attachment sites for macroinvertebrates (see appendix H for examples). Observe whether or not any of these structures exist within a 0.5 m radius of the transect point, or a radius equal to one half the distance between transect points—whichever is smaller.
    - **Geomorphic channel unit (GCU).** Record the geomorphic channel unit (i.e., run, riffle, glide, pool, etc.) that is present at the transect point (see appendix I for examples). This may be the same or different from the transect-scale GCU. Choose a type from the list for the transect-scale GCUs.
- **Woody debris**. Measure the length and diameter of all large woody debris that crosses the transect and is greater than 5 cm diameter and/or longer than 1 m. Mea-

sure the length and diameter of up to twenty pieces of fine woody debris (<5 cm diameter). If a large quantity of fine woody debris is present along the transect, work your way across the transect and select twenty pieces at random, using a method similar to that described for the pebble count above (#3). If only a portion of the log/limb is in contact with the water, only the portion that is in contact is measured. Measure the largest diameter that is in the stream of each piece of woody debris. If the piece is not cylindrical, visually estimate what the diameter of a cylindrical piece of the same volume would be.

- **Riparian canopy closure**. Canopy closure refers to the proportion of the sky hemisphere obscured by vegetation when viewed from a single point (Jennings et al. 1999). Measure riparian canopy closure in four directions from points in the center of the stream and from a point on each side of the stream using a concave spherical densiometer. The densiometer is modified by drawing a right angle on the mirror surface with an indelible marker (fig. 6-5). For all measurements, the densiometer is held along the transect line, 30 cm above the water surface. The center of stream measurements are made at a point halfway between the left and right edges of the water and the stream edge measurements are made with the densiometer held 30 cm from the water's edge. Make a measurement at each of these points a measurement facing upstream, downstream, and toward each bank. Count the number of point intersections (maximum is 17) covered by any overhanging vegetation (i.e., herbaceous, shrub, or tree). Record this number on the datasheet. A total of 12 readings (204 points) are made per transect. At transects that are less than 1 m in wetted width, only the four center readings (68 points) are collected.

  It is extremely important to keep the densiometer in the same position for each reading. You may wish to use the measuring tape or a small tripod as a guide to maintain the densiometer in the same position relative to the water's edge as you rotate. It is also important to keep the densiometer level using the bubble level and to view the densiometer from the same angle with each reading. This can be accomplished by positioning yourself so that the top of your forehead appears in the top-center of the mirror as you make the reading.

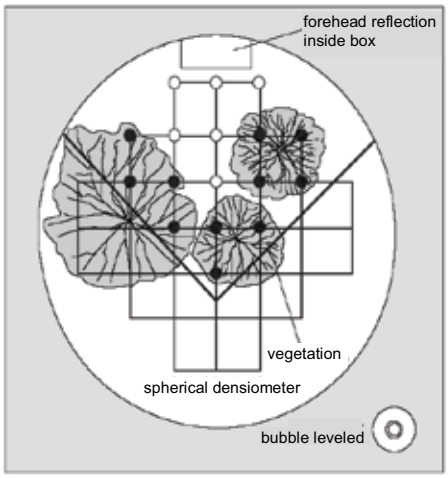

Figure 6-5. A concave spherical densiometer. Note the bubble level, line marking right angle (above which points are counted), and 17 points of intersection. Closed circles represent line intersections where vegetation is present and consequently counted in measurement of canopy closure (example shows 11 out of 17 points) (Fitzpatrick at el. 1998).

- **Solar Pathfinder™** (optional). The amount of solar radiation reaching the stream surface is estimated using a Solar Pathfinder™ (fig. 6-6). This instrument is used to determine the amount of shading provided by canyon walls while further account-

ing for latitude, magnetic declination, time of year, and time of day. The quantity of solar radiation that reaches the stream surface can influence thermal and light inputs, which in turn may influence stream productivity.

Solar Pathfinder™ measurements are made at a reach when the valley or cliff walls are clearly visible and are not obscured by overstory canopy cover. The approximate latitude of the reach should be determined ahead of time, so that the appropriate sunpath diagram for that latitude can be used for the measurement. Magnetic declination at the reach location must also be determined ahead of time, and the Solar Pathfinder™ should be adjusted for declination by rotating the unit around the base. Stand in the center of the stream. Align the compass in the solar pathfinder to find true south, making sure that the top of the sunpath diagram is facing true south and the Solar Pathfinder™ is level. Stabilize the unit (on tripod or by hand). The unit is easier to use in the absence of direct sunlight.

Once the Solar Pathfinder™ has been properly set up, record the sunrise and sunset times for each month using the outline of the canyon or valley wall, as shown in Figure 6-7. Months are listed in the center of the diagram, from top to bottom. Hours, shown in half hour increments, are located along the bottom of the Solar Pathfinder grid. Sunrise is indicated at the point where the cliff outline first intersects the month and hour on the left. Sunset is indicated at the second intersection. Round each measurement of time to the nearest half hour. When the cliff outline does not intersect the grid, sunrise and sunset are the earliest and latest possible hours for that month.

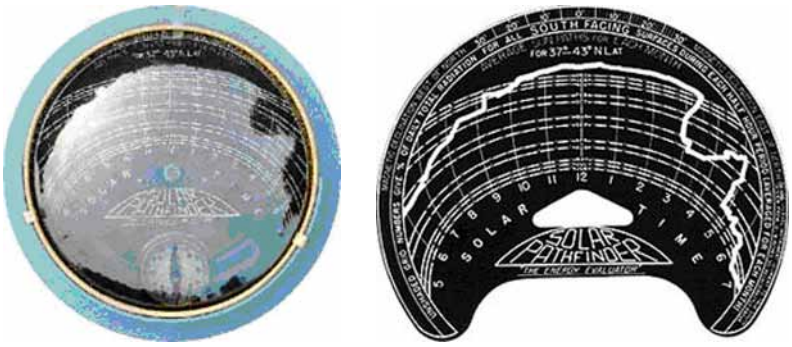

Figure 6-6. Solar Pathfinder™ (left) and Sunpath diagram (right)

In the example tracing above, this particular site has only 78% solar availability for December [obtained by adding the unshaded numbers along the December sunpath (7+8+8+8+8+7+7+6+5+4)]. August had 97% solar availability (1+2+2+3+4+5+6+6+7+7+7+7+7+7+6+6+5+4+3+2).

The small numbers across the arcs represent the percentage of solar insolation in half-hour segments throughout the day – each month's arc totaling 100%. The sum of the unshaded numbers along a particular monthly sunpath represents the percent of the total available solar energy for an average day during that month, as compared to a completely unobstructed site. NREL insolation data can be obtained using the "fixed tilt" chart at 0 degrees (horizontal) tilt and using the same math.

Figure 6-7. Measuring solar irradiation using a Solar Pathfinder™. Photo courtesy of NPS.

3 Wrap-up tasks

The following tasks should be done after sampling has been completed.

1. Check datasheets and sample labels for completeness.
2. Ensure that sample jars are tightly closed, sealed with electrical tape, and properly labeled before leaving the field site. If there is sufficient ETOH remaining top off the samples so that they are filled to the cap prior to leaving the sampling site.
3. Remove all flagging and temporary markers from the reach.

Standard Operating Procedure #7: Hydrologic Monitoring

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) describes procedures for documenting hydrologic site conditions, techniques for velocity and discharge measurement, and the measurement of NPS core water quality parameters.

Methods included are based on the Rantz et al. (1982); the *USGS National Field Manual for the Collection of Water-Quality Data* Chapters A6.1, 6.2, 6.3, 6.4 and 6.7 (USGS variously dated); Sharrow et al. (2007); and specific equipment operating manuals.

Aquatic macroinvertebrates in streams are highly correlated with stream velocity, streamflow regime, and water quality. These hydrologic characteristics exert a strong influence on aquatic macroinvertebrate populations and many stream organisms are vulnerable to changes in the quantity and quality of water.

NPS core water quality parameters, including temperature, pH, specific conductivity, dissolved oxygen, turbidity, and discharge will be measured during each SCPN aquatic macroinvertebrate sampling event. Discrete velocity measurements will also be collected at numerous locations in conjunction with other physical habitat measurements (see SOP #6).

1 Site information

Listed below is information about the site that should be recorded on the *Hydrology Datasheet* (see figs. 7-1 to 7-4 on pages 101 -104) for each site visit.

- **Park code**. Record the park code.
- **Site name**. Record the site name (e.g., Capulin Creek at Base Camp Gauging Station).

- **Date**. Record the date in the format YYYYMonDD (e.g., 2008Jan01).
- **Site code**. Record the site code (e.g., BANDCAP01).
- **Observer**. Record the initials of the crew member conducting observations
- **Recorder**. Record the initials of the crew member recording data.
- **Start time**. Use military format, e.g., 1300 or 0845. Indicate MST or MDT.
- **End time**. Use military format, e.g., 1300 or 0845. Indicate MST or MDT.
- Other sampling work done. Note if samples are being collected on same day for other SCPN monitoring projects (i.e., aquatic macroinvertebrates).

2. Stream channel and flow conditions at the water quality sampling site

Enter the following information in the appropriate section of the *Hydrology Datasheet*.

2.1 Stream channel description

- **Channel**. Record a description of the channel characteristics of the specific site where water quality measurements are made. Choices include pool, riffle, open channel, braided, or backwater. Ideally water quality measurements will be made in an open channel or a riffle.
- **Substrate**. Record a description of all particle size classes present in the channel substrate at the specific site where water quality measurements are made. Identify the dominant size class at the site. Also record whether vegetation, wood, or other objects are present in the water at the site. Use size ranges and descriptions in Table 7-1 to describe the range and distribution of substrate sizes present (Kaufmann and Robison 1998).

2.2 Flow description

Describe flow conditions at the water quality sampling site.

- **Stream physical appearance** (select one):
  - Clear: crystal clear, transparent water
  - Milky: not quite crystal clear; cloudy white or grey
  - Foamy: natural or from pollution
  - Tea-colored: clear, natural coloration from wetland
  - Muddy: cloudy brown due to high sediment levels
  - Green: algal coloration evident
  - Scum/Odor: green or muddy plus extensive floating scum or foul odor
  - Other: include a written explanation
- **Flow mixing**. Select one: Excellent, Good, Fair, Poor.
- **Flow severity**. Record a qualitative determination of flow severity based on the descriptions in Table 7-2.
- **Hydrograph limb**. Record a qualitative determination of hydrograph limb based on the descriptions in Table 7-3.

2.3 Flood evidence

- Record your observations. Important observations may include the markers of any recent high discharges, such as fresh debris lines above the active channel or on floodplain vegetation. Note if grasses or shrubs are laid over, if there has been recent deposition of sediments on the floodplain, or any evidence of vegetation, channel, or

Table 7-1. Substrate particle size classes

Size class	Definition
Clay	Grains not visible, smooth texture
Silt	Grains not visible, gritty texture
Sand	Grains visible, gritty, up to ladybug size
Gravel	Ladybug to tennis ball size
Cobble	Tennis ball to basketball size
Boulder	Basketball to car size
Bedrock	Larger than a car
Vegetation	Any size
Wood	Any size
Other	Describe in comments field

Table 7-2. Flow severity

New STORET code	NPS-WRD description	Old STORET code
Dry	No visible water in stream (typical of dry period for an ephemeral/intermittent stream).	1
No flow	Discrete pools of water with no apparent connecting flow (at surface).	No old code
Low	Base flow for a stream or flow within roughly 10% to 20% of base flow condition.	2
Normal	When stream flow is considered normal (greatest time that stream is characterized by this in terms of flow quantity, level, or general range of flow during a falling or rising hydroperiod, but above base flow).	3
Above normal	Bank full flow or approaching bank full (generally within upper 20% of bank full flow condition).	4
Flood	Flow extends outside normal bank full condition or spreads across floodplain.	5

Table 7-3. Hydrographic limb

New STORET code	STORET description	Old STORET code
BASE	Base	1
RISING	Rising	2
PEAK	Peak	3
FALLING	Falling	4

bank scouring. If there is evidence of flooding not included in the above list, describe in the comments section. Be sure to note if there is no evidence of recent flooding.

3 Weather

Note whether there was any precipitation and what kind. Record the following:

- precipitation within 24 hours prior to sampling (y/n)
- precipitation during sampling (select one: none, rain, freezing rain, hail, sleet, or snow)

4 Stream discharge and velocity measurements

4.1 Pre-trip preparation

Prior to each field trip all hydrologic equipment should be checked to verify that it is in optimum working condition. Detailed guidelines describing steps for ensuring equipment is ready for field trips are included in SCPN's *Water Quality Monitoring Protocol* (Monroe and Bliss, in preparation)(SOP #4). Necessary equipment for obtaining discharge and water quality measurements are listed in Table 1-1 (SOP #1).

4.2 General description of the discharge measurement procedure

The hydrologic flow regime is an important factor influencing aquatic communities. A discharge measurement should be made as part of each SCPN aquatic macroinvertebrate sampling event, and if available, streamflow data should be obtained from gaging stations near aquatic macroinvertebrate sampling sites. Discharge measurement techniques will follow methods described in Rantz and others (1982). A detailed description of discharge measurement procedures is provided in the SCPN's *Water Quality Monitoring Protocol* (SOP #5). SCPN will use a Sontek FlowTracker Handheld Acoustic Doppler Velocimeter (ADV), a Price AA current meter, a Price Pygmy current meter, or a Hach Flo-Mate to make discharge measurements in streams. Current meter measurements will be made using a top-setting wading rod. Complete instructions for this equipment and relevant software can be obtained for free from the manufacturers' websites and are available in electronic format on the SCPN server.

General guidelines for selecting a discharge measurement site and taking measurements are listed below. Methods presented here are appropriate for use when measuring discharge in wadeable streams.

- A discharge measurement site should meet the following criteria:
  - The measurement section should be within a straight reach.
  - Streamlines should be parallel.
  - The streambed should be relatively uniform and free of numerous boulders, debris, and heavy aquatic growth.
  - The flow should be relatively uniform and free of eddies, slack water, and excessive turbulence.
- Stretch a tagline or tape across the channel and determine and record the wetted channel width.
- Velocity measurements are made at a minimum of 20 stations along the transect. Minimum station width is 5 cm. If a stream is too narrow to measure velocity at 20 stations then measure the entire wetted channel at 5 cm intervals.
- The person making the velocity measurement should place the current meter in the water and should stand an arms-length distance downstream so as not to disturb the flow path.
- Always start at the station closest to the left side of the channel to measure the depth of water using the wading rod. Record this value on the datasheet.
- The current meter should be set at a depth on the wading rod such that velocity is measured at a depth which is 0.6 of the depth from the surface of water in the channel.
- The current meter should always be oriented perpendicular to the tagline.
- Measure the velocity for a minimum of 40 seconds.

- Repeat these steps at each station.
- Record computed discharge.

4.3 General description of the velocity measurement procedure

Current meters or similar instruments are used to measure the velocity of flowing water. Methods for measuring velocity presented here are appropriate to use when measuring stream flow velocity in wadeable streams. SCPN will use a Sontek FlowTracker Handheld Acoustic Doppler Velocimeter (FlowTracker) or a Hach Flo-Mate to measure stream velocity at aquatic macroinvertebrate monitoring sites. Current meter measurements will be made using a top-setting wading rod.

Microhabitat measurements are collected at each quantitative macroinvertebrate sampling location. At each physical habitat transect, **measure stream width, depth, and velocity at five equidistant points**. These measurements should be made in coordination with other measurements made at the quantitative aquatic macroinvertebrate sampling sites and physical habitat transects. Record the data on the appropriate datasheets (see SOPs #4 and #6).

Follow these general guidelines when making stream flow velocity measurements:

- Stretch a tagline or tape across the channel and determine and record the wetted channel width.
- Determine the position of five equidistant points along the transect by dividing wetted channel width by six.
- The person making the velocity measurement should place the current meter in the water and should stand downstream of the current meter at an arms-length distance so as not to disturb the flow path.
- Always start at the station closest to the left side of the channel measure the depth of water using the wading rod.
- The current meter should be set at a depth on the wading rod such that velocity is measured at a depth which is 0.6 of the depth from the surface of water in the channel.
- The current meter should always be oriented perpendicular to the tagline.
- Measure the velocity for a minimum of 40 seconds.

Repeat these steps at each of the five stations.

5 Water quality measurements

Aquatic macroinvertebrates are highly correlated with water quality. Many stream organisms are sensitive to changes in water quality, and the quality of water can exerts a strong influence on aquatic communities. Changes in diversity, composition, or abundance of macroinvertebrate communities can reflect changes in water quality.

SCPN will use a Hach-Hydrolab MS5 Minisonde or similar instrument for determining NPS core water quality parameters including temperature, pH, specific conductivity, and dissolved oxygen in the field. A Recon/Rugged Reader running HydrasPocket3 or a laptop PC will be used to communicate with MS5 Minisondes. A Hach 2100P Turbidimeter will be used to measure turbidity. Complete instructions for this equipment and relevant software can be obtained for free from the manufacturers' websites and are available in electronic format on the SCPN server. Detailed descriptions of procedures for measuring the NPS core water quality parameters are provided in SCPN's *Water Quality*

Monitoring Protocol (SOP #5).

The most current version of all Hach-Hydrolab software should be loaded on to all SCPN water resource office and field computers. SCPN water resource crew members should be thoroughly familiar with all equipment and software prior to going into the field. Prior to each sampling trip, the trip leader must ensure that all equipment needed for water quality measurements are in working order.

5.1 Multi-parameter Sondes

5.1.1 Field calibration of multi-parameter Sondes

Prior to each set of field measurements, calibrate the pH and conductivity sensors using a 2-point pH calibration in 7.0 and 10.0 standards, and a 2-point conductivity calibration in air (0 us/cm) and 1413 µs/cm standard. Cool both the sonde (with flow-through cap attached) and the calibration standards to ambient water temperature by immersing in the stream for 15 minutes. Take pre- and post- calibration readings of standard solutions for pH and conductivity. Record these values, as well as the temperature at the time of calibration, on the *Hydrology Datasheet*. Dissolved oxygen sensor calibration and temperature sensors accuracy should be checked in the lab. Find detailed descriptions of field calibration procedures in SCPN's *Water Quality Monitoring Protocol* (SOP #5).

After the crew has determined whether an aquatic macroinvertebrate monitoring site can be sampled (described in SOP #3), the crew member responsible for water quality sampling should go to the upstream boundary of the sampling reach and locate an undisturbed area in the stream for placement of the water quality sonde. The sonde should be placed in a section of the stream where depth is greater than 4 cm, the water is visibly flowing, and flow is sufficiently mixed to allow for representative measurements. Be careful to avoid direct contact between bottom substrates and probes. The unit should be turned on and allowed to equilibrate according to manufacturers specifications. Find complete instructions for the following activities in the appropriate equipment manuals and in SCPN's *Water Quality Monitoring Protocol* (SOP #5).

Follow these general guidelines when making water quality measurements using a multi-parameter sonde:

(1) Place the sonde, with the flow-through cap installed, in the stream and allow it to equilibrate to the stream water temperature (this usually takes at least 5 minutes). Meanwhile, make sure the clock in the display and the sonde are synchronized to local date/time

(2) Open the Hydras 3 Pocket software on the Recon, and click **Monitoring**. Select **Time Series** and a 10-second sampling interval, and click **Start**. Data collection will begin. Click the **Graph** button to view the measurements as they are collected, and change the **Time Range** to 5 min.

(3) Allow all the core parameter curves to flatten out in Graph mode, and return to the **Monitoring Status** screen by clicking **OK** in the upper-right corner. Next, click **Stop** and exit to the main menu (do not save data).

(4) Re-start **Monitoring** mode (using a 10-second interval) and, as soon as 7 samples have been taken, click the **Stop** button. Next, click the **Statistics** button, and verify that the ranges (maxima minus minima) of each parameter meet the stabilization criteria in Table 7-4.

(5) If the criteria are met, record the mean parameter values on the *Hydrology Datasheet*; otherwise, repeat step (c) until criteria are met.

(6) Assign data file names using the following file naming guidelines. Record the file

name on the *hydrology datasheet*. For example: 2008OCT10BANDCAP01, where digits 1-9 are from the date and digits 10-18 are the **Site Code**.

(7) Collect water quality data during the entire aquatic macroinvertebrate sampling event. If possible deploy the sonde overnight or for a period of 24 hours. Collect data at 15 minute intervals. To facilitate synchronization with streamflow gauges or other dataloggers, these data should consistently be recorded on the quarter hour (e.g., 1200, 1215, 1230, and 1245) using the Log (Minisonde) option.

(8) Record the start and stop times of the log file on the *hydrology datasheet*. Be sure to note times as either MST or MDT.

(9) Record field parameter values again after all other sampling activities have been completed.

(10) Stop data collection and remove the sonde from the water.

(11) Sonde data files can be viewed on the Recon/Rugged Reader or on a field pc.

(12) All data files should be downloaded to the pc immediately following each field trip. To do so, connect the Recon to the PC via a USB cable, and then (on the PC) navigate to "My Computer…Mobile Device." Next, navigate to the folder in the Recon's memory where you saved the files, and copy and paste them into the appropriate SCPN network folder.

5.2 Turbidity

Turbidity is measured and reported in nephelometric turbidity units (NTU) using the Hach 2100P portable turbidity meter. Find detailed instructions for the use of the Hach 2100P turbidimeter in SCPN's *Water Quality Monitoring Protocol* (see SOPs #4 and #5) and in the Hach 2100P turbidimeter equipment manual (Hach 200l) found on the SCPN server. The turbidity meter should be calibrated in the lab and the calibration should be checked every time the meter is used. Record calibration standard values and meter readings in the meter log book and on the *hydrology datasheet*.

Table 7-4. Recommended instrument stabilization criteria for recording field measurements (from USGS National Field Manual and NPS-WRD).

Standard direct field measurement	Stabilization criteria for measurements (variability/repeatability should be within the value shown)
Temperature	
Thermistor or thermometer	0.2°C
Liquid-in-glass thermometer	0.5°C
Conductivity (Specific Cond.)	
When <100 uS/cm	5.0%
When >100 uS/cm	3.0%
pH	
Meter displays to 0.01	
Dissolved oxygen	
Amperometric method	0.3 mg/L

5.2.1 Collecting samples for turbidity measurement

- Turbidity samples should be collected at the upper end of the aquatic macroinvertebrate monitoring reach.

- Ensure the sample is representative and that the flow is well mixed at the sampling point.
- At most sites, turbidity values will be less than 1000 NTU, so serial dilutions will not be required. Therefore, at most sites, three sample vials (~20 mL clear glass, Hach item # 2434706) should be dipped in the stream and filled in rapid succession. At sites, such as Chinle Wash, where turbidity has historically exceeded 1000 NTU, a single amber glass, 1-liter bottle should be filled and kept on ice until serial dilutions can be performed.
- Fill the bottle by lowering it slowly into the stream at the centroid of flow. Ensure the sample is representative and that the flow is well mixed at the sampling point.
- Turbidity measurements should be made in the field whenever possible. If it is necessary to store samples, the holding time should not exceed 24 hrs (ASTM International 2003). Samples should be stored at ≤4°C to prevent biodegradation of solids.
- Use an indelible marker to label the bottle with sample site, date, and time (be sure to note MST or MDT).

5.2.2 Measuring the turbidity of water samples with a turbidimeter

(From: USGS National Field Manual, Ch. 6.7.3A.)

- Place turbidity meter on a level surface to help avoid stray light entering the measurement chamber.
- Use a location with low light.
- Avoid trying to run extremely high color or organic matter samples, or else dilute. Otherwise the sample may be over range.
- Turbidity readings can be affected by unmatched cell orientation, condensation, gas bubbles, fingerprints, scratches, or dirt on the surfaces of the sample cell or turbidity probe.
- Shake the sample bottle vigorously to disperse all of the solids. Pour the sample into a sample cell to the line marked on the neck. Do not touch the cell walls with fingers.
- Remove condensation from the cell with a clean, soft lint-free cloth or tissue.
- Apply a thin coat of silicon oil on the outside of the cell about every third time the cell is wiped free of moisture. The oil will mask minor imperfections and scratches; too much oil will attract dirt and could foul the cell compartment.
- Insert the sample cell so that the arrow on the cell faces the notch on the turbidimeter sample cell chamber.
- Close turbidimeter lid. Ensure that **signal average** and **signal average** are turned on.
- Press the **read** button to obtain a turbidity reading.
- Record all of the measurement values on the *hydrology datasheet*.

6 Water and air temperature

Stream temperature is one of the most important physical variables controlling aquatic ecosystems. Hynes (1970) described effects of water temperature on primary production, algae, higher plants, invertebrates, and fish, in running waters. Stream water temperatures are influenced by time of year, water source, solar radiation (including shading), air temperature, climate, and geologic setting.

6.1 Instantaneous temperature

Collect instantaneous temperature readings in the air and the stream with a NIST

traceable digital thermometer (such as a Hanna CheckTemp). The accuracy of all thermometers used in the field should be checked against a separate NIST-traceable thermometer in the lab (see SOP #5 of SCPN's Water Quality Monitoring Protocol). Field checking thermometer accuracy by comparing readings with another field thermometer does not substitute for required laboratory accuracy documentation procedures. Check the meter batteries for proper voltage before use in field. All temperatures should be recorded in Celsius.

Measuring stream water temperature:

- Submerge the thermometer sensor in a well-mixed portion of the stream.
- Wait for the thermometer to equilibrate to the water temperature (see table 7-4 for recommended stabilization criteria).
- Record the value on the water quality field form.
- Remove the thermometer and dry completely.
- Report the time(s) at which water temperatures were measured. Be sure to note if time is in MST or MDT.

Measuring air temperature:

- Find a completely shaded area that is about 2 m above the ground surface and place the thermometer so that the metal part is suspended in the air.
- Allow the thermometer to equilibrate to the air temperature.
- Record the value on the hydrology datasheet.
- Report the time(s) at which air temperatures were measured. Be sure to note if time is in MST or MDT.

6.2 Continuous temperature data collection

Temperature logger selection criteria should include consideration of measurement range and accuracy, data storage capacity, expected battery life, and instrument durability. Onset Computer Corporation manufactures a variety of commonly used temperature data loggers. SCPN uses Onset HOBO® Pendants to collect continuous water and air temperature data at the network's aquatic macroinvertebrate monitoring sites. If possible, use the same model of temperature logger at all monitoring sites throughout the network. Communication between Pendants and a PC is accomplished through use of an Onset Optic USB Base Station or a Onset HOBO® Waterproof Shuttle, a coupler, and HOBOware® software. Complete instructions for this equipment and software are available in electronic format on the SCPN server.

Each SCPN temperature logger should be thoroughly documented. The following information should be entered in a file on the SCPN server: manufacturer, model, serial number, range, accuracy, date of purchase.

It is important to check the accuracy of each temperature logger against a NIST-traceable thermometer in the lab before and after field deployment. This procedure is described in detail in SOP #5 of SCPN's *Water Quality Monitoring Protocol*.

Most data loggers have large data storage capacity and can be programmed to measure and record temperatures at a variety of time intervals. It is desirable to capture temperatures representative of fluctuations over 24 hour periods and through the course of a year. To capture this variability in water and air temperature SCPN temperature loggers will be programmed to sense and record data at 15 minute intervals.

Following are basic instructions for deploying Hobo ® Pendant loggers. Complete instructions are provided in SCPN's *Water Quality Monitoring Protocol* (see SOPs #4 and #5) and in Onset manuals and equipment documentation found on the SCPN server. **Note: After launching a Pendant using the HoboWare program, be sure to close the program before disconnecting the Optic USB Base Station or Waterproof Shuttle from the PC; otherwise, the log file could be corrupted.**

- Time – Make sure the PC time is accurate and is set to Mountain Standard Time (MST). Synchronize the Onset Optic USB Base Station or Onset HOBO® Waterproof Shuttle clocks with the PC and then set the Pendant clock.
- Units – Always record temperature units to the tenth of a degree in Celsius (0.1C).
- Channels – Select both channels (temperature and battery voltage).
- Description – Enter the site code (e.g., BANDRIT01). This will later be included in the file name that is automatically generated when a log file is downloaded and saved.
- Launch time – Set the launch time so that temperature will be sensed and recorded at even 15 minute intervals (1200, 1215, 1230, etc.). Ideally, the Pendant should be launched on-site immediately before it is deployed. Pendants may be launched in advance of deployment (e.g., if a laptop will not available in the field). In either case, make sure to record the actual time of Pendant deployment on the datasheet and be sure to note if time is in MST or MDT.

Always bring a small Philips screwdriver and spare Pendant, desiccant packet, attachment cord (see below), and batteries in the field. Also, bring a scrub pad for cleaning grime/biofilm from water temperature Pendants.

6.2.1 Installation

Aquatic temperature loggers should be placed at a location in the stream channel where the water is adequately mixed and not influenced by localized warm or cool water sources, such as ground water, point sources, lake outlets, or direct sunlight. Well-mixed waters can often be found in the thalweg (lowest point in the channel) of riffles. Shaded sites with moderately turbulent flows tend to make good logger placement spots. Backwater pools and standing water should be avoided. To verify that the site is well mixed horizontally and vertically, take ten measurements across the stream width with a digital thermometer. Be sure to select a site where the logger is likely to be submerged throughout the year and will be protected from high flows. Make sure the temperature logger is completely submerged and is not in contact with the bottom or with another mass that could serve as a heat sink/source.

Attach the aquatic temperature logger to a stable, permanent object, such as a tree root or large rock. In streams with high velocities (such as seasonal runoff events), a permanent marker, such as a piece of rebar, may need to be installed and the Pendant attached to it. This may also be the case in streams having no natural anchoring objects (roots or rocks), e.g., streams with mud as their primary substrate.

Air temperature loggers should be placed at a location near the stream channel where the air is adequately mixed and not influenced by localized warm or cool sources, such as bedrock or direct sunlight. Ideally, temperature loggers should be placed about 2 m above ground surface in a well shaded area. Suspending temperature loggers from the branch of a tree with dense foliage is often the best choice.

Use a piece of thin, strong, weather-resistant cord (available from outdoor gear shops) to attach Pendants to their anchors. Cord that is a natural, drab color is preferred, as it will

be less noticeable to passersby. Use a knot that will not come undone, even if it means that it may need to be cut to remove the Pendant. The cord and Pendant should be tied to the anchor so as to minimize change in Pendant position over time as the result of high winds or stream velocities.

Record a thorough description of the location where each temperature logger is deployed. This is very important to help ensure the logger can be relocated and to account for factors that may influence temperatures. The description should include a site map, photographs of the temperature logger (upstream, downstream, and across the transect), and directions to the site from relatively permanent landmarks. Obtain GPS coordinates of the location if possible.

6.2.2 Temperature logger maintenance and downloading

Data should be downloaded from aquatic and air temperature loggers during each site visit. This reduces the risk of losing significant amounts of data. This is particularly important at sites where high stream flow conditions occur. Each time data is retrieved from a temperature logger, the batteries and LED lights should be checked (indicating operational status), and the exterior of the logger cleaned if necessary. The logger's desiccant pack should be inspected approximately every 6 months, and replaced if it is no longer bright blue. The following information should be recorded when inspecting and/or downloading:

- Site code
- Observer
- Date (local time zone)
- Time (use a GPS, cell phone, laptop or other device with a reliable clock; include seconds if possible). Be sure to note time as MST or MDT.
- Instantaneous temperature (use digital thermometer, in as close proximity to Pendant as possible)
- Battery status (% remaining; see below)
- File name
- Serial number
- Notes on sensor condition or problems with data retrieval

There are two methods for downloading data from Pendants:

1. **Pendant data is downloaded directly to a laptop, via a coupler** (either a Waterproof Shuttle with a USB cable attached, or an Optic USB Base Station). The data in the Pendant is transferred to the laptop, but also remains on the Pendant. Choose the option to stop the Pendant, and then re-launch it after downloading and saving the data file (see file naming conventions below). Re-launching the Pendant will reset its memory. This is important to do, because Pendants have no "wraparound" memory capability; that is, if the memory becomes full while logging, it will stop logging, rather than continuing with data collection and overwriting the oldest data.
2. **Pendant data is downloaded to a Waterproof Shuttle** (if a laptop is unavailable). The data in the Pendant is transferred to the shuttle and the Pendant's memory is reset. The Pendant will automatically begin recording data, using the same settings (time interval, channels, etc.) that were set in the last manual launch. The data file must later be transferred from the shuttle to a PC (see below).

Use method (1) when possible, because this is the only way the Pendant battery can also be checked (also, it reduces the number of downloading steps). Use discretion in

determining whether or not to replace a battery, based on: the percentage of remaining power, the duration of deployment, and the anticipated date of next site visit. Err on the side of premature battery replacement. (Because SCPN has limited experience with Hobo Pendants, our knowledge of battery discharge rates is presently very limited; once we have more data, this SOP will be updated with more explicit guidelines for battery replacement.) .

Data files will automatically be given a name by the HoboWare Pro software program, which will be the "Description" field entered at time of launch, followed by the download date and time. When saving this file to its final destination folder (on the SCPN server and local PCs), make sure to change the file name to the SCPN naming convention of: "YYYYMmmDD_SITECODE" (e.g., "2010Sep22_BANDRIT01"). If the file is named in one way and later changed to another name, record the change in the "Temperature Logger Log File," an Excel spreadsheet maintained on the SCPN server.

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Hydrology Datasheet

Park code:_____ Site name:_____Date (YYYYMonDD):_____

Site code: _____ Observer(s):_____

Start time: _____ End time: _____MST or MDT (circle one)

Site access notes, general observations, and other work done:

Precipitation during sampling (circle one): None Rain Freezing rain Hail Sleet Snow

Precipitation 24 hours prior to sampling (circle one): Yes No

Stream channel and flow conditions at the water quality sampling site											
Stream Channel	**Channel**	Pool		Riffle		Open channel		Braided		Backwater	
	Substrate *Check all present and circle dominant*	Clay *Grains not visible, smooth texture*	Silt *Grains not visible, gritty texture*	Sand *Grains visible, gritty, up to ladybug size*	Gravel *Ladybug to tennis ball*	Cobble *Tennis ball to basketball*	Boulder *Basketball to car*	Bedrock *Larger than a car*	Vegetation	Wood	Other
Flow	**Stream color**	Clear	Milky	Foamy	Tea	Muddy	Green	Scum/odor	Other:		
	Flow mixing	Excellent	Good	Fair	Poor	% Ice cover:		Average ice thickness:			
	Flow severity	Dry	No flow	Low	Normal	Above normal	Flood	***Comments:***			
	Hydrograph limb	Base	Rising	Peak	Falling						
Flood evidence (Check all that apply)		None									
		Fresh debris line in channel above active channel									
		Grasses/shrubs laid over									
		Recent flood event greater than baseflow but less than bankfull									
		Recent deposition of sediments on floodplain									
		Riparian vegetation scoured away									
		Other (note in comments)									

Aquatic and air temperature loggers			
Aquatic temperature logger		**Air temperature logger**	
Manufacturer/model:	Serial number:	Manufacturer/model:	Serial number:
Download time:	Battery%:	Download time:	Battery %:
Notes on sensor condition and actions taken:		Notes on sensor condition and actions taken:	
Data file name:		Data file name:	
NIST-Traceable thermometer model and serial number:			
NIST thermometer temp at time of download (°C):		Temperature at time of download (°C):	

Photo documentation			Observer:	
Time	**Photo file number**	**Description**	**Bearing**	**Flash on?**

Figure 7-1. ***Hydrology Datasheet*****, page 1**

Site code:	**Site name:**	**Date:**
Discharge measurement		
Start time:	End time:	Observer:
Discharge method (circle one) Flow meter	Flume	Volumetric / Visual estimate:
Flow meter time zone (circle one): MST MDT		File name:
Flow meter make/model/serial #:	Pygmy meter spin test (2–4 minutes OK):	
FlowTracker passes quality control test (circle): yes no	Discharge (m^3/s):	ft^3/s:
Discharge measurement location (e.g. distance upstream from gage):		
Control location, description, and condition:		
Estimate of measurement accuracy (circle one): Excellent (<2%) Good (<5%) Fair (<8%) Poor (>8%)		
Estimate total percent of flow captured by measurement:		
Discharge measurement comments:		

Current meter						Volumetric	
Point	**Method (circle)**	**Location (m)**	**Depth (m)**	**Velocity 1 (m/s)**	**Velocity 2 (m/s)**	**Container description:**	**Container size:**
LEW						Try	Time to fill (seconds)
1	0.2/0.8 0.6					1	
2	0.2/0.8 0.6					2	
3	0.2/0.8 0.6					3	
4	0.2/0.8 0.6					4	
5	0.2/0.8 0.6					5	
6	0.2/0.8 0.6					6	
7	0.2/0.8 0.6					7	
8	0.2/0.8 0.6					8	
9	0.2/0.8 0.6					9	
10	0.2/0.8 0.6					10	
11	0.2/0.8 0.6						
12	0.2/0.8 0.6					**Gage height**	
13	0.2/0.8 0.6					Time	Height (feet)
14	0.2/0.8 0.6						
15	0.2/0.8 0.6						
16	0.2/0.8 0.6						
17	0.2/0.8 0.6						
18	0.2/0.8 0.6						
19	0.2/0.8 0.6						
20	0.2/0.8 0.6						
21	0.2/0.8 0.6						
22	0.2/0.8 0.6						
23	0.2/0.8 0.6						
24	0.2/0.8 0.6						
25	0.2/0.8 0.6						
26	0.2/0.8 0.6						
27	0.2/0.8 0.6						
28	0.2/0.8 0.6						
29	0.2/0.8 0.6						
30	0.2/0.8 0.6						
REW	0.2/0.8 0.6						

Figure 7-2. *Hydrology Datasheet*, page 2

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Site code:	Site name:	Date:	Observer:

Field calibration of water quality instrument

Calibration date:	Water quality instrument make and model:
Calibration time:	Water quality instrument SCPN name:
Instrument set to local time (circle one)? Yes No	Stream water temperature (ºC) at time of calibration:

Parameter	Standard value	Lot number	Pre-calibration		Post-calibration	
			Reading	Temperature (ºC)	Reading	Temperature (ºC)
pH	7.00					
	10.00					
Specific conductivity	0 µs/cm (air, dry)					
	1413 µs/cm					
	Other: _____ µs/cm					
Dissolved oxygen	100% saturation (water saturated w/air)					
	Barometric pressure (mmHg):					

Calibration notes:

Water quality field measurements

Multi-parameter sonde (attended)							Multi-parameter sonde (deployed)
Time	Battery (%)	Water temperature (ºC)	pH	Specific conductivity (µS/cm)	Dissolved oxygen (mg O_2/L)	Dissolved oxygen (%Sat)	Start date and time:
							Start battery % left:
							Sampling interval:
							End date and time:
							End battery % left:
							Log file name(s):

File name(s):

Comments on water quality data collection:

Turbidity

Turbidimeter	Make/model:	Serial #:	Observer:
Are signal average and auto range turned on? yes no			Date of last calibration:

Calibration check with secondary Gelex standards			Sample readings			
Calibration check	Date:	Time:				
Assigned value	Acceptable range	Reading	Sample #	Reading(s) (NTU)		

cfs = m^3/s * 35.31	$P_{mmHg} = 25.4 \times P_{inHg}$	FlowTracker transmitter to sampling volume = 10 cm
deg F = 1.8 (deg C + 32)	$P_{mb} = 33.8639 \times P_{inHg}$	SNR ≥10 best; 4–10 okay, <4 bad
m×3.28 = ft		Divide stream into 20–30 sections, ≤5% of flow in each

Figure 7-3. *Hydrology Datasheet*, page 3

Site code:	**Site name:**	**Date:**

Bacteria sample collection and processing			
Processed by:	Tray(s) read by:		
Incubation start time:	Incubation end date:	End time:	
Incubator make/model:	**Item name**	**Lot number**	**Expiration date**
Temperature logged during incubation: yes no	Idexx 120mL vessel		
Temperature logger make/model:	Idexx Quanti-tray 2000		
Logger serial number:	Idexx Colilert		
Logger data file name:			

Incubator temperature			
Event occurred and/or action taken	**Date**	**Time**	**Temperature**

Bacteria tray readings				
	Positive large wells		**Positive small wells**	
Tray 1: total coliform (yellow wells)				
E. coli (yellow & fluorescent wells)				
Tray 2 (circle): blank duplicate				
Total coliform				
E. coli				

Comment on bacteria samples:

Sample collection, processing & shipment			All bottles collected by: NWQL samples processed by:		
Sample collection time:			**Processing time:**		
Filter make/model	**Quantity used**	**Lot number**	Samples chilled: yes no		
			Filtration location: On-site At car Indoors Chamber		
			Pump make/serial number:		
Bottle or acid type	**Quantity used**	**Lot number/treatment/ schedule number**			
			Lab name		
			Shipping method		
			Drop date & time		
			Lab name		
			Shipping method		
			Drop date & time		
			Tracking #		

Comments on sample collection, processing and shipment:

Figure 7-4. *Hydrology Datasheet*, page 4

Standard Operating Procedure #8: Sample Preparation, Labeling and Shipping

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) describes methods for preparing, labeling, and shipping aquatic macroinvertebrate samples. Field technicians should be provided a copy of this SOP before the season and all methods described here should be covered thoroughly in the pre-season training and workshop.

1 Preparation of samples

Initial preparation of each sample should be done while in the field. Sample preparation for shipment is done in the SCPN laboratory.

(1) While still in the field, with individual samples in bucket, pick out any large debris, and rinse well over bucket. Elutriate the sample by swirling the water and contents in the bucket, and pour the non-sediment portion into a 500 µm mesh sieve. Add more water to the bucket, swirl and pour contents into the sieve. Repeat this procedure several times until all insects and organic debris are emptied onto sieve and only inorganic sediment remains.

(2) Gently dispense the sorted sample from the sieve into a wide mouth, plastic sample jar (500 or 1000 mL depending on sample size). The jar should be no more than ½ to ¾ full. A second jar may be used if the sample is too large for one jar. Rinse any remaining debris in the sieve to a corner and gently place into the jar. Check the sieve for any remaining organisms.

(3) Place a waterproof label on the inside of each jar as it is processed (noting the appropriate labeling instrument below in section 2) , and add enough 95% ethyl alcohol to accomplish a 1:1 ratio of sample material and ethanol. The objective is to create a solution of 70–80% ethanol in the sample for long term storage.

(4) Seal the sample jar tightly so that no leakage occurs prior to sorting back in the lab. If there is a sufficient hike between the sampling reach and the vehicle, seal the jar with electrical tape before hiking out of the site.

(5) Once in the lab, top off each sampling jar with any needed additional alcohol. Place a label on the outside of the sampling jar.

(6) Seal the sample jar with a ring of sturdy tape (electrical tape will work) around the cap and neck of the sample jar so no leakage of the sample occurs.

2 Labeling samples

Each sample jar must have a label attached to the outside and a label placed inside the container as well. If a sample requires multiple containers each container should be clearly marked as 1 of 5, 2 of 5, etc. Ethanol will dissolve ink, so if ethanol is used as a preservative, do not use a pen or a sharpie to label the samples; use pencil on laser-printed labels.

- **External labels**. Use a laser printer to print labels on heavy-weight paper (Rite in the Rain) or sticky labels. Once adhered to bottle, cover the outside label with clear packing tape.
- **Internal labels**. For internal labels use a heavy weight cotton fiber paper (Rite in the Rain) and a No. 2 pencil. Laser printed labels will also work on heavy paper.
- **Information to be included on internal and external labels** (fig. 8-1): site code, collection date, sample type (quantitative or qualitative), replicate number, name of person who collected the sample, and number of jars containing the sample.

NPS – Southern Colorado Plateau Network
Aquatic Macroinvertebrate Monitoring
Project

Site Code:

Date:

Sample Type: Quantitative ____

Replicate (circle 1): 1 2 3 4 5

Qualitative _____

Collected by:

Jar _____ of _____

Figure 8-1. Example sample label

3 Preparation and shipping of samples

At the end of each sampling season, samples should be shipped as a batch to the contract laboratory. Several safety and transportation regulations relating to how samples are packed, labeled, and shipped must be observed by law. Each technician who is responsible for shipping samples must be trained in shipping hazardous materials (i.e., ethanol). The shipping technician should obtain the most current U.S. Department of Transportation

(see http://hazmat.dot.gov) and transportation agent (such as Federal Express) requirements on packing and shipping samples.

3.1 Packing and shipping samples

(1) If necessary, add ethanol to completely fill each sample bottle to minimize void space.

(2) Clean sample bottle threads to ensure that bottle lids fit securely. Sand or other debris that is trapped in the threads might cause sample leakage.

(3) Stretch a strip of high-quality, plastic tape (for example, 3M Scotch ™ Brand 471) around the lid-bottle seal in the direction of the closing lid to prevent leakage.

(4) Protect the sample labels during shipping by covering with clear packing tape.

(5) Place each sample bottle in a sturdy (i.e., freezer quality) re-sealable plastic bag and expel the air.

(6) Prepare the exterior of a plastic cooler by affixing orientation arrows and all required safety and hazard information and labels.

(7) Line the inside of the container with a layer of bubble packing or other suitable shock-absorbing material.

(8) Line the container with two nested heavy-duty trash bags.

(9) Place a layer of absorbent material (i.e., multi-ply paper padding, newspaper, etc.) in the bottom of the inner trash bag. Do not use Styrofoam peanuts, shredded paper, or vermiculite.

(10) Tightly pack sample bottles against each other inside the trash bag. Ensure that bottles and re-sealable plastic bags are upright. Highlight samples on the packing list as they are placed in the container.

(11) Place additional absorbent material around bottles as necessary to fill gaps and close both trash bags with a tie.

(12) Place a layer of bubble packing on top of the trash bags along with internal shipping documents. Place shipping documents (safety information, packing lists) for each container in a re-sealable bag and put the bag on top of the packed samples. Safety document should include 24 hour emergency contact information for the contract laboratory and a copy of all applicable documentation for shipping hazardous material.

(13) Close the shipping container with heavy-duty tape.

(14) Complete all required hazardous materials shipping paperwork.

(15) Use a reliable commercial shipping company (such as Federal Express). **It is ILLEGAL** to ship samples by air.

(16) Label outside of shipping container with destination and return addresses. Include packing list (fig. 8-2).

Sample code	Date collected	County	State	Hydrological unit	EcoRegion	Sample type	Rep	Habitat	Device	Size
CACHITSA01	2008Sep23	Apache	Arizona	14080204	Arizona/New Mexico Plateau	quantitative	1	riffle	Surber	500µm
CACHITSA01	2008Sep23	Apache	Arizona	14080204	Arizona/New Mexico Plateau	quantitative	2	riffle	Surber	500µm
CACHITSA01	2008Sep23	Apache	Arizona	14080204	Arizona/New Mexico Plateau	quantitative	3	riffle	Surber	500µm
CACHITSA01	2008Sep23	Apache	Arizona	14080204	Arizona/New Mexico Plateau	quantitative	4	riffle	Surber	500µm
CACHITSA01	2008Sep23	Apache	Arizona	14080204	Arizona/New Mexico Plateau	quantitative	5	riffle	Surber	500µm
CACHITSA01	2008Sep23	Apache	Arizona	14080204	Arizona/New Mexico Plateau	qualitative	n/a	all	Surber	500µm
CACHITSA01	2008Sep23	Apache	Arizona	14080204	Arizona/New Mexico Plateau	qualitative	n/a	all	Surber	500µm
CACHITSA01	2008Sep23	Apache	Arizona	14080204	Arizona/New Mexico Plateau	qualitative	n/a	all	Surber	500µm
GLCAICOY01	2008May29	Garfield	Utah	14070005	Colorado Plateau	qualitative	n/a	all	Surber	500µm
GLCAICOY01	2008Sep10	Garfield	Utah	14070005	Colorado Plateau	qualitative	n/a	all	Surber	500µm
GLCAICOY01	2008Sep10	Garfield	Utah	14070005	Colorado Plateau	qualitative	n/a	all	Surber	500µm
MEVEIMAN01	2008Sep16	San Juan	Colorado	14080107	Colorado Plateau	quantitative	1	riffle	Surber	500µm
MEVEIMAN01	2008Sep16	San Juan	Colorado	14080107	Colorado Plateau	quantitative	2	riffle	Surber	500µm
MEVEIMAN01	2008Sep16	San Juan	Colorado	14080107	Colorado Plateau	quantitative	3	riffle	Surber	500µm
MEVEIMAN01	2008Sep16	San Juan	Colorado	14080107	Colorado Plateau	quantitative	4	riffle	Surber	500µm
MEVEIMAN01	2008Sep16	San Juan	Colorado	14080107	Colorado Plateau	quantitative	5	riffle	Surber	500µm
MEVEIMAN01	2008Sep17	San Juan	Colorado	14080107	Colorado Plateau	qualitative	n/a	all	Surber	500µm
MEVEIMAN01	2008Sep17	San Juan	Colorado	14080107	Colorado Plateau	qualitative	n/a	all	Surber	500µm
MEVEIMAN02	2008Sep15	San Juan	Colorado	14080107	Colorado Plateau	quantitative	1	riffle	Surber	500µm
MEVEIMAN02	2008Sep15	San Juan	Colorado	14080107	Colorado Plateau	quantitative	2	riffle	Surber	500µm
MEVEIMAN02	2008Sep15	San Juan	Colorado	14080107	Colorado Plateau	quantitative	3	riffle	Surber	500µm
MEVEIMAN02	2008Sep15	San Juan	Colorado	14080107	Colorado Plateau	quantitative	4	riffle	Surber	500µm
MEVEIMAN02	2008Sep15	San Juan	Colorado	14080107	Colorado Plateau	quantitative	5	riffle	Surber	500µm
MEVEIMAN02	2008Sep15	San Juan	Colorado	14080107	Colorado Plateau	qualitative	n/a	all	Surber	500µm
MEVEIMAN02	2008Sep15	San Juan	Colorado	14080107	Colorado Plateau	qualitative	n/a	all	Surber	500µm

Figure 8-2. Example of packing list for NAMC Lab

Standard Operating Procedure #9: After the Field Season

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) outlines steps to be completed periodically following field activities. Twice per year a comprehensive inventory of all field equipment and supplies will help ensure all tasks are efficiently accomplished and program objectives are met. Additionally, project documents including the SCPN aquatic macroinvertebrate monitoring protocol, site and field folders, equipment logs, and QA/QC documentation should be reviewed on an annual basis. All data should be entered to appropriate databases and archived properly.

1 Returning field equipment

- **Clean all equipment before storage**. Each field crew member should ensure that the equipment they were issued at the beginning of the season is clean and fully operational. Any problems with equipment should be reported to the lead technician.
- **Sign in and store field equipment**. The lead technician should sign in all gear that was issued at the beginning of the season. Any damaged equipment should be set aside to be repaired or replaced; all other equipment should be properly stored.
- **Repair/replace damaged equipment**. When possible, damaged equipment should be repaired. Otherwise, damaged equipment should be replaced to ensure that all necessary equipment is functional and accounted for before the next field season.

2 Datasheets and data management

(1) **Scan original datasheets**. Ensure that all original datasheets have been scanned and stored digitally as pdf files.

(2) **Archive original datasheets**. Organize and file datasheets by sampling location.

(3) **Proofread datasheets.** Proofread the digital copy of the datasheets to ensure that they are complete and legible. All datasheets should have been reviewed for completeness in the field, but some deficiencies may not be identified until later.

(4) **Mark corrections on original datasheets with pen**. If changes to data on the forms need to be made after data collection, they should be made by drawing a horizontal line through the original value and writing the new value adjacent to the original value with the date and initials of the person making the change. Corrected errors and changes made on a datasheet should be circled using a red marker. A short explanation of the change should be included in the margin of that datasheet. Corrected datasheets should be re-scanned.

(5) **Create or update database log**. Include the date and name of the technician entering data. Use the database log to keep notes on data entry, including suggestions for updates, errors encountered, and who entered or proofread the data.

(6) **Finish entering any remaining data into the appropriate database**.

(7) **Proofread data entry**. After the data have been entered by one person, a different person should proofread the data. Enter errors or changes into the database log.

3 Summarizing field notes

- **Finish identifying and storing all photos from field season**.
- **Compile trip reports from the sampling season**. The lead technician should compile all sampling reports that were written during the sampling season.

4 Reporting scientific collecting activities

- **Prepare and submit reports**. Prepare and submit reports for all scientific collecting activities via the NPS Research Permit and Reporting System (RPRS) web site (http://science.nature.nps.gov/research).

Standard Operating Procedure #10: Project Workspace

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) describes how and where data and other records, both digital and hard-copy, are stored for the project. Guidelines for structuring and accessing digital data are provided, as well as specific standards for digital file and folder naming. The archiving and management of records should be carefully accomplished based on the direction provided by this SOP.

1 File directory structure

A section of the network file sever is reserved for the aquatic macroinvertebrate monitoring project. The space will include a working file section as well as an archival section. Permissions allow project staff members to have access to needed files within this workspace. Prior to each season, the SCPN data manager will create a network account for each new staff member to give them access to the project workspace.

The file structure within this workspace is shown in Figure 10-1. Certain folders should be divided into separate folders for each calendar year. This will make it easier to identify and move these files to the project archives at the end of each season.

2 Naming conventions

2.1 Folder naming standards

In all cases, folder names should follow these guidelines:

- Use a 4-letter park code (e.g., BAND).
- Do not use spaces or special characters in the folder name.

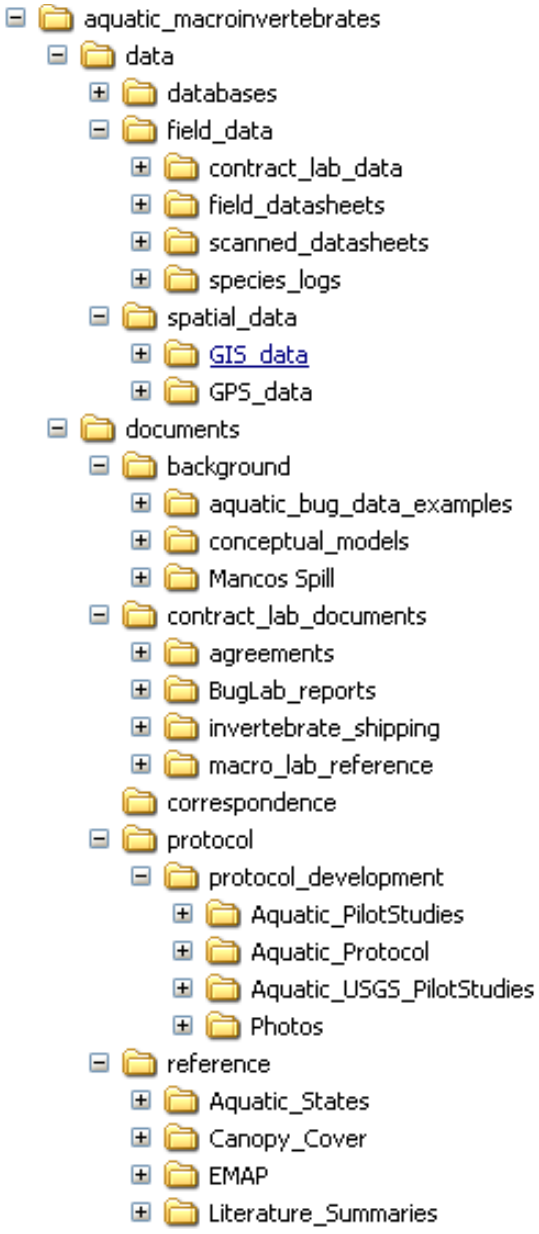


Figure 10-1. Example of file directory structure

- Use the underscore ("_") character to separate words in folder names.
- Try to limit folder names to 20 characters or fewer.
- Dates should be formatted YYYYMonDD (e.g., 2008Jan01 is January 1, 2008) where "Mon" is always the first three letters of the month.
- Subfolders named old or temp indicate a temporary nature and should eventually be removed after project completion.
- Here is a folder name example: BAND_2008Jan01.

2.2 File naming standards

In all cases, file names should follow these guidelines:

- Use a 4-letter park code (e.g., BAND).
- Use a site ID (e.g., BANDCAP01).
- Do not use spaces or special characters in the file name.

- Use the underscore ("_") character to separate file name components.
- Dates should be formatted as YYYYMonDD (e.g., 2008Jan01 is January 1, 2008) where "Mon" is always the first three letters of the month.
- Use leading zeroes for numbers 1 through 9, for sorting purposes.
- File names should be as short as possible, but include all mandatory information.
- The file name should be unique so that another electronic file is not likely to have the same name on the SCPN file server.
- Do not use version numbers on working documents (e.g., version1, final, etc). The file date (YYYYMonDD) will be used as your file version.
- Here are examples: BAND_BANDCAP01_2008Jan01_taxa.xls
  GLCA_GLCACOY01_2008Oct26.jpg

3 Archival and records management

All project files should be reviewed and organized by the project manager on a regular basis. Decisions on what to retain and what to destroy should be made following the guidelines stipulated in NPS Director's Order 19. This order provides a schedule for how long various kinds of records should be retained.

3.1 Digital data

Once the master project dataset and metadata are considered final, the data manager will place a copy of the dataset and the metadata record into the appropriate folder within the archive directory on the network server. These archived files will be stored in read-only format. Any subsequent changes made to this database must be documented in an edit log and in the metadata. In addition to archiving the database copy in its native format, all tables will be archived in a comma-delimited ASCII format that is platform-independent. This archiving will use the Access_to_ascii.mdb utility developed by CAKN. The project name and the term "Arc" should be included in the filename, with ASCII files including a .txt file extension and Access files including an .mdb file extension (e.g., Aq_Mac_Arc_2008Nov01.mdb).

Prior to any major changes of a dataset, a copy should be stored with the appropriate version number to allow for tracking of changes over time. Versions of archived datasets should be marked by adding a three digit number to the file name, with the first version being numbered 001 (e.g., Aq_Mac_BE_2008Nov01_v001, for the first version of a back-end data file at the end of the 2008 field season). Each additional version is assigned a sequentially higher number. Frequent users of the data should be notified of the updates and provided with a copy of the most recently archived version.

Additional digital files to be archived include all digital photos and contract lab spreadsheets associated with that field season and any digital files associated with data analysis products and project reporting. Official project reports will be cataloged in the online NPS Integrated Resource Management Applications. All digital materials are stored in the network office and can be made available to park curators upon request.

3.2 Hardcopy materials

Hardcopy materials (e.g., datasheet, field notebooks, photo prints, reports) are stored in the network office. Both the project manager and SCPN staff will work with the curatorial staff at the park(s) to achieve timely and efficient archiving of hardcopy materials.

Standard Operating Procedure #11: Data Entry and Verification

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This SOP describes the general procedures for entry and verification of field data in the working project database. For related guidance and a clarification of the distinction between the working database and the master database, refer to protocol Chapter 5: Data Management.

1 Data entry

Data entry should occur as soon as possible after data collection is completed. It should be completed by the person who collected the data or someone who is familiar with the project and data collection methods. The primary goal of data entry is to transcribe the data from paper records into the computer with 100% accuracy. It is the project manager and the data manager's shared responsibility to ensure that all data entry staff understand how to enter data and follow all applicable SOPs. Those entering data are responsible for becoming familiar with the field datasheets, the database, and any standard codes for data entry.

Each data entry form has built-in quality-assurance components, such as pick lists and validation rules, to test for missing data or illogical combinations. Although the database permits users to view the raw data tables and other database objects, users are strongly encouraged to use only the pre-built forms to ensure the maximum level of quality assurance.

As data are being entered, the person entering the data should visually review each data entry form to make sure that the data on screen match the datasheets. This should be done for each record prior to moving to the next form for data entry. At regular intervals and at the end of the field season, the water resources staff and data manager should inspect the data that have been entered to check for completeness and to identify avoidable errors.

2 Database instructions

2.1 Getting started

The Aquatic Macroinvertebrate Monitoring Database is fully documented in Appendix E. The working back-end database file should be stored on the server in the project workspace (see SOP #10) so that others can enter data into the same back-end file. The back-end file has "_be_" as part of its name. For enhanced performance, users should copy the front-end database onto their workstation hard drives and open it there. This front-end copy may be considered "disposable" because it does not contain any data, but rather acts as an interface with data residing in the back-end working database.

When new versions of the front-end application are released, there should be no need to move or alter the back-end file. Instead, the front-end file may be deleted and replaced with the new version, which will be named in a manner reflecting the update. When this occurs, the front-end application will prompt the user to update the links to the back-end database file. This update will only need to be done once for each new release of the front-end database.

2.2 The application startup form

The startup form is the entry point for the application. Double-clicking the network name at the top left of the form will open the web site for the Southern Colorado Plateau Network. Double-clicking the NPS Arrowhead or the title "**National Park Service**" at the top right of the form will open a browser and navigate to the National Park Service web site (www.nps.gov).

Also at the top right of the form is an **Exit** button which can be used to close the application.

A tabbed menu resides at the lower left corner of the form. It contains the *Main Menu* tab, the *Defaults* tab, and the *About* tab, with information about the application. Each of the tabs will be examined in more detail in the sections that follow.

At the bottom center-right of the form is a box that displays the current location of the back-end data file to which the application is linked.

2.2.1 *Main menu* tab

The *Main menu* tab of the working front-end application (fig. 11-1) has the following functional components, which are accessed from the application startup form that opens automatically when the application starts:

- **Enter / edit data**. Opens a form to confirm default settings (for example, user) prior to continuing to the aquatic macroinvertebrate monitoring data entry screens.
- **Track lab samples**. Opens a form that allows tracking of samples sent to and from the contract lab
- **Import lab data**. Opens a form that allows automatic import of digital aquatic macroinvertebrate data that are received from the contract laboratory.
- **Proof records**. Opens the main data entry form in proofing mode and tracks all changes made by the user. This is for data verification.
- **QA checks**. Opens the data validation tool that checks for missing data and illogical values. See SOP #12 for details.
- **View shutter bar.** Allows the user to view database objects (tables, queries, and forms).

Figure 11-1. The *Main Menu* tab of the *Aquatic Macroinvertebrate Monitoring Database* startup form

- **Back up data**. Creates a date-stamped copy of the back-end database file.
- **Connect data tables.** Verifies the connection to the back-end working database file, and provides the option to redirect or update that connection.

2.2.1.1 **Connect data tables**. The application has a separate front-end (user interface) and back-end (data tables). In order for the application to work properly, the front-end file must be connected to the correct back-end file. Clicking the **Connect data tables** button on the *Main Menu* tab opens the *Update Data Table Connections* form (fig. 11-2), which is used to establish the link from the front-end to the back-end.

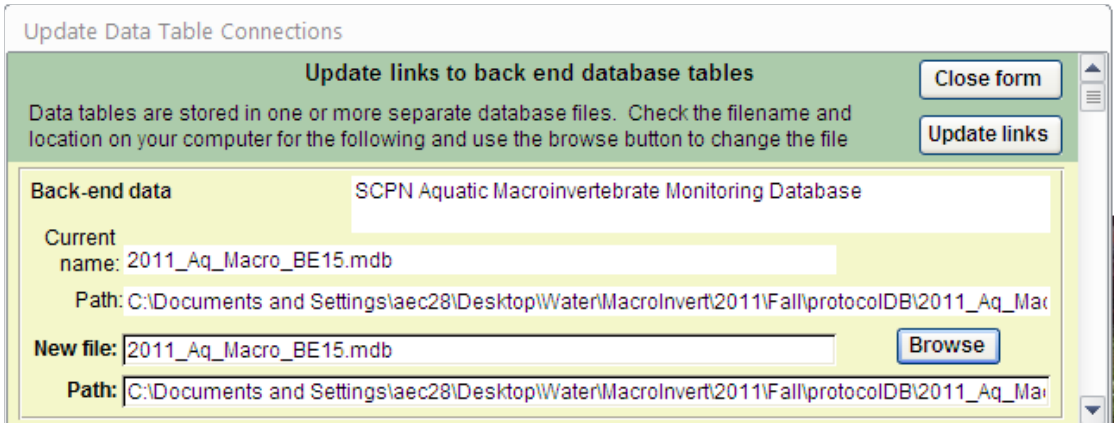


Figure 11-2. *Update Data Table Connections* form opened by clicking the Connect data tables button

The name and path of the current back-end file are displayed. To change the back-end file connection, click the **Browse** button, select a new back-end file, and click the **Open** button. To make the new connection, click the **Update links** button. If the connection is made, a success message will be displayed.

2.2.1.2 **Enter/edit data**. Clicking on **Enter/edit** data from the *Main menu* tab will open the dialog to set application defaults (fig. 11-3). Once the application defaults are set, the *Data Gateway* form (fig. 11-4) will open.

- *Data Gateway* form.

  This form displays location and event information and is designed to help the user determine which record to edit/view.

  Filters for **Park code, Site Name, Site Code, Year,** and **Visit Date** can be set by selecting from the drop-down lists at the top of the form in the **Filters** box. Filters can be removed by clicking the toggle button that says **Filter Is On**.

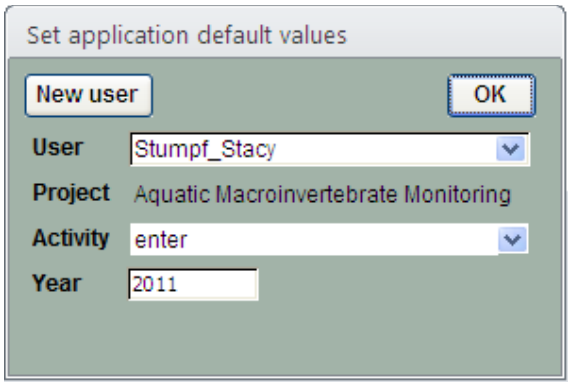


Figure 11-3. ***Set application default values*** **form**

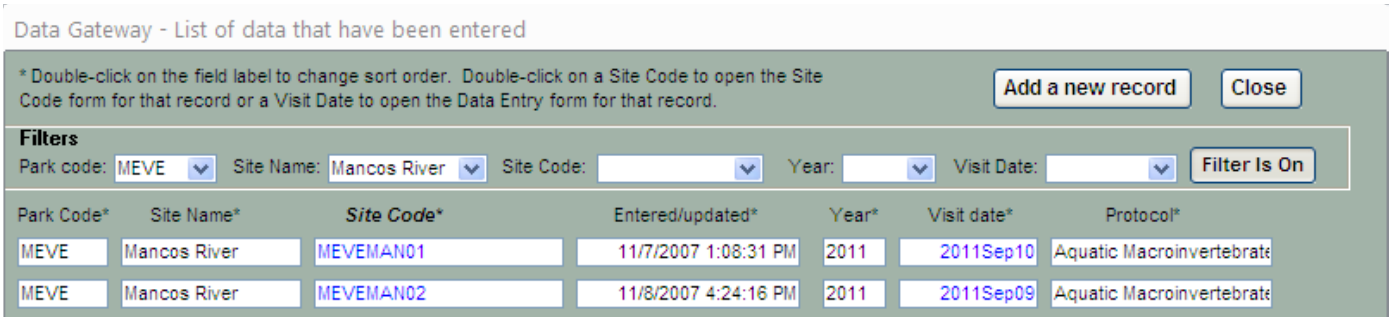


Figure 11-4. ***Data Gateway*** **form**

When the filter is removed, the toggle button will say "Filter Is Off" and all records will be displayed. Optionally, a specific filter can be removed by deleting the text that is currently displayed in one of the filter controls.

In addition to filters, there are options for sorting the records on the *Data Gateway* form. Double-clicking any of the column headings will cause the records to be sorted in ascending order by that column value. The column heading will change to a bold italic format to indicate that it is the column being used to determine sort order. If the same column is double-clicked a second time, the records will be sorted in descending order by that column value.

Double-clicking **Visit Date** will open the *Data Entry* form for that particular record. If a sampling event record has not been added for a particular location, when that blank cell under **Visit Date** is double-clicked, a new data entry record will be opened.

To add a new data entry record, click the **Add a new record** button at the top of the form.

- *Data entry* form

  The main *Data Entry* form (fig. 11-5) is used to select **Park Code, Site Name,** and **Site Code**, as well as to enter information about sampling events, information about the people who participated in the sampling events, and protocol-specific information.

  Park codes, site names, and site codes that were previously entered can be selected from a dropdown list; new site names and site codes can be entered by clicking on **Add New Site Name** and **Add New Site Code** (see below- *Site Name* form and *Site Code* form).

  Event information to enter includes sampling dates and times, and other event details.

  Information about people who participated in the sampling event can be entered in the *Observers* subform. Contacts can be selected from the drop-down list. If a new contact needs to be entered, click the **Add a person** button at the bottom to open the View and edit *contact information* form (fig. 11-8 on page 12).

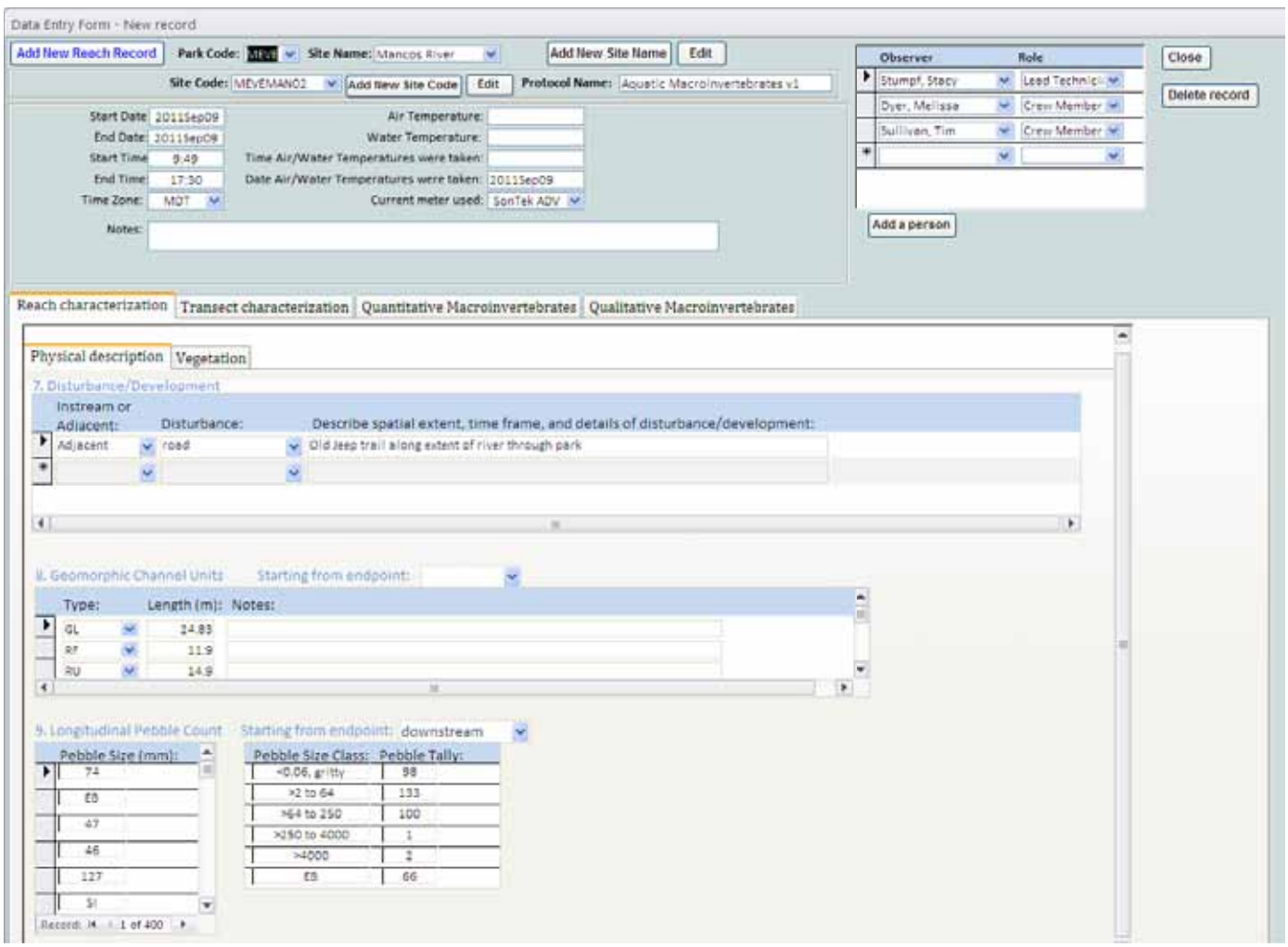


Figure 11-5. *Data Entry* form, accessed through the *Data Gateway* form

- *Site Name* form. If the **Site Name** drop-down list on the *Data Entry* form does not include the desired value, click on the **Add New Site Name** button. This will open the *Site Name* form (fig. 11-6). Likewise, clicking on the **Edit** button (from the *Data Entry* form) opens the *Site Name* form and allows the user to update information. Values entered here include **Site name, Description,** and **Notes**. **Park code** is automatically populated from the *Data Entry* form.

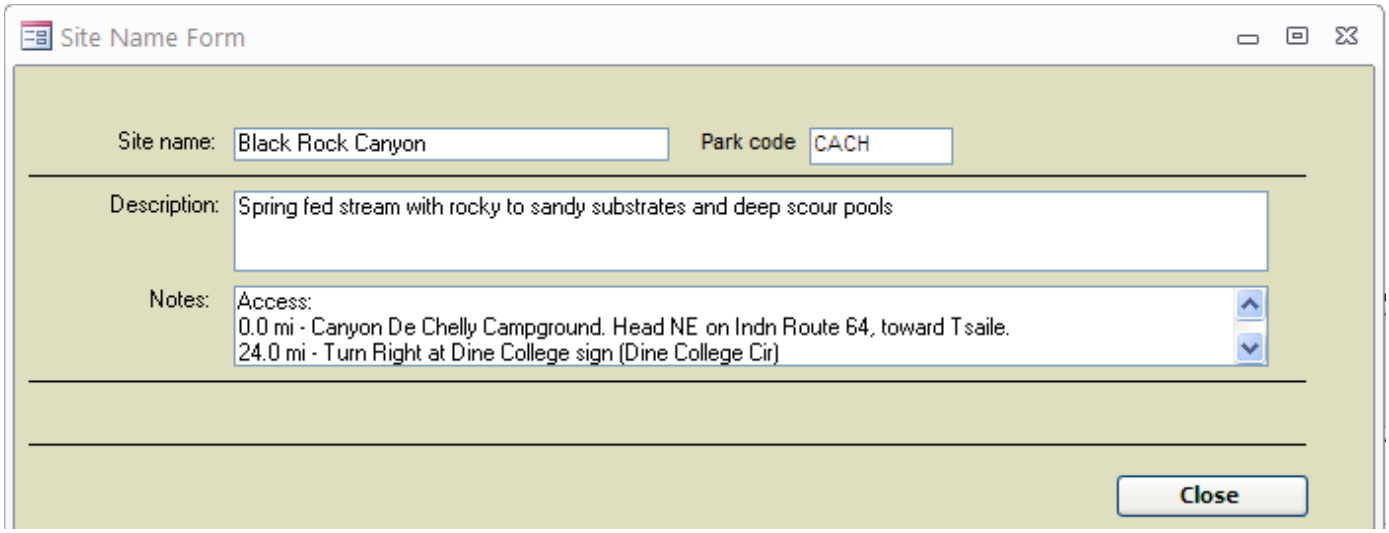


Figure 11-6. *Site Name* form, accessed through the *Data Entry* form

- *Site Code* form. If the **Site Code** drop-down list on the *Data Entry* form does not include a desired value, click on the **Add New Site Code** button. This will open the *Site Code* form (fig. 11-7). Likewise, clicking on the **Edit** button (from the *Data Entry* form) opens the same form and allows the user to update information. Values entered here include **Site code, Site code notes,** and **Access notes**. **Park code** and **Site name** are automatically populated from the *Data Entry* form.

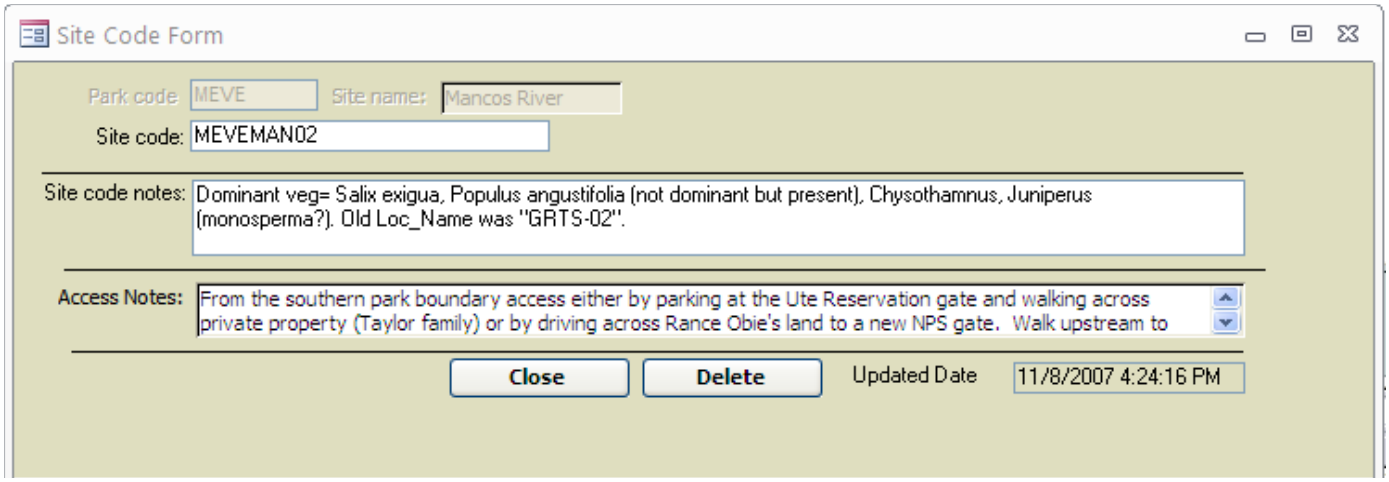


Figure 11-7. *Site Code* form, accessed through the *Data Entry* form

- *View and edit contact information* form. The *View and edit contact information* form (fig. 11-8) is used to enter details about individuals who participate in data collection, and who enter information in the database. This form is accessed by clicking the **Add a person** button from the *Data Entry* form. Enter **First name, Middle initial, Last name, Organization, Position/title, Work phone and Extension, Email address, Address information**, including **Address type, Street address, City, State, Zip code**, and **Country**, and any **Comments**.

  Previously entered addresses can be selected from the **Address 1** drop-down list, and the associated street address, city, state, zip, and country values will fill in automatically. The **Organization** and **Position/title** drop-down lists will also allow selection from previously entered values or new entries. The contact ID value, which uniquely identifies a contact, is automatically generated by the application.

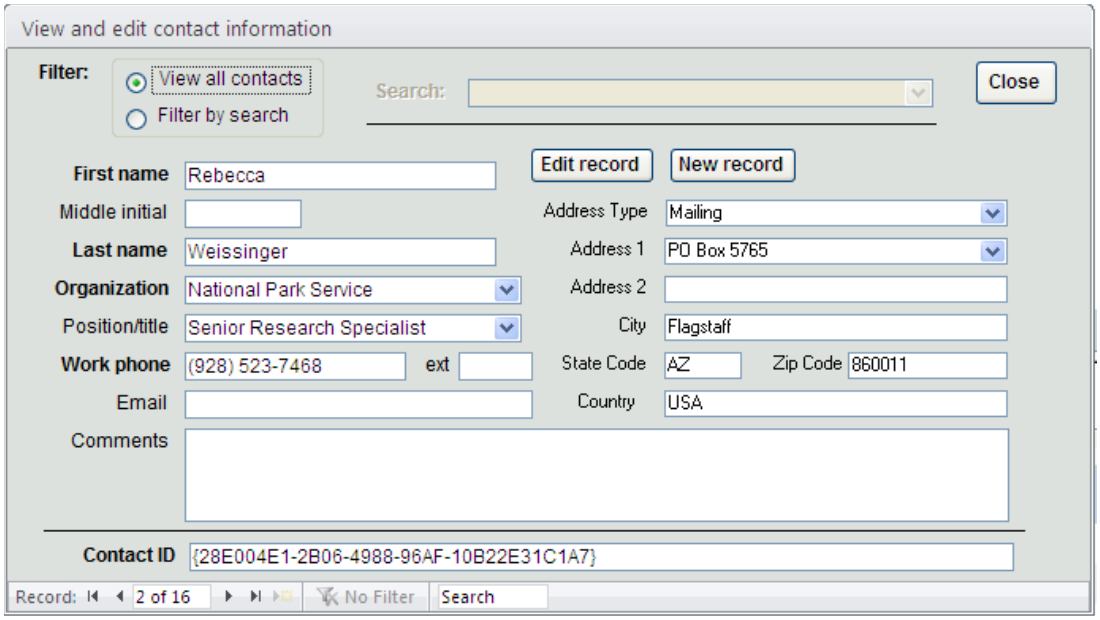


Figure 11-8. *View and edit contact information* form, accessed through the *Data Entry* form

Four tabs exist in the main form: *Reach characterization*, *Transect characterization*, *Quantitative Macroinvertebrates*, and *Qualitative Macroinvertebrates*. These will be discussed below.

- *Reach characterization* tab. Under the *Reach characterization* tab of the *Data entry* form are two tabs used to describe the reach: *Physical description* tab and *Vegetation* tab (fig. 11-9).

  - The *Physical description* tab includes three subforms: *Disturbance/Development*, *Geomorphic channel units*, and *Longitudinal pebble count* subforms. On the *Disturbance/Development* form (fig. 11-10), choose "Instream" or "Adjacent" and the **Disturbance** from the drop-down menus, and add a description.

    On the *Geomorphic channel units* form (fig. 11-11), enter whether the sampling was started upstream or downstream. Then enter **Type, Length,** and any comments in **Notes**.

    On the *Longitudinal pebble count* form (fig. 11-12), enter whether the sampling was started upstream or downstream from the drop-down menu after "starting from endpoint". Then enter the **Pebble size** (mm). The Pebble **size class** (mm) and **Pebble tally** are automatically populated.

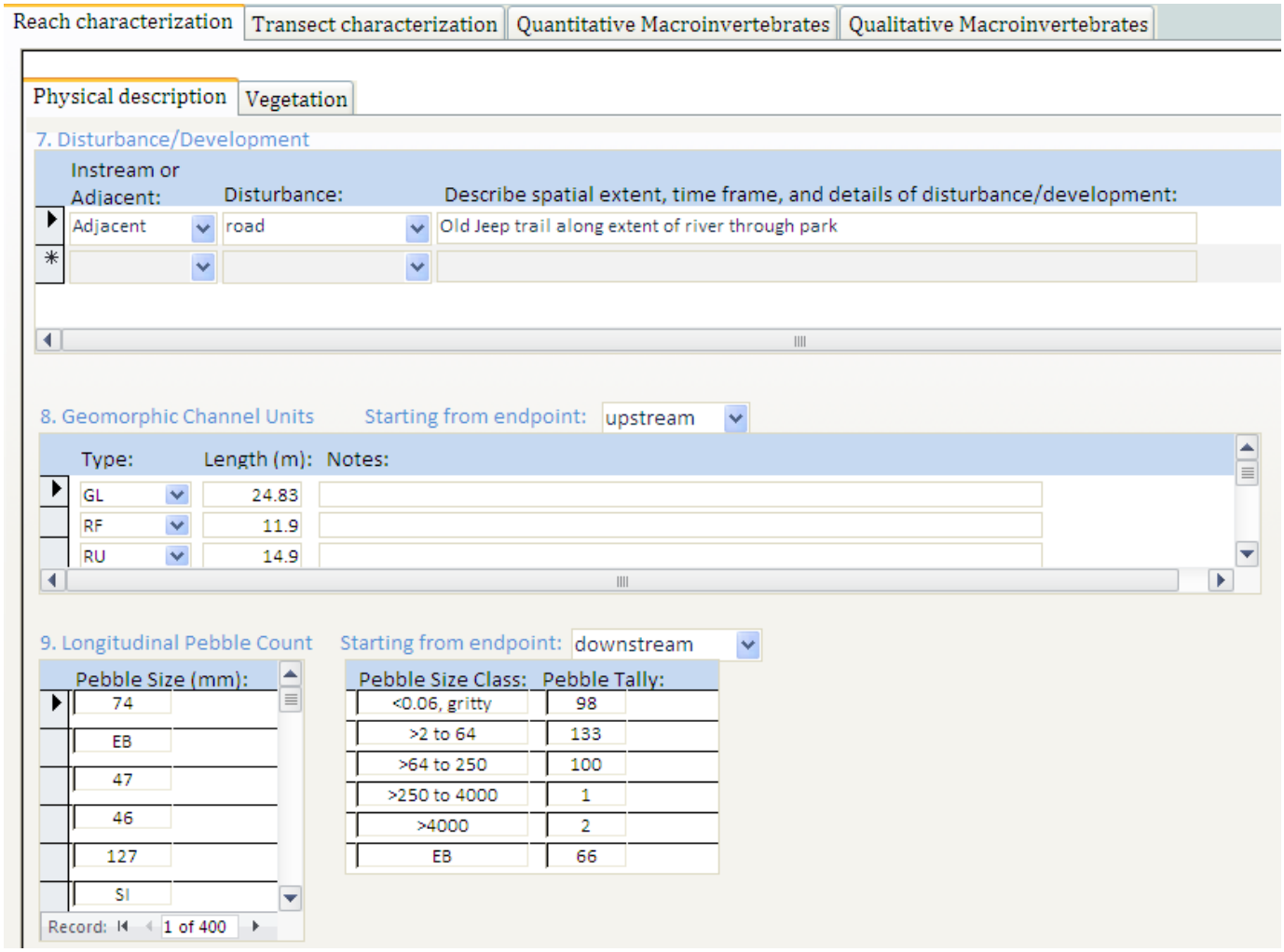


Figure 11-9. ***Reach characterization*** **tab of the** ***Data Entry*** **form, showing the** ***Physical description*** **tab open**

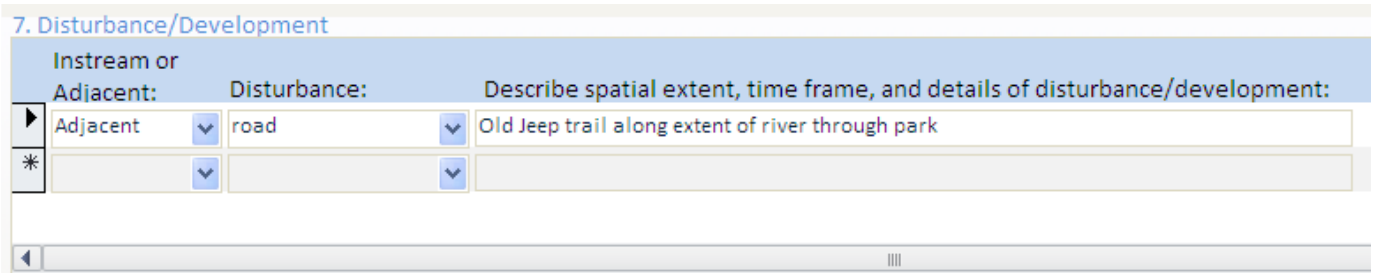


Figure 11-10. ***Disturbance/Development*** **subform of the** ***Physical description*** **tab**

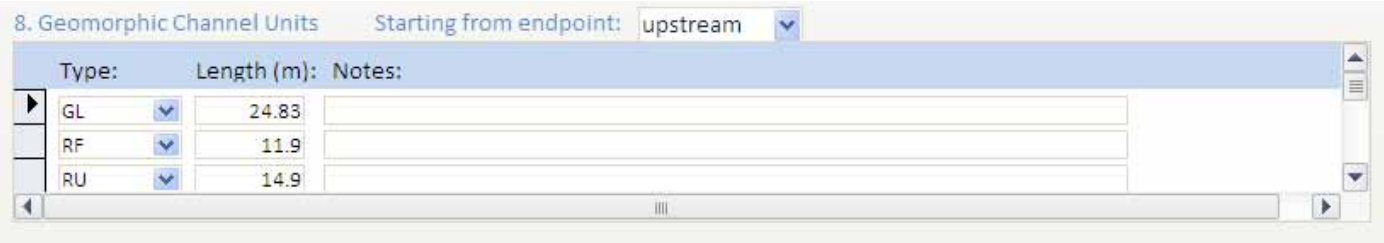


Figure 11-11. ***Geomorphic Channel Units*** **subform of the** ***Physical description*** **tab**

9. Longitudinal Pebble Count — Starting from endpoint: downstream

Pebble Size (mm):
74
EB
47
46
127
SI

Record: 1 of 400

Pebble Size Class:	Pebble Tally:
<0.06, gritty	98
>2 to 64	133
>64 to 250	100
>250 to 4000	1
>4000	2
EB	66

Figure 11-12. ***Longitudinal Pebble Count*** **subform of the** ***Physical description*** **tab**

- The *Vegetation* tab has three subforms: *Dominant physiognomic class*, *Riparian cover by vegetation association*, and *Canopy cover and dominant species by vegetation stratum* subforms.

On the *Dominant physiognomic class* form (fig. 11-13), simply choose the **Dominant physiognomic class**, from the dropdown list.

On the *Riparian cover by vegetation map class* form (fig. 11-14), choose the **Vegetation map class** and **Cover class** from the dropdown lists.

On the *Canopy cover and dominant species by vegetation stratum* form (fig. 11-15) , choose the **Stratum** (Tree, Shrub, or Herbaceous), **Canopy cover class**, and enter the **Dominant species.**

7. Dominant physiognomic class

Shrubland

Figure 11-13. ***Dominant physiognomic class*** **form of the** ***Vegetation*** **tab**

8. Riparian cover by vegetation map class

Vegetation map class:	Cover class:
Narrowleaf Cottonwood- Rocky Mountain Juniper Woodland	2
Coyote Willow/ Mesic Forb Shrubland	7

Figure 11-14. ***Riparian cover by vegetation association*** **form of the** ***Vegetation*** **tab**

9. Canopy cover and dominant species by vegetation stratum

Stratum:	Canopy cover class:	Dominant species:
Tree	6	Juniper sp.
Shrub	5	coyote willow

Figure 11-15. ***Canopy cover and dominant species by vegetation stratum*** **form of the** ***Vegetation*** **tab**

- *Transect characterization* **tab.** There are eleven transects per reach and a record must be created for each in the *Transect characterization* **tab (fig. 11-16)**. Enter the **Transect Number**. Enter additional details about the channel. This form includes three tabs: T*ransect point measurements, Woody debris, and Riparian canopy closure* tab; *Solar radiation* tab; and *Photos* tab. When one transect entry is complete, click on **Add New Transect** to enter the next transect.

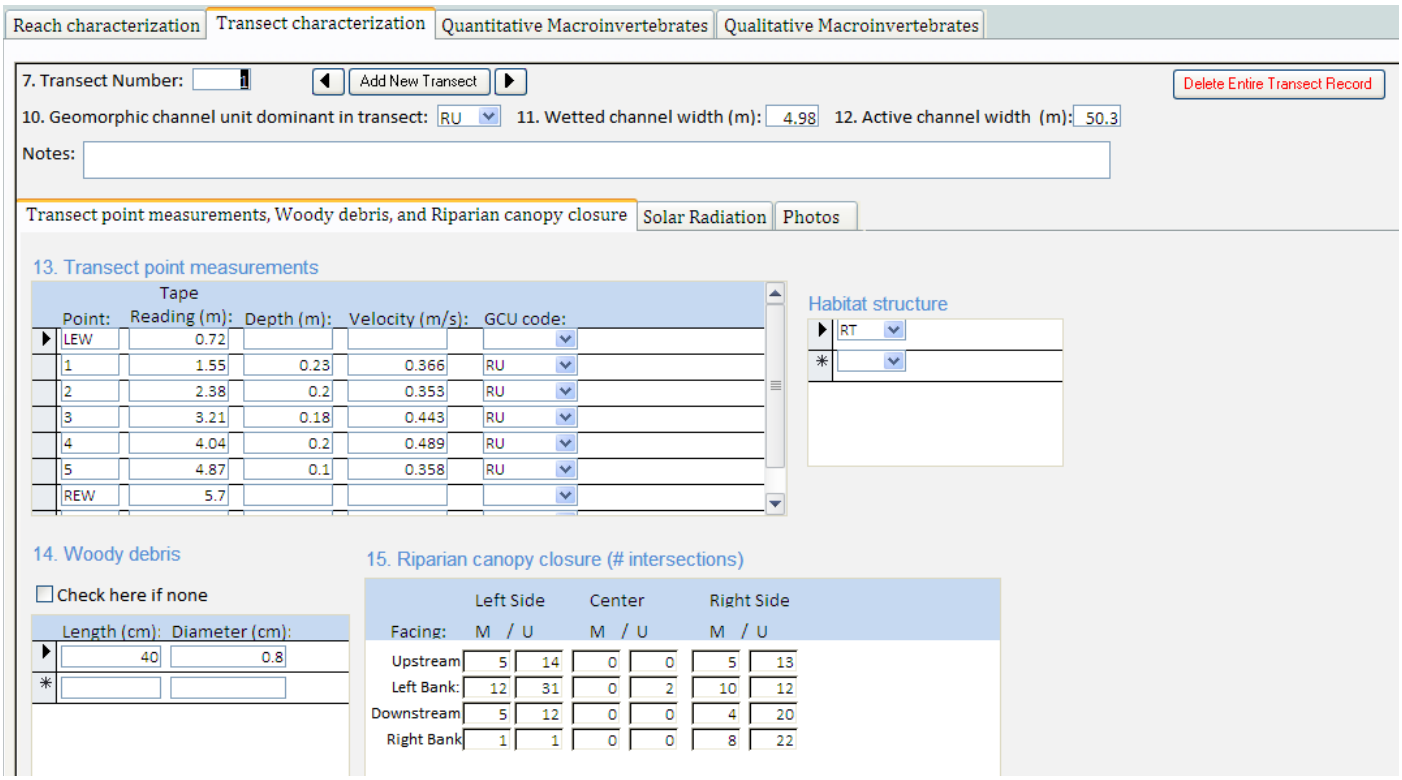


Figure 11-16. ***Transect characterization*** **tab of the** ***Data Entry*** **form, showing the** ***Transect point measurements, Woody debris, and Riparian canopy closure*** **tab open**

- The *Transect point measurements, Woody debris, and Riparian canopy closure* tab holds three forms. On the *Transect point measurements* form (fig. 11-17), enter five points as well as "left edge of water" (LEW) and "right edge of water" (**REW**). Enter **Tape Reading** (m) for all seven points. Enter, **Depth (m), Velocity (m/s)**, and **GCU** for the five points within the stream.

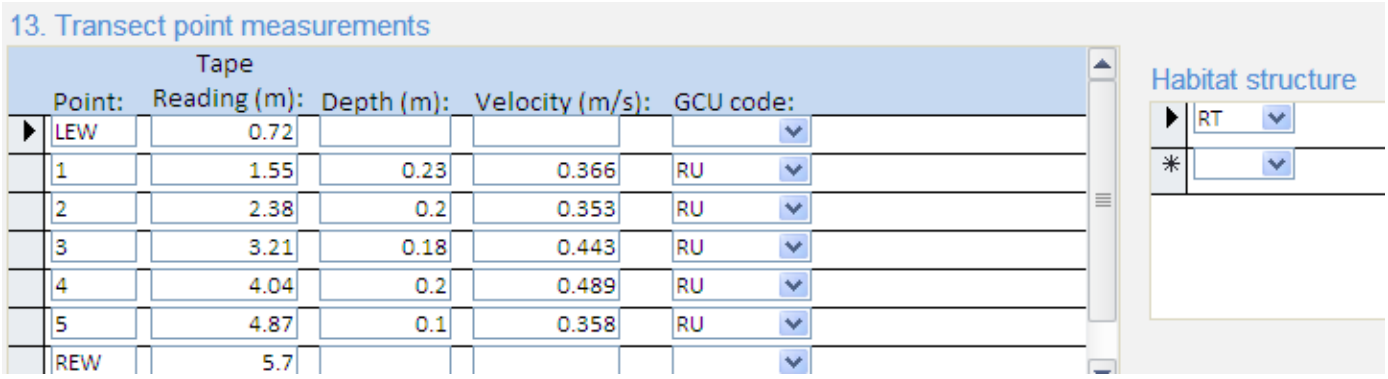


Figure 11-17. ***Transect point measurements form*** **of the** ***Transect point measurements, Woody debris, and Riparian canopy closure*** **tab**

In the *Habitat structure* subform, enter one or more habitat types for each of the seven points.

In the *Woody debris* form (fig. 11-18), enter **Length** and **Diameter** of each piece of woody debris. Mark the **Check here if none** box, if there was no woody debris at the reach.

In the *Riparian canopy closure* form (fig. 11-19), enter the number of intersections for each direction.

14. Woody debris

☐ Check here if none

Length (cm):	Diameter (cm):
40	0.8

Figure 11-18. ***Woody debris*** **form of the** ***Transect point measurements, Woody debris, and Riparian canopy closure*** **tab**

15. Riparian canopy closure (# intersections)

	Left Side		Center		Right Side	
Facing:	M	/ U	M	/ U	M	/ U
Upstream	5	14	0	0	5	13
Left Bank:	12	31	0	2	10	12
Downstream	5	12	0	0	4	20
Right Bank	1	1	0	0	8	22

Figure 11-19. ***Riparian canopy closure*** **form of the** ***Transect point measurements, Woody debris, and Riparian canopy closure*** **tab**

- *Solar radiation* tab and form (fig. 11-20). Enter the sunrise and sunset times for each month. Solar radiation is calculated in a query using the methods outlined in SOP #6.

Transect point measurements, Woody debris, and Riparian canopy closure | Solar Radiation | Photos

Dec Sunrise:	9:00	Dec Sunset:	15:30
Jan Sunrise:	9:00	Jan Sunset:	15:30
Nov Sunrise:	9:00	Nov Sunset:	15:30
Feb Sunrise:	8:30	Feb Sunset:	16:00
Oct Sunrise:	8:30	Oct Sunset:	16:00
Mar Sunrise	8:00	Mar Sunset:	16:00
Sep Sunrise:	8:00	Sep Sunset:	16:30
Apr Sunrise	8:00	Apr Sunset:	16:30
Aug Sunrise:	8:00	Aug Sunset:	16:30
May Sunrise	7:30	May Sunset:	17:00
Jul Sunrise:	7:30	Jul Sunset:	17:00
Jun Sunrise:	7:30	Jun Sunset:	17:00

Figure 11-20. ***Solar Radiation*** **tab and form of the** ***Transect characterization*** **tab**

- *Photos* tab and form (fig. 11-21). Clicking on the **Browse** button opens a dialog that allows the user to navigate to the stored photos. Selecting a photo file automatically sets the picture **Name** and **Path**. Where applicable, add **Direction** and **Notes**.

Transect point measurements, Woody debris, and Riparian canopy closure | Solar Radiation | Photos

Name:	Direction:	Path:	Notes	
IMG_0009.jpg	upstream	Z:\Active_Projects\I&M_Projects\Monitoring\Water_Resourc	photo is looking upstream	Browse
IMG_0010.jpg	downstream	Z:\Active_Projects\I&M_Projects\Monitoring\Water_Resourc	photo is looking downstream	Browse
				Browse

Figure 11-21. ***Photos*** **tab and form of the** ***Transect characterization*** **tab**

- *Quantitative Macroinvertebrates* tab (fig. 11-22). A **Sample location number** must be entered for each of the five samples per reach. Enter **Water depth** (m), **Velocity** (m/s), and any **Notes**. When the data entry for a sample location number is complete, click **Add New Sample Number** to make another entry.

  The *Quantitative Macroinvertebrates* tab contains four forms. Enter data into the *Particle embeddedness* form and the *Particle size classes* form. **Substrate size** will be automatically populated. Particle size groups across all sample locations are automatically tallied. Data are imported into the *Taxa* form, which is for viewing data (see **Import lab data** below).

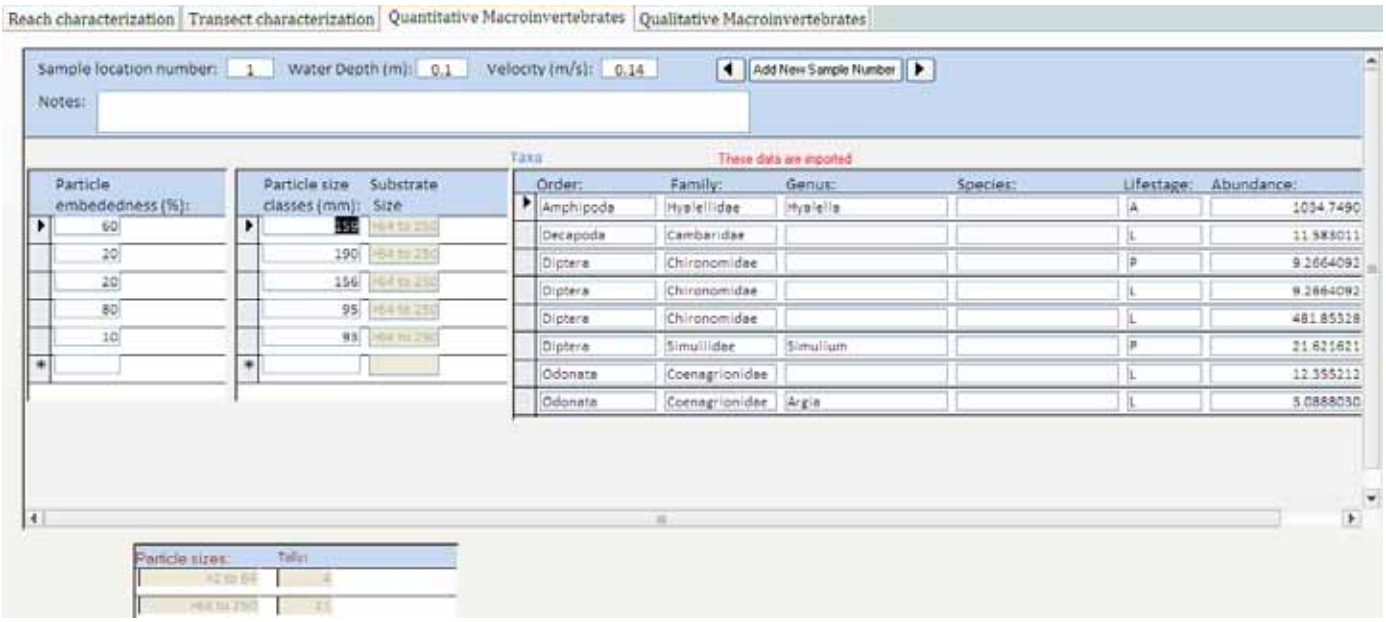


Figure 11-22. ***Quantitative Macroinvertebrates*** **tab of the** ***Data Entry*** **form**

- The *Qualitative Macroinvertebrates* tab (fig. 11-23). In the *Habitat types sampled* **form**, choose values for **Substrate Type, Depth Category,** and **Flow Velocity Category** from the dropdown lists. Data are imported into the *Taxa* form, which is for viewing data (see **Import lab data** next page).

Figure 11-23. ***Qualitatative Macroinvertebrates*** **tab of the** ***Data Entry*** **form**

2.2.1.3 **Track lab samples**. Clicking on the **Track lab samples** button from the *Main menu* tab opens the *Lab Samples Tracking* form (fig. 11-24). This form is used to enter data for samples that will be sent to the contract lab. The form displays **Park code, Site name, Site code**, and **Sampling date**. Enter the number of quantitative bottles and qualitative jars for each record. Choose the **Lab Name** from the dropdown list. Enter **Number of samples shipped, Date shipped to lab, Date data were delivered, Date deliverables were received, Deliverables received**, and any **Notes**. Check **Included in shipment** if the samples from the sampling event are related to the same lab and shipping date. Repeat this procedure for samples that are going to a different lab.

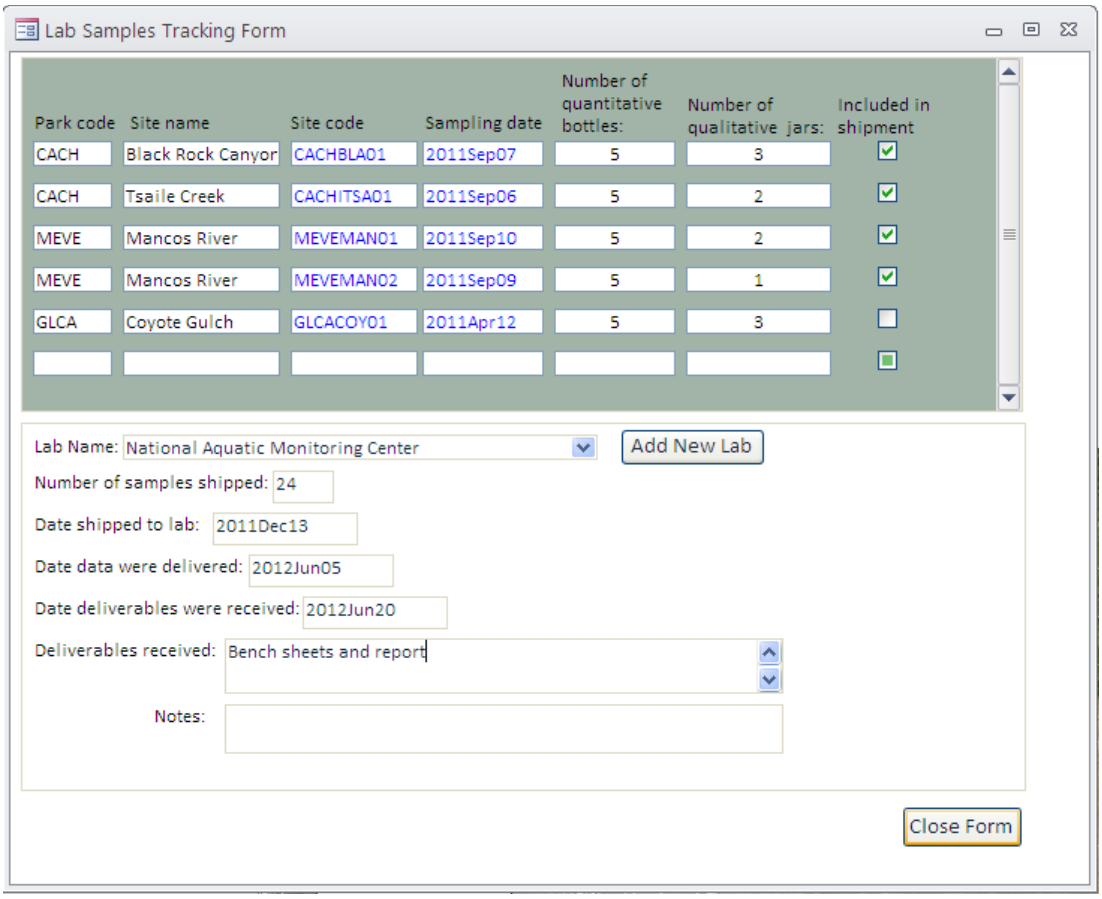


Figure 11-24. ***Lab Samples Tracking*** **form from the** ***Track Lab Samples*** **option on the** ***Main menu tab***

If the desired contract lab is not on the dropdown list, click on **Add New Lab** to open the *Contract lab information* form (fig. 11-25). Enter **Lab Name, Address, City, State, Zip Code, Country, Email, Phone, Fax,** and any **Notes.**

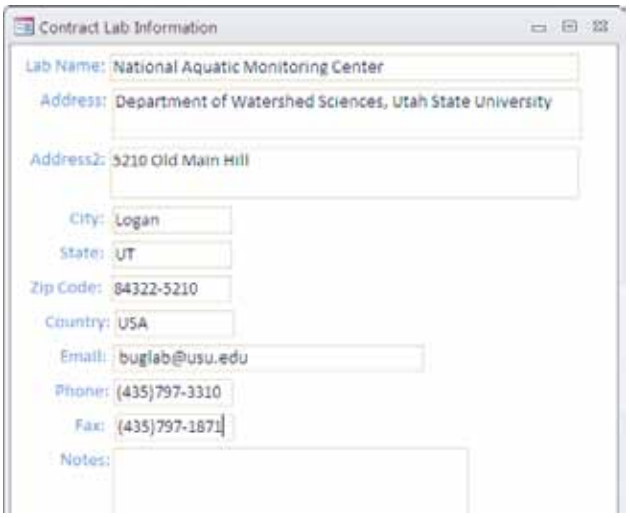


Figure 11-25. ***Contract Lab Information*** **form, accessed through the** ***Lab Samples Tracking*** **form**

2.2.1.4 **Import lab data.** Digital macroinvertebrate taxa files are received from the contract laboratory and can be imported into the database. Because the data are for the entire sampling season, the import process only needs to be done once per sampling season. Click the **Import lab data** button on the *Main menu* tab to open the *Import aquatic macroinvertebrate lab data* form (fig. 11-26).

Click **Browse** and navigate to the file to be imported. Then click **Import File.** A message will appear when the data have been successfully updated. The data can then be viewed through the *Data Entry* form.

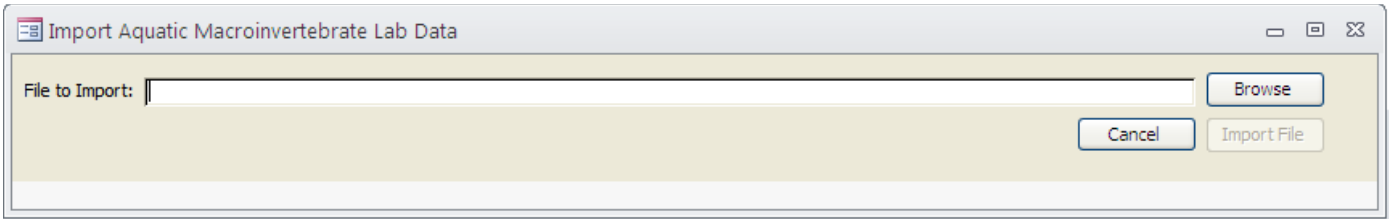


Figure 11-26. ***Import Aquatic Macroinvertebrate Lab Data*** **form opened by the** ***Import lab data*** **button on the** ***Main Menu***

2.2.1.5 **Proof data**. Clicking the **Proof records** button from the *Main menu* tab opens the *Proofing Switchboard* form (fig. 11-27). Enter **Start Date** and **End Date**; if no dates are entered, the database will automatically take the earliest and latest dates, respectively. Enter the percent of records to be proofed (usually 10%) and click **Enter.** This will open the *Proofing* form (fig. 11-28), which displays the subset of records to be proofed.

Selecting a record and clicking **Proof Record** opens this record in the *Data Entry* form. If any errors are found, they should be corrected. The **Corrected** box on the *Proofing* form will be checked if any errors were corrected. When all records are proofed, click on **Done Proofing**. This navigates back to the *Proofing Switchboard*.

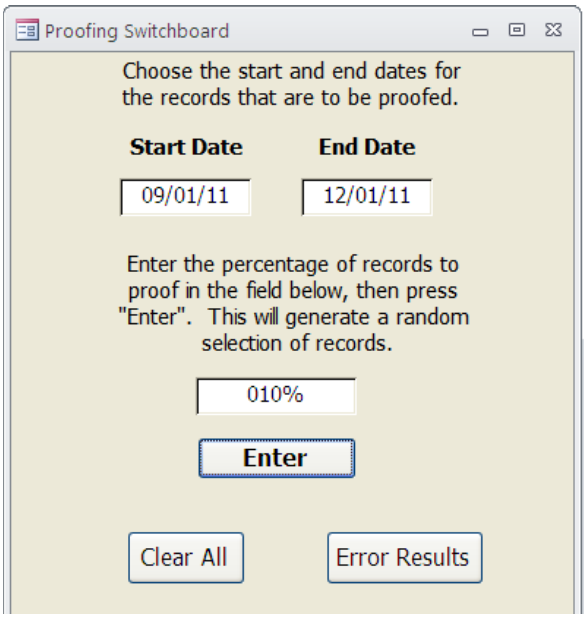


Figure 11-27. ***Proofing Switchboard*** **opened by the** ***Proof records*** **button on the** ***Main menu*** **tab**

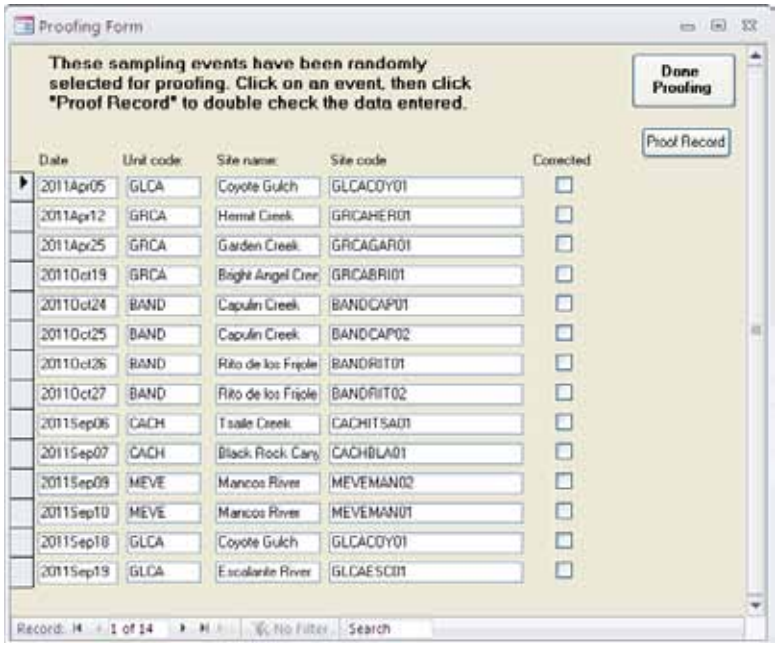


Figure 11-28. ***Proofing*** **form, accessed through the** ***Proofing Switchboard***

From the *Proofing Switchboard*, clicking on **Error Results** opens the *Proofing Results* form (fig. 11-29). Enter **Start Date** and **End Date**. Click on **% of Records with Errors** to see the error rate. If the error rate is greater than 10%, the user will be instructed to error check all records. Click on **Field Errors** to see a report of which errors were most frequently corrected (fig. 11-30).

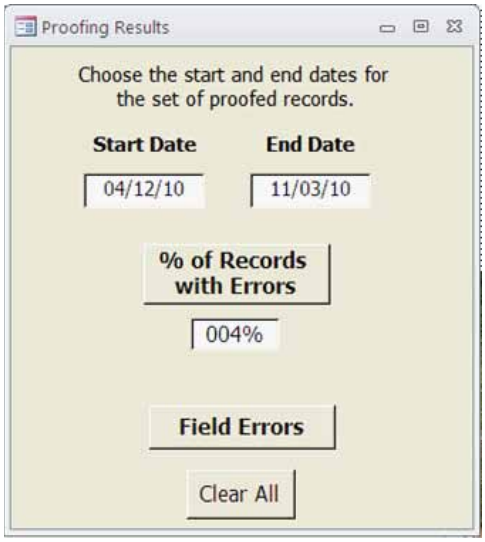
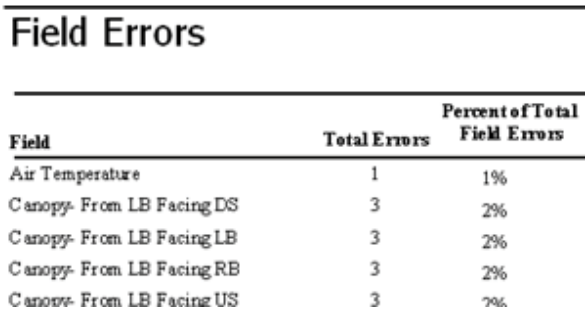


Figure 11-29. *Proofing Results* form, accessed through the *Proofing Switchboard*



Field Errors

Field	Total Errors	Percent of Total Field Errors
Air Temperature	1	1%
Canopy- From LB Facing DS	3	2%
Canopy- From LB Facing LB	3	2%
Canopy- From LB Facing RB	3	2%
Canopy- From LB Facing US	3	2%

Figure 11-30. *Field Errors* report, accessed through the *Proofing Results* form

2.2.1.6 **QA checks**. The **QA checks** button on the *Main menu* tab opens the *Data Validation and Quality Review* tool. This tool allows the user to run pre-built queries that display records for which data should be checked. The database application facilitates data validation by showing the results of pre-built queries that check for data integrity, data outliers and missing values, and illogical values. The user may then fix these problems and document the fixes. See SOP #12 for instructions on this tool.

2.2.1.7 **View shutter bar**. Clicking the **View Shutter Bar** button on the *Main menu* tab displays all of the tables, queries, forms, reports, macros, and modules in the application (fig. 11-31). Exercise caution when working with objects directly in the shutter bar. To hide the shutter bar once you have opened it, click the Shutter Bar Open/Close arrows next to **Forms** bar.

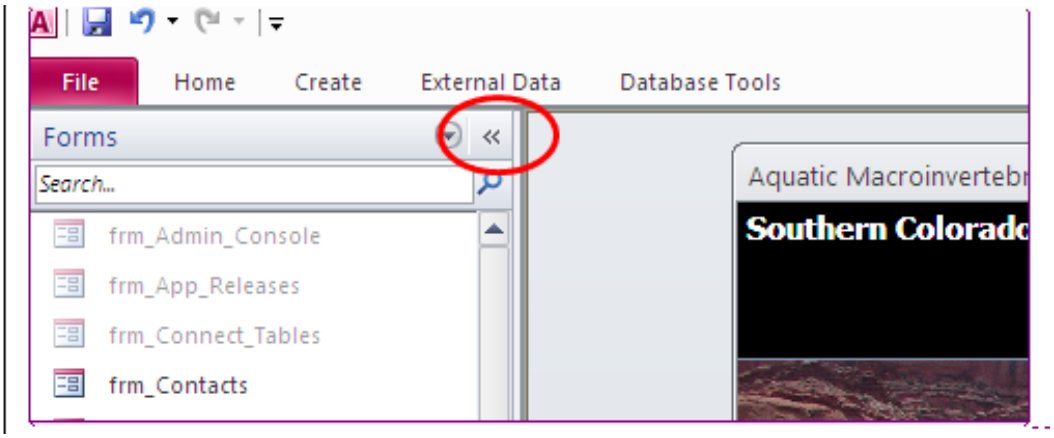


Figure 11-31. The screen shot displays the results of clicking the *View shutter bar* button on the *Main menu,* with the button used to hide the shutter bar circled in red.

2.2.1.8 **Back up data**. Clicking the **Back up data** button on the *Main menu* tab will open a **Yes/No** box asking if the user would like to make a backup copy of the data. If **Yes** is selected, the user will be prompted to select a folder in which to place the backup copy. The backup files will be named by adding the current date, time, and user's initials to the end of the back-end file name (e.g., aq_mac_BE_v1.0_20070605_1711_SM.mdb for a backup file created on June 5, 2007 at 5:11PM by Steve Monroe). Back-up copies are used for the current field season only and will not be archived. All such backups may be deleted after the quality review and certification of the data. Clicking the **Save** button creates the backup file and displays a success message.

2.2.2 Defaults tab

The *Defaults* tab (fig. 11-32) provides feedback on the current default values and check boxes for automatic backups on startup, backups on exit, data file compaction on exit, and link verification on startup.

Figure 11-32. ***Defaults*** **tab of the** ***Aquatic Macroinvertebrate Monitoring Database*** **startup form**

2.2.2.1 **Current defaults**. The *current defaults* section of the *Defaults* menu displays values for **Project, User, Activity,** and **Year**. To change values, click the **Change** button to bring up the *Set application* ***default values*** form (fig. 11-33). **User** and **Activity** can be selected from a drop-down list. Click the **New user** button to add a new user (see the *View and edit contact information* form section of this document for more information). When you have finished entering default values, click the **OK** button to return to the *Default* tab.

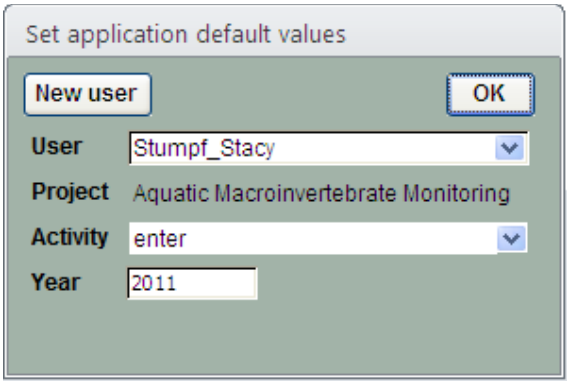


Figure 11-33. ***Set application default values*** **form**

2.2.2.2 Automatic backups. The application can be set to automatically prompt for backups every time it is started and/or every time it is closed, using the **Exit** button on the main form. Making backups before and after data entry sessions is recommended, in case of database corruption or data entry mistakes. Backups can also be run manually by clicking the **Back up data** button on the *Main menu* tab.

2.2.2.3 **Compact back-end on exit.** Compaction causes Microsoft Access to optimize the organization of the file, making it smaller and quicker to access data. Check the option to **Compact back-end on exit** so that the application will compact the data file that is linked to the front-end when the application is closed using the **Exit** button on the main form.

2.2.2.4 Verify Table links on startup. The application is structured with a front-end (user interface) and a back-end (data tables). In order for the application to work properly, the front-end must be linked to the tables in the back-end. When this box is checked (recommended), the link to the back-end file(s) will be checked when the application is started.

2.2.3 *About* tab

The *About* tab (fig. 34) of the application startup form presents information about the application, including version number, application author, author organization, author phone, and author email (click to email).

Buttons for viewing release history and reporting bugs are also provided on the *About* tab.

2.2.3.1 **View release history**. From the *About* tab on the application startup form click on the **View release history** button to open the *Application Releases* form (fig. 11-35). This form provides information about all of the different versions of the application that have been released. It is filled in by the application developer before the application is distributed and is therefore read-only.

Included in the *Application Releases* form are **Database title, version number,** and release

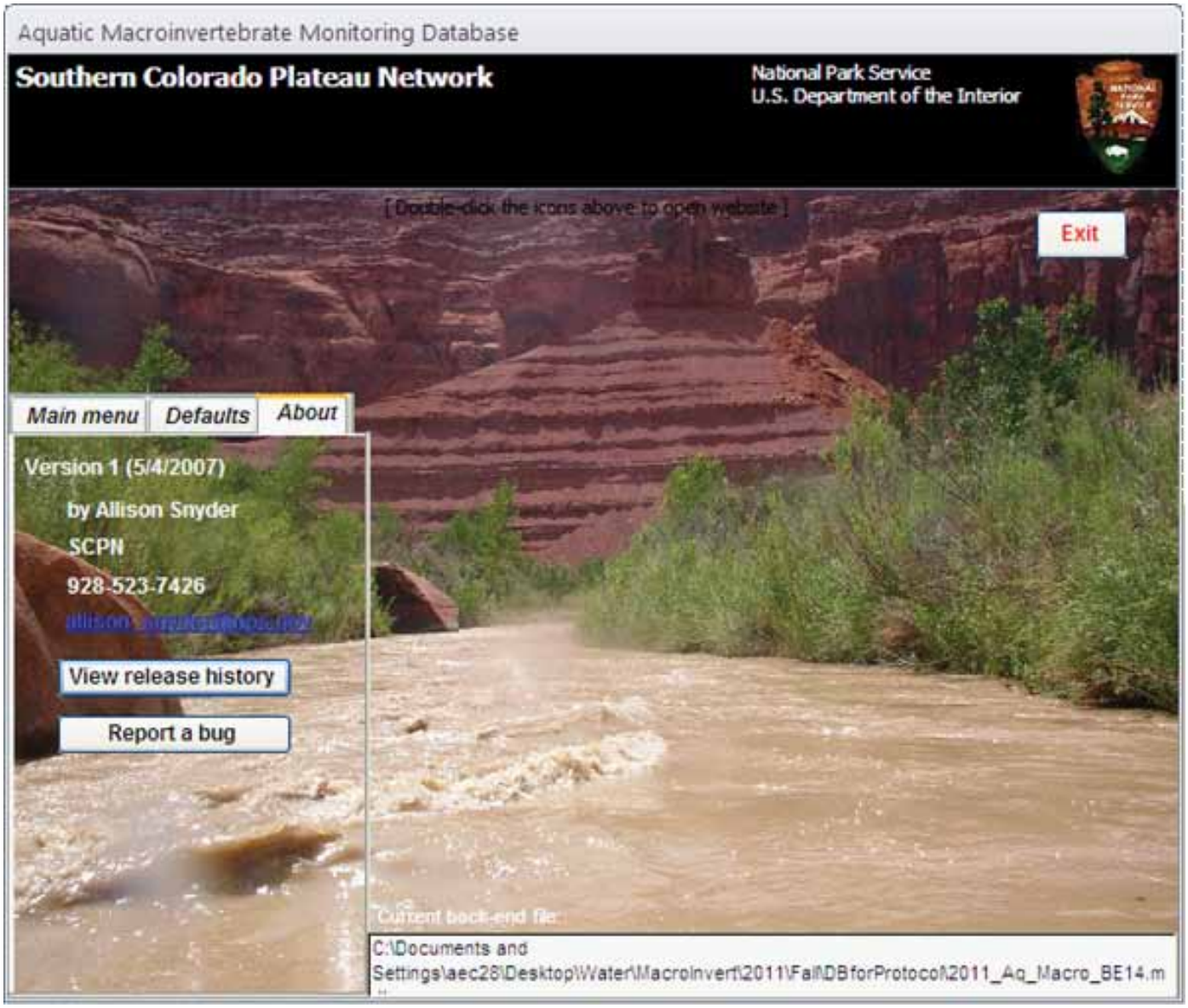


Figure 11-34. ***About*** **tab of the** ***Aquatic Macroinvertebrate Monitoring Database*** **startup form**

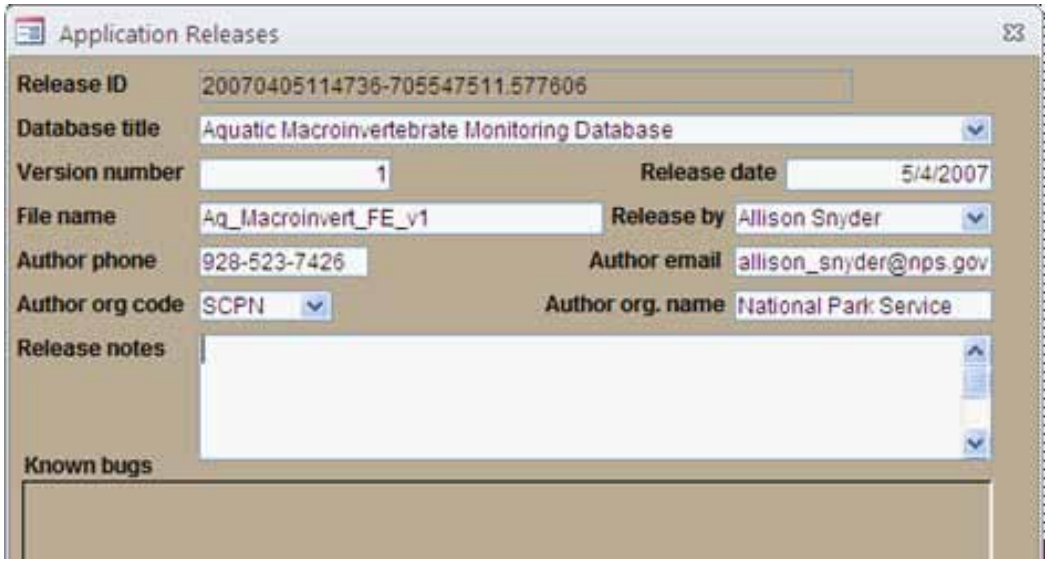


Figure 11-35. ***Application Releases*** **form, opened by clicking the** ***View release history*** **button on the** ***About*** **tab**

information about the application, information about the author of the application, and program bug information.

2.2.3.2 **Report a bug**. Clicking the **Report a bug** button on the *About* tab will prompt the user to contact the application developer with the details of the bug. Developer contact information is located above the **Report a bug** button.

The following information is useful when reporting a bug:

- application name
- application version
- name of the form/report you were on when the bug happened
- action, if any, you took right before the bug occurred
- screen capture of any error messages

Standard Operating Procedure #12: Data Quality Review

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) describes the procedures for validation of data in the working project database. Data validation is the process of checking data for completeness, structural integrity, and logical consistency. It must be done after every field season's data have been entered. The database application facilitates this process by showing the results of pre-built queries that check for data integrity, data outliers, missing values, and illogical values. The user may then fix these problems and document the fixes.

1 Data quality review

Table 12-1 shows an example of the automated validation checks that are performed on the data. These queries return records that need to be fixed or verified. Errors and inconsistencies that cannot be fixed are described in the Notes/Comments within the table where the problem occurs. A description of the resulting errors and why edits were not made is also documented and included in the metadata. The data manager will help construct new database queries or modify existing ones as needed.

The queries are named and numbered hierarchically so that high-order data should be fixed before low-order data. One change in a high-order table may affect many low-order records.

2 Using database quality review tools

From the database switchboard, click **QA checks**. This will open the *Data validation and quality review tool*. Upon opening, the tool automatically runs the validation queries and stores the results in a table built into the front-end database (tbl_QA_Results). Each time

Table 12-1. Example of validation queries in the Aquatic Macroinvertebrate database

Query name	Returns records meeting the following criteria:
qry_Val_1a_Reach	Missing park code, reach name, reach notes, or access notes
qry_Val_2a_Event_Dates	Date does not fall within sampling range
qry_Val_2b_Events	Missing start date, end date, start time, or end time
qry_Val_3a_Event_Spp	Missing species or TSN
qry_Val_3c_Event_Details	Shows all records that have missing data in any of the Event Details fields
qry_Val_4b_Qual_Habitats	Missing substrate type, depth category, or flow velocity category
qry_Val_5a_Quant	Missing replicate, water depth, velocity, or sample number
qry_Val_5b_Quant_Sub_Embed	Missing substrate embeddedness
qry_Val_5c_Quant_Sub_Size	Missing substrate size
qry_Val_6a_TransectsSampled	Number of transects sampled does not equal eleven
qry_Val_6b_Transects	Missing transect number, habitat type, wetted channel width, or active channel width
qry_Val_6c_Transect_Pebble	Shows all records in tbl_Transect_Pebble. User needs to search for blank records—can't isolate blank records or they will be out of context.
qry_Val_6d_Transect_Point	Missing tape reading for all points. Missing depth, velocity, or habitat type for in-stream points (not right or left bank).
qry_Val_6e_Transect_Canopy	Missing canopy cover for any direction from left bank, right bank, or stream center
qry_Val_6f_Transect_Pt_Struc	Missing structure
qry_Val_6g_Transect_Photos	Missing photo name, storage path, or direction
qry_Val_6h_Transect_WD	Missing diameter or length
qry_Val_6i_Pebbles	All records. User needs to search for blank records—can't isolate blank records or they will be out of context.
qry_Val_6j_Solar_Rad	Missing solar radiation data for any month, sunrise or sunset

the query results are refreshed, or the quality assurance review form is re-opened, the number of records returned and the run times are rewritten so that the most recent result set is always available; any remedy description and the user name for the person making the edits is retained between runs of the queries. The results from the validation queries will be stored in the metadata.

2.1 ***Results summary*** *tab*

The *Results summary* tab (fig. 12-1) displays each query with its **Query name**, **Type**, **N recs** (number of records returned by the query), whether the validation for that query is **Done**, the **Last run time**, and a **Description**. Clicking the button to **Refresh results** may need to be done periodically as changes in one part of the data structure may change the number of records returned by other queries.

2.2 ***View and fix query results*** *tab*

Clicking on a query name in the *Results summary* tab opens the query in the *View and fix query results* tab (fig. 12-2). This form displays the data and allows the user to fix the data and/or to provide details. In the upper right-hand corner, clicking on the **Edit** option button allows data editing. Clicking **Design View** will allow the user to see how the query is designed.

2.3 ***Browse data tables*** *tab*

The *Browse data tables* tab (fig. 12-3) enables the user to edit erroneous data directly in the data table, for situations where direct editing is not allowed in the query results form.

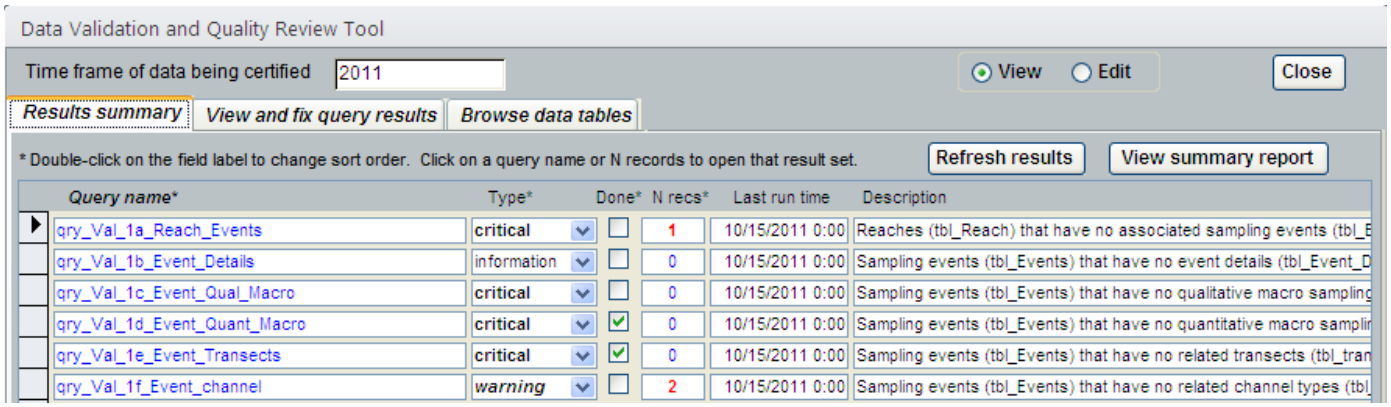


Figure 12-1. Contents of the *Results summary* tab

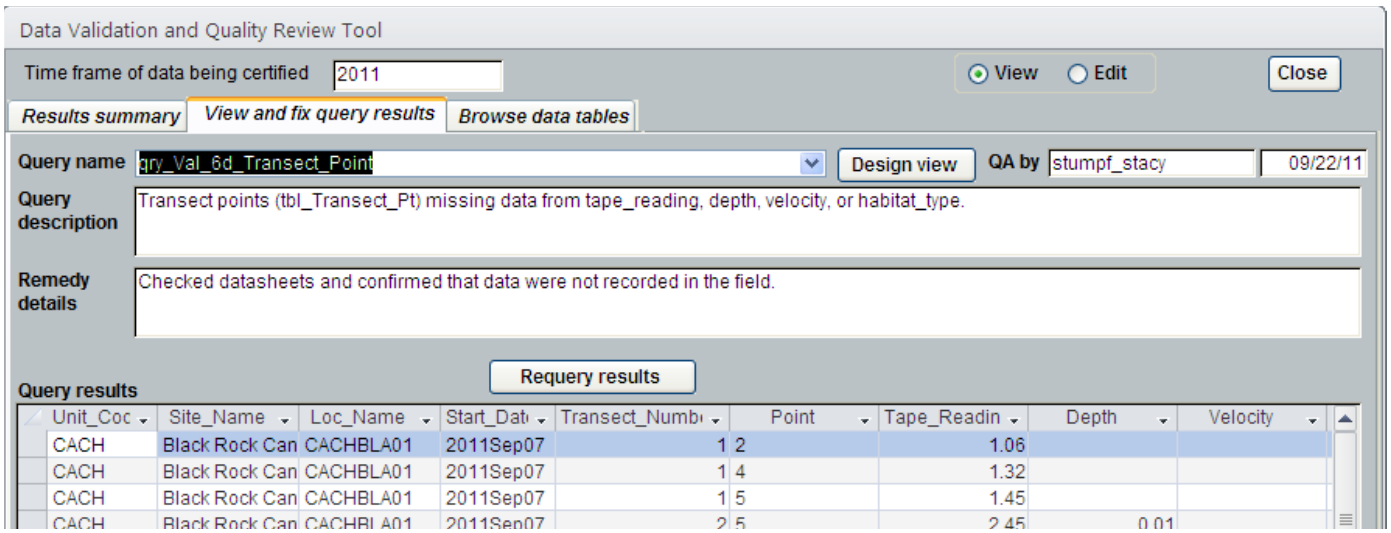


Figure 12-2. Contents of the *View and fix query results* tab

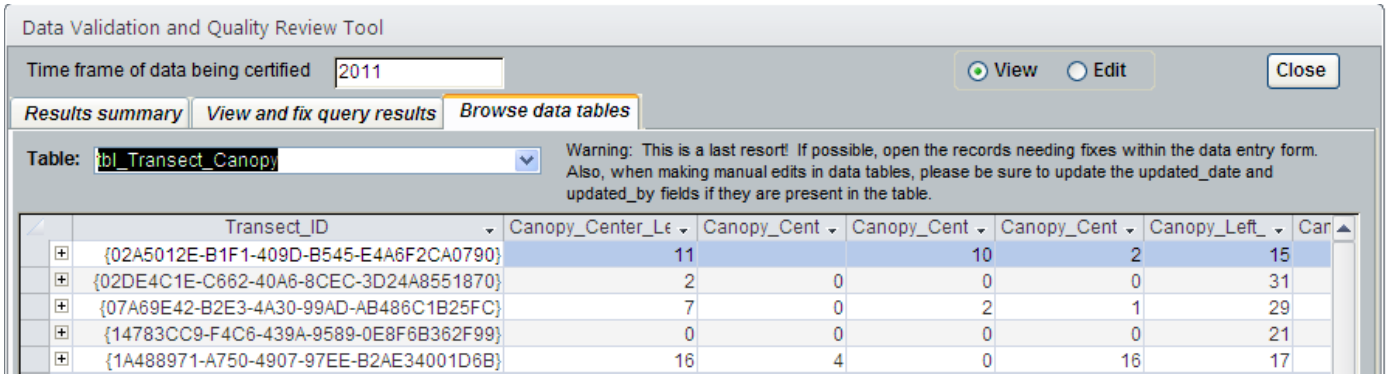


Figure 12-3. Contents of the *Browse data tables* tab

The user should toggle between the tabs to complete validation. As edits are made to the data, the user should return to the *Results summary* tab—this will allow users to check the **Done** checkbox when data from a query is validated. Re-running the query, if corrected, should return no results, and once all queries return zero records, this section of data validation is complete. In some cases, data cannot be fixed and therefore the queries will return records, even though the data validation is complete. All results from validation will be included in the metadata.

Standard Operating Procedure #13: Data Summary and Reporting

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) describes the steps required to prepare and summarize macroinvertebrate and habitat data for analysis and provides guidelines for preparing annual summary reports.

1 Aquatic macroinvertebrate data

1.1 Data preparation

Data processing with IDAS: We are using Invertebrate Data Analysis System (IDAS) software to process aquatic macroinvertebrate data for analysis (Cuffney 2003). The IDAS software package is a special purpose program written in Microsoft Visual Basic 6.0 to provide USGS NAWQA program biologists and others with a flexible and efficient mechanism for preparing macroinvertebrate data for use in other analytical programs. It consists of five program modules that allow the user to manipulate data sets, calculate community metrics, and export data to other programs. The processing steps we are using are summarized here. See the IDAS User's Manual (Cuffney 2003) for full details.

- **Taxonomic resolution**. The contract laboratory will identify individuals to the lowest practical taxonomic unit (specified in appendix D, table D-2). This is the preferred level of taxonomic resolution for data analysis.
- **Deletions based on laboratory processing notes**. Macroinvertebrate occurrences based on poor quality specimens (e.g., immature, damaged, poorly mounted) are deleted. This can be done for all records or only for those records resulting in an ambiguous identification. The decision of whether to delete a record based on processing notes depends on the amount of information that will be lost in relation to the reduction in ambiguous taxa.

- **Deletions based on life stage**. In some cases, multiple life stages (larva, pupa, adult) of the same species will be included as separate entries in the raw dataset. While it is appropriate to retain individuals in aquatic life stages for data analysis, terrestrial adults should be omitted, as their place of origin is unknown. Non-aquatic adult insects are defined as adults in the orders Ephemeroptera, Odonata, Plecoptera, Megaloptera, Neuroptera, Trichoptera, Lepidoptera, Hymenoptera, and Diptera. Records of terrestrial adults in these orders will be omitted in preparation for analysis.
- **Combining life stages**. Separate entries for life stages of the same species should be combined (by summing the abundances) into a single entry. For aquatic taxa, larva, pupa and adult stages will be combined. For terrestrial taxa, this step will occur after Deletions based on life stage and thus will combine larva and pupa life stages.
- **Resolving taxonomic ambiguities**. Taxonomic ambiguities arise when individual organisms in a sample or set of samples are identified to different levels in the taxonomic hierarchy that are nested within each other. For example, in a sample where individuals are identified as Ephemerellidae, Ephemerella sp. Ephemerella subvaria, and Ephemerella invaria, each of these would be considered an ambiguous taxon.

  For the most part, we expect macroinvertebrate communities to be similar among sites within a stream in a given year. Therefore we will usually resolve taxonomic ambiguities on a combined-sample basis rather than on a sample-by-sample basis. While taxonomic ambiguities can be handled in several ways (Cuffney 2003), our preferred option is distributing ambiguous parent abundance among children in accordance with the relative abundance of each child.

  This option tends to retain the most information and is the best method to use for quantitative data, provided that the analyst is comfortable with the assumptions that must be made to redistribute the taxa. The suitability of this method will vary by sample, and the other methods presented here may need to be used under some circumstances. Life stage information and laboratory notes may also aid in determining the best method to use. Regardless of which methods are used, detailed documentation of these decisions should be kept so that the dataset can be reproduced at a later date.

- **Rare taxa**. Taxa can be rare because they occur at few sites or because they occur at very low abundances. Rare taxa can cause skewed distributions in community data and can have a disproportionate influence on the outcome of some types of analyses. There are many conflicting viewpoints on whether or not to retain or delete rare taxa for multivariate analyses and metric calculation (see Cao et al. 2001). Preliminary analyses (e.g., outlier analysis) will also help to determine whether or not to delete rare taxa.

  If rare taxa are deleted, deletion must be done in a systematic way. Typically, criteria are set to define a taxon as rare (e.g., taxon occurs in <10% of samples, or taxon composes <1% of abundance in an individual sample), and all taxa that fall below the specified criteria are deleted. If this is done, all the steps involved in deleting rare taxa and the criteria that are used should be carefully documented.

1.2 Formatting data for analysis

For multivariate analysis, community data are typically formatted as a site-by-species matrix containing the raw abundances of each taxon.

1.3 Data transformations

Some types of analyses (e.g., regression, correlation, some multivariate analyses) require that data are normally distributed; however, community data is rarely normally

distributed. Log_{10} or square root transformations may improve distributions of raw abundance data to satisfy the assumption of normality, and the arcsine square root transformation may be used on proportional abundance data to improve the distribution. Visualizing these data in histograms or performing outlier analysis will determine whether data require transformation.

1.4 Classification of taxa into functional groups

For analysis of macroinvertebrate community function, macroinvertebrate taxa must be classified into functional groups. Functional groups may consist of classifications according to feeding guilds, habit guilds, morphology, life cycle attributes, and dispersal attributes, to name a few. Feeding and habit guilds have conventionally been used in bioassessments, but as more data become available, other functional groups may also be incorporated. Most of the functional classifications for aquatic insects are based on information provided in Merritt and Cummins (1996). For other aquatic macroinvertebrate taxa (non-insects), Thorp and Covich (1991) is a useful reference. These references both provide detailed ecological information on individual macroinvertebrate taxa; however the information is not presented in a form that is directly useable for data analysis.

Barbour et al. (1999) and Poff et al. (2006) are the recommended tabular sources for functional classifications. These sources include classifications limited to tolerance, feeding, and habit, and thus have been widely used for analyzing state, EMAP, and NAWQA data. Classifications from these sources are the default data used to calculate metrics in the IDAS program. Poff et al. (2006) is a more recent source of functional classifications, and incorporates a wide variety of trait classifications including morphological, ecological, life history, and mobility/dispersal characteristics for 311 genera and 78 families of lotic insects in tabular form. This source may provide supplementary information for other traits of interest.

Functional classifications should be assigned to taxa at the level of species or genera whenever possible. Family-level classifications are acceptable if lower-taxonomic-level information is not available.

1.5 Metric calculation

The metrics shown in Table 13-1 are examples of those that can used to describe macroinvertebrate community structure. These metrics can be used as a starting point for statistical analysis of data collected during the initial years of monitoring. As more data are collected and analyzed over time, alternate metrics and indices may be selected. Formulas for calculating most metrics can be found in Cuffney et al. (2003).

2 Preparation and summary of habitat data

Habitat data will be used to complement macroinvertebrate community data and is summarized at the reach scale. The following information may be used to generate habitat variables that will be relevant to macroinvertebrate community structure and function.

- **Geomorphic Channel Units (GCUs**). Geomorphic channel unit data are collected at several spatial scales (reach, transect, and microhabitat). At all three spatial scales, these data can be summarized in terms of the proportional composition of each type of GCU (percent riffle, percent pool, etc.). In addition, the number of GCUs can be calculated with the reach-scale data to provide a coarse measure of habitat diversity.
- **Transect data**. Data collected at transects, including stream depth, stream velocity, percent canopy closure, and percent daily solar radiation should be summarized by

Table 13-1. Example of some metrics that can be used to describe macroinvertebrate community structure

Metric type	Metric	Definition
Abundance/Richness/Diversity	Total abundance	Total number of individuals.
	Taxa richness	Total number of taxa (measures the overall variety of macroinvertebrates in a sample).
	Simpson's diversity	A measure of the variety of taxa that takes into account the relative abundance of each taxon. $D = \sum(n_i(n_i - 1)/N(N-1))$
Tolerance	Dominant taxa	Measures the dominance of the most abundant taxa. Typically calculated as dominant 2, 3, 4, or 5 taxa.
	Relative abundance tolerant taxa	Percent of individuals considered to be sensitive to perturbation.
	Percent richness of tolerant taxa	Percent of taxa considered to be sensitive to perturbation.
Functional-Feeding	Relative abundance collector-filterers	Percent of individuals that filter fine particulate organic matter from the water column.
	Percent richness collector-filterers	Percent of taxa that filter fine particulate matter from the water column.
	Relative abundance scrapers	Percent of individuals that scrape or graze upon periphyton.
Functional-Habit	Relative abundance burrowers	Percent of individuals that move between substrate particles (typically fine substrates).
	Percent richness burrowers	Percent of taxa that move between substrate particles (typically fine substrates).
	Relative abundance clingers	Percent of individuals that have fixed retreats or adaptations for attachment to surfaces in flowing water.
	Percent richness clingers	Percent of taxa that have fixed retreats or adaptations for attachment to surfaces in flowing water.
Composition	Number of EPT taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).
	Relative abundance EPT	Percent of individuals in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).
	Relative abundance Ephemeroptera	Percent of individuals that are mayflies.
	Relative abundance Plecoptera	Percent of individuals that are stoneflies (for streams >1,500 m in elevation).
	Relative abundance Trichoptera	Percent of individuals that are caddisflies.
	Hydroptilidae+ Hydropsychidae/Trichoptera	Percent of trichopteran individuals in Hydroptilidae plus Hydropsychidae (ratio of tolerant caddisfly abundance to total caddisfly abundance).
	Relative abundance noninsect taxa	Percent of individuals that are not insects.
	Relative abundance Chironomidae	Percent of individuals that are midges.

calculating the mean and standard deviation for each.

- **Pebble count data**. The pebble count data can provide several measures to characterize substrate size and streambed heterogeneity. Variables that may be relevant to macroinvertebrate data include percent fine sediments (<2 mm), and median, mean, and standard deviation of particle sizes.
- **Microhabitat data**. Data collected at macroinvertebrate sampling locations, including stream depth, stream velocity, particle embeddedness, and substrate particle size should be summarized by calculating the mean and standard deviation for each.

3 Preparation of annual summary reports

For each year that sampling occurs, annual reports will be generated for individual streams. The main objectives of these reports are to (1) document the monitoring activities that occurred (b) summarize data that were collected, and (c) where appropriate, place these data in the context of aquatic habitat, biological condition, and management actions within the park through time. Annual reports will consist of the following main sections (see appendix G for an example report):

(1) **Introduction**. This section includes the background, purpose, and objectives of the monitoring effort, park- or site- specific objectives, and report-specific objectives.

(2) **Background**. This section describes the stream and monitored stream reaches as well as a description of management concerns for aquatic resources in the park. New and ongoing park management activities with the potential to impact water quality, stream habitat, or macroinvertebrate communities at the monitoring site should be noted here.

(3) **Methods.** This section includes a summary of monitoring activities conducted on each stream during the current year. This summary should include a description of sampling reaches, the dates that sampling occurred, types of samples and other data that were collected, and description of related SCPN monitoring efforts (e.g., water quality, riparian). Field and laboratory methods are summarized briefly with reference to the protocol for more detail.

(4). **Results**. This section summarizes macroinvertebrate monitoring data in graphical and/or tabular form. If available, selected data from previous years could be included to provide a frame of reference for the present year's data. The report should also include a reach-scale summary of the physical habitat data including measures of central tendency and variability. Documentation of antecedent hydrologic, climatic, and/or watershed conditions (if information is available) that may influence this year's data should also be included in this section.

(5) **Discussion**. This section contains information describing the current condition of aquatic habitat and macroinvertebrate communities, and how they compare to conditions in previous years, within the region, or in areas with similar management strategies. The discussion also places this year's monitoring efforts within the context of previous years (for example, samples were collected later this year than in previous years; or, annual precipitation was far below average, resulting in drought conditions).

(6) **Literature cited**. This section provides details for literature cited in the text.

4 Preparation of periodic trend reports

Trend reports, based on comprehensive statistical analyses of long-term data, will be prepared every five years. The main objectives of trend reports, as described in Thomas et al. (2006), are to (1) report patterns and trends in condition of resources being monitored, (2) report new characteristics of resources and correlations among related vital signs, (3) report the degree of change that can be detected by the current level of sampling, and (4) provide interpretation of monitoring data in a park context. Appendix F provides an example using aquatic macroinvertebrate abundance data and several multivariate analysis methods to examine and test for temporal change.

Standard Operating Procedure #14: Revising the Protocol Narrative and SOPs

Version 1.00

Revision History Log

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

This standard operating procedure (SOP) explains how to make and track changes to the *Aquatic Macroinvertebrate Monitoring Protocol for the Southern Colorado Plateau Network* and associated SOPs. Over time, the protocol narrative and SOPs may require modifications. The following procedures must be followed when making changes to ensure that previous data collection and processing procedures are clearly understood and accounted for when using and interpreting historical data sets. Similarly, clearly articulating new methods is critical to credible interpretation of data acquired after the implementation of changes. Personnel making changes must be familiar with this SOP to ensure that proper reviews are conducted and that documentation standards are followed.

1 Modifications

Small changes or additions to existing methods will be reviewed in-house by SCPN staff. An outside review will be encouraged by the network for major changes in methods.

2 Revision history

All changes must be documented, and updated protocol versions must be recorded in the Revision History Log that accompanies the protocol narrative and each SOP. Changes are recorded only in the protocol narrative or the SOP being modified. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02, etc.) for minor changes. Major revisions will be designated with the next whole number (e.g., version 2.0, 3.0, 4.0, etc.). When the new version is done, record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

3 Narrative and SOP updates may occur independently

A change in one SOP will not necessarily invoke changes in other SOPs, and a narrative update may not require SOP modifications. All narrative and SOP version changes must be noted in the Master Version Table (MVT), which is maintained in this SOP (table 14-1). Any time a narrative or an SOP version change occurs, a new Version Key number (VK#) must be created and recorded in the MVT, along with the date of the change and the versions of the narrative and SOPs in effect. The VK number increments by whole integers (e.g., 1, 2, 3, 4, 5). Updates to the MVT also must be provided to the SCPN data manager for inclusion in the MVT database. The VK# number is essential for project information to be properly interpreted and analyzed. Protocol narrative changes are recorded in Table 14-2. The protocol narrative, SOPs, and data should not be distributed independently of this table.

4 New versions

New versions of the protocol narrative and SOPs must be posted on the SCPN web page. Previous versions of the protocol narrative and SOPs must be archived in the appropriate library.

Table 14-1. Master Version Table, *Aquatic Macroinvertebrate Monitoring Protocol for the Southern Colorado Plateau Network*

Version key#	Date of change	Narrative	SOP #1	SOP #2	SOP #3	SOP #4	SOP #5	SOP #6	SOP #7	SOP #8	SOP #9	SOP #10	SOP #11	SOP #12	SOP #13

Table 14-2. Revision History Log: Protocol narrative Version 1.00

Previous version number	Revision date	Author	Changes made	Section and paragraph	Reason	Approved by	New version number

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision; identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

Appendices

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Appendix A. Aquatic Macroinvertebrate Sampling Techniques Utilized by State and Federal Agencies on the Colorado Plateau

1 Quantitative sampling methods

Table A-1 summarizes different quantitative sampling methods for state and federal agencies within the Colorado Plateau. See Table A-2 for agency contact information.

1.1 Arizona State Department of Environmental Quality

Methods described are taken from the *Biocriteria Program Quality Assurance Program Plan from the Arizona Department of Environmental Quality* (Arizona Department of Environmental Quality 2005. Appendix A. pages A1-A3).

Macroinvertebrate samples are collected from riffle habitats in small streams during the spring period (April–May for warm water streams [<1,500 m in elevation] and May–June for cold water streams [>1,500 m in elevation]). This sampling procedure is considered "semi-quantitative" by the Arizona Department of Environmental Quality (Patti Spindler, Arizona State Department of Environmental Quality, personal communication 2005). Samples are collected using a 500 μm mesh D-frame. Sampling starts at the lowest riffle in the selected reach and proceeds upstream through the riffle. The sampling consists of a timed three-minute composite of kick samples collected from three riffle habitats within the reach. Three or more riffles are selected that represent the range of substrate sizes, velocities, depths and habitats within the reach. Each habitat is sampled for one minute for a total of three minutes. Samples are processed on a 500 μm mesh steel sieve.

1.2 Colorado Department of Public Health and Environment

Methods described are taken from the *Sampling, Analysis and Assessment Plan (SAAP) for the Collection and Preservation of Benthic Macroinvertebrates* (Colorado Department of Public Health and Environment 2005, pg. 5-9).

Semi-quantitative samples are collected at a minimum of two locations from riffle/run habitats. Sampling locations are selected randomly or systematically. At each sampling location, a one square meter area is sampled using a kick net that has a mesh size of 500 to 600 μm. Each sampling location is sampled for a period of 30 to 60 seconds by kicking and moving the substrate to dislodge the macroinvertebrates and allow the current to sweep them into the net. The amount of time each location is sampled is recorded. The samples for each kick net are processed separately for laboratory analysis and are not composite samples. Colorado recommends that samples are collected during baseflow in late summer/fall for mountain streams, and April/May for plains streams, but does not provide a recommendation for xeric streams (Colorado Department of Public Health and Environment, 2005).

1.3 New Mexico Environment Department

Methods described are taken from *The 2007 NMED/SWQB Standard Operating Procedures for Data Collection* (Surface Water Quality Bureau, New Mexico Environment Department. 2009. Section 10.0 *Biological Sampling*, Section 10.1 *Benthic Macroinvertebrates*, pg. 81-84).

The state of New Mexico currently follows the Environmental Monitoring and Assessment Program (EMAP) aquatic macroinvertebrate sampling methods, using

quantitative methods for collection of reach-wide (multi-habitat) samples as well as for targeted-riffle samples. Samples are collected using a 30 cm wide D-frame kick net with a mesh size of 500 μm and a sample area of 0.09 m^2 . This protocol is described below in the EMAP section and can be found in the *EMAP Surface Water Western Pilot Study: Field Operations Manual for Streams* (Peck et al. 2006).

1.4 Utah State Department of Environmental Quality

Methods described are taken from the *Monitoring Manual* (Utah Department of Environmental Quality, Division of Water Quality. 2006. Section 11.0 *Macroinvertebrate Program*, 11-1 to 11-3).

The state of Utah currently follows the EMAP aquatic macroinvertebrate sampling methods, using the "Targeted Riffle Sample" protocol. This protocol is described below in the EMAP section and can be found in the *EMAP Surface Water Western Pilot Study: Field Operations Manual for Streams* (Peck et al. 2006). In Utah, samples are collected from perennial streams in Sept–Oct.

1.5 U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program

Methods described are taken from the *Revised Protocols for Sampling Algal, Invertebrate, and Fish Communities as Part of the National Water-Quality Assessment* (*NAWQA*) *Program* (Moulton et al. 2002, Section 5.3, pages 37-40, 42-48).

Semi-quantitative samples are collected using a Slack sampler in five riffle sections along the reach. The sampling location for each discrete collection should be consistent with respect to substrate type, current velocity, depth, and debris accumulation. Each collection is taken from a 0.25 m^2 area immediately upstream of the Slack sampler (total area sampled = 1.25 m^2). The Slack sampler is positioned perpendicular to the direction of flow and pressed tightly against the stream bottom. The depth of water, substrate type, percent substrate embeddedness, and velocity of each discrete collection is recorded. Large debris is included in the sample if >50 percent of the surface is within the sampling area. Debris is inspected for attached organisms and removed by picking, rinsing or gently scrubbing the surfaces in front of the Slack sampler. The debris can also be placed in a bucket and inspected when the sample is processed. The sampling area is disturbed to an approximate depth of 10 cm with a hand rake. The substrate should not be kicked, and collecting excess amounts of sand and gravel in the net should be avoided. The composite sample is elutriated and then sieved using a 500 μm mesh steel sieve.

1.6 U.S. Environmental Protection Agency EMAP

Methods described are taken from the *EMAP Surface Water Western Pilot Study: Field Operations Manual for Streams* (Peck et al. 2006). The EMAP program uses quantitative methods for collection of reach-wide (multi-habitat) samples as well as for targeted-riffle samples.

1.6.1 Reach-wide sample collection

Sampling reaches consist of 11 equidistant transects labeled A-M, with A being the transect at the lowest point of the reach and M at the uppermost part of the reach. Potential sampling locations include points located at ¼, ½, and ¾ of the stream width (termed Left, Center, and Right), one meter downstream of each transect. Sampling proceeds from downstream to upstream, and collections are made at one of the three potential sampling locations one meter downstream of each transect. Sample locations at each transect are selected systematically following the random start at transect A. At each sampling location, a Slack sampler with a 500 μm mesh net is positioned securely on the stream bottom. A rectangular quadrant that is

approximately one net width wide and one net width long is visually approximated upstream from the net. The area within this quadrant is approximately 0.25 m^2. The sampling location is then inspected for heavy organisms, such as mussels and snails which are placed in the net if found. Loose rocks and large substrate in the sampling location are picked up and rubbed by hand in front of the net to remove any adhering organisms. The remaining substrate within the quadrant is then vigorously kicked for 30 seconds. After 30 seconds, the substrate is examined for any macroinvertebrates that remain attached to rocks and other debris. Samples are composited in a bucket and then poured through a 500 μm mesh sieve.

1.6.2 Targeted-riffle sample collection

Prior to sampling, the approximate area and number of riffle habitat units within the reach is visually estimated. A unit must be greater than 0.09 m^2 to be considered. If less than 5.94 m^2 of riffle habitat are present, targeted-riffle samples are not collected. If greater than 5.94 m^2 of riffle habitat are present, 8 locations distributed throughout the reach are selected for sampling. Sampling proceeds from downstream to upstream using a Slack sampler with a 500 μm mesh. A rectangular quadrant that is approximately one net width wide and one net width long is visually approximated upstream from the net. The area within this quadrant is approximately 0.25 m^2. The sampling location is then inspected for heavy organisms, such as mussels and snails which are placed in the net if found. Loose rocks and large substrate in the sampling location are picked up and rubbed by hand in front of the net to remove any adhering organisms. The remaining substrate within the quadrant is then vigorously kicked for 30 seconds. After 30 seconds, the substrate is examined for any macroinvertebrates that remain attached to rocks and other debris. Samples are composited in a bucket and then run through a 500 μm mesh sieve. For each sampling location, nearest transect location and the predominant substrate size/type are recorded.

Table A-1. Summary of field methods for collecting quantitative targeted-habitat macroinvertebrate samples among state and federal agencies

State/Program	Sampling apparatus	Sampling area (per replicate, in m^2)	Mesh size (μm)	Habitat type sampled	# Sampling locations	Replication strategy for discrete samples	Sampling location selection method	Sampling effort standardization method
Arizona	D-frame kick net	N/A	500	Riffle	3	Composited	Targeted	3 Minute Timed Kick
Colorado	D-frame kick net	1	500–600	Riffle or Run	≥ 2	Replicates	Targeted Random/ Systematic Selection	Area
New Mexico	D-frame kick net	0.09	500	Riffle	8	Composited	Targeted Random/ Systematic Selection	Area
Utah	Slack sampler	0.09	500	Riffle	10	Composited	Targeted Random/ Systematic Selection	Area
NAWQA	Slack sampler	0.25	500	Riffle	5	Composited	Targeted	Area
EMAP	Slack sampler	0.09	500	Riffle	8	Composited	Targeted Random/ Systematic Selection	Area
SCPN I&M	Slack sampler	0.25	500	Riffle	5	Replicates	Targeted	Area

2 Qualitative sampling methods

2.1 Colorado Department of Public Health and Environment

Methods described are taken from the *Sampling, Analysis and Assessment Plan (SAAP) for the Collection and Preservation of Benthic Macroinvertebrates* (Colorado Department of Public Health and Environment 2005. pg. 6-9).

Qualitative multi-habitat sample collection methods are similar to the U.S. Geological Survey National Water-Quality Assessment Program qualitative sampling protocol (see below); however, there are no constraints on the distribution of effort across habitat types. Aquatic macroinvertebrates are collected from as many habitats as possible and composited into a single jar for identification. A D-frame kick net with a 500 to 600 μm mesh net is used for sampling. The sample is collected by kicking and moving the substrate to dislodge macroinvertebrates and allow the current to sweep them into the net. This protocol recommends that macroinvertebrates are sampled twice per year. If there is only one sampling period, it should occur during base flow periods. The second sample would be collected in the spring before runoff.

2.2 U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program

Methods described are taken from the *Revised Protocols for Sampling Algal, Invertebrate, and Fish Communities as Part of the National Water-Quality Assessment (NAWQA) Program* (Moulton et al. 2002, Section 5.4, pg. 41-48).

Qualitative macroinvertebrate samples are collected using a D-frame kick net with a 500 μm mesh net. Each site is sampled for one hour. Habitats throughout the reach are identified and counted so that they can be sampled proportionately. Allotted time for sampling each habitat is determined by dividing the one hour time limit by the number of habitat types. At each habitat location, the substrate is sampled by vigorously kicking, jabbing, dipping, or sweeping the substrate with the kick net. Macroinvertebrates may also be handpicked from substrate when necessary. Samples are composited into a 5-gallon bucket, elutriated and then sieved using a 500 μm mesh steel sieve.

Table A-2. Contact information for state agencies

Arizona Water Quality Standards and Assessments Arizona Department of Environmental Quality 1110 W Washington St. Phoenix, AZ 85007 (602) 771-4616	**Colorado** Water Quality Control Division Colorado Department of Public Health and Environment 4300 Cherry Creek Drive South Denver, CO 80246 (303) 692-3500
New Mexico Surface Water Quality Bureau New Mexico Environment Department 1190 S. St Francis Dr. N2050 Santa Fe, NM 87502 (505) 476-3671	**Utah** Division of Water Quality Utah Department of Environmental Quality 288 North 1460 West Salt Lake City, UT 84116 (801) 538-6146

Appendix B. Aquatic Macroinvertebrate Monitoring Sites in the Southern Colorado Plateau Network

Table B-1. Preliminary list of aquatic macroinvertebrate monitoring sites in the Southern Colorado Plateau Network. These sites are on perennial streams and are co-located with either water quality monitoring sites, integrated riparian monitoring sites, or both. Aquatic macroinvertebrate index sampling periods are based on periods identified by the appropriate individual states.

Park	Stream	Integrated riparian	Water quality	Aquatic macroinvertebrates	Aquatic macroinvertebrate index sampling periods
BAND	Capulin Creek	X	X	X	August–November
	Rito de los Frijoles	-	X	X	August–November
CACH	Tsaile Creek	-	X	X	September–October
	Black Rock Canyon	-	-	X	September–October
GLCA	Coyote Gulch	X	X	X	September–October
	Escalante	-	-	X	September–October
GRCA	Garden Creek	-	X	X	April–May
	Hermit Creek	-	X	X	April–May
	Bright Angel Creek	-	X	X	April–May
MEVE	Mancos River	X	X	X	September–October

Appendix C. Yearly Project Task List

Table C-1. This table identifies each task by project stage, indicates who is responsible, and establishes the timing for its execution. Protocol sections and SOPs are referred to as appropriate.

Stage	Task description	Responsibility	Timing
Preparation	Initiate announcements for seasonal technician positions, begin hiring.	project manager	Jan–Feb
	Determine field season objectives and general schedule.	project manager, lead technician	Feb
	Notify data manager and GIS specialist of needs for the coming season (maps, GPS support, etc.).	project manager	Feb
	Submit/renew research permit applications.	project manager	Feb for spring work; Jul for fall work
	Ensure all hazardous material shipping and transport certifications are current.	lead technician	Jan–Mar
	Order equipment and supplies.	lead technician	Feb–Mar
	Develop detailed field schedule; make logistic arrangements.	lead technician	Mar for spring work; Jul for fall work
	Generate site folders including site coordinates, field maps, aerial photographs, and access information.	lead technician and GIS specialist	Mar for spring work; Jul for fall work
	Initiate computer access and key requests.	project manager or lead technician	Mid–Mar
	Ensure that project workspace is ready for use and implement working database copy.	data manager	By Apr 1
	Provide database/GPS training as needed.	data manager and GIS specialist	By Apr 1
	Train field crew in sampling methods.	project manager and lead technician	Apr
	Arrange lab contract or cooperative agreement for upcoming fiscal year.	project manager	Jul–Aug
Data collection	Notify park contacts of schedule/ itinerary; obtain backcountry permits.	lead technician	1 month prior to field trip; GRCA 4 months prior
	Update and load data dictionary, background maps and target coordinates into GPS units.	GIS specialist	1 wk prior to field trip
	Collect field observations/samples.	crew	Apr–Jun, Sep–Oct
	Prepare and ship invert samples.	crew	July and November
	Review data forms after each sampling day.	crew	Daily
	Check in with park contacts and project manager.	lead technician	After each fieldtrip
	De-brief crew on operations, field methods, gear needs, etc.	lead technician	After each field trip
	Download and process GPS data.	GIS specialist	After each field trip
	Download water quality data from instruments.	crew or lead technician	After each field trip
	Download and organize digital images.	crew	After each field trip
	Scan datasheets.	crew	After each field trip
	Write trip report.	lead technician	After each field trip

Table C-1. (*continued*)

Stage	Task description	Responsibility	Timing
Data entry, verification & validation	Enter field data into working database.	crew	Jul for spring sampling; Nov for fall sampling
	Field data verification	lead technician, crew	Jul for spring sampling; Nov for fall sampling
	Merge and export GPS data. Upload processed and verified GPS data to database.	GIS specialist and data manager	Aug for spring sampling; Jan for fall sampling
	Upload water quality data into database.	crew	July for spring sampling; Nov for fall sampling
	Field data validation (tabular and spatial).	lead technician, data manager and GIS specialist	Aug for spring sampling; Jan for fall sampling
	Upload laboratory data into database.	crew	Jan for spring samples; May for fall samples
	Laboratory data validation	lead technician and data manager	Jan for spring samples; May for fall samples
Data management	Upload working data into master project database.	data manager	Feb for spring sampling; Jun for fall sampling
	Create/update project metadata records.	data manager and project manager	Feb for spring sampling; Jun for fall sampling
	Certify database.	data manager	Mar for spring sampling; July for fall sampling
Data summary & reporting	Prepare and submit IARs.	lead technician & project manager	Jan–Mar
	Export automated summary queries and reports from database.	data manager	Feb for spring sampling; Jun for fall sampling
	Complete data processing steps in IDAS.	project manager	Feb for spring sampling; Jun for fall sampling
	Generate report-quality map output for reports.	GIS specialist	Feb for spring sampling; Jun for fall sampling
	Prepare draft annual reports; complete internal review.	project manager; program manager	Mar for spring sampling; Jul for fall sampling
Posting & distribution	Post annual reports to website and distribute to parks.	data manager and project manager	Apr for spring sampling; Aug for fall sampling
	Submit metadata to NPS IMRA.	data manager	Apr for spring sampling; Aug for fall sampling
	Create and update bibliographic and species records in NPS IRMA.	data manager	Upon receipt
Archival & collections	Archive all digital and hardcopy products.	project manager and data manager	Ongoing
	Work with park curators to manage reference collections.	data manager	Ongoing
Season close-out	Inventory equipment and supplies.	lead technician	Nov–Dec
	Meet to discuss recent field season and any needed changes to protocols, database, or analysis and reporting procedures.	project manager, lead technician, data manager, GIS specialist, and program manager	By Dec 15

Appendix D. Guidelines and Standards for Selecting a Contract Laboratory for Macroinvertebrate Sorting and Identification

In order to ensure accurate and reliable macroinvertebrate identification, macroinvertebrate samples will be sent to an established laboratory with stringent and clearly defined quality assurance/quality control procedures. This is an important component of the monitoring effort due to the possibility of inconsistency with taxonomic resolution. Moreover, it is necessary to establish minimum standards for macroinvertebrate sorting and identification to ensure compatibility with data collected by other agencies (see table D-1 for a summary of laboratory standards for agencies on the Colorado Plateau). This section provides guidelines for selecting a contract laboratory and an overview of the standards for sorting, sub-sampling, and identification of aquatic macroinvertebrate samples.

Table D-1. Laboratory standards for aquatic macroinvertebrate samples of state and federal agencies on the Colorado Plateau. Information provided in this table was obtained from the documents referenced in Appendix A, unless otherwise noted.

	Sorting minimum magnification	Subsampling method	Sorting QA/QC	Taxonomic QA/QC
Arizona	6-10X	500 fixed count	10% checked	10% checked, voucher/ verification
Colorado	not specified	300 fixed count	not specified	voucher/verification
New Mexico	not specified	300 fixed count	10% checked	voucher/verification
Utah	7X	600 fixed count	spot checks and analysis of sample sorting data trends	voucher/verification
NAWQA	10X	300 fixed count	all samples re-sorted for 10% at the time of original sort	10% checked, voucher/ verification
EMAP	not specified*	200 fixed count	10% checked*	voucher/verification*
NPS	7X	500 fixed count	10% checked	10% checked, voucher/ verification

*Barbour et al. 1999, Rapid Bioassessment Protocols

1 Contract laboratory selection

To maintain consistency in taxonomic identifications, using an established laboratory for sample processing is critical. The four laboratories currently being used for macroinvertebrate identification by state and federal agencies within the Colorado Plateau are (1) the U.S. Geological Survey National Water Quality Laboratory in Denver Colorado (processing, taxonomy, and QA/QC described in Moulton et al. 2000), (2) EcoAnalysts in Moscow, Idaho (information at http://www.ecoanalysts.com), (3) the Bureau of Land Management BugLab at Utah State University in Logan, Utah (detailed methods and QA/QC at http://www1.usu.edu/buglab/process/QAQC.html), and (4) Rhithron Associates Inc. in Missoula, Montana (detailed methods and QA/QC at http://www.rhithron.com/qualitysystems.php).

Sample sorting and identification costs will vary and must be negotiated with individual laboratories. The cost of sample processing will vary over time and with market forces, such as supply and demand. Factors that will influence the cost include: turn-around-

time, the level of taxonomic resolution required, subsample size, the type of preservative used, mesh size of the collection net and sieve apparatus used in the field, sample area, the type of habitat that was sampled, and geographic region where the sample was collected.

2 Laboratory standards

2.1 Sample cleaning and sorting

Sample cleaning and sorting must be done under a dissecting scope, with a minimum of 7x magnification. The sample is visually inspected to determine whether subsampling procedures should be employed. If it is obvious the sample contains far fewer individuals than the target count (500 individuals for this protocol), the sample is completely sorted. If the abundance of macroinvertebrates appears higher, subsampling procedures should be used.

2.2 Subsampling

Subsampling reduces the effort required for the sorting and identification of macroinvertebrates, and provides an accurate estimate for the time expenditure (Barbour and Gerritsen 1996). Vinson and Hawkins (1996) and Barbour and Gerritsen (1996) provide arguments for a fixed-count method, which is the preferred sub-sampling technique for the Environmental Protection Agency's Environmental Monitoring and Assessment Program (ENAP) and U.S. Geological Survey National Water-Quality Assessment Program (NAWQA) protocols (Klemm 1990, Moulton et al. 2000). For this protocol, a minimum fixed-count of 500 organisms is required for sub-sampling.

If there are greater than 500 macroinvertebrates present, the entire sample must be subsampled. This is typically done with a grid-type sample splitter (e.g. a Caton splitter, Caton 1991). Individual portions in the grid are randomly selected for sorting until the target fixed-count (500 organisms) ± 20% is reached. Damaged or immature specimens, terrestrial adults, eggs, exuviae, and empty shells or cases are not included in this count. The total number of grids that were sorted is noted.

The sorted debris residue should be preserved in 95% ethanol in a separate container. Length of storage and archiving is determined by the laboratory or benthic section supervisor. The sorted 500-organism (± 20%) sub-sample should be preserved in 70% ethanol in glass vials.

2.3 Sorting quality assurance and control

A minimum of ten percent of the sorted samples should be examined by laboratory QC personnel, or a qualified co-worker, to ensure that at least 90% of the macroinvertebrates have been removed. The QC worker will examine the grids chosen and the tray used for sorting, and will look for organisms missed by the sorter. Organisms found will be added to the sample vials. If the QC worker finds less than 10 organisms (or 10% in larger sub-samples) remaining in the grids or sorting tray, the sample passes; if more than 10 (or 10%) are found, the sample fails. If the first 10% of the sample lot fails, a second 10% of the sample lot will be checked by the QC worker.

2.4 Taxonomic identification and enumeration

Taxonomic identification must be completed by a professional taxonomist who has a lot of of experience processing and identifying aquatic macroinvertebrate samples. Macroinvertebrates must be identified to the lowest practical level (table D-2) using a dissecting microscope, and published taxonomic keys. Chironomid larvae typically cannot be identified under a dissecting microscope, and should be mounted on slides

in an appropriate medium and identified to genus using a compound microscope. Each taxon found in a sample is recorded and enumerated. Any difficulties encountered during identification (e.g., missing gills) should also be noted. To archive samples, specimen vials are placed in jars with a small amount of denatured 70% ethanol and tightly capped.

Table D-2. Lowest practical level of identification for specific taxonomic groups

Taxon group	Lowest practical level	Taxon group	Lowest practical level
Annelida		Muscidae	Family
Hirudinea	Genus/species	Pelecorhynchidae	Genus
Oligochaeta	Order	Psychodidae	Genus
Arthropoda		Ptychopteridae	Genus
Hydracarina	Order	Sciomyzidae	Family
Crustacea		Simuliidae	Genus
Anostraca	Genus/species	Stratiomyidae	Genus
Cladocera	Genus/species	Tabanidae	Genus
Copepoda	Genus/species	Tanyderidae	Genus
Decapoda	Genus/species	Thaumaleidae	Genus
Ostracoda	Order/family/genus	Tipulidae	Genus
Amphipoda	Genus/species	Ephemeroptera	Genus/species
Isopoda	Genus	Ephemerellidae	Species
Insecta		Hemiptera	Genus/species
Collembola	Order	Lepidoptera	Genus
Coleoptera	Genus/species	Megaloptera	Genus/species
Curculionidae	Family	Odonata	Genus/species
Heteroceridae	Family	Plecoptera	Genus/species
Ptiliidae	Family	Pteronarcyidae	Species
Diptera		Taeniopterygidae	Family/genus
Atherceridae	Genus	Trichoptera	Genus/species
Blephariceridae	Genus/species	Coelenterata	Class
Ceratopogonidae	Genus	Mollusca	
Chaoboridae	Genus/species	Gastropoda	Family/genus/species
Chironomidae	Subfamily	Pelecypoda	Order/family/genus
Culicidae	Genus	Sphaeriidae	Genus/species
Deuterophlebiidae	Genus/species	Nematoda	Phylum
Dixidae	Genus	Nematomorphora	Phylum
Dolichopodidae	Family	Porifera	Phylum
Empididae	Genus	Turbellaria	Class
Ephydridae	Family		

2.5 Taxonomic identification quality assurance and control

A second taxonomist who was not responsible for the original identifications will spot check a minimum of 10% of the samples with the recorded identifications.

A voucher collection of all taxa must also be maintained. These specimens should be properly labeled, preserved, and stored in the laboratory for future reference. The voucher collection containing each identified taxon is verified by the second taxonomist. Validated

specimens will contain a label with the word "val." and the 1st initial and last name of the person validating the identification.

2.6 Deliverables

The contract laboratory will provide a reference collection. In addition, the lab should return the data in a format that will be compatible with the database where the data will be stored. It is important to provide the contract laboratory with an example or template of the preferred data format, preferably at the same time that the samples are shipped to the lab. This template should include space for all of the information that is on the sample label and packing list. The template should also include columns for the proportion of the sample that was subsampled, counts of organisms, all levels (phylum, class, order, etc.) of taxonomic information for each identification, lifestage information, and notes related to identifications (eg. damaged, immature, etc.). The laboratory should also provide the QA/QC results for sorting and identification in a separate worksheet.

2.7 Turn-around time

Turn-around time for sample data will vary among laboratories and among years. Turnaround time should be considered when selecting and negotiating with a contract laboratory. A reasonable turn-around time to expect is 4-6 months.

Appendix E. Aquatic Macroinvertebrate Monitoring Protocol Database Documentation

1 Purpose

This appendix documents the aquatic macroinvertebrate database for the SCPN. Microsoft Access is the primary software used to manage data.

2 Aquatic macroinvertebrate database data model

The Aquatic Macroinvertebrate database employs a front-end/back-end configuration. The front-end file (aq_mac_FE_v1.0.mdb) contains the forms, queries, modules, macros, and reports, as well as a Back-End Linking Utility that allows the user to control the front-end/back-end file link. The back-end file (aq_mac_BE_v1.0.mdb) contains the data tables. This front-end/back-end configuration allows for continual improvements to the user interface (i.e., the various forms and queries for getting data into and out of the database) without requiring duplication or modification of the underlying data tables. Figure E-1 shows the relationships among the primary tables in the database. The database is based on the National Park Service Natural Resources Database Template (NRDT) Version 3.

3 Documentation of database tables

The following tables describe all the fields in the tables of the aquatic macroinvertebrate database.

Table E-1: *tbl_Stream*. Stores data about the stream. There is one record for each stream.

Field name	Field type	Size	Field description
Site_ID	Replication ID	16	Primary key, site (stream) identifier
Site_Name	Text	100	Unique name or code for a stream—here this is the stream name
Site_Des	Text	255	Description for a stream
Unit_Code	Text	4	4-letter park, monument or network code
Site_Notes	Memo	NA	General notes on the site

Table E-2: *tbl_Reach*. Stores information about the stream reach. There is one record for each reach.

Field name	Field type	Size	Field description
Location_ID	Replication ID	16	Primary key, location (reach) identifier
Site_ID	Replication ID	16	Foreign key. Links to tbl_Stream
Loc_Name	Text	9	Name of the location. In this database, the location name is the reach code.
Updated_Date	Date/time	10	Date of entry or last change
Loc_Notes	Memo	NA	General notes on the location
Access_Notes	Memo	NA	Any notes on references or access to the site- so that a future sampler can find the same reach.
Description	Memo	NA	Reach-level description

Table E-3: *tbl_Events*. Stores information about each sampling event. There is one record for each sampling event.

Field name	Field type	Size	Field description
Event_ID	ReplicationID	16	Primary key. Sampling event identifier
Location_ID	ReplicationID	16	Foreign key. Links to tbl_Reach

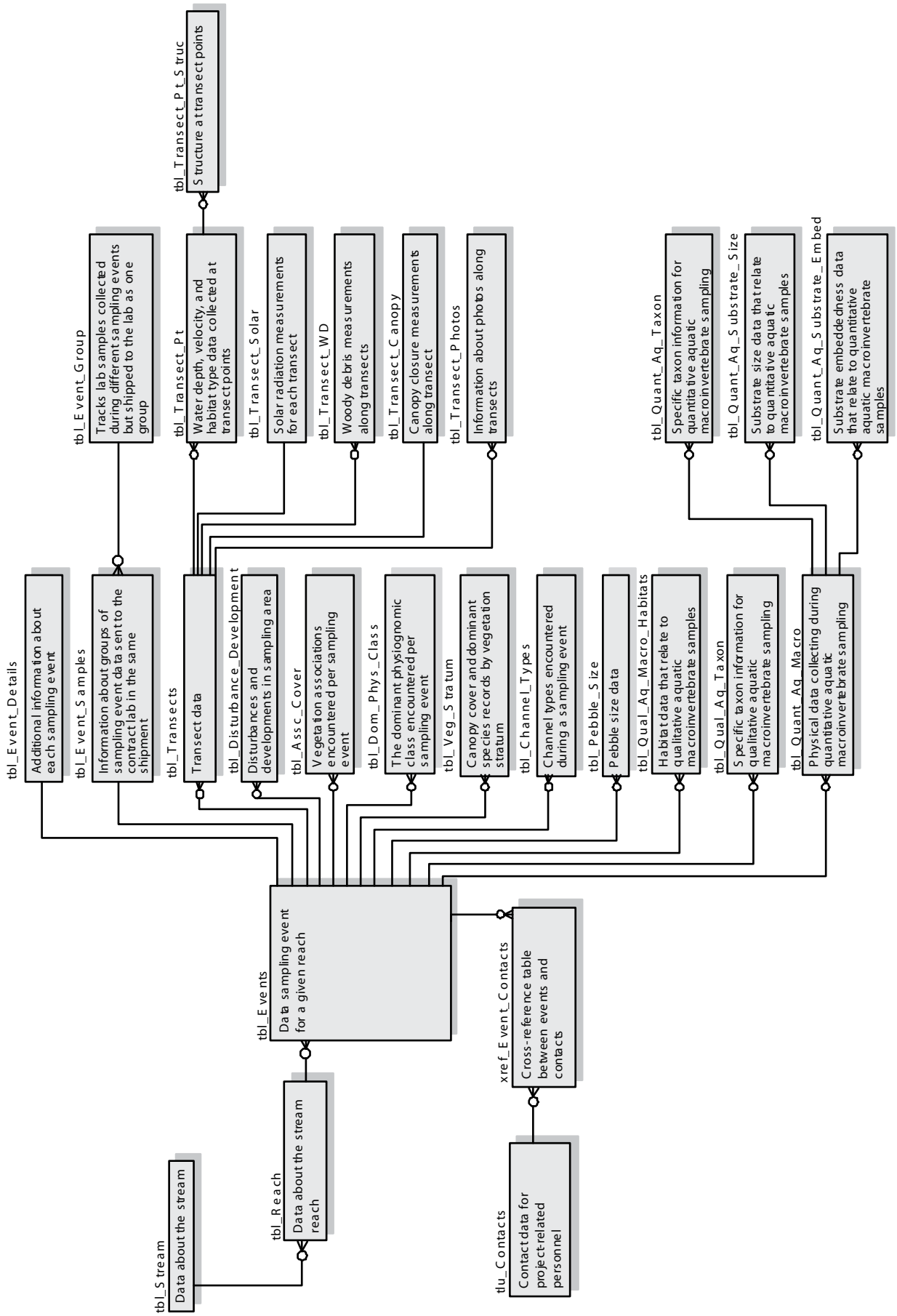


Figure E-1. Data structure of Aquatic Macroinvertebrate database

Table E-3: *tbl_Events*. (*continued*)

Field name	Field type	Size	Field description
Protocol_Name	Text	100	Protocol version used in this sampling event
Start_Date	Text	9	Starting date for the event. In format YYYYMonDD
End_Date	Text	9	Ending date for the event. In format YYYYMonDD
Start_Time	Date/Time	8	Starting time for the event
End_Time	Date/Time	8	Ending time for the event
Time_Zone	Text	3	Time zone during sampling. Either Mountain Standard Time (MST) or Mountain Daylight Time (MDT)
Notes	Memo	NA	Any notes for this sampling event

Table E-4: *tbl_Event_Details*. Stores sampling event details. Provides additional information about each sampling event. There is one record in this table for every record in *tbl_Events*.

Field name	Field type	Size	Field description
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Date_Temp	Text	9	In the rare event that sampling a reach takes more than one day, this is to record the date (to note that it is the 2nd day, for example) that the air and water temperature were taken.
Event_Notes	Memo	NA	General notes on the event
Temp_air	Double	8	Air temperature in degrees Celsius
Temp_water	Double	8	Water temperature in degrees Celsius
Time_Temp	Date/Time	8	Time of day that air and water temperatures were taken
Velocity_meter	Text	50	Type of velocity meter used
GCU_StartFrom	Text	10	Geomorphic channel unit sampling started upstream or down-stream
LogPebCt_StartFrom	Text	10	Longitudinal pebble count sampling started upstream or down-stream

Table E-5: *tbl_Assc_Cover.* Stores vegetation associations encountered per sampling event.

Field name	Field type	Size	Field description
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Veg_Assc	Text	255	Vegetation association
Cover	Long Integer	4	Cover class (area of reach covered by assocation)

Table E-6: *tbl_Dom_Phys_Class.* Stores the dominant physiognomic class encountered per sampling event.

Field name	Field type	Size	Field description
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Dom_Phys_Class	Text	50	Dominant physiognomic class

Table E-7: *tbl_Veg_Stratum.* Stores canopy cover and dominant species records by vegetation stratum.

Field name	Field type	Size	Field description
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Stratum	Text	50	Vegetation stratum: tree, shrub, or herbaceous
Can_Cov_Class	Integer	2	Canopy cover class; see tlu_Cover_Veg
Dom_Spp	Text	255	List of dominant species in each strata

Table E-8: *tbl_Disturbance_Development.* Stores data for disturbances and developments in sampling area.

Field name	Field type	Size	Field description
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Instream_Adjacent	Text	50	Notes if disturbance/development is instream or adjacent to stream
Disturbance	Text	50	Type of disturbance or development
Comments	Memo	255	Comments about disturbance or development

Table E-9: *tbl_Event_Group*. Used to track lab samples that were collected during different sampling events but where shipped to the contract lab as one group.

Field name	Field type	Size	Field description
Event_Group_ID	ReplicationID	16	Primary key. Event group identifier
Lab_ID	ReplicationID	16	Used to link to tlu_Lab_Info
Samples_Shipped	Long Integer	4	Total number of samples shipped to lab
Date_Shipped	Text	9	Date that samples were shipped to lab
Date_Data_Delivered	Text	9	Date that the lab notified SCPN of results
Date_Del_Received	Text	9	Date that deliverables were received from lab
Del_Received	Memo	NA	Deliverables that were received from lab
Notes	Memo	NA	Notes about event group

Table E-10: *tbl_Event_Samples.* Stores information about groups of sampling event data that were sent to the contract lab in the same shipment.

Field name	Field type	Size	Field description
Field Name	Field Type	Size	Field Description
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Event_Group_ID	ReplicationID	50	Foreign key. Links to tbl_Event_Group
Quant_Bottles	Integer	2	Number of bottles shipped to lab that held quantitative samples
Qual_Jars	Integer	2	Number of jars shipped to lab that held qualitative samples
Lab_group_include	Boolean	1	Comments about disturbance or development

Table E-11: *tbl_Channel_Types*. Stores data for all channel types encountered during a sampling event.

Field name	Field type	Size	Field description
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Geomorph_channel	Text	2	Geomorphic channel unit type (e.g., riffle, run, glide)
Notes	Memo	NA	Any notes about channel types sampling
Reach_length	Double	8	Length of geomorphic channel unit

Table E-12: *tbl_Qual_Aq_Macro_Habitats.* Stores habitat data that relate to qualitative aquatic macroinvertebrate samples.

Field name	Field type	Size	Field description
Depth_category	Text	50	Depth of water- deep (deeper than net height) or shallow (shallower than net height)
Flow_Velocity_Category	Text	50	Water flow velocity- fast , moderate , or slow
Notes	Memo	NA	Any notes about aquatic macroinvertebrate habitats
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Substrate_Type	Text	50	Type of substrate at sampling point (e.g., bedrock, boulder, gravel)

Table E-13: *tbl_Qual_Aq_Taxon.* Stores specific taxon information for qualitative aquatic macroinvertebrate sampling. These data are imported from a digital file provided by the contract laboratory.

Field name	Field type	Size	Field description
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Number_Individuals	Long Integer	4	Number of individuals of taxon
Phylum	Text	255	Taxon phylum
Class	Text	255	Taxon class
Order	Text	255	Taxon order
Suborder	Text	255	Taxon suborder
Family	Text	255	Taxon family
Subfamily	Text	255	Taxon subfamily
Tribe	Text	255	Taxon tribe
Genus	Text	255	Taxon genus
Species	Text	255	Taxon species
BU_ID	Text	255	The taxonomic name provided by the Biological Group at the USGS's National Water Quality Laboratory. BU_ID's may include conditional or provisional identifications.
SortCode	Double	8	A number that allows data to be sorted into phylogenetic order
Lifestage	Text	255	One of four stages (egg, larva, pupa, and adult) in the development of insects.
Notes	Memo	NA	General notes about sample
LabCount	Text	255	Lab count
Abundance	Double	8	The number of organisms in a sample, either for the whole sample or for each taxon.
SMCOD	Text	255	Sample identification code – A 16 character alphanumeric code that uniquely identifies each sample component.

Table E-14: *tbl_Quant_Aq_Macro*. Stores physical data collecting during quantitative aquatic macroinvertebrate sampling.

Field name	Field type	Size	Field description
Quant_Taxon_ID	ReplicationID	16	Primary key. Quantitative aquatic macroinvertebrate table row identifier
Depth_Water	Double	8	The water depth in the center of the sampling area at each sampling location.
Event_ID	ReplicationID	16	Links to tbl_Events
Notes	Memo	NA	Any notes about quantitative sampling event
Replicate	Long Integer	4	Replicate number (5 samples per reach)
Velocity	Double	8	The velocity (meters/second) in the center of the sampling area at each sampling location

Table E-15: *tbl_Quant_Aq_Substrate_Size.* Stores substrate size data that relate to quantitative aquatic macroinvertebrate samples.

Field name	Field type	Size	Field description
Quant_Taxon_ID	ReplicationID	16	Foreign key. Links to tbl_Quant_Aq_Macro
Substrate_Size	Double	8	Substrate size b-axis diameter, in mm, (of five substrate particles) in the sampling area.

Table E-16: *tbl_Quant_Aq_Substrate_Embed*. Stores substrate embeddedness data that relate to quantitative aquatic macroinvertebrate samples.

Field name	Field type	Size	Field description
Quant_Taxon_ID	ReplicationID	16	Foreign key. Links to tbl_Quant_Aq_Macro
Substrate_Embed	Long Integer	4	The degree to which gravel-sized and larger particles are surrounded or enclosed by finer-sized particles. Recorded as a percent.

Table E-17: *tbl_Quant_Aq_Taxon.* Stores specific taxon information for quantitative aquatic macroinvertebrate sampling. These data are imported from digital files provided by the contract laboratory.

Field name	Field type	Size	Field description
Qual_Taxon_ID	ReplicationID	16	Foreign key. Links. to tbl_Quant_Aq_Macro
Number_Individuals	Long Integer	4	Number of individuals of taxon
Phylum	Text	255	Taxon phylum
Class	Text	255	Taxon class
Order	Text	255	Taxon order
Suborder	Text	255	Taxon suborder
Family	Text	255	Taxon family
Subfamily	Text	255	Taxon subfamily
Tribe	Text	255	Taxon tribe
Genus	Text	255	Taxon genus
Species	Text	255	Taxon species
BU_ID	Text	255	The taxonomic name provided by the Biological Group at the USGS's National Water Quality Laboratory. BU_ID's may include conditional or provisional identifications.
SortCode	Double	8	A number that allows data to be sorted into phylogenetic order
Lifestage	Text	255	One of four stages (egg, larva, pupa, and adult) in the development of insects
Notes	Memo	NA	General notes about sample
LabCount	Text	255	Lab count
Abundance	Double	8	The number of organisms in a sample, either for the whole sample or for each taxon
SMCOD	Text	255	Sample identification code—A 16 character alphanumeric code that uniquely identifies each sample component

Table E-18: *tbl_Pebble_Size.* Stores pebble size data. A minimum of 400 samples are collected along entire reach.

Field name	Field type	Size	Field description
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Pebble_Size	Text	50	Pebble size, in (mm)
Order	Long Integer	4	The order in which the data were entered.

Table E-19: *tbl_Transect_Canopy*. Stores canopy closure data collected along transects.

Field name	Field type	Size	Field description
Transect_ID	ReplicationID	16	Foreign key. Links to tbl_Transects
Canopy_Center_Down	Integer	2	Canopy closure from stream center, measurement is made facing downstream
Canopy_Center_Left	Integer	2	Canopy closure from stream center, measurement is made facing the left bank
Canopy_Center_Right	Integer	2	Canopy closure from stream center, measurement is made facing the right bank
Canopy_Center_Up	Integer	2	Canopy closure from stream center, measurement is made facing upstream

Table E-19: *tbl_Transect_Canopy*. (*continued*)

Field name	Field type	Size	Field description
Canopy_Left_Down	Integer	2	Canopy closure from left bank, measurement is made facing downstream
Canopy_Left_Left	Integer	2	Canopy closure from left bank, measurement is made facing the left bank
Canopy_Left_Right	Integer	2	Canopy closure from left bank, measurement is made facing the right bank
Canopy_Left_Up	Integer	2	Canopy closure from left bank, measurement is made facing upstream
Canopy_Right_Down	Integer	2	Canopy closure from right bank, measurement is made facing downstream
Canopy_Right_Left	Integer	2	Canopy closure from right bank, measurement is made facing the left bank
Canopy_Right_Right	Integer	2	Canopy closure from right bank, measurement is made facing the right bank
Canopy_Right_Up	Integer	2	Canopy closure from right bank, measurement is made facing upstream
Canopy_Center_Left_m	Integer	2	Canopy closure from stream center, measurement is made facing the left bank. Modified method.
Canopy_Center_Up_m	Integer	2	Canopy closure from stream center, measurement is made facing upstream. Modified method.
Canopy_Center_Right_m	Integer	2	Canopy closure from stream center, measurement is made facing the right bank. Modified method.
Canopy_Center_Down_m	Integer	2	Canopy closure from stream center, measurement is made facing downstream. Modified method.
Canopy_Left_Left_m	Integer	2	Canopy closure from left bank, measurement is made facing the left bank. Modified method.
Canopy_Left_Up_m	Integer	2	Canopy closure from left bank, measurement is made facing upstream. Modified method.
Canopy_Left_Right_m	Integer	2	Canopy closure from left bank, measurement is made facing the right bank. Modified method.
Canopy_Left_Down_m	Integer	2	Canopy closure from left bank, measurement is made facing downstream. Modified method.
Canopy_Right_Left_m	Integer	2	Canopy closure from right bank, measurement is made facing the left bank. Modified method.
Canopy_Right_Up_m	Integer	2	Canopy closure from right bank, measurement is made facing upstream. Modified method.
Canopy_Right_Right_m	Integer	2	Canopy closure from right bank, measurement is made facing the right bank. Modified method.
Canopy_Right_Down_m	Integer	2	Canopy closure from right bank, measurement is made facing downstream. Modified method.

Table E-20: *tbl_Transect_Pt.* Stores water depth, velocity, and habitat type data collected at transect points.

Field name	Field type	Size	Field description
Transect_Pt_ID	ReplicationID	16	Primary key. Transect point table row identifier
Depth	Double	8	The depth of the stream.
Habitat_Type	Text	50	The dominant geomorphic channel form for each transect.
Point	Integer	2	Depth, velocity, habitat structure, and geomorphic channel unit type are recorded at each of five equidistant points along the transect.
Tape_Reading	Double	8	The distance from the transect point to the left edge (facing downstream) of water.
Transect_ID	ReplicationID	16	Foreign key. Links to tbl_Transects
Velocity	Double	8	The velocity at the sampling location.

Table E-21: *tbl_Transect_Photos*. Stores data about photos taken along transects (generally 1, 6, and 11).

Field name	Field type	Size	Field description
Transect_Pt_ID	ReplicationID	16	Foreign key. Links to tbl_Transects
Photo_Name	Text	255	Name of photo
Path	Memo	NA	Path to location where photo is stored
Direction	Text	20	Direction photo was taken (generally upstream or downstream)
Notes	Memo	NA	Any notes about the photo

Table E-22: *tbl_Transect_Pt_Structure.* Stores data about structure (e.g., algal mat, vegetation, rocks) at transect points.

Field name	Field type	Size	Field description
Structure	Text	50	The structures that may provide habitat for macroinvertebrates at the water's edge and at each transect point
Transect_Pt_ID	ReplicationID	16	Foreign key. Links to tbl_Transect_Pt

Table E-23: *tbl_Transect_WD_Debris.* Stores data about woody debris along transects.

Field name	Field type	Size	Field description
Diameter	Double	8	The diameter of each piece of woody debris
Length	Double	8	The length of each piece of woody debris
Transect_ID	ReplicationID	16	Foreign key. Links to tbl_Transects

Table E-24: *tbl_Transects.* Stores transect data.

Field name	Field type	Size	Field description
Transect_ID	ReplicationID	16	Primary key. Transect table row identifier
Channel_Width_Active	Double	8	The distance between the left and right streamward boundaries of riparian vegetation.
Channel_Width_Wet	Double	8	The distance between the left and right edges of the water
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Notes	Memo	NA	Any notes about the transect sampling event
Transect_Number	Integer	2	The sequential number of each transect (usually 1 through 11) for each site. Transect #1 is the located furthest downstream while transect #11 is the furthest upstream in the selected reach.
No_WD_Pres	Boolean	1	Check if no woody debris is present on this transect

Table E-25: *tbl_Transect_Solar.* Stores solar radiation measurements for each transect.

Field name	Field type	Size	Field description
Transect_ID	ReplicationID	16	Foreign key. Links to tbl_Transects
Dec_Sunrise	Date/Time	8	Solar radiation measurement for December sunrise
Jan_Sunrise	Date/Time	8	Solar radiation measurement for January sunrise
Nov_Sunrise	Date/Time	8	Solar radiation measurement for November sunrise
Feb_Sunrise	Date/Time	8	Solar radiation measurement for February sunrise
Oct_Sunrise	Date/Time	8	Solar radiation measurement for October sunrise
Mar_Sunrise	Date/Time	8	Solar radiation measurement for March sunrise
Sep_Sunrise	Date/Time	8	Solar radiation measurement for September sunrise

Table E-25: *tbl_Transect_Solar.* (*continued*)

Field name	Field type	Size	Field description
Apr_Sunrise	Date/Time	8	Solar radiation measurement for April sunrise
Aug_Sunrise	Date/Time	8	Solar radiation measurement for August sunrise
May_Sunrise	Date/Time	8	Solar radiation measurement for May sunrise
Jul_Sunrise	Date/Time	8	Solar radiation measurement for July sunrise
Jun_Sunrise	Date/Time	8	Solar radiation measurement for June sunrise
Dec_Sunset	Date/Time	8	Solar radiation measurement for December sunset
Jan_ Sunset	Date/Time	8	Solar radiation measurement for January sunset
Nov_ Sunset	Date/Time	8	Solar radiation measurement for November sunset
Feb_Sunset	Date/Time	8	Solar radiation measurement for February sunset
Oct_Sunset	Date/Time	8	Solar radiation measurement for October sunset
Mar_Sunset	Date/Time	8	Solar radiation measurement for March sunset
Sep_Sunset	Date/Time	8	Solar radiation measurement for September sunset
Apr_Sunset	Date/Time	8	Solar radiation measurement for April sunset
Aug_Sunset	Date/Time	8	Solar radiation measurement for August sunset
May_Sunset	Date/Time	8	Solar radiation measurement for May sunset
Jul_Sunset	Date/Time	8	Solar radiation measurement for July sunset
Jun_Sunset	Date/Time	8	Solar radiation measurement for June sunset

Table E-26: *tlu_Geomorphic_channel_types.* Look-up table for geomorphic channel types.

Field name	Field type	Size	Field description
Code	Text	50	Geomorphic channel type code
Description	Text	50	Geomorphic channel type code description

Table E-27: *tlu_Parks.* Look-up table for parks in SCPN.

Field name	Field type	Size	Field description
Park	Text	50	Full name of park
Unit_Code	Text	4	4- letter park code

Table E-28: *tlu_sort_size_class.* Allows pebble sorting by size in data entry form.

Field name	Field type	Size	Field description
Sort_Order	Integer	2	Sort order of pebble size classes- solely for use in data entry form
Size_Class	Text	50	Pebble size class (higher end of range)

Table E-29: *tlu_substrate.* Look-up table for substrates.

Field name	Field type	Size	Field description
Description	Text	50	Description of substrate, where applicable
Sort_Order	Integer	2	Sort order of substrate types- solely for use in data entry form
Type	Text	50	Type of substrate

Table E-30: *tlu_Contacts*. Lookup table for observers, recorders, and data enterers.

Field name	Field type	Size	Field description
Contact_ID	ReplicationID	16	Primary key. Contact identifier
Last_Name	Text	50	Last name
First_Name	Text	50	First name
Middle_Init	Text	4	Middle initial
Organization	Text	50	Organization or employer
Position_title	Text	50	Title or position description
Address_type	Text	50	Address (mailing, physical, both)
Address	Text	50	Street Address
Address2	Text	50	Address line 2, suite, apartment number
City	Text	50	City or town
State_Code	Text	8	State or province
Zip_Code	Text	50	Zip code (postal)
Country	Text	50	Country
Email_Address	Text	50	E-mail address
Work_phone	Text	50	Phone number
Work_extension	Text	50	Phone extension
Contact_notes	Memo	NA	Contact notes, if any

Table E-31: *xref_Event_Contacts.* Cross- reference table that links to both tbl_Events and tlu_Contacts. Tracks which contact is connected to each event, as well the contact role.

Field name	Field type	Size	Field description
Event_ID	ReplicationID	16	Foreign key. Links to tbl_Events
Contact_ID	ReplicationID	16	Foreign key. Links to tlu_Contacts
Contact_Role	Text	50	The contact's role in the protocol

Table E-32: *tbl_DB_Meta.* Database description and links to I&M metadata tools.

Field name	Field type	Size	Field description
DB_Meta_ID	ReplicationID	16	Local primary key
Db_Desc	Memo	NA	Description of database purpose
Meta_MID	ReplicationID	16	Links to NR-GIS Metadata Database

Table E-33: *tbl_DB_Revisions.* Database revision history data.

Field name	Field type	Size	Field description
Revision_ID	Text	50	Primary key. Database revision (version) number or code
Revision_Contact_ID	ReplicationID	16	Links to tlu_Contacts
DB_Meta_ID	ReplicationID	16	Links to tbl_DB_Meta
Revision_Date	Date/Time	8	Database revision date
Revision_Reason	Memo	NA	Reason for the database revision
Revision_Desc	Memo	NA	Revision description

Table E-34: *tbl_Proof.* Stores information on which records have been proofed, and of those, which records have been corrected.

Field name	Field type	Size	Field description
Corrected	Boolean	1	Was record corrected for errors?
Event_ID	ReplicationID	16	Event identifier of record being proofed
Loc_Name	Text	50	Name of reach
Proof_Count	Long Integer	4	How many times the records was proofed
Proof_Date	Date/Time	8	Date record was proofed
Proofed	Text	3	Was record proofed (Y/N)
Proof_Reader	Text	50	Person who proofed the record
Start_Date	Date/Time	8	Sampling event date
Unit_Code	Text	4	4 letter unit code of park

Table E-35: *tbl_Proof_Tracking.* Tallies error corrections during proofing. Used to populate *tbl_Field_Data* and generate reports.

Field name	Field type	Size	Field description
Event_Date	Date/Time	8	Sampling event date
Field	Text	50	Field in table that was corrected for errors
Proof_Date	Date/Time	8	Date the record was proofed
Was	Memo	NA	The value in the field before it was updated to the correct value
Changed_To	Memo	NA	What the value in the "Was" field was changed to (the corrected value)
Park	Text	50	Park where error was fixed
Stream	Text	50	Stream where error was fixed
Reach	Text	50	Reach where error was fixed

Table E-36: *tbl_Field_Errors.* Stores the total number of errors per field. Data stored is temporary and is deleted after each calculation of total of field errors.

Field name	Field type	Size	Field description
Field	Text	50	Field in table that was corrected for errors
Total_Errors	Long Integer	4	Total number of errors made in the field

Table E-37: *tlu_Dom_Phys_Class.* Lookup table for dominant physiognomic class.

Field name	Field type	Size	Field description
Type	Text	255	Vegetation type
Cover	Text	255	Describes canopy cover of vegetation type
Height	Text	255	Describes canopy height of vegetation type

Table E-38: *tlu_Lab_Info.* Lookup table for contract lab contact information.

Field name	Field type	Size	Field description
Lab_ID	ReplicationID	16	Primary key. Lab identifier
Lab_Name	Text	50	Lab name
Address	Text	50	Street Address
Address2	Text	50	Address line 2, suite, apartment number

Table E-38: *tlu_Lab_Info. (continued)*

Field name	Field type	Size	Field description
City	Text	50	City or town
State_Code	Text	8	State or province
Zip_Code	Text	50	Zip code (postal)
Country	Text	50	Country
Email_Address	Text	50	E-mail address
Phone	Text	50	Phone number
Fax	Text	50	Fax number
Contact_notes	Memo	NA	Contact notes, if any

Table E-39: *tlu_Veg_Assc.* Lookup table for vegetation associations by park.

Field name	Field type	Size	Field description
Park	Text	4	4-letter park, monument or network code
Veg_Assc	Text	255	Vegetation association

Appendix F. Example Analysis of Multivariate Macroinvertebrate Community Measures

1 Introduction

In this example, we use aquatic macroinvertebrate abundance data to demonstrate several multivariate analysis methods to examine and test for temporal change. These data are courtesy of Dr. Eric Dinger, an Associate Researcher at the National Aquatic Monitoring Center at Utah State University (Dinger 2006). The original study collected aquatic macroinvertebrate data from six sites at Fossil Creek, Arizona. The data analyzed here (tables F-1 and F-2, see page F4) are from two of these study sites and were collected once each year from 2004 to 2006.

The first objective of this analysis was to determine if there were changes among the sampled years in the macroinvertebrate communities from a single site, and if so, which species contributed the most to the observed interannual differences. We tested the null hypothesis that there were no differences among the samples by year. For the two site analysis, we tested an additional hypothesis that there were no differences among the samples by site.

2 Methods

The data used in this example were from Fossil Creek, a perennial, travertine depositing tributary to the Verde River in central Arizona. Samples were collected from two sites: one located immediately downstream of a concrete dam near Fossil Springs (site 1), and one above the Irving power plant (site 2) (figure F1). These springs are the source of Fossil Creek's 43 cfs baseflow. From 1915 through 2005, the dam diverted the entire baseflow of Fossil Creek to supply water to an offline hydroelectric power plant. The powerplant was decommissioned in 2005 and the entire flow of the creek was returned to the natural channel. At each sampling site, 5 core samples, or replications, were collected to assess abundances of aquatic macroinvertebrate species. The samples were collected once each year during the following dates for site 1: October 13, 2004; September 13, 2005; and August 22, 2006; sampling dates for site 2 were October 18, 2004; September 12, 2005; and August 24, 2006. To facilitate data analysis, the replications were coded as follows: A1-A5 = samples from 2004, B1-B5 = samples from 2005, and C1-C5 = samples from 2006. Replicate samples were collected with a Surber sampler (250 μm mesh size, 0.093 $m^{2)}$ during each sampling event. The sample area was agitated and scrubbed. Samples were filtered in the field and preserved in 95% ethanol. Organisms were enumerated and identified in the laboratory to the lowest practical level (Dinger 2006).

Prior to running multivariate statistical techniques, an analysis of the 15 samples was conducted to evaluate outliers, and the raw data were square-root transformed to downweight the contribution of species that were rare and those with relatively large abundances. Although there were several species (at each site) that only occurred once during the entire sampling period, none of these were eliminated from this analysis because of the objective to examine species diversity patterns, and the planned analyses involved using ordinations that compare rank order distances, not the actual distances among samples.

The multivariate analyses focus on determining interannual differences at the community level using NMDS (non-metric multi-dimensional scaling) ordination and ANOSIM (analysis of similarity). The ordinations provide visual representations of trends in species abundances, and ANOSIM is used to test sampling variation between replicates within a

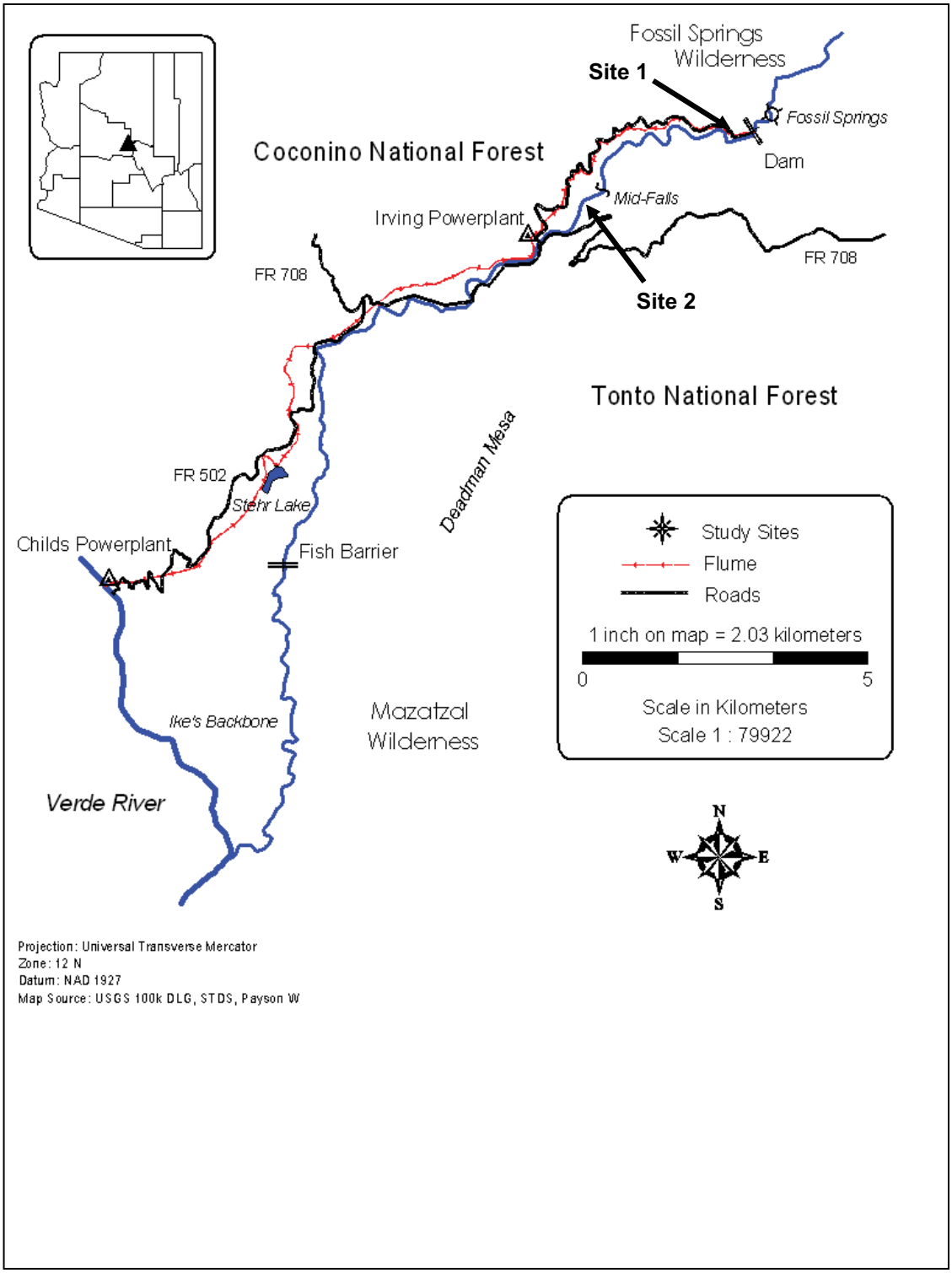


Figure F-1. Map of Fossil Creek, Arizona showing study sites (modified from Dinger 2006)

sampling period (year) and to detect interannual differences. Polar ordination (involving calculation of Bray-Curtis distances among samples) was run prior to conducting NMDS and ANOSIM to provide a resemblance matrix of Bray-Curtis similarities that serve as the input values for these tests. Cluster analysis of the Bray-Curtis distances was also conducted to provide similarity groupings to help interpret the results. An exploratory analysis of similarity percentages (SIMPER) was conducted to determine which

macroinvertebrate taxa contributed the most to the observed similarity patterns. Software packages used include PC-ORD for outlier analysis and PRIMER for ordinations, ANOSIM, and SIMPER.

3 Results and discussion

3.1 Outlier analysis and pre-treatment

Outliers are atypical observations that may have profound influence on statistically-derived relationships and results. Although it is believed that all data presented in Tables F-1 and F-2 (see page F4) are from valid samples, it is worthwhile to check for sample outliers before analyzing community measures. The data analyzed and presented in these next three sections pertain only to site 1 and address the first objective of determining interannual differences.

An outlier analysis of the raw abundance data from site 1 using the Euclidean distance measure is shown in Table F-3. Of the 15 samples, only B1 (from 2005) was found to be an outlier when using the common criterion of a standard deviation > 2.0. Outliers can also be evaluated through scatterplots. The graph shown in Figure F-2 indicates a weak relationship between total abundance and species richness, and sample B1 is one of several samples that could be considered an outlier.

Given its abundance values, its location in the scatterplot, and the analysis objectives, this sample was retained for further analysis.

Table F-3. Outlier analysis of the average Euclidean distance and standard deviation by sample for the data set shown in Table F-1

Rank	Entity name	Average distance	Standard deviation
1	B1	67.72146	2.37465
2	B3	54.53489	1.27983
3	B4	54.31404	1.26149
4	B5	50.46777	0.94216
5	C3	41.93753	0.23393
6	A5	36.92933	-0.18188
7	B2	36.32128	-0.23236
8	A1	31.88199	-0.60093
9	A4	31.66120	-0.61927
10	C1	31.55445	-0.62813
11	C5	31.39581	-0.64130
12	C2	30.59179	-0.70805
13	A3	29.24240	-0.82009
14	C4	29.20117	-0.82351
15	A2	29.04433	-0.83653
10	C1	31.55445	-0.62813
11	C5	31.39581	-0.64130
12	C2	30.59179	-0.70805
13	A3	29.24240	-0.82009
14	C4	29.20117	-0.82351
15	A2	29.04433	-0.83653

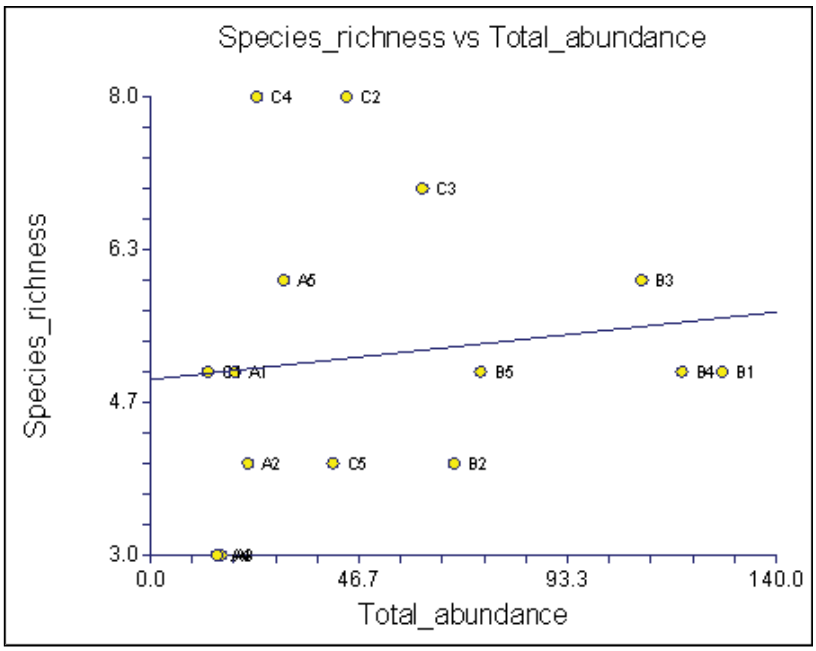


Figure F-2. Scatterplot of total abundance vs. species richness by sample for the data set shown in Table F-1. A least-squares regression line is included to help evaluate the relationship.

Table F-1. Abundance data for 22 species by replication (rep) and year, including total abundances and species richness (SR), collected from a site below the dam (site 1) in Fossil Creek, AZ.

Year	Rep	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	Total	SR
2004	A1	7							6		3				2							1		19	5
2004	A2	5			1				15						1									22	4
2004	A3								14						1						1			16	3
2004	A4	7							6						2									15	3
2004	A5	17		1					3						7	1	1							30	6
2005	B1						2		74					3	48							1		128	5
2005	B2		2						40					5	21									68	4
2005	B3		16		1	2			31						58		2							110	6
2005	B4		16						52					1	49				1					119	5
2005	B5		28						4						40				1		1			74	5
2006	C1		3					1	7			1								1				13	5
2006	C2		3		2	1	1	4	25						2							6		44	8
2006	C3		4					2	48	1			1				1						4	61	7
2006	C4		4			1	1		12			1			2			1					2	24	8
2006	C5		11					4	24													2		41	4

Table F-2. Abundance data for 18 species by replication (rep) and year, including total abundances and species richness (SR), collected from a site above the Irving power plant (site 2) in Fossil Creek, AZ.

Year	Rep	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	Total	SR
2004	A1	1					39				1		1					1		43	5
2004	A2						35				2	1								38	3
2004	A3	8					26											1		35	3
2004	A4						13													13	1
2004	A5	2					16						3					1		22	4
2005	B1						1	2											2	5	3
2005	B2				1			5			1									7	3
2005	B3		2				1													3	2
2005	B4		5														1			6	2
2006	C1					1	12	1	2											16	4
2006	C2					3	53							3		1	5			65	5
2006	C3			1			73							3						77	3
2006	C4					1	30			1				2	1					35	5
2006	C5					1	13													14	2

Other common techniques used to assess data normality and dispersion include evaluations of skewness, kurtosis, and the coefficient of variation, or CV. Skewness is a measure of symmetry, or more accurately, the lack of symmetry. A data set is symmetric if the distribution of points both to the left and right of the center point are similar (a normal distribution has a skewness value of 3.0). Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. Data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails; data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. Skewness and kurtosis can be evaluated with histograms and by their numerical values. Given the sparse data set evaluated here, we examine these measures and the CV by their individual values (table F-4). The coefficient of variation is a measure of dispersion of a distribution and is the ratio of the standard deviation to the mean. Distributions with high variance have CVs > 100%; variables with coefficients of variation that are less than 50% are generally desirable.

Because biotic data often contain a few species having large abundances and few-to-many species having very small abundances, transformations of the data are employed to downweight these factors and to "normalize" the data set. We employed a square root transformation to the raw data and evaluated its effect in terms of data normality and outliers. The level of skewness, kurtosis, and the CV decreased, and it diminished the outlier effect of the large total abundance of sample B1 (tables F-4 and F-5). However, a new potential outlier, A5, was identified. Given its data (table F-1), its location in the scatterplot (figure F-2), and the analysis objectives, this sample was retained for further analysis.

Table F-4. Average skewness (and difference from 3.0), average kurtosis, and the coefficient of variation (CV) of the samples for the raw data set (table F-1) and the data set after a square root transformation

Data set	Average skewness	Average kurtosis	Coefficient of Variation (%)
Raw	3.55 (0.55)	13.61	75.98
Transformed	2.62 (0.38)	7.45	38.70

3.2 Cluster analysis and ordination

The Bray-Curtis distance measure was selected as the basis for multivariate analysis, and so a polar ordination was conducted of the transformed data set. A cluster analysis (using the Bray-Curtis distances) revealed distinct groupings of the samples by year (figure F-3). This result indicates that variation among the samples within years is less than the variation among years.

A visual representation of the variation among samples is shown by the 2-D and 3-D NMDS ordinations (figures F-4 and F-5). In both ordinations, the samples for each year are clustered together, and the clusters occupy different spaces, indicating interannual change. In general, the spaces among yearly samples appear less than the spaces among years. The adequacy of the ordination can be ascertained by the stress value, which is a measure of the mismatch between the rank order distances in the original data compared to the rank order

Table F-5. Outlier analysis of the average Euclidean distance and standard deviation by sample for the square root transformed data

Rank	Entity name	Average distance	Standard deviation
1	A5	0.67129	2.20449
2	C1	0.63299	1.37006
3	A1	0.60549	0.77105
4	C3	0.60251	0.70605
5	B5	0.59722	0.59068
6	A4	0.57483	0.10303
7	B1	0.56950	-0.01311
8	A3	0.56572	-0.09550
9	C4	0.55731	-0.27864
10	C5	0.55655	-0.29514
11	A2	0.54323	-0.58530
12	C2	0.53557	-0.75233
13	B3	0.52354	-1.01430
14	B4	0.51294	-1.24531
15	B2	0.50282	-1.46573

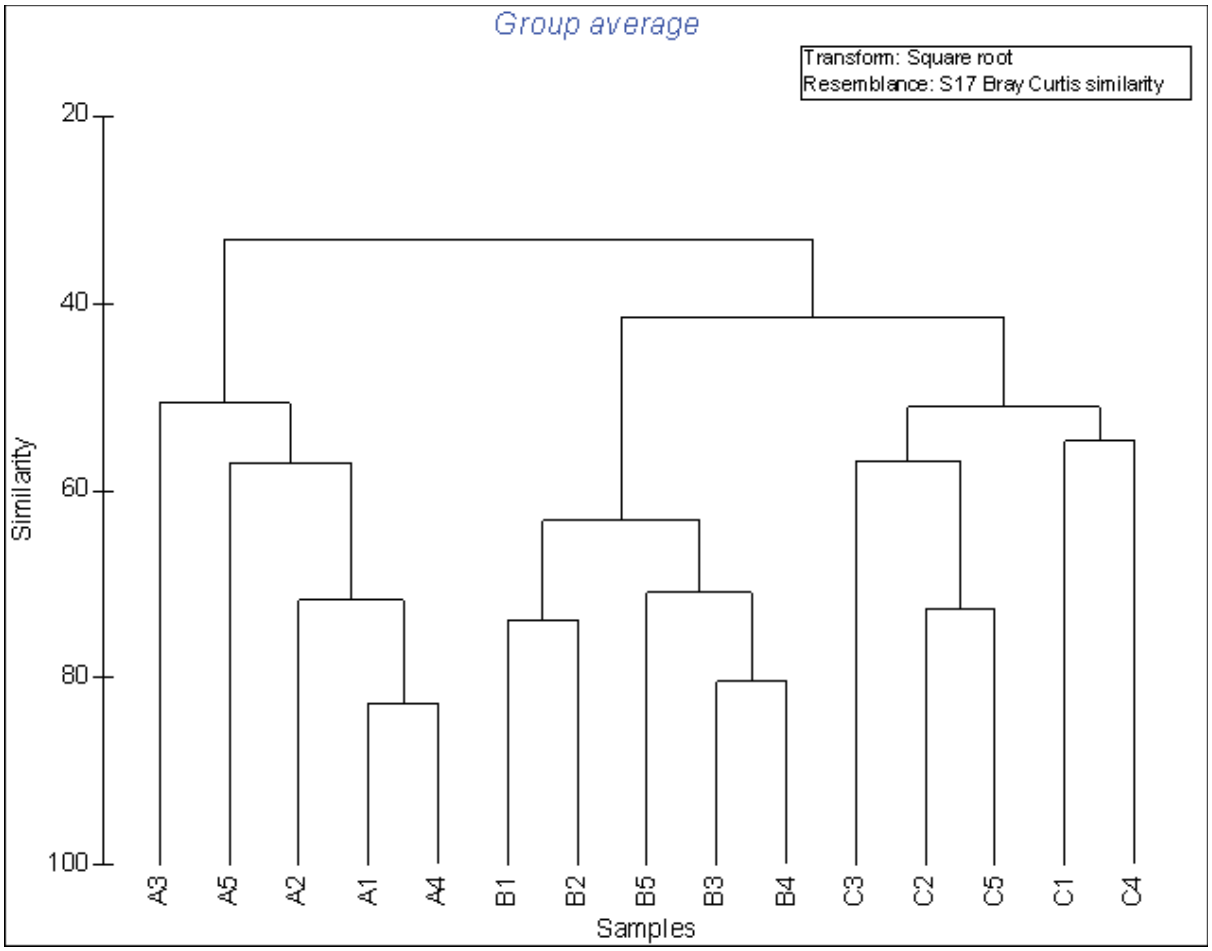


Figure F-3. Result of cluster analysis using Bray-Curtis distances. The samples correspond to the replications shown in Table F-1.

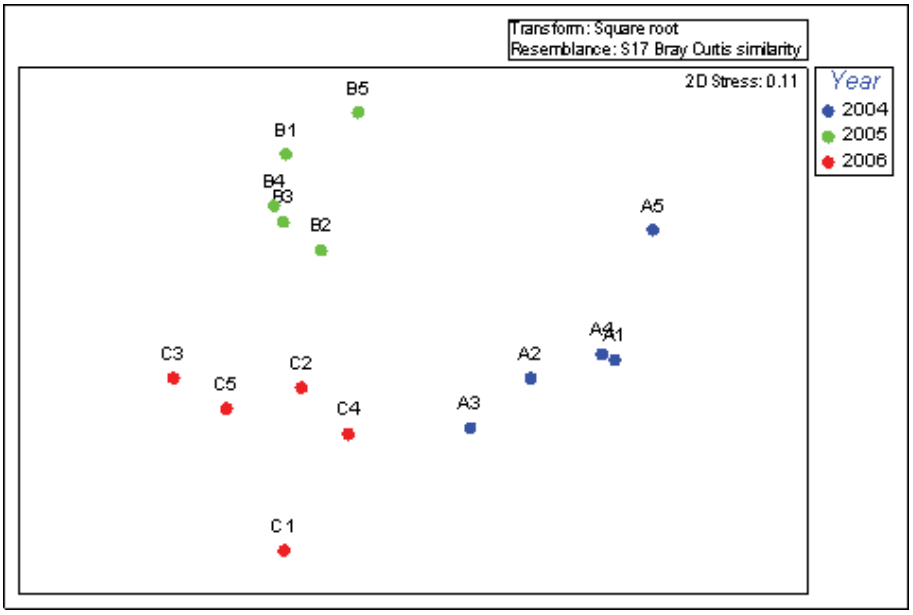


Figure F-4. NMDS 2-D ordination result. The samples correspond to the replications shown in Table F-1.

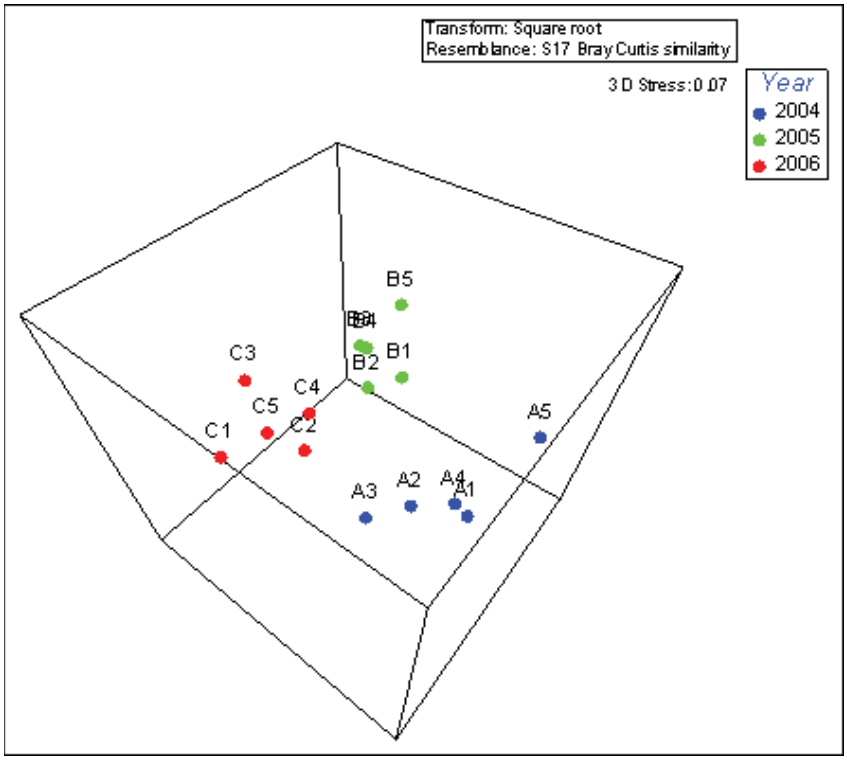


Figure F-5. NMDS 3-D ordination result. The samples correspond to the replications shown in Table F-1.

distances in the ordination. The stress values for both dimensions are low, indicating good ordinations with no real prospect of misleading interpretation. In comparing the two dimensions, the decrease in the stress value from 0.11 to 0.07 indicates that the higher dimension adds additional information about the overall structure of the data set.

3.3 Analysis of similarity (ANOSIM) and similarity percentages (SIMPER)

The global R statistic from ANOSIM (Clarke and Gorley 2006) was used to test the hypothesis that there are no differences among the samples by the year factor: a value of 0 indicates that the average rank resemblance among and within years is much the same, whereas a value of 1 indicates no resemblance overlap among years and complete differences (all samples within years are more similar to each other than any samples from different years). The histogram in Figure F-6 shows the actual R statistic (0.887, shown as a line) for the macroinvertebrate data set is very different compared to the likely spread of R values (derived from random permutations) if the null hypothesis was true. Thus, the null hypothesis is rejected ($p < 0.001$), and we conclude that there are significant differences among the samples by the year factor.

The ANOSIM test of pairwise interannual comparisons showed significant differences among all possible comparisons (table F-6). This test compares the difference of average rank dissimilarities between and within years, with R scaled from 0 (no differences) to 1 (all dissimilarities between years are larger than any dissimilarity among reps within either year). The R statistic provides more valuable information than the significance level because it is largely not a function of the number of samples (or replicates), whereas the p value (or significance level) can partly be a function of the 'power' supplied by the number of samples.

The observed interannual differences in macroinvertebrate communities are most likely

caused by the most abundant species. The results of analysis of similarity percentages (SIMPER) indicated that four species in particular (S1, S2, S8, and S14) were found to contribute the most to the dissimilarity between all possible years (tables F-1 and F-7).

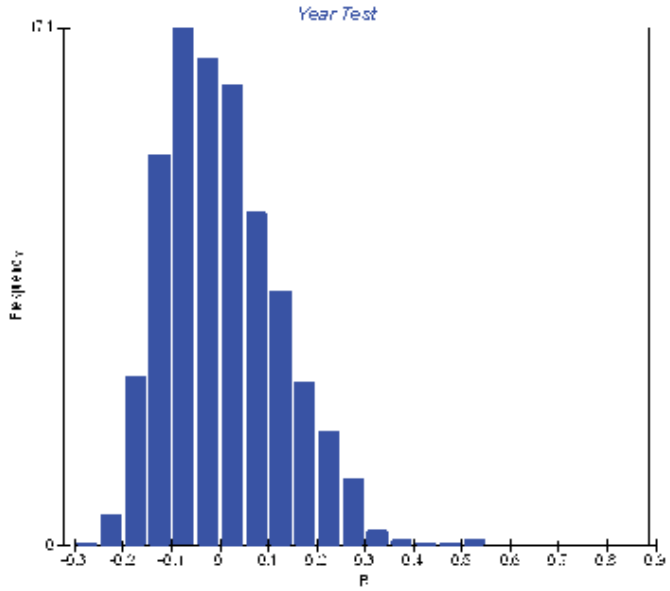


Figure F-6. Histogram from 999 permutations of the ANOSIM test statistic (R) and the true value of R (line at 0.887) for the data tested.

Table F-6. ANOSIM results of the pairwise tests between all possible years

Test	R statistic	Significance level (p)
2004 vs. 2005	0.936	0.001
2004 vs. 2006	0.904	0.001
2005 vs. 2006	0.816	0.001

Table F-7. Results of analysis of similarity percentages (SIMPER; using Bray-Curtis similarity), showing the four most important species contributing to interannual dissimilarities

Interannual	Species	Average Dissimilarity	% Contribution
2004 / 2005	S14	18.97	28.33
	S8	12.89	19.24
	S2	11.30	16.87
	S1	8.62	12.88
2004 / 2006	S1	11.06	16.57
	S2	10.75	16.11
	S8	9.02	13.50
	S7	6.21	9.30
2005 / 2006	S14	19.46	33.23
	S8	8.57	14.64
	S2	6.41	10.94
	S7	4.16	7.11

3.4 Analysis of two sites within Fossil Creek

To learn more about spatial variation and the data analysis process when monitoring data from two sites within a stream are available, additional analyses were conducted by adding data from a separate site, above the power plant, to the data set analyzed previously. This new data set is similar to that from the dam site; it is composed of species abundances from a total of 14 samples (replicates) from similar (but not exact) dates from 2004, 2005, and 2006. As with the dam site, no samples were eliminated and the data were square-root transformed prior to running multivariate statistical tests. NMDS ordinations were conducted to provide visual representations of temporal and spatial variation. A 2-way crossed ANOSIM test was used to evaluate both a temporal effect (interannual differences) and a spatial or site effect among the samples.

<u>Ordination results</u>

A visual representation of the variation among the 29 total samples is shown by the 2-D NMDS ordination (figures F-7 and F-8). In both ordinations, the samples for each site within each year are generally clustered together, indicating both spatial and temporal

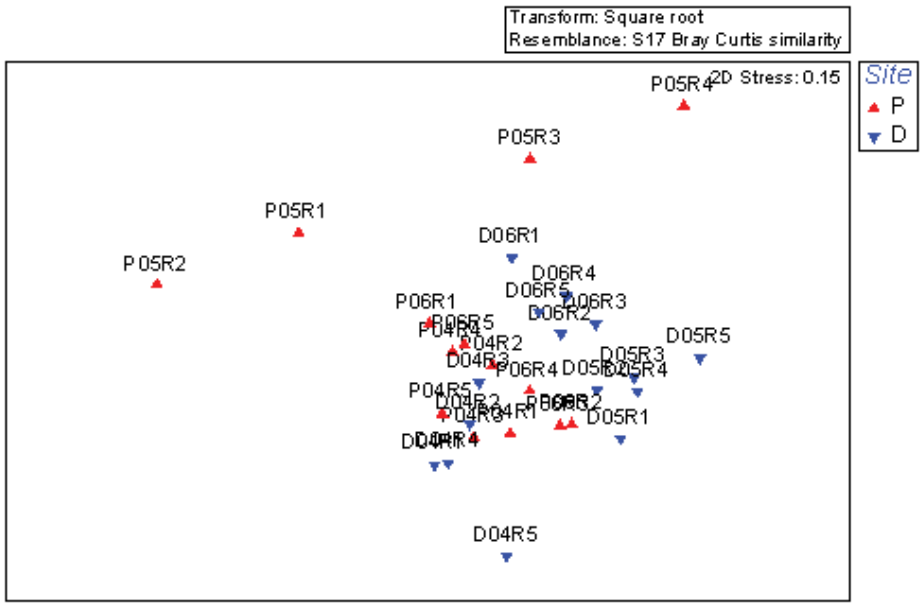


Figure F-7. NMDS 2-D ordination result. The red and blue samples correspond to the replications from the power plant site and dam site, respectively, with the year and sample number following the site code (e.g., P05R3 is sample 3 from 2005 from the power plant site).

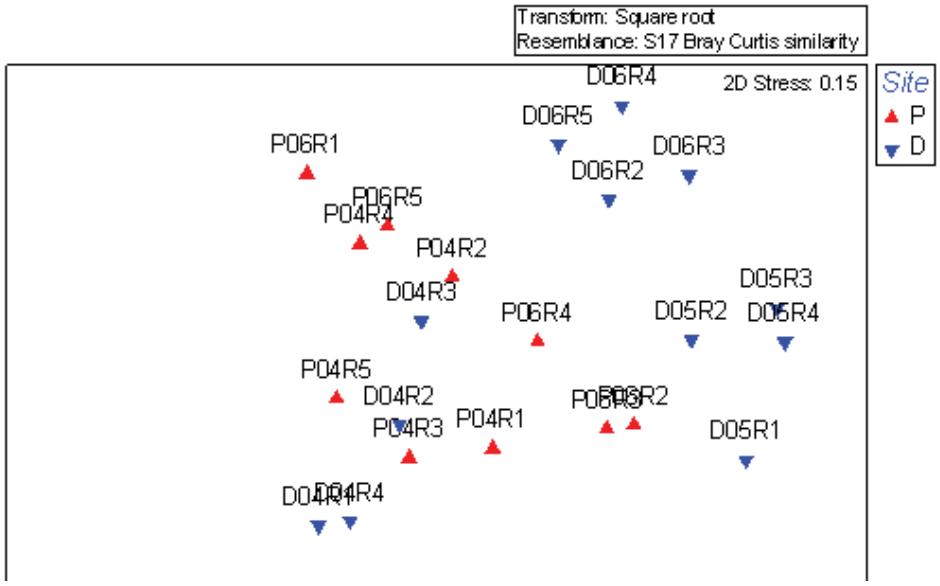
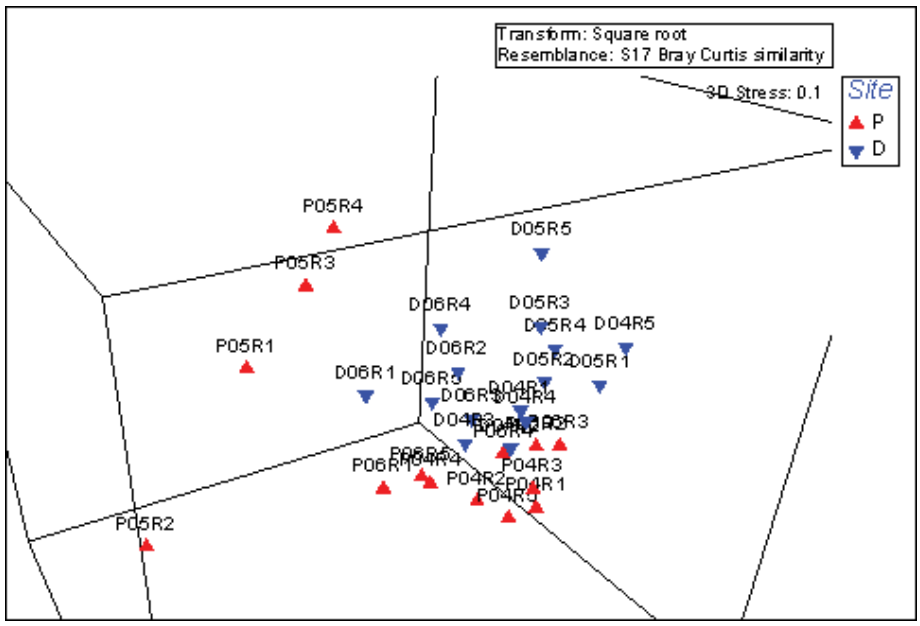


Figure F-8. A zoomed-in view of the 2-D ordination result shown in Figure F-7

differences. A zoomed-in view of Figure F-7 is shown in Figure F-8, and this shows that some samples from the same year but different sites (i.e., P04R2 and D04R3; D04R2 and P04R3) are actually more similar to each other than samples from the same site and year. The stress value for this ordination is 0.15, indicating a potentially useful to good ordination.

The 3-D NMDS ordination (figure F-9) represents a better ordination with a stress value of 0.1 indicating no real prospect of misleading interpretation; thus, the higher dimension adds additional information about the overall structure of the data set. The samples from different sites occupy different regions, and are clustered together with most samples from a given year clustered as well. As shown in Figure F-7, all 4 samples from the power plant site during 2005 appear to have greater variation and occupy a different region from the other samples, indicating both spatial and temporal variation.

Figure F-9. NMDS 3-D ordination result, with coding as described for Figure F-7



ANOSIM Results

Using a 2 way crossed ANOSIM, the global R statistic showed that there was a year effect (or annual differences) and a spatial or site effect among the samples. This result was anticipated for three reasons: interannual differences were already demonstrated for the dam site; the actual sampling dates between the two sites occurred during the same month but were a few days apart (e.g., Oct. 13 and Oct. 18, 2004 for the dam and power plant site, respectively); and the sites presumably represented different habitats along Fossil Creek. The histograms in Figure F-10 show the result of testing for the year effect and the site effect. The global R statistic is 0.732 and 0.557 for the year and site tests, respectively, and thus the null hypotheses were rejected ($p = 0.001$).

The test of pairwise interannual change showed significant differences among all possible comparisons (table F-8). This indicates significant year to year change in species abundances across both sites, suggesting (perhaps) that species at both sites are responding to change similarly.

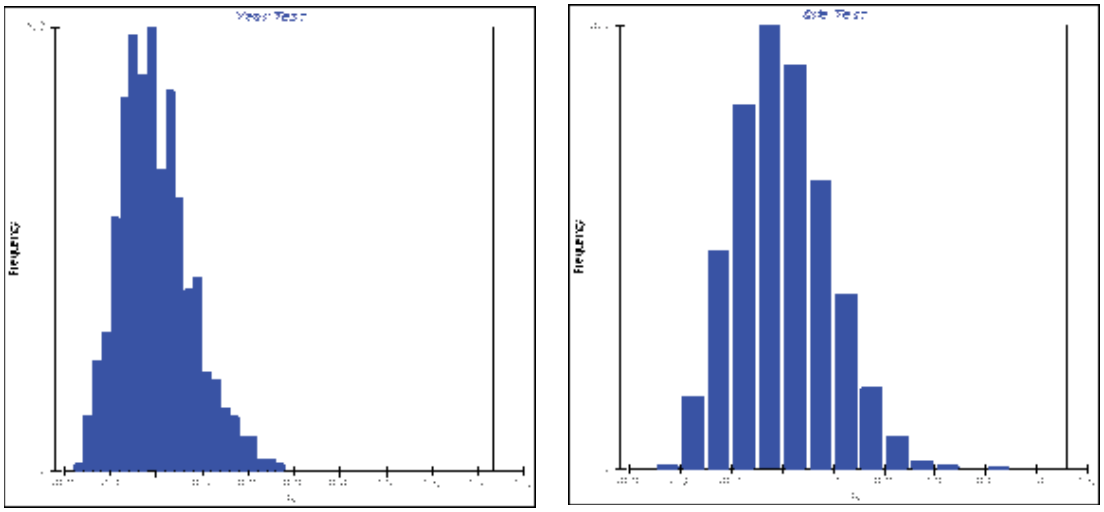


Figure F-10. Histogram from 999 permutations of the ANOSIM test statistic and the true value of R (vertical lines) for the data tested for differences among the 3 years and across 2 sites (A), and differences between the 2 sites and across all years (B)

Table F-8. ANOSIM results of the pairwise tests between all possible years involving samples from 2 sites

Test	R statistic	Significance level (p)
2004 vs. 2005	0.829	0.001
2004 vs. 2006	0.674	0.002
2005 vs. 2006	0.759	0.001

Appendix G. Example Annual Data Summary Report:

Aquatic Macroinvertebrate and Physical Habitat Monitoring for Capulin Creek in Bandelier National Monument: 2008 Summary Report

National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Aquatic Macroinvertebrate and Physical Habitat Monitoring for Capulin Creek in Bandelier National Monument

2008 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2010/030

ON THE COVER
Capulin Creek Crossing, Bandelier National Monument
Photo by Stacy Stumpf

Aquatic Macroinvertebrate and Physical Habitat Monitoring in Capulin Creek in Bandelier National Monument

2008 Summary Report

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

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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 authors 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 and Ellen Soles was the crew member in 2008. SCPN staff provided support for the project.

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NPS 315/101098, 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).

In 2007 SCPN implemented monitoring of aquatic macroinvertebrates on Capulin Creek in Bandelier National Monument (BAND) (Stumpf and Monroe 2009). During 2008 the SCPN Water Resources field crew collected macroinvertebrate samples and physical habitat data from two monitoring sites established in 2007.

- *Capulin Creek at Base Camp Gauging Station* (BANDCAP01), identified in this report as CAP01 (see Appendix A for list of locations, codes, and common names of sampling sites), is located less than 0.3 km upstream from the backcountry ranger cabin and was selected to be co-located with a network water quality monitoring site. The site is located at a discontinued US Geological Survey streamflow gauging station (Capulin Canyon at Ranger Cabin-station number 083133655). The channel substrate at this site is primarily cobble, and the stream flows through an alder (*Alnus* sp.), boxelder (*Acer negundo*) and narrowleaf cottonwood (*Populus angustifolia*) woodland.
- *Capulin Creek above Painted Cave* (BANDCAP02), identified in this report as CAP02, is located 1.8 km up canyon from the Painted Cave and 2.6 km downstream from base camp. This site was selected using the Generalized Random-Tessellation Stratified (GRTS) design, and is surrounded by ponderosa pine (*Pinus ponderosa*), alder, boxelder, and New Mexico olive (*Forestiera pubescens*), and has a mostly fine/sand substrate.

The purpose of this report is to (a) document the monitoring activities that 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.

The Capulin Creek watershed is a designated wilderness area, managed for recreational use within park boundaries. The U.S. Forest Service manages land in the upper reaches of the watershed for recreation and timber harvest. In 1996 the Dome Fire burned several thousand acres in Capulin Creek watershed, and, although terrestrial and aquatic communities appear to have been recovering over the past 10 years, effects of the fire are still apparent. Large quantities of woody debris have accumulated on the floodplain and in the stream channel, and fine sediments are abundant and mobile in the system. Roads and timber harvest on Santa Fe National Forest land also have the potential to affect the stream ecosystem. Aquatic macroinvertebrates were sampled in streams at BAND, before the fire, by Pippin and Pippin (1981), and post-fire by Vieria et al. (2004) and MacRury and Clements (2002).

Native Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*) populations were extirpated from Capulin Creek by flood events following the Dome fire. The New Mexico Department of Game and Fish, Bandelier National Monument, and the Santa Fe National Forest have been collaborating to reintroduce this species to the creek. One hundred Rio Grande cutthroat trout were reintroduced in March 2006, and land managers have been evaluating the idea of placing native Rio Grande Sucker and native Rio Grande Chub in Capulin Creek as well (S. Fettig, personal communication 2/27/08).

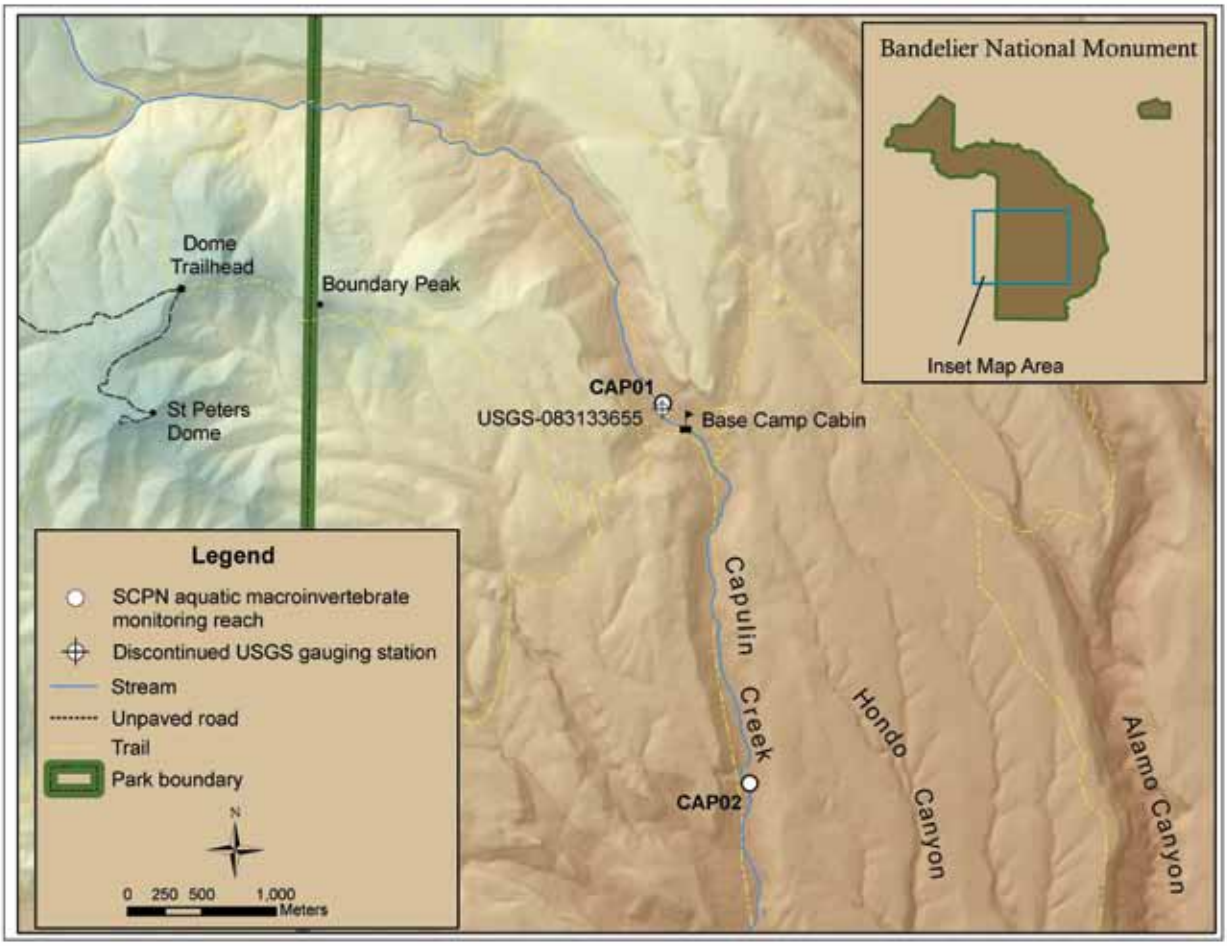


Figure 1. Map showing locations of SCPN monitoring sites CAP01 and CAP02 in Capulin Creek at Bandelier National Monument.

2 Methods

2.1 Field Methods

In general, index periods for macroinvertebrate sample collection by the SCPN should coincide with the states' index periods to ensure compatibility of monitoring samples (Brasher *in review*). In New Mexico, the sampling window is from August to mid-November (NMED-SWQB 2007). On October 7-8, 2008, we collected aquatic macroinvertebrate samples and physical habitat data at monitoring sites CAP01 and CAP02. Each site consists of a 150-meter reach, composed of 11 transects, spaced 15 m apart (fig. 2). 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*).

Two types of aquatic macroinvertebrate samples were collected in 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 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, 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.

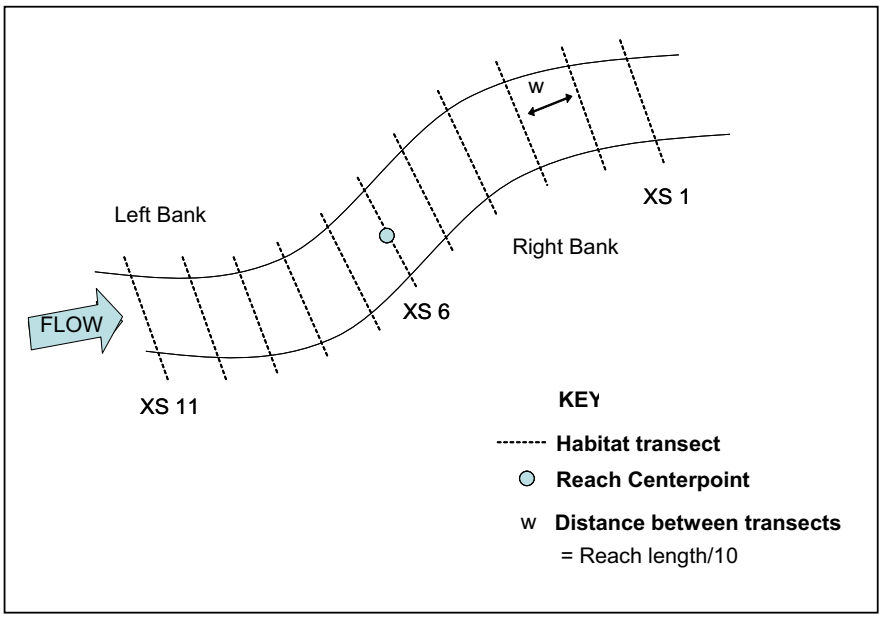


Figure 2. General aquatic-macroinvertebrate sampling reach layout

2.2 Laboratory Methods

Aquatic macroinvertebrate samples were sent to the National Aquatic Monitoring Center's Bug Lab, a Bureau of Land Management laboratory at Utah State University in Logan, Utah. 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. To ensure data quality, 10 percent of the identified samples were re-identified by a second certified taxonomist.

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.

3 Results

3.1 Summary of Aquatic Macroinvertebrate Community Data

Table 1 presents data describing aquatic macroinvertebrate communities from samples collected from CAP01 and CAP02 in 2008. Key metrics calculated for samples collected during 2008, as well as in 2007, are presented in Table 1. For all tables and figures listed in this section, sampling reach results are presented in left to right order corresponding to upstream to downstream position along the stream. Figures in this section refer to quantitative data unless otherwise noted.

Abundance. Overall, mean abundance was greatest at CAP01 in both 2007 and 2008. We found that the total abundance at CAP01 increased by 20% between 2007 and 2008, while it decreased by 18% for CAP02 during the same time period. Furthermore, in 2008, the mean abundance for CAP01 was twice as high as the mean abundance for CAP02. (fig. 3).

Taxa richness. In 2008, mean taxa richness for the quantitative samples was 1.5 times higher at CAP01 than at CAP02. Mean richness in the qualitative samples at CAP01 decreased by 13 taxa from 2007 to 2008, but richness in the qualitative samples at CAP02 increased by 5 taxa (fig. 4). Mean taxa richness for the qualitative samples was slightly higher at CAP02 than at CAP01.

Diversity. Taxonomic diversity was 8% higher at CAP01 than at CAP02 in 2008, and had increased by 9.5% at CAP02 from 2007 to 2008. Functional diversity decreased 11% at CAP02 in 2008 (fig. 5).

Table 1. Summary of aquatic macroinvertebrate metrics for Capulin Creek in Bandelier National Park. 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	**CAP01**		**CAP02**	
Metric	**2007**	**2008**	**2007**	**2008**
Taxa Richness	43.00	30.00	27.00	32.00
Richness - Tolerant taxa (%)	9.30	7.41	11.54	25.81
Richness - Filterer-collectors (%)	11.63	10.34	15.38	6.45
Richness - Scrapers (%)	9.30	6.90	3.85	6.45
Number of EPT taxa	19.00	14.00	8.00	10.00
Richness - EPT taxa (%)	44.19	46.67	29.63	31.25
Richness - Ephmeroptera (%)	16.28	16.67	7.41	9.38
Richness - Plecoptera (%)	9.30	10.00	7.41	12.50
Richness - Trichoptera (%)	18.60	20.00	14.81	9.38
Richness - non-Insect taxa (%)	4.65	3.33	7.41	6.25
Richness - Chironomids (%)	6.98	10.00	11.11	9.38

Quantitative Samples	**CAP01**				**CAP02**			
	2007		**2008**		**2007**		**2008**	
Metric	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Total Abundance	456.30	278.53	545.00	191.79	240.40	196.25	229.20	245.08
Taxa Richness	24.40	8.26	28.00	5.15	13.40	7.09	17.40	9.07
Simpson's Diversity - Taxonomic	0.86	0.03	0.87	0.02	0.73	0.06	0.80	0.13
Simpson's Diversity - Functional Group	0.67	0.05	0.70	0.01	0.65	0.05	0.62	0.09
Dominant Taxa	28.95	8.78	22.58	4.00	43.57	7.79	37.05	17.50
Relative Abundance - Tolerant taxa	2.23	3.78	0.47	0.27	7.02	9.87	6.87	6.99
Percent Richness - Tolerant taxa	4.61	4.89	7.41	3.96	10.78	7.25	16.88	7.33
Relative Abundance - Filterer-collector	15.84	3.20	29.64	9.83	4.85	4.71	2.07	3.18
Percent Richness - Filterer-collector	14.50	2.97	11.87	3.95	13.56	10.81	7.06	6.54
Relative Abundance - Scrapers	4.64	2.11	10.49	6.38	2.59	2.95	22.24	13.48
Number of EPT Taxa	11.40	2.70	12.80	1.92	4.60	3.05	4.80	4.82
Relative Abundance - EPT taxa	54.51	12.45	66.28	12.87	52.33	13.17	15.63	13.47
Relative Abundance - Ephmeroptera	29.10	10.08	26.11	4.79	1.14	0.92	5.55	5.69
Relative Abundance - Plecoptera	13.80	6.65	12.25	3.24	49.07	11.56	9.35	8.70
Relative Abundance - Trichoptera	11.61	3.84	27.91	10.41	2.12	4.02	0.73	1.01
Relative Abundance - non-insect taxa	0.69	1.18	0.58	0.19	1.15	1.52	7.50	7.47
Relative Abundance - Chironomids	27.49	12.60	13.33	8.85	35.73	17.62	41.97	20.50

Figure 3. Total abundance. Mean total aquatic macroinvertebrate abundance in quantitative samples collected from sampling reaches in Capulin Creek at BAND, in 2007 and 2008. Expressed as the mean number of individuals per quantitative targeted habitat sample.

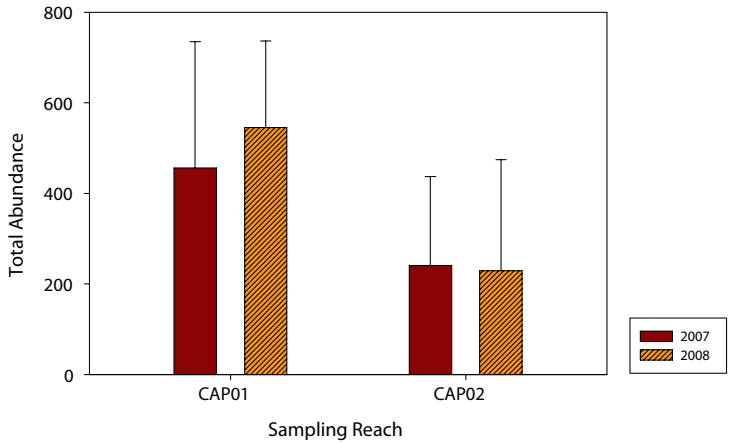
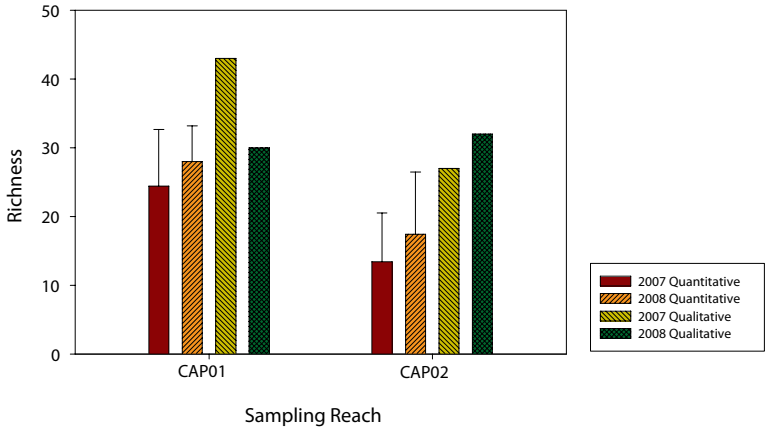
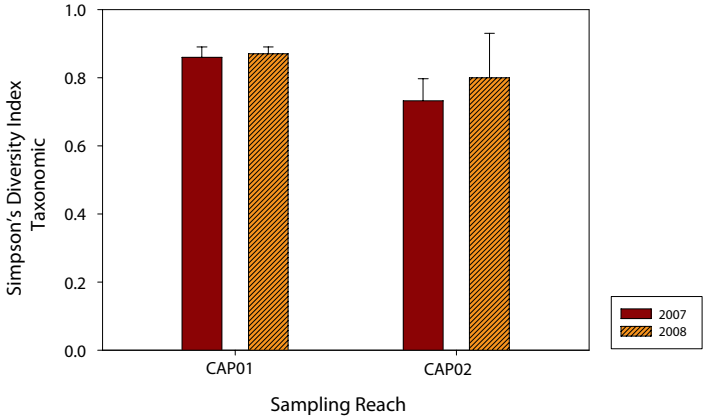


Figure 4. Taxa richness. Mean number of taxa found in quantitative, targeted riffle habitat samples and qualitative, multihabitat samples collected from sampling reaches in Capulin Creek at BAND in 2007 and 2008.





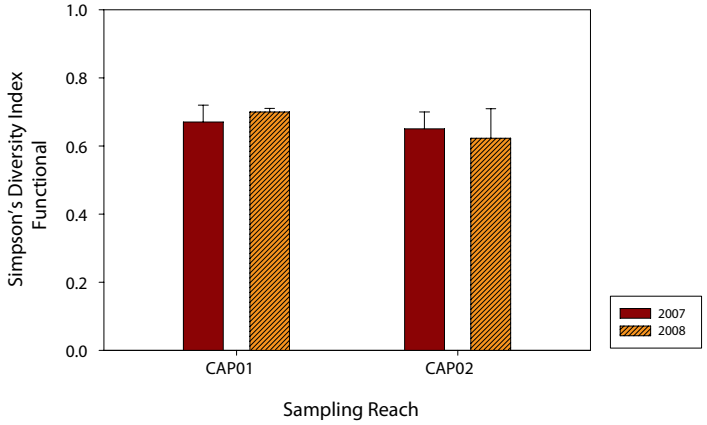


Figure 5. Diversity. Simpson's Diversity Index for taxonomic (upper) and functional diversity (lower) in quantitative targeted riffle habitat samples collected from sampling reaches in Capulin Creek at BAND in 2007 and 2008. Values expressed are means of all samples collected from each site.

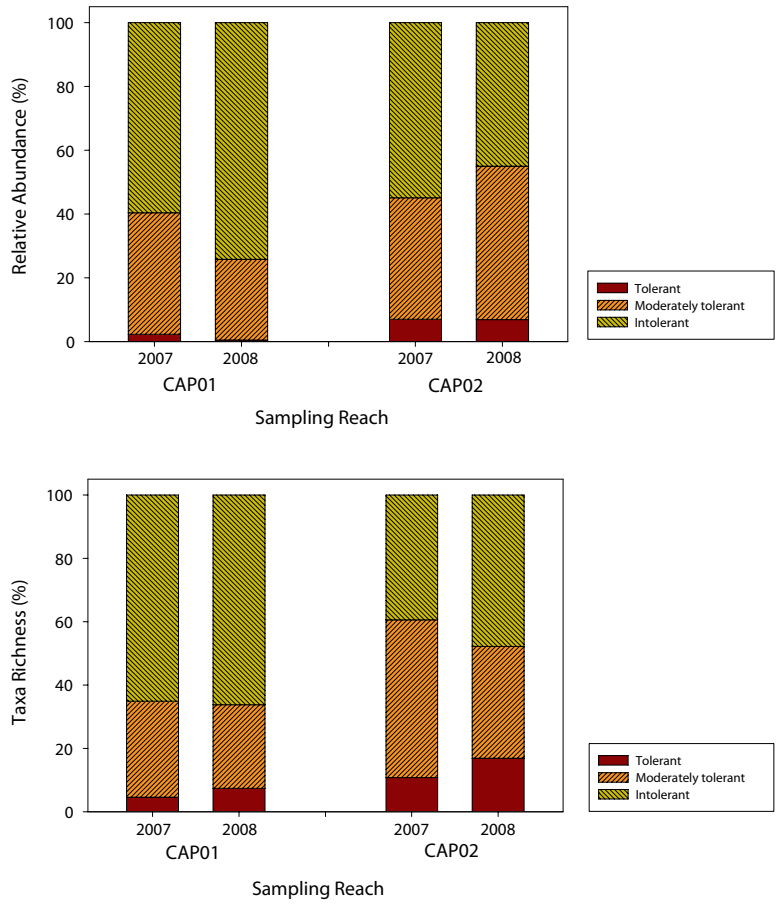


Figure 6. Ecological tolerance. Mean relative abundance (top) and richness (bottom) of aquatic macroinvertebrate taxa in samples collected from sampling reaches in Capulin Creek at BAND in 2007 and 2008, based on their tolerance to perturbation.

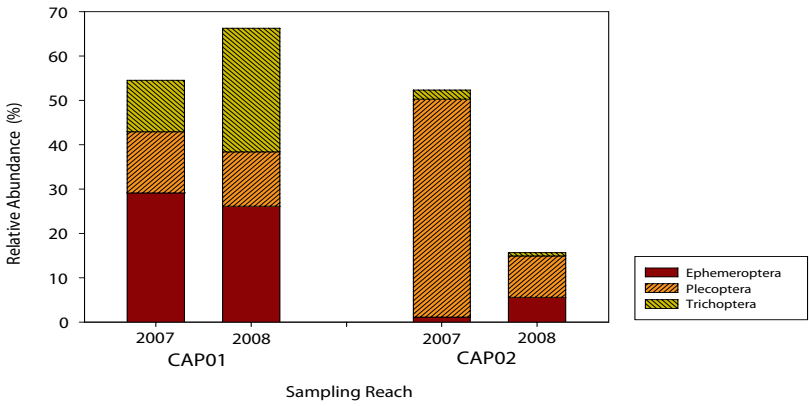


Figure 7. EPT abundance. Relative abundance of Ephemeropteran (mayflies), Plecopteran (stoneflies), and Trichopteran (caddisflies) species. in aquatic macroinvertebrate samples collected from sampling reaches in Capulin Creek at BAND in 2007 and 2008, expressed as a percentage.

Tolerant taxa. In 2008 relative abundance for tolerant taxa decreased by 79% at CAP01, only slightly at CAP02, and was four times greater at CAP02 than at CAP01 (fig. 6, top). While the number of tolerant individuals decreased across both reaches in 2008, the number of tolerant taxa increased: tolerant taxa richness increased by 61% at CAP01 and 56 % at CAP02 (fig. 6, bottom).

EPT taxa. Relative abundance of EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera) declined by 22% at CAP01 and 70% at CAP02 from 2007 to 2008 (fig. 7). CAP02 had 76% fewer individuals of EPT taxa than CAP01. Losses in abundance of EPT taxa at CAP02 are due to losses in relative abundance of Plecopteran and Trichopteran taxa, which declined 80% and 66% respectively.

Aquatic macroinvertebrate orders. In 2008, the largest increase in relative abundance at CAP01 was for the order Trichoptera, which more than doubled between 2007 and 2008 (fig. 8). At CAP02, Coleopterans increased sixfold, Ephemeropterans increased fourfold, and Odonates increased by 2.5 times their abundances in 2007. Organisms in the "Other" category, i.e. those that do not fall into one of the major orders of macroinvertebrates, such as Gastropods and Amphipods, increased fourfold at CAP02 between 2007 and 2008. We also saw large decreases in several orders from 2007 to 2008. Chironomids decreased 57% at CAP01, and Plecopterans decreased by 76% at CAP02.

We also saw large differences in the relative abundance of orders across sampling reaches. CAP01 had 4 times the number of Ephemeroptera and 21 times the number of Trichopterans as CAP02. Coleopterans and Dipterans in the Family Chironomidae were both nearly 3 times greater in number at CAP02 than at CAP01. Organisms lumped into the category Other were 78% more abundant at CAP02 than CAP01.

Functional feeding groups. During 2008 Collector-gatherers dominated functional group abundance at both sampling reaches, making up nearly 41% of the individuals at CAP01 and 50% of the

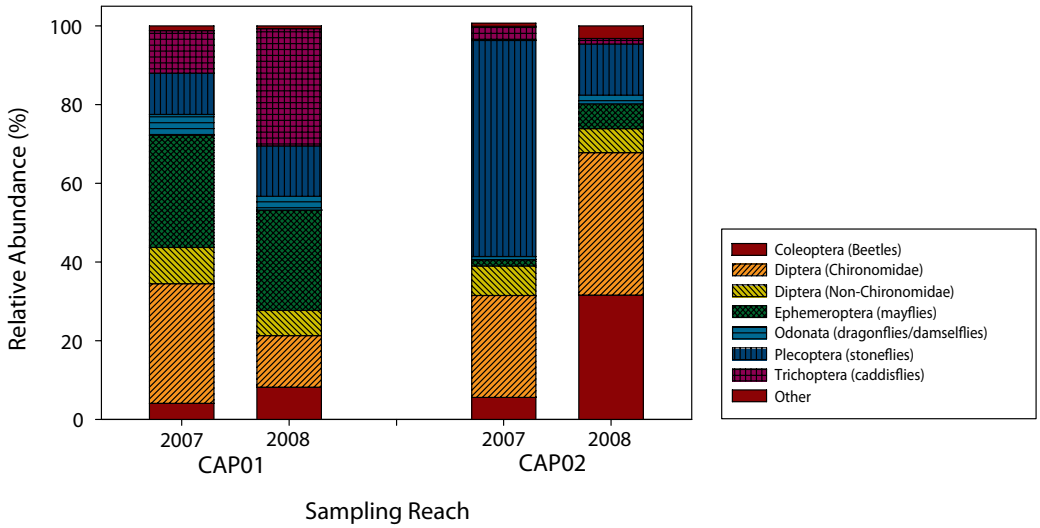


Figure 8. Aquatic macroinvertebrate order abundance. Proportion of aquatic macroinvertebrate individuals by taxonomic order in quantitative targeted riffle samples collected from Capulin Creek in Bandelier National Monument in 2007 and 2008.

individuals at CAP02. CAP01 had 27% more collector-filterer individuals than CAP02 in 2008. There were twice the number of scrapers at CAP02 than at CAP01 in 2008. Collector-filterers increased in abundance by 87% at CAP01 between 2007 and 2008 while predator abundance declined by 49%. Collector-gatherers increased by 63% at CAP02 and scrapers increased over 8 fold between sampling years. Shredders declined by 84% between sampling years at CAP02 (fig. 9).

3.2 Summary of Physical Habitat Characteristics for Capulin Creek

This section presents data describing physical habitat characteristics collected at CAP01 and CAP02 during 2007 and 2008. These data are summarized in Table 2; additional transect and microhabitat data can be found in Appendix D. We could not measure velocity or depth at Transect 4 in CAP01 due to the large amount of woody debris present, or in CAP02 because a large rock bridge had forced flow below the surface at the time of our visit.

Transect level. Mean velocity along each transect (under "Channel dimensions" in table 2) was seven times greater at CAP01 than at CAP02. Riparian cover, as described by canopy closure, was greatest in the CAP02 reach, with 98% of the reach enclosed in the riparian canopy (table 2).

Channel structure dynamics are represented by particle size distributions in Figure 10, based on modified Wolman pebble counts. Particle size distributions were dominated primarily by finer sedi-

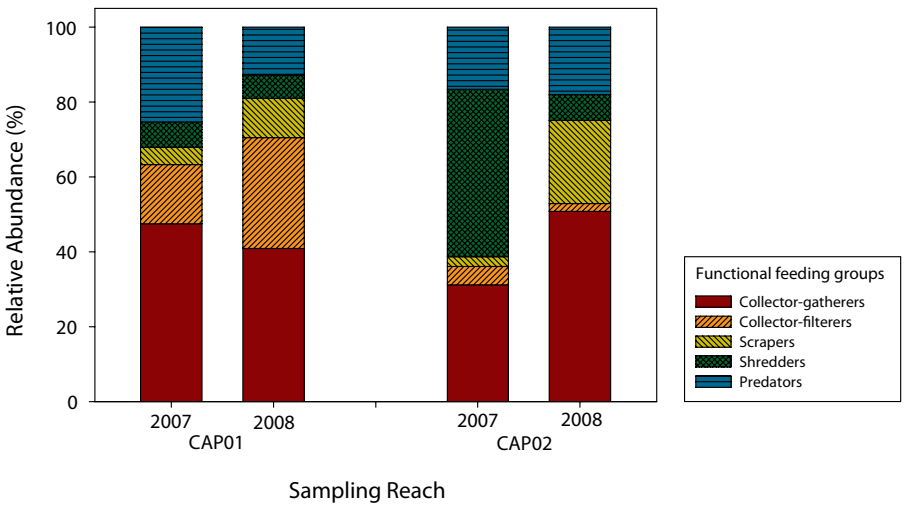
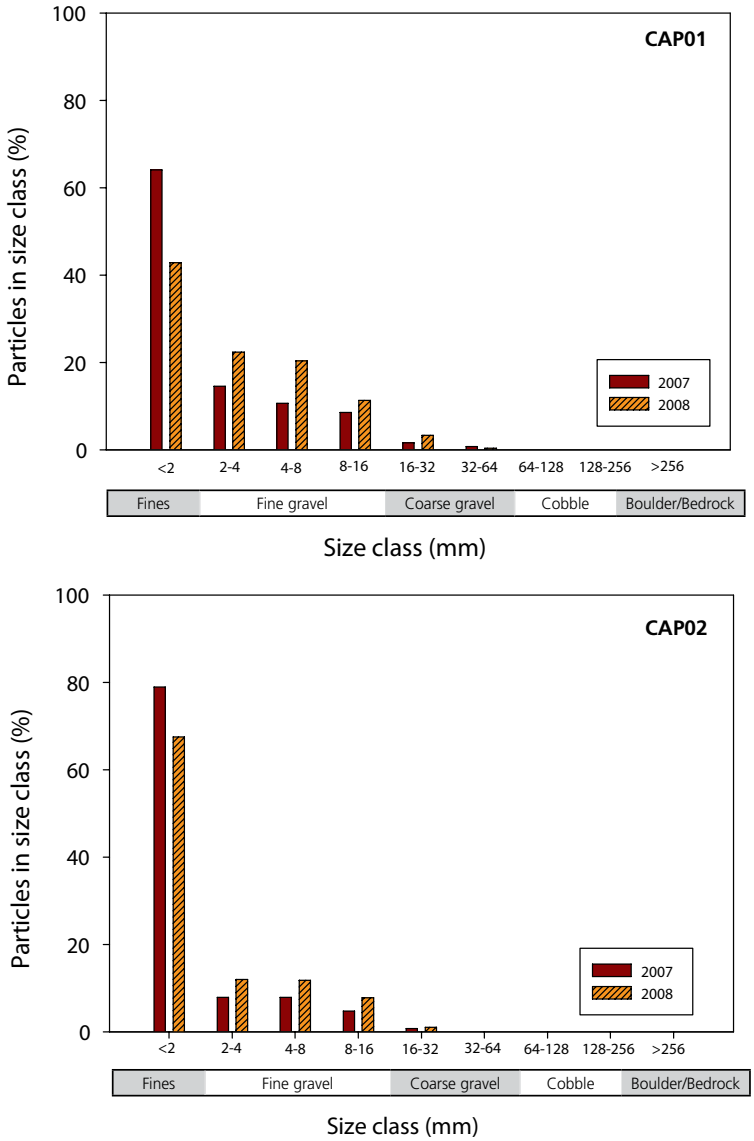


Figure 9. Functional group abundance. Proportion of abundance for functional feeding groups in quantitative targeted riffle samples from Capulin Creek at BAND in 2007 and 2008.



ments in both reaches. The proportion of particles in the fines size class (<2mm) was greater downstream. No sediment particles larger than coarse gravel were present in either of the sampling reaches in 2008. We found that the percentage of fines particles had decreased by 33% at CAP01, and 14% at CAP02 since 2007. Fine to coarse gravels increased at both sampling reaches from 2007 to 2008. At CAP01 fine gravels increased by 91% and at CAP02 they increased by 62%. At CAP02, the 8-16 mm grain category posted the largest increase of 62% (fig. 10)

Aquatic macroinvertebrate habitat was dominated by rock along the CAP01 sampling reach, where the proportion of rock increased by 26% from 2007 - 2008. Forty percent of the sampling reach at CAP01 lacked habitat suitable for aquatic macroinvertebrates, an increase of 88% from the previous year. Forty-five percent of the CAP02 sampling reach lacked appropriate habitat cover for aquatic macroinverte-

Figure 10. Channel surface substrate particle size distribution. Particle size distribution, based on modified Wolman pebble counts, of macroinvertebrate sampling reaches CAP01 (upper chart) and CAP02 (lower chart) in Capulin Creek at BAND, 2008.

Table 2. Summary of physical habitat data at the microhabitat, transect, and reach levels in Capulin Creek at BAND, 2008. Measures of particle embeddedness and canopy closure are described as percentages. Wetted and active channels are described as widths. NC = not collected.

Physical Habitat	CAP01				CAP02			
Metric	2007		2008		2007		2008	
Microhabitat level	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Riffles								
Velocity (m/s)	0.23	0.10	0.35	0.2	0.19	0.23	0.21	0.14
Depth (m)	0.07	0.02	0.09	0.02	0.06	0.03	0.05	0.02
Particle size (mm)	10.33	1.14	9.58	2.31	9.07	1.33	8.52	1.10
Embeddedness (%)	14.36	5.09	30.28	12.86	9.20	6.10	29.52	10.62
Transect level								
Channel dimensions								
Velocity (m/s)	0.06	0.04	0.14	0.06	0.04	0.03	0.02	0.02
Depth (m)	0.07	0.05	0.06	0.04	0.06	0.03	0.07	0.05
Wetted channel (m)	1.30	0.39	1.31	0.40	1.18	0.35	0.86	0.41
Active channel (m)	2.29	0.87	5.47	2.26	1.70	0.44	4.16	1.89
Riparian cover								
Canopy closure (%)	87.39	21.03	91.09	28.03	70.56	15.18	97.93	7.04
Reach level								
Water quality	**Value**		**Value**		**Value**		**Value**	
Temperature (°C)	11.5	–	11.3	–	11.4	–	11.2	–
Specific conductivity (µS/cm)*	NC	–	150	–	NC	–	165	–
pH	NC	–	8.0	–	NC	–	7.7	–
Dissolved oxygen (% saturation)	NC	–	10.5	–	NC	–	10.6	–
Turbidity (NTU)**	NC	–	0.5	–	NC	–	1.9	–

* Microsiemens per cm
** Nephelometric Turbidity Units

brates—an increase of 68% from 2007. The remaining habitat sampled at CAP02 was composed of 23% vegetation, 23% rock, and 6% woody debris. Woody debris declined the most between sampling years, with a 84% decrease at CAP01 and a 63% decrease at CAP02 (fig. 11).

Reach level. In 2008 riffles, runs, and cascades were the dominant geomorphic channel units (GCUs) at CAP01 (fig. 11). Runs and cascades both increased by 38% at CAP01 in 2008, while riffles increased by 67%. CAP02 was dominated by riffles and runs. Dammed pools were six times more abundant in CAP02 than CAP01, and runs were twice as abundant at CAP02 (fig. 12). For a complete description of GCUs see Brasher et al. (*in review*).

3.3 Antecedent Conditions

Streamflow and climate are not monitored at Capulin Creek. Climate data for 2007 and 2008 was collected from Bandelier National Monument (Beeley personal communication 2009). In 2008 average temperatures were cooler than or near the temperature recorded in 2007. During the months

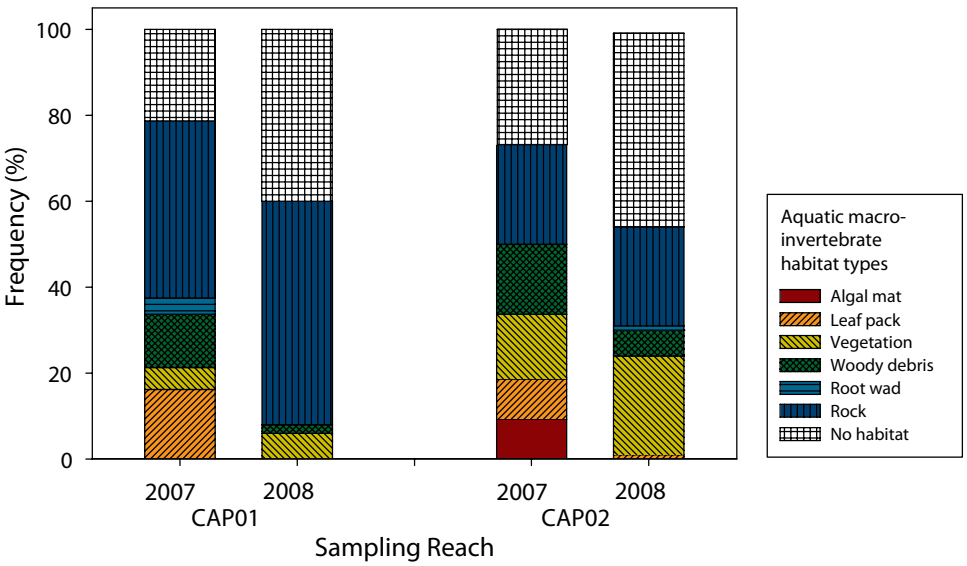


Figure 11. **Aquatic macroinvertebrate habitat.** Macroinvertebrate habitat characterization based upon line point intercept data collected from habitat transects in sampling reaches on Capulin Creek at Bandelier National Monument in 2007 and 2008.

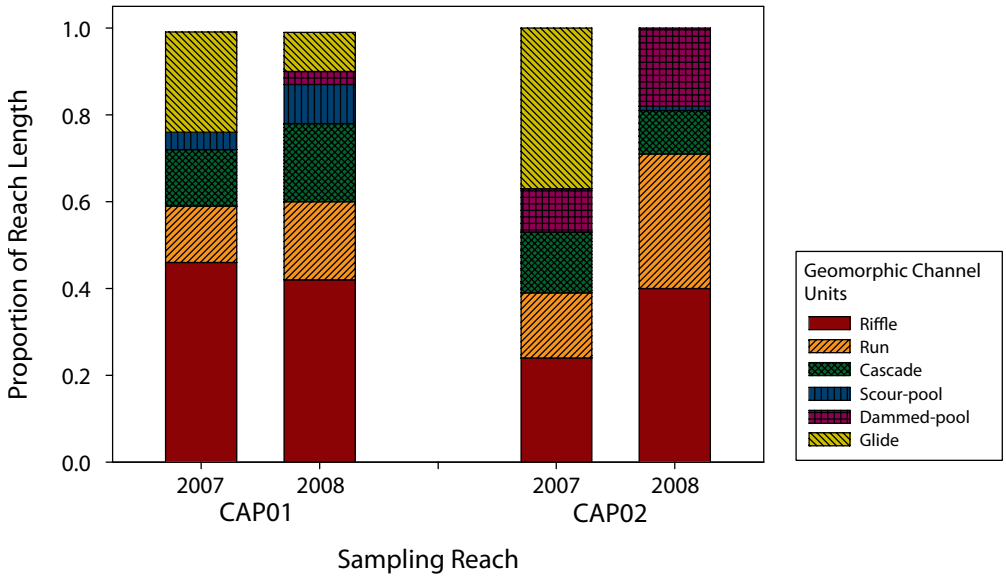


Figure 12. Geomorphic channel units. Geomorphic channel unit characterization of sampling reaches on Capulin Creek at Bandelier National Monument. in 2007 and 2008.

of March, July, and August in 2008 average daily temperature was nearly 2 °C cooler compared to 2007. Daily maximum temperatures were 3° C cooler for July and August in 2008 compared to 2007 (fig. 13). Total precipitation data for 2008 indicate that precipitation events were less severe, but more frequent than in 2007, especially during the monsoonal months of July, August, and September (fig. 14).

4 Discussion

This report presents data from SCPN's second year of monitoring aquatic macroinvertebrates and

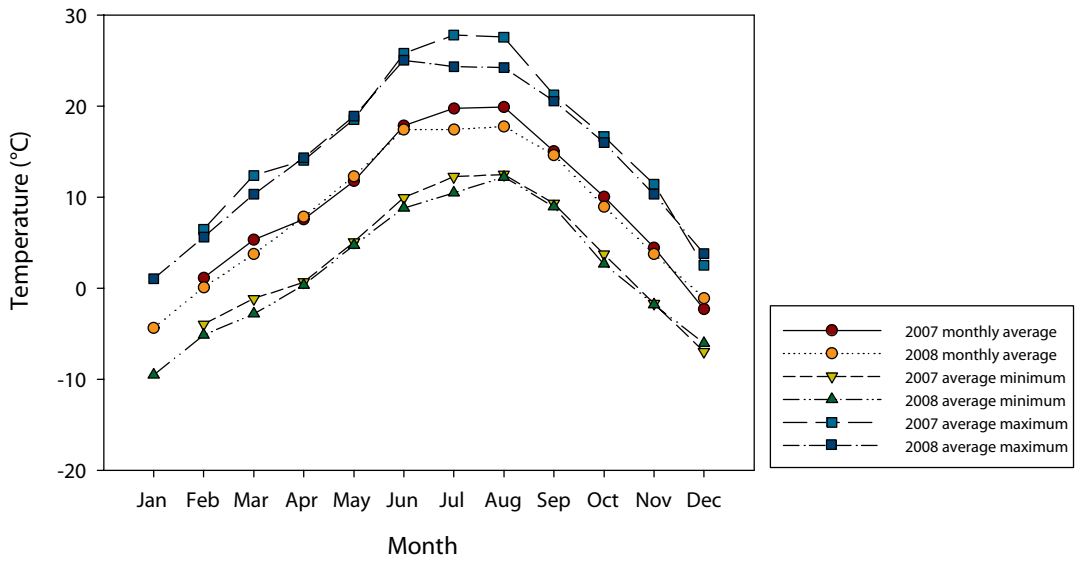


Figure 13. Average monthly temperature. Comparison of the average monthly temperature and average monthly maximum and minimum temperatures for Capulin Creek in 2007 and 2008 (Beeley, pers. comm 2009).

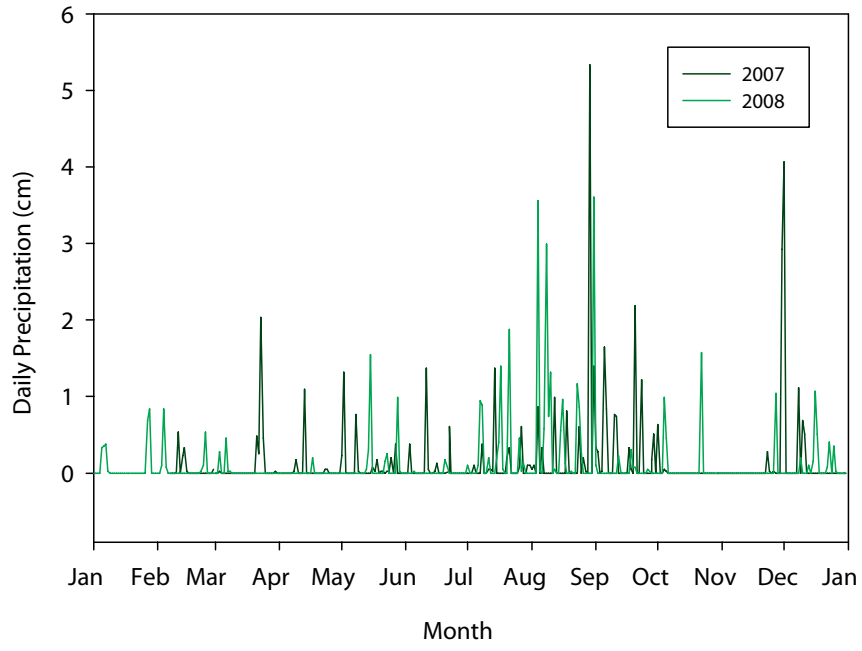


Figure 14. Total daily precipitation. Comparison of the total daily precipitation for Capulin Creek in 2007 and 2008 (Beeley, pers. comm. 2009).

physical habitat. 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

The data from samples collected in 2008 suggested that the targeted riffle sampling habitats in the upper reach of the watershed (CAP01) were richer in taxa, more diverse, both taxonomically and functionally, and contained a higher number of individuals than the lower reach (CAP02) (table 1). These results were consistent with our findings from our first year of sampling in 2007 (Stumpf and Monroe 2009). Calculations of Simpson's Diversity Index for taxonomic differences in quantitative samples suggest that the riffle habitats are quite diverse.

However, we did not get a similar result when we compared taxa richness from the qualitative samples collected at both reaches. We found more taxa (32) in qualitative samples collected along CAP02 than in those collected from CAP01 (30), even though we sampled fewer (20) habitat types along the CAP02 reach than we did along CAP01 reach (28, unpublished data). One possible explanation for this difference may be that there was twice as much woody debris along CAP02 than along CAP01 (fig. 12), providing greater resource availability and resulting in greater diversity of taxa. In addition, we found 28% more shredder taxa at CAP02, which may also be explained by the abundance of woody debris present.

4.2 Ecological Tolerance

Tolerance describes how well a species 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. Abundance of intolerant taxa was very high in samples collected from CAP01, while abundance of tolerant taxa was extremely low (<1%). The great abundance of intolerant taxa in this sampling reach suggested that the aquatic habitats and macroinvertebrate assemblages along this reach were in good condition and experiencing little disturbance. Conditions downstream appeared to be somewhat different than conditions in CAP01. Samples collected from CAP02 showed a decline in intolerant species and a large increase in moderately tolerant and tolerant species abundances. While we have no data to suggest the cause of the difference, these data do suggest that stream conditions are different at the two sampling reaches.

4.3 Physical Habitat Diversity

Our second year of physical habitat data indicate that in the reaches we sampled, substrate was dominated by finer sediments. In addition, we found that the proportion of fine sediments (<2 mm) present in the channel was 25% greater at CAP02. This finding may explain the decrease in EPT and Collector-filterer taxa, and the decrease in their abundances in the CAP02 quantitative samples. Both groups of organisms have been shown to be sensitive to the effects of sedimentation (Angradi 1999; Grubbs and Taylor 2004; Spindler 2004).

5 Literature Cited

Angradi, T. R. 1999. Fine sediment and macroinvertebrate assemblages in Appalachian streams: A field experiment with biomonitoring applications. Journal of the North American Benthological Society **18**:49–66.

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. Aquatic macroinvertebrate monitoring protocol for the Southern and Northern Colorado Plateau Networks of the National Park Service. Natural Resource Technical Report, *in review*.

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 on the Colorado Plateau. Unpublished report prepared for the Southern and Northern Colorado Plateau Networks. 156 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.

Grubbs, S. A., and J. M. Taylor. 2004. The influence of flow-impounded river regulation of the distribution of riverine macroinvertebrates of Mammoth Caves National Park, Kentucky, U.S.A. Hydrobiologia **520**:19–28.

MacRury, N. and W. Clements. 2002. Ecological, hydrological, and geo-chemical effects of fire on canyon watersheds in Bandelier National Monument, New Mexico. National Park Service. Final Technical Report. 48pp.

National Atmospheric Deposition Program (NRSP-3). 2009. NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, Illinois 61820.

National Park Service (NPS). K. Beeley, Personal communication, 2009

New Mexico Environment Department, Surface Water Quality Bureau (NMED-SWQB). 2007. The 2007 NMED/SWQB Standard Operating Procedures for Data Collection. 184 pp. http://www.nmenv.state.nm.us/swqb/sop/SWQBMASStandardOperatingProcedures.

New Mexico Environment Department. 2008. Record of decision for the 2008-2010 303(d)/305(b) integrated list for assessed surface waters. Surface Water Quality Bureau. Santa Fe, New Mexico. 336 pp.

Pippin W. F. and B. D. Pippin. 1981. Aquatic invertebrates from Capulin Creek, Bandelier National Monument, New Mexico. National Park Service, Natural Resource Program Center, Fort Collins, Colorado, USA.

Scott, M. L., A. M. D. Brasher, A. M. Caires, E. W. Reynolds, and M. E. Miller. 2005. The structure and functioning of riparian and aquatic ecosystems of the Colorado Plateau: Conceptual models to inform monitoring. Report to the Southern and Northern Colorado Plateau Networks. 99 pp.

Spindler, P. 2004. Stream channel morphology and benthic macroinvertebrate community

associations in the San Pedro River and Verde River Basins of Arizona, 1999–2002. Arizona Department of Environmental Quality. Open File Report 04-01. 26 pp.

Stumpf, S. E., and S. A. Monroe. 2009. Aquatic macroinvertebrate and physical habitat monitoring for Bandelier National Monument: 2007 summary report. Natural Resource Data Series NPS/SCPN/NRDS—2009/003. National Park Service, Fort Collins, Colorado.

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.

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 names, codes and location information for Bandelier National Monument

Horizontal coordinates are reported in Universal Transverse Mercator (UTM) Projection, Zone 13, 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)
BANDCAP01	*Capulin Creek at Base Camp Gauging Station*	CAP01	379713	3958026	1904
BANDCAP02	*Capulin Creek above Painted Cave*	CAP02	380300	3955457	1791

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.
	Hydroptilidae+ Hydropsychidae:	
Trichoptera	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.

* Brasher et al. (*in review*)

Appendix C Aquatic macroinvertebrate taxa collected from Capulin Creek at BAND in 2008

Phylum	Class	Order	Suborder	Family	Genus	Species	Common Name
Annelida	Clitellata						segmented worms
Arthropoda	Arachnida	Trombidiformes					water mites
Arthropoda	Arachnida	Trombidiformes	Prostigmata	Hygrobatidae	*Hygrobates*		water mites
Arthropoda	Arachnida	Trombidiformes	Prostigmata	Lebertiidae	*Lebertia*		water mites
Arthropoda	Arachnida	Trombidiformes	Prostigmata	Sperchonidae	*Sperchon*		water mites
Arthropoda	Arachnida	Trombidiformes	Prostigmata	Torrenticolidae	*Torrenticola*		water mites
Arthropoda	Entognatha	Collembola					springtails
Arthropoda	Insecta	Coleoptera	Polyphaga	Dryopidae	*Helichus*		long-toed water beetles
Arthropoda	Insecta	Coleoptera	Adephaga	Dytiscidae			predacious diving beetles
Arthropoda	Insecta	Coleoptera	Adephaga	Dytiscidae	*Agabus*		predacious diving beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Cleptelmis*	*addenda*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Narpus*	*concolor*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Optioservus*		riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Optioservus*	*divergens*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Optioservus*	*divergens/ pecosensis*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Optioservus*	*quadrimaculatus*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Zaitzevia*	*parvulus*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Zaitzevia*	*parvula*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Hydrophilidae			water scavenger beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Hydrophilidae	*Paracymus*		water scavenger beetles
Arthropoda	Insecta	Diptera					flies
Arthropoda	Insecta	Diptera		Ceratopogonidae			biting midges
Arthropoda	Insecta	Diptera		Ceratopogonidae	*Atrichopogon*		biting midges
Arthropoda	Insecta	Diptera		Ceratopogonidae	*Culicoides*		biting midges
Arthropoda	Insecta	Diptera		Ceratopogonidae	*Probezzia*		biting midges
Arthropoda	Insecta	Diptera		Thaumaleidae			trickle midges
Arthropoda	Insecta	Diptera	Brachycera	Dolichopodidae			long-legged flies
Arthropoda	Insecta	Diptera	Brachycera	Empididae	*Neoplasta*		dagger flies
Arthropoda	Insecta	Diptera	Brachycera	Stratiomyidae	*Caloparyphus*		soldier flies
Arthropoda	Insecta	Diptera	Nematocera	Chironomidae			midges
Arthropoda	Insecta	Diptera	Nematocera	Dixidae	*Dixa*		meniscus midges

Appendix C. Aquatic macroinvertebrate taxa collected in Capulin Creek, 2008 *continued*

Phylum	Class	Order	Suborder	Family	Genus	Species	Common Name
Annelida	Clitellata						segmented worms
Arthropoda	Arachnida	Trombidiformes					water mites
Arthropoda	Arachnida	Trombidiformes	Prostigmata	Hygrobatidae	*Hygrobates*		water mites
Arthropoda	Arachnida	Trombidiformes	Prostigmata	Lebertiidae	*Lebertia*		water mites
Arthropoda	Arachnida	Trombidiformes	Prostigmata	Sperchonidae	*Sperchon*		water mites
Arthropoda	Arachnida	Trombidiformes	Prostigmata	Torrenticolidae	*Torrenticola*		water mites
Arthropoda	Entognatha	Collembola					springtails
Arthropoda	Insecta	Coleoptera	Polyphaga	Dryopidae	*Helichus*		long-toed water beetles
Arthropoda	Insecta	Coleoptera	Adephaga	Dytiscidae			predacious diving beetles
Arthropoda	Insecta	Coleoptera	Adephaga	Dytiscidae	*Agabus*		predacious diving beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae			riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Cleptelmis*	*addenda*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Narpus*	*concolor*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Optioservus*		riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Optioservus*	*divergens*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Optioservus*	*divergens/ pecosensis*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Optioservus*	*quadrimaculatus*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Zaitzevia*	*parvulus*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Elmidae	*Zaitzevia*	*parvula*	riffle beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Hydrophilidae			water scavenger beetles
Arthropoda	Insecta	Coleoptera	Polyphaga	Hydrophilidae	*Paracymus*		water scavenger beetles
Arthropoda	Insecta	Diptera					flies
Arthropoda	Insecta	Diptera		Ceratopogonidae			biting midges
Arthropoda	Insecta	Diptera		Ceratopogonidae	*Atrichopogon*		biting midges
Arthropoda	Insecta	Diptera		Ceratopogonidae	*Culicoides*		biting midges
Arthropoda	Insecta	Diptera		Ceratopogonidae	*Probezzia*		biting midges
Arthropoda	Insecta	Diptera		Thaumaleidae			trickle midges
Arthropoda	Insecta	Diptera	Brachycera	Dolichopodidae			long-legged flies
Arthropoda	Insecta	Diptera	Brachycera	Empididae	*Neoplasta*		dagger flies
Arthropoda	Insecta	Diptera	Brachycera	Stratiomyidae	*Caloparyphus*		soldier flies
Arthropoda	Insecta	Diptera	Nematocera	Chironomidae			midges

Appendix C. Aquatic macroinvertebrate taxa collected in Capulin Creek, 2008 *continued*

Phylum	Class	Order	Suborder	Family	Genus	Species	Common Name
Arthropoda	Insecta	Diptera	Nematocera	Dixidae	*Dixa*		meniscus midges
Arthropoda	Insecta	Diptera	Nematocera	Psychodidae	Pericoma		moth flies/sand flies
Arthropoda	Insecta	Diptera	Nematocera	Simuliidae			black flies
Arthropoda	Insecta	Diptera	Nematocera	Simuliidae	Simulium		black flies
Arthropoda	Insecta	Diptera	Nematocera	Tipulidae			crane flies
Arthropoda	Insecta	Diptera	Nematocera	Tipulidae	Antocha	monticola	crane flies
Arthropoda	Insecta	Diptera	Nematocera	Tipulidae	Dicranota		crane flies
Arthropoda	Insecta	Diptera	Nematocera	Tipulidae	Limnophila		crane flies
Arthropoda	Insecta	Diptera	Nematocera	Tipulidae	Limonia		crane flies
Arthropoda	Insecta	Diptera	Nematocera	Tipulidae	Pedicia		crane flies
Arthropoda	Insecta	Diptera	Nematocera	Tipulidae	Rhabdomastix		crane flies
Arthropoda	Insecta	Diptera	Nematocera	Tipulidae	Tipula		crane flies
Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Ephemerellidae			spiny crawler mayflies
Arthropoda	Insecta	Ephemeroptera	Furcatergalia	Leptohyphidae			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	Pisciforma	Baetidae	Callibaetis		small minnow mayflies
Arthropoda	Insecta	Ephemeroptera	Pisciforma	Baetidae	Diphetor	hageni	small minnow mayflies
Arthropoda	Insecta	Ephemeroptera	Pisciforma	Baetidae	Fallceon	quilleri	small minnow mayflies
Arthropoda	Insecta	Ephemeroptera	Setisura	Heptageniidae			stream mayflies
Arthropoda	Insecta	Ephemeroptera	Setisura	Heptageniidae	Cinygmula		stream mayflies
Arthropoda	Insecta	Hemiptera	Heteroptera	Veliidae	Microvelia		broad-shoulder water striders
Arthropoda	Insecta	Odonata	Anisoptera	Aeshnidae			darners
Arthropoda	Insecta	Odonata	Anisoptera	Aeshnidae	Oplonaeschna	armata	darners
Arthropoda	Insecta	Odonata	Anisoptera	Cordulegastridae	Cordulegaster	dorsalis	spiketails
Arthropoda	Insecta	Odonata	Zygoptera	Coenagrionidae			narrow-winged damselflies
Arthropoda	Insecta	Odonata	Zygoptera	Coenagrionidae	Argia		narrow-winged damselflies
Arthropoda	Insecta	Plecoptera					stoneflies
Arthropoda	Insecta	Plecoptera	Euholognatha	Capniidae			small winter stoneflies
Arthropoda	Insecta	Plecoptera	Euholognatha	Nemouridae			spring stoneflies
Arthropoda	Insecta	Plecoptera	Euholognatha	Nemouridae	Zapada	cinctipes	spring stoneflies

Appendix C. Aquatic macroinvertebrate taxa collected in Capulin Creek, 2008 *continued*

Phylum	Class	Order	Suborder	Family	Genus	Species	Common Name
Arthropoda	Insecta	Plecoptera	Systellognatha	Chloroperlidae			green stonflies
Arthropoda	Insecta	Plecoptera	Systellognatha	Chloroperlidae	Sweltsa		green stonflies
Arthropoda	Insecta	Plecoptera	Systellognatha	Perlodidae			common stoneflies
Arthropoda	Insecta	Plecoptera	Systellognatha	Perlodidae	Isoperla		common stoneflies
Arthropoda	Insecta	Trichoptera					caddisflies
Arthropoda	Insecta	Trichoptera		Calamoceratidae	Phylloicus		comblipped case maker caddisfly
Arthropoda	Insecta	Trichoptera		Glossosomatidae			saddle case maker caddisflly
Arthropoda	Insecta	Trichoptera		Glossosomatidae	Glossosoma		saddle case maker caddisflly
Arthropoda	Insecta	Trichoptera		Helicopsychidae	Helicopsyche		snail case maker caddisfly
Arthropoda	Insecta	Trichoptera		Hydropsychidae			common net-spinner caddisfly
Arthropoda	Insecta	Trichoptera		Hydropsychidae	Cheumatopsyche		common net-spinner caddisfly
Arthropoda	Insecta	Trichoptera		Hydropsychidae	Hydropsyche		common net-spinner caddisfly
Arthropoda	Insecta	Trichoptera		Hydroptilidae			purse case maker caddisfly
Arthropoda	Insecta	Trichoptera		Hydroptilidae	Hydroptila		purse case maker caddisfly
Arthropoda	Insecta	Trichoptera		Lepidostomatidae	Lepidostoma		lepidostomatid case maker caddisfly
Arthropoda	Insecta	Trichoptera		Leptoceridae	Oecetis		longhorned case maker caddisfly
Arthropoda	Insecta	Trichoptera		Limnephilidae			northern case maker caddisfly
Arthropoda	Insecta	Trichoptera		Polycentropodidae	Polycentropus		trumpetnet & tubemaking caddisfly
Arthropoda	Insecta	Trichoptera		Sericostomatidae	Gumaga		bushtailed case maker caddisfly
Mollusca	Bivalvia	Veneroida		Pisidiidae	Pisidium		peaclams

Appendix D Physical habitat data collected from Capulin Creek at BAND, 2008

Channel Dimensions	Velocity (m/s)		Depth (m)		Wetted	Active
	Mean	SD	Mean	SD	Channel (m)	Channel (m)
CAP01						
1	0.15	0.14	0.04	0.01	1.30	4.35
2	0.10	0.08	0.05	0.04	1.30	3.40
3	0.14	0.11	0.04	0.02	1.90	5.40
4	-	-	-	-	0.85	10.90
5	0.19	0.20	0.04	0.02	0.93	7.15
6	0.07	0.10	0.07	0.06	1.69	5.00
7	0.12	0.21	0.16	0.26	1.10	5.20
8	0.27	0.23	0.04	0.01	0.87	4.40
9	0.13	0.09	0.03	0.02	1.05	3.10
10	0.10	0.11	0.04	0.04	1.50	7.40
11	0.11	0.17	0.04	0.04	1.92	3.89
CAP02						
1	0.05	0.01	0.15	0.06	0.68	4.80
2	0.00	< 0.01	0.01	0.01	1.34	3.10
3	0.03	0.03	0.11	0.02	0.65	2.83
4	-	-	-	-	0.00	2.84
5	0.02	0.02	0.06	0.02	1.27	2.58
6	0.03	0.03	0.06	0.03	1.03	8.55
7	0.03	0.03	0.13	0.02	0.79	6.80
8	0.00	< 0.01	0.01	0.01	0.60	3.95
9	0.03	0.03	0.08	0.03	0.70	3.81
10	0.00	< 0.01	0.03	0.03	1.05	2.93
11	0.01	0.01	0.08	0.01	1.39	3.55

Appendix H. Examples of Selected Macroinvertebrate Habitat Structures

NPS photo

Figure H-1. Algal mat

NPS photo

Figure H-2. Leaf pack

NPS photo

Figure H-3. Rocks

NPS photo

Figure H-4. Vegetation

NPS photo

Figure H-5. Woody debris

Appendix I. Geomorphic Channel Unit Descriptions

NPS photo

Figure I-1. Backwater: standing water, disconnected from main channel during low flow (foreground, right)

NPS photo

Figure I-2. Cascade: turbulent series of short falls and small scour basins; prominent feature of high gradient bedrock and cascade reaches

NPS photo

Figure I-3. Chute: narrow, high-gradient slots in bedrock containing fast moving water

NPS photo

Figure I-4. Dammed Pool: impoundment of water formed by an obstruction (e.g., debris, beaver dam, and landslide)

NPS photo

Figure I-5. Exposed rock or bar: found in bedrock, cascade, step-pool, and pool-riffle reaches. Narrow, high-gradient slots or chutes containing fast moving water, with pools above and/or below.

NPS photo

Figure I-6. Falls: vertical drop of water spanning a flow obstruction; commonly found in bedrock, cascade, and step-pool stream reaches

NPS photo

Figure I-7. Glide: non-turbulent, fast-moving water; found in bedrock, cascade, step-pool, and pool-riffle reaches

NPS photo

Figure I-8. Rapid: moderate gradient, deep, longitudinally planar turbulent flow; prominent feature of plane-bed streams

NPS photo

Figure I-9. Riffle: most common type of turbulent flow in lower gradient alluvial channels; found in plane bed and pool-riffle reaches

NPS photo

Figure I-10. Run: non-turbulent, fast-moving water in lower gradient alluvial channels; typically deeper than riffles or glides

NPS photo

Figure I-11. Scour Pool: depression in stream bed formed by scouring action

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