

Suggested Biomonitoring Protocol and Status of Stream Quality at Six Great Plains National Parks

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Abstract.—To develop a biomonitoring protocol for streams in National Parks in the Great Plains, the variation of some commonly used invertebrate community indices was measured for 10 warmwater stream sites during February– November 1989 and for 3 warmwater stream sites during June– August 1989. Streams were sampled with a square-foot Surber sampler or a Hester-Dendy artificial substrate sampler. Significant heterogeneity of variance of invertebrate density ($P < 0.05$) among sites suggested that sampler efficiency influenced sample variance. Model III (mixed model) analysis of variance was used to examine temporal variance (among sampling dates, across sites) for invertebrate community indices. For data collected with a Surber sampler, all temporal components, across a year, were significant ($P < 0.01$) and were 2.17–6.07 times greater than variance among samples collected at a site during a single date. Within a season, temporal components for 7 of 9 indices were significant ($P < 0.01$) and were 2.13–3.45 times greater than variance among samples collected at a site during a single date. For data collected with a Hester-Dendy sampler, temporal components for 6 of 9 indices, across a year, were significant ($P < 0.05$) and were 0.87–6.29 times greater than variance among samples collected at a site during a colonization period. Estimated variance of indices for samples that were collected at different dates within a year and at different dates within a season indicated that, for a given number of temporal samples, variance would be much lower for the latter. Results indicate that the optimum protocol for monitoring warmwater streams would include the collection of five replicate samples during three sampling period or colonization periods in June–August. Biological criteria thresholds for Surber sampler data, based on variance estimates, indicate that the family biotic index must increase by 0.74 and ratio of Ephemeroptera, Trichoptera, and Plecoptera abundance to Chironomidae abundance, family level richness and diversity must decrease by 0.03, 0.75, and 0.16, respectively, to exceed the criteria. Biological criteria thresholds for Hester-Dendy sampler data, based on variance estimates, indicate that the family biotic index must increase by 0.74 and invertebrate density, genus level richness and diversity must decrease by 1257 m², 4.6, and 0.23, respectively, to exceed the criteria. Exceedance of more than two criteria suggest that additional study is required to determine the nature of the biological impact.

Trend analysis of all available data suggested a significant decrease in stream quality at Skegg's Branch and Wilson's Creek at Wilson's Creek National Battlefield from 1988-95, whereas water quality at Pipestone Creek in Pipestone National Monument increased from 1989-95. The most recent water quality ratings for all sites were also reported.

INTRODUCTION

Quantitative analyses of invertebrate community data are increasingly being used by natural resource professionals to monitor stream water quality and as a basis for formulating stream management regulations (Cairns Jr. and Pratt 1993; Resh and McElray 1993). Unfortunately, resource professionals are rarely afforded the opportunity to examine the adequacy of their data and, if necessary, revise their monitoring protocol. The ability to statistically detect phenomena (e.g., a change in community structure over time) depend upon the quality of the data (Cliff 1987). High variance is one factor that influences the ability to statistically detect phenomena (Gold 1969) and can be overcome by increasing sample size and/or collecting samples in a manner that minimizes variance (Snedecor and Cochran 1967; Sokal and Rohlf 1981). Consequently, collecting too few samples or collecting samples in an inappropriate manner can impede the ability to detect changes in stream quality. In addition, monitoring protocols should take into account the cost of collecting samples and should attempt to minimize both variance and costs (Peterson and Rabeni 1995). Thus, developing a sampling strategy that maximizes biological insight and minimizes costs is an important objective while developing a monitoring protocol.

Sampling strategy is not the only factor that should be considered when developing monitoring protocols. Using biological criteria (e.g., community indices) that have no sound biological basis or that are insensitive to change may impede the ability to detect changes in stream quality. Distinguishing the effects of stream quality on the structure of the lotic community is the purpose of monitoring protocols. Biological criteria that do not accurately portray the aspects of lotic community structure that are influenced by stream quality may be useless as indicators (Karr 1981; Karr 1991; Resh and McElray 1993). In addition, biological criteria impairment thresholds, i.e., the values that are used to determine the significance of a change in community structure, should have statistical and/or biological significance (Bode and Novak 1995). Thus, another important objective while developing a monitoring protocol should be to develop biological criteria that are biologically valid and statistically sound.

The study objectives were to: (1) identify the main sources of variation in invertebrate community structure in warmwater streams at six National Parks in the Great Plains, (2) devise the most cost efficient sampling strategy, and (3) develop biological criteria for detecting changes in water quality. In addition, stream quality trends and the most recent status of stream water quality at the Great Plains National Parks were investigated.

METHODS

Study sites

Streams in six Great Plains National Parks (Table 1) were sampled intensively from 1988 through 1989 (Harris et al. 1990) and sporadically from 1990 through 1995 (National Park Service, unpublished data). The most complete data set available, across sites, are for 1989. Consequently, within year variance was assessed and stream quality monitoring protocol synthesized, using the 1989 data. In addition, data for more than one sampling date within a season were only available for Wilson's Creek National Battlefield, which was used to assess within season (i.e., summer, defined here as June-August) variance. Long term trends were examined using all data available. A description of the history of each park and of the habitat and biota at each site are provided in Harris et al. (1990).

Sampling methods

In streams with well developed riffle-pool patterns, riffles were sampled with a square-foot (0.0929 m²) Surber sampler with capture net mesh size ≤ 1.05 mm (Table 1). The sampler was placed in areas of a riffle with sufficient current and depth to wash dislodged organisms into the capture net (Harris et al. 1990). Substrate within the sampler was disturbed with a garden cultivator or similar device to a depth of 8-10 cm to dislodge organisms. Individual rocks within the sampler were scrubbed to dislodge clinging organisms. Five replicate samples were collected from each riffle during a sampling date. Each sample was placed in a plastic bag and preserved in 5% formalin.

The Niobrara River at Agate Fossil Beds National Monument and Cub Creek at Homestead National Monument were sampled with Hester-Dendy multiplate samplers (Rosenburg and Resh 1982). Each Hester-Dendy sampler consisted of nine 57.76 cm² square hardboard plates, separated by 3 mm spacers, and connected by a long eye bolt, providing 0.0929 m² of surface area for invertebrate colonization (Harris et al. 1990). Five replicate samplers at each site were suspended in the water column with a nylon cord. After a 30- 35 day colonization period, samplers were removed from the stream, placed in plastic bags, and preserved in 5% formalin.

All samples were brought back to the laboratory and macroinvertebrates were counted, identified to the lowest practical taxonomic level, and stored in 80% ethanol (Harris et al. 1990).

Community indices

Total density of invertebrates, across taxa, have been used to assess stream quality (Plafkin et al. 1989). In general, invertebrate densities tend to decrease when communities are exposed to some sort of distress such as water pollution or habitat alteration (Resh and Grodhaus 1983). The density of invertebrates, across taxa, was calculated for each replicate sample by dividing the number of invertebrates collected by the area of each sampler, 0.0929 m².

Biotic indices (BI) are commonly used as an indicators of water quality (Resh and Jackson. 1993; Resh and McElray 1993). BI use taxon specific (families, genera, or species) pollution tolerance values to calculate index scores which are then used to assess stream quality. Family biotic index (FBI) scores were calculated for all sites using family tolerance scores from Hilsenhoff (1988) (Appendix A). In addition, the biotic index for Ozark streams (OBI) (Jones et al. 1981) and Missouri Biotic Index (MBI) (Youngsteadt and Witherspoon undated), were calculated for data from streams in SW Missouri at George Washington Carver National Monument and Wilson's Creek National Battlefield. All BI were calculated for each replicate sample as:

$$BI = \sum n_i * a_i / N;$$

where N is the total number of individuals in the sample, n_i is the total number of individuals and

a_i the tolerance value for the i th family or taxa. FBI scores were adjusted for seasonal changes in invertebrate community structure by subtracting 0.18 from summer sample scores and adding 0.13 to spring and fall sample scores.

The ratio of Ephemeroptera, Trichoptera, and Plecoptera (EPT) abundance to Chironomidae abundance has also been used to evaluate stream quality (Resh and Grodhaus 1983). In general, EPT taxa are thought to be relatively pollution intolerant, whereas Chironomidae are considered pollution tolerant, resulting in large ratio values for better quality streams and lower values for poorer quality streams. The EPT ratios (R) were calculated for each replicate sample as:

$$R = \text{EPT}/[\text{EPT} + \text{C}];$$

where EPT is the abundance of EPT taxa and C is the abundance of Chironomidae.

Richness (e.g., total number of taxa or families), can be a useful criterion to describe the biological quality of a stream (Resh and Grodhaus 1983). Low richness may indicate that a stream has been subject to one or more perturbations (e.g., pollution), whereas high values suggest a more stable or quality environment. Richness of each replicate sample was determined at the family, genus, and taxa (i.e., species or lowest) level of identification.

Diversity is a measure of how the number of individuals are divided among the species in a community and it can be useful to describe the structure of a invertebrate community. Maximum diversity of a community is when the individuals are distributed as evenly as possible among species (Pielou 1966), which suggest better stream quality (Resh and Jackson 1993). Shannon-Wiener diversity indices (H) in Pielou (1966) were calculated for each replicate sample at the family, genus, and taxa level of identification as:

$$H = -\sum (n_i/N) \ln(n_i/N);$$

where N is the total number of individuals in the sample, n_i is the total number of individuals in the i th family, genus, or taxa.

Statistical analysis

The composition of invertebrate samples (e.g., number of taxa) can be influenced by the sampling method. Artificial substrate samplers, such as the Hester-Dendy multiplate sampler, rely on invertebrate colonization within a predetermined time period to characterize the invertebrate community. Consequently, artificial substrate samplers may under represent or miss certain invertebrate taxa, such as species which burrow in the stream bottom, and over represent taxa that rapidly colonize (Rosenburg and Resh 1982). In contrast, bottom samplers, such as the Surber sampler, can consistently collect borrowing species. However, the composition of bottom samples are influenced by the physical habitat at a site, such substrate types (Resh and McElray 1993). To avoid the potential influence of sampling method on the development of monitoring protocol, Hester-Dendy and Surber sampler data were analyzed separately.

The normality of the distribution of the community indices for each site and sampling date were assessed using Lilliefors' test (Lilliefors 1967). Bartlett's test for equality of variance (Snedecor and Cochran 1967) was used to compare the magnitude of the variance of community indices among sites for each sampling date. Significantly non-normal indices ($P < 0.05$) or indices with significantly different variances ($P < 0.05$) were transformed and reexamined.

Many of the indices may provide redundant information on stream quality and would, therefore, be unnecessary to calculate. To assess the relation among indices, Pearson correlations were run among all pairs of indices. In addition, principal component analysis (PCA) was done on the correlation matrix of the indices to evaluate index redundancy.

Within year (i.e., 1989) or season variation of community indices, across sites, was assessed with a mixed model (model III) ANOVA using site as a fixed factor and sampling date as a random factor. A mixed model ANOVA differs from the more familiar fixed (model I) and random (model II) models by containing both fixed and random factors (Neter et al. 1990), the designation of which depends mainly upon intent of the analysis (Lewis 1978) provided that the assumptions regarding proper randomization are fulfilled.

A crossed nested design ANOVA was used to assess the variability among dates within a site. Sampling dates were nested within site because sampling dates within a year or season differed among sites. In addition, the variability among dates could be assessed without being affected by differences among sites. Residuals were inspected for normality, constancy of variance, and independence.

Variance within a year or season was estimated from the ANOVA expected mean squares following Snedecor and Cochran (1967):

$$S^2_D = (MS_D - MS_E)/n$$

$$S^2_E = MS_E$$

where: S^2 = variance, MS = mean square, D = dates, E = error (i.e., variance among replicates at a site on a sampling date), and n = the harmonic mean of the number of dates sampled at each site.

Total variance (V) can be estimated from the individual components above with:

$$V = (S^2_D/d) + (S^2_E/nd)$$

where S^2 = variance, D = dates, E = error, d = number of dates sampled within a year or season, and n = the number of replicate samples collected at a site on each date. Using the above equation, I assumed that 5 replicate samples would be collected at a site on each date ($n=5$) to graph the number of temporal samples (i.e., sampling dates) versus estimated variance for invertebrate density from all sites and all community indices from Wilson's Creek National Battlefield summer 1989 data and 1989 Hester-Dendy data.

Biological criteria impairment thresholds are the level of change in an index that would be considered significant enough to indicate impairment (e.g., pollution) to the aquatic community. To determine the community index thresholds for Great Plains National Park streams, I assumed that a one tailed t-test would be used to compare an index from one year to the next or before and after the implementation of a new management strategy. The minimum detectable change in a

community index can be calculated by using a rearrangement of the t-test formula (Parkinson et al. 1988):

$$p = \sqrt{((SD/X)^2 k)/N}; \quad (1)$$

where N is the total number of samples (i.e., dates*replicates), k is a constant that varies with α level and statistical power (Snedecor and Cochran 1967), SD^2 and X are the variance and community index mean for a site respectively, and p is the detectible change expresses as a proportion of the mean. The threshold (T) is the minimum change of an index that can be statistically detected and is a function of p and X:

$$T = pX. \quad (2)$$

By combining equations 1 and 2 the threshold is:

$$T = X\sqrt{((SD^2/X^2*k)/N)}. \quad (3)$$

The right half of the equation 3 can be simplified as:

$$T = X\sqrt{((SD^2*k)/N*(1/X^2))}, \quad (4)$$

$$T = X\sqrt{((SD^2*k)/N)} * \sqrt{(1/X^2)}, \quad (5)$$

$$T = X\sqrt{((SD^2*k)/N)} * (1/X), \quad (6)$$

$$T = \sqrt{((SD^2*k)/N)}. \quad (7)$$

Thus, the impairment threshold (T) is a function of the estimated variance, SD^2 , the total number of samples, N, and the constant that varies with α level and statistical power, k. Equation 7 was used to calculate thresholds for community indices and total variance estimates from Wilson's Creek National Battlefield summer data and Hester-Dendy sampler data, with $\alpha=0.05$ and 80% statistical power ($k=12.57$).

Linear regression was used to examine trends in index values for each site during the study, with date as the independent and community index as the dependent variables. Community indices that were tested include total invertebrate density, FBI, EPT ratio, and family richness and

diversity. Trends were considered significant at $\alpha = 0.01$ to control possible increases in type I error associated with multiple testing (Neter et al. 1990). Residuals were inspected for outliers, normality, and independence. If necessary, data were transformed to satisfy assumptions of normality and constancy of variance.

RESULTS

Lilliefors' test of 1989 data indicated that the indices did not significantly deviate from normality ($P > 0.05$). However, variance was significantly heterogeneous among sites for total invertebrate density and EPT ratio ($P < 0.05$) for Surber sampler data. Inspection of the data suggested that variance of invertebrate density was proportional to the means. After square root transformation, variances were not significantly heterogeneous ($P > 0.05$). EPT ratio at West Branch Wapsinonoc appeared to vary less than other sites. I was unable to remedy the heterogeneity via transformation. After excluding this site, Bartlett's test indicated that variances were not significantly heterogeneous ($P > 0.05$).

Surber sampler

Pearson correlation of community indices indicated that invertebrate density was positively significantly correlated ($P < 0.05$) with family biotic index (FBI) and the biotic index for Ozark streams (OBI) (Table 2). The FBI was significantly negatively correlated ($P < 0.01$) with EPT ratio, family diversity, genus diversity and taxa diversity, whereas it was positively correlated ($P < 0.01$) with Missouri biotic index (MBI) and OBI, the latter two being positively intercorrelated. EPT ratio was positively correlated with all diversity and richness measures and negatively correlated with the MBI and OBI, the latter two were negatively correlated with all diversity and richness measures (Table 2).

Principal component analysis reflected the correlation matrix. Measures of richness and diversity had the largest positive loadings on principal component 1 (Table 3), which accounted for 57.1% of the variability of the 9 indices. FBI had the largest absolute loading on principal

component 2 followed by EPT ratio, the loading on the former was positive, the latter, negative. Total density had the largest positive loading on principal component 3, which accounted for 12.3% of the variability of the 9 indices.

All indices varied significantly ($P < 0.01$) across time, within a year (Table 4). Variance among sampling dates within year was 2.17- 6.07 times greater than variation among replicate samples taken during a sampling date, with the smallest among date/ among replicate ratio for family (2.17) and genus (2.74) richness and the largest for total density (6.83).

Seven of the 9 indices varied significantly ($P < 0.05$) across time, within summer, for sites at Wilson's Creek National Battlefield (Table 5). Variance did not differ significantly for family richness and diversity. In contrast to within year variance, variance among sampling dates during the summer was 0.37- 3.45 times greater than variation among replicate samples taken during a sampling date. The smallest among date/ among replicate ratio was for family richness (0.37) and diversity (0.39) and largest for EPT ratio (3.45). In all cases, within season variance for genus and taxa level measures were greater than for family measures (Table 5).

Estimated total variance of invertebrate density for samples that were collected at different dates within a year and at different dates within a season indicated that, for a given number of temporal samples, variance would be much lower for the latter (Figure 1). The greater variance among sampling dates within a year appeared to be unrelated to variance among replicates collected on the same date, which were 23.02 and 20.11 for within a year and within a season, respectively.

Estimated total variance for invertebrate density (Figure 1) and the EPT ratio (Figure 2) indicated that the greatest reduction in total variance per temporal sample would occur if 5 replicate samples were collected during 2-3 randomly selected days during the summer. In addition, the reduction in total variance per temporal sample decreased >3 temporal samples.

Similar to invertebrate density, estimates of total variance for the FBI (Figure 2), indicated that the greatest decrease in total variance per temporal sample would occur if 5 replicate samples were collected during 3 randomly selected days during the summer, while the reduction in total

variance per sample would decrease for >3 temporal samples.

The greatest reduction in total variance for taxa and genus diversity per temporal sample was also when 5 replicate samples were collected on 3 sampling days during the summer. However, the reduction in total variance per temporal sample >3 days was larger than invertebrate density, FBI, EPT ratio, and family diversity. Total variance of family diversity, in contrast to the other indices, was reduced much less with additional temporal samples (Figure 2).

Similar to the other indices, the greatest reduction in total variance of richness measures per temporal sample occurred when 5 replicate samples were collected on 3 sampling days during the summer (Figure 3). However, the reduction in total variance per temporal sample >3 days was greater for genus and taxa richness.

Biological criteria impairment thresholds for the sites sampled with the Surber sampler were calculated with total variance estimates for 5 replicates per sampling date and 3 sampling dates within the summer, for a total of 15 samples. To exceed the criteria, total density must decrease by 1827 m², whereas the FBI must increase by 0.74 (Table 6), the average difference between water quality classes (Table 7). The remaining indices must decrease; EPT ratio by 0.03, family richness and diversity by 0.75 and 0.16, genus richness and diversity by 1.82 and 0.23, taxa richness and diversity by 2.83 and 0.38, respectively, to exceed the criteria.

Hester-Dendy sampler

A complete 1989 data set for Hester-Dendy sampler data was only available for the two sites at Homestead National Monument. Therefore, I assumed that the results of the analysis of the Homestead National Monument data would be applicable to other Hester-Dendy sampler sites.

Pearson correlation of community indices indicated that the FBI was significantly negatively correlated ($P < 0.05$) with EPT ratio, and family, genus, and taxa richness (Table 8). EPT ratio was significantly positively correlated ($P < 0.01$) with all diversity and richness measures the latter were significantly intercorrelated ($P < 0.01$). Total invertebrate density was not significantly correlated ($P > 0.05$) with any community index.

Principal component analysis reflected the correlation matrix with the EPT ratio and the measures of richness and diversity with the largest positive loadings on principal component 1, which accounted for 62.4% of the variability of the 9 indices (Table 9). Total density had the largest positive loading on principal component 2. The FBI had the largest positive loading on principal component 3, which accounted for 10.8% of the variability of the 9 indices.

Six of the 9 indices varied significantly ($P < 0.05$) among dates, within a year, for sites at Homestead National Monument (Table 10). Variance did not differ significantly for the FBI, EPT ratio, and family diversity, with the among date variance for the latter two being negative. Consequently, they were treated as zero for threshold calculations. For the indices with the among date variance > 0 , the among date variance was 1.28- 6.29 times greater than variation among replicate samples taken during a sampling date. The smallest among date/ among replicate ratio was for taxa diversity (1.28) and largest for family richness (6.29).

Estimated total variance of invertebrate density (Figure 4) indicated that the greatest reduction in total variance per temporal sample would occur if 5 replicate samples were collected during 3 randomly selected colonization periods. The reduction in total variance per temporal sample decreased beyond 2 temporal samples, but was still substantial.

The greatest reduction in total variance for richness measures and the FBI per temporal sample was when 5 replicate samples were collected during 3 randomly selected colonization periods (Figures 5 and 6). Similar to total density, the reduction in total variance per temporal sample > 3 colonization periods was still be fairly high.

The greatest reduction in total variance for taxa and genus diversity per temporal sample was when 5 replicate samples were collected during 2 randomly selected colonization periods (Figure 6). In addition, the reduction in total variance per temporal sample > 2 colonization periods was fairly low

Biological criteria impairment thresholds for the sites sampled with the Hester-Dendy sampler were calculated with total variance estimates for 5 replicates per colonization period and 3

colonization periods within the year, for a total of 15 samples. To exceed the criteria, total density must decrease by 1257 m², whereas the FBI must increase by 0.74 (Table 11), the average difference between water quality classes (Table 7). The remaining indices must decrease; EPT ratio by 0.01, family richness and diversity by 8.60 and 0.14, genus richness and diversity by 4.60 and 0.23, taxa richness and diversity by 4.89 and 0.23, respectively, to exceed the criteria.

Status of stream water quality

Community indices in both sites at Agate Fossil Bed National Monument did not vary significantly ($P>0.01$) from 1989-1995.

The density of aquatic invertebrates in HMS1 and HMS2 (Figures 7 and 8) and family richness in HMS2 (Figure 9) at Homestead National Monument increased significantly ($P<0.01$) from 1989-1995. The remaining indices at HMS1 and HMS2 sites did not vary significantly ($P>0.01$) during the same time period.

The FBI in the PPS1 site at Pipestone National Monument decreased significantly ($P=0.0029$) from 1989-1995 (Figure 10), whereas the remaining indices at PPS1 and PPS2 sites did not vary significantly ($P>0.01$) during the same time period.

The density of aquatic invertebrates (Figure 12) and family richness (Figure 13) in HHR at Herbert Hoover National Historic Site decreased significantly ($P<0.01$) from 1989-1990. The remaining indices did not vary significantly ($P>0.01$) during the same time period.

Community indices in both sites at George Washington Carver National Monument did not vary significantly ($P>0.01$) from 1989-1995.

The FBI increased (Figures 13, 16, and 18) and family richness (Figures 14, 17, and 20) decreased significantly ($P<0.01$) from 1989-1995 in all three sites at Wilson's Creek National Battlefield. Family diversity decreased significantly ($P<0.01$) at UPPER and SKEGGS (Figures 15 and 21). In addition, the EPT ratio significantly decreased ($P<0.0001$) at SKEGGS during the same time period (Figure 19). The remaining indices did not vary significantly at any of the sites ($P>0.01$) during the same time period.

Water quality ratings, based on FBI scores, for the most recent year for which data is available indicated that water quality in the Niobrara River at Agate Fossil Beds National Monument was fairly poor to poor (Table 12). Water quality in Cub Creek at Homestead National Monument was poor. Carver's and William's Branch at George Washington Carver National Monument water quality was fair, whereas water quality in West Branch Wapsinonoc Creek at Herbert Hoover National Historic Site was poor. Among the parks, the best water quality was in Pipestone Creek at Pipestone National Monument which had a good rating. In contrast, Wilson's Creek and Skegg's Branch at Wilson's Creek National Battlefield had fairly poor water quality ratings.

Water quality ratings for streams in SW Missouri, based on the biotic index for Ozark streams (OBI) (Jones et al. 1981) and Missouri Biotic Index (MBI) (Youngsteadt and Witherspoon undated), indicated that Carver's and William's Branch at George Washington Carver National Monument which had ratings from the OBI as slightly enriched and the MBI as little or none (1.94) and slightly enriched, respectively during 1992. Wilson's Creek and Skegg's Branch at Wilson's Creek National Battlefield had enriched and moderate pollution water quality ratings for the OBI and MBI, respectively.

DISCUSSION

Monitoring protocol

Sampling methods.- Choosing the appropriate sampling device is one of the most critical aspects of biomonitoring (Resh and McElray 1993). Thus, the first step of a monitoring protocol should be to establish a basis for choosing the appropriate sampling method. Stream benthic macroinvertebrate sampling devices can be roughly divided into 2 categories, artificial substrate samplers (e.g., Hester-Dendy) and natural substrate samplers (e.g., Surber). Substrate is standardized for artificial substrate samplers, which usually results in lower variability among

samples (Rosenburg and Resh 1982). However, in an extensive investigation of the effectiveness of various sampling devices, Voshell et al. (1989) concluded that direct sampling of natural substrate is preferable to artificial substrate samplers when appropriate natural substrate is available (e.g., gravel or rocky substrate). Thus, I suggest that the square-foot Surber sampler be used in streams with suitable substrate and, to maintain consistency with previously collected data, samples should be collected from riffles. In streams without gravel or rocky substrate, I suggest that Hester-Dendy multiplate samplers be used and, to maintain consistency with previously collected data, the colonization period should be 30-35 days long.

Sampling frequency.- The within year variation was much greater than the within summer variation for all community indices, which was consistent with previous investigations (see Resh and Rosenberg (1989) for a review). Consequently, a large number of samples would have to be collected throughout the year to be able to detect changes in stream quality, whereas a fewer number of samples would need to be collected within a season to detect an identical change in stream quality. An optimal monitoring protocol takes into account the cost of collecting samples and attempts to minimize both variance and costs (Peterson and Rabeni 1995). Thus, the optimal protocol for monitoring stream quality at National Parks in the Great Plains would be to collect samples during a single season, the summer. Within the summer, the reduction in variance per temporal sample decreased after more than three sampling periods for most indices (Figures 1-6). In other words, the cost per reduction in variance increased if samples were collected during more than three sampling periods. Therefore, I suggest that the monitoring protocol include the collection of five replicate Surber samples or five Hester-Dendy samplers on three sampling periods during the summer. In addition, I suggest that one sampling period be randomly selected per summer month to ensure proper interspersation.

Indices.- Biomonitoring protocols should use a multimetric approach to characterize stream quality because criteria (i.e., indices) often measure different aspects of the community (Bode and Novak 1995; Yoder and Rankin 1995). Biological criteria should measure aspects such as

community structure (richness, diversity), taxonomic composition (biotic indices, EPT ratios), and biological process (production, density) (Barbour et al. 1995). In addition, criteria should be selected on the basis of low variability (Resh and McElroy 1993). The low correlation of the family biotic index (FBI) with richness measures and its principal component loadings suggest that the FBI is measuring an aspect of the community not measured by the other indices, taxonomic composition. Similarly, the low correlation of invertebrate density and other community indices and its principal component loadings suggest that invertebrate density is measuring an aspect of the community not measured by the other indices, biological process. Invertebrate density estimates for raw (i.e., untransformed) Surber sample data were significantly heteroscedastic possibly due to differences in operator efficiency, mesh size, or a combination of both. Therefore, impairment criteria calculated for summer data from Wilson's Creek sites may not be applicable to all sites. Consequently, I recommend that the FBI should be used, in part, to monitor stream quality at all sites and invertebrate density at sites where the Hester-Dendy sampler is used.

The ratio of Ephemeroptera, Trichoptera, and Plecoptera abundance to Chironomidae abundance (EPT ratio) was correlated with richness and diversity measures and the FBI. However, principal component loading patterns differed between Surber and Hester-Dendy data, probably due to differences in the ability of each gear to sample aquatic invertebrates (Barton and Metcalfe-Smith 1992). The EPT ratio for Surber sampler data had large loadings on components with diversity and richness measures (positive) and the FBI (negative), whereas it only had high loadings on the component with richness and diversity measures for Hester-Dendy data. High loadings and correlations among indices suggest that they are redundant, i.e., they measuring the same aspect of the community (Hannaford and Resh 1995). Therefore, the EPT ratio and the richness and diversity measures are providing the same information about the community structure at sites sampled with the Hester-Dendy sampler. The high positive and negative principal component loadings for the EPT ratio from Surber data suggest that it may be measuring a slightly different aspect of taxonomic composition. Consequently, I suggest that the EPT ratio be used to

monitor communities only at sites where the Surber sampler is used.

The large correlations among richness and diversity measures and their high positive loadings on the same principal component suggest that they are measuring the same aspect, community structure. However, family level and genus level richness and diversity measures had the lowest variance for the Surber and Hester-Dendy data, respectively. Therefore, these indices may be more sensitive to changes in stream quality. In addition, higher taxonomic level measures have been used successfully to monitor stream quality (Kaesler and Herricks 1979; Osborne et al. 1980; Waterhouse and Farrell 1985). I recommend that community structure be characterized by family level richness and diversity at sites where the Surber sampler is used, whereas genus level measures should be used for Hester-Dendy sampler sites.

Criteria implementation.- To effectively detect changes in stream quality at National Parks in the Great Plains, I believe monitoring protocols should be implemented in a logical, integrated manner (Figure 22). Replicate samples should be collected during the summer with standardized methods and identified to the lowest taxonomic level. Indices should be calculated and compared to reference values to determine if they exceed biological criteria impairment thresholds (Table 13). I suggest that the protocol use reference values from the 1989 data because they are from the earliest and most complete data set available (Appendix B). I also suggest that the protocol initially use the biological criteria impairment thresholds calculated from the summer data from Wilson's Creek National Battlefield (WC). The similarity of variances (i.e., homogeneity) within a year for most indices suggested that the WC impairment thresholds are applicable to the other sites that use the Surber sampler. Differences between the index mean and reference condition which exceed the threshold indicate statistically significant change ($\alpha=0.05$). Because of the potential effects of multiple testing (Neter et al. 1990), I suggest that more than two indices should exceed the biological criteria impairment thresholds before concluding significant impact (Figure 22). However, I caution that statistical significance can be found even without human induced impact

(McElravy et al. 1989). The potential causes for the changes should be interpreted in light of other biological evidence (Norris and Georges 1993). Therefore, I recommend that the potentially impacted stream be thoroughly studied to determine the nature of the impacts.

Additional comments.- Monitoring trends through time or changes in stream quality from year to year differs from assessing the biological integrity (i.e., health) of a stream. When monitoring, community indices from a stream are compared to values from the previous year or a reference year, whereas community indices for a stream are compared to indices from reference streams when assessing biological integrity. With the former method, statistically significant changes in stream quality can be detected from the data. However, biological significance can only be inferred. To assess biological significance, the variability among indices for streams with similar water quality classes (e.g., good, fair, poor) should be determined. It would be preferable from a biological and legal standpoint to be able to assess biologically and statistically significant changes in stream quality (Adler 1995). Unfortunately, this data is not available. Most of the states that contain the National Parks are in the early stages of developing biological criteria and reference stream conditions are currently unavailable (Southerland and Stribbing 1995). Therefore, I recommend that in the future, Park Service personnel contact the respective resource agencies, obtain the information on their biological criteria, and integrate it into the monitoring protocol.

Consistency is one of the most important aspects of stream monitoring protocols. Differences in gear operation, specimen identification, and data entry can add significant variance to data (Hannaford and Resh 1995). To increase consistency among streams and between years, I recommend that the biomonitoring be conducted by the same individual or groups of individuals and that all data should be archived in the same location. Stream quality may also improve markedly through time which could lead to changes in mean index values and/or within season variability. In addition, Hester-Dendy thresholds were based upon data from across a year. Therefore, I suggest that reference values, thresholds, and sample size requirements be periodically

reevaluated and, if necessary, updated.

Status of stream water quality

As discussed above, assessing the biological integrity of a stream requires a comparison of community indices with reference streams. Biotic index ratings are based upon comparisons of the range of values for communities in reference streams and can be used to assess biological integrity (Karr 1991; Barbour et al. 1995; Yoder and Rankin 1995). Unfortunately, many biotic indices are region or stream specific because they use tolerance scores for species with limited geographical distributions. Therefore, established indices should be applied cautiously to new systems (Norris and Georges 1993). The family biotic index (FBI) was developed by Hilsenhoff (1988) for Wisconsin streams and has been modified for use on other systems (Plafkin et al. 1989). The FBI uses average tolerance values of arthropod species within a family and can be used to assess the water quality in streams with different species. Consequently, the FBI may be applicable over a larger geographical areas. The correlation between the FBI and the biotic indices for Missouri streams and the similarity in water quality ratings suggest that the FBI ratings may be applied with caution to evaluate the current biological integrity of National Park streams in the Great Plains.

The water quality of the Niobrara River at Agate Fossil Bed National Monument didn't appear to change significantly from 1989-95. The most recent FBI indicated that the water quality was fair to fairly poor, probably due to slight organic enrichment from the agricultural runoff (Harris et al. 1990).

Trend analysis of community indices suggested that water quality in Cub Creek at Homestead National Monument increased 1989-95. However, the amount of data may not be adequate, with only five samples collected in four years, and too few samples may lead to spurious results (Snedecor and Cochran 1967). In addition, the low density data were collected by Harris et al. (1990), whereas the high density data were consistently collected by Equatics (National Park Service unpublished data). Thus, the significant trends may be a result of too few samples, differences in sampling, or a combination of both. Cub Creek water quality was rated as poor for

1995, the most recent year available, probably due to significant nutrient enrichment from agricultural runoff (Harris et al. 1990).

The water quality at Pipestone Creek in Pipestone National Monument increased from 1989-95. Harris et al. (1990) reported significant water quality impacts from agricultural runoff and small industrial and urban sources. However, in 1993 the water quality rating was good. The apparent improvement in water quality may have been due to beneficial changes in land use or wastewater treatment.

Analysis of community indices from West Branch Wapsinonoc at Herbert Hoover National Historic Site during 1989-90 suggested a decrease in stream quality. However, the data did not cover a full range of seasons and the trend may have been seasonal. West Branch Wapsinonoc water quality was rated as poor, probably due to significant nutrient enrichment from agricultural runoff (Harris et al. 1990).

The water quality of Carver's and William's Branch in George Washington Carver National Monument didn't appear to change significantly from 1989-95. Harris et al. (1990) reported significant ground and surface water contamination of Carver's and William's Branch. Nonetheless the FBI suggested that the water quality in Carver's and William's Branch during 1995 were fair. The discrepancy may be due to an improvement in water quality due to beneficial changes in land use or wastewater treatment. Another possibility is that the FBI scores were an artifact of too few samples and not an accurate depiction of the actual conditions.

Trend analysis of stream quality suggested a significant decrease at Skegg's Branch and Wilson's Creek at Wilson's Creek National Battlefield from 1988-95. The Wilson's Creek National Battlefield data was the most comprehensive data set available with at least two sampling periods per year. In addition, the same trend was exhibited by most indices. Therefore, the negative trend in water quality may be quite serious. Harris et al. (1990) identified wastewater and farm runoff as the most significant factors affecting water quality in Skegg's Branch and Wilson's Creek. The decrease in stream quality and the poor water quality ratings were possibly due to the

explosive population growth in the region and it's affect on wastewater amounts and quality. I suggest that the Park Service consider an in depth investigation of Skegg's Branch and Wilson's Creek to determine nature of the decrease in stream quality and to find possible remedies.

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Table 1. Names, codes, and locations and method of stream monitoring sites at Great Plains National Parks from Harris et al. (1990).

<u>Park name</u>	<u>Park code</u>	<u>Gear type</u>	<u>Monitoring site code</u>	<u>Location</u>
Agate Fossil Beds National Monument	AGFO	Hester-Dendy	AFB1	Niobrara River, 110 m west of Hwy-29 bridge
			AFB3	Niobrara River, 25 m above visitor's trail crossing
Homestead National Monument	HOME	Hester-Dendy	HMS1	Cub Creek, SW corner of park
			HMS2	Cub Creek, 50 m NE of State Hwy- 4 before creek exits park
Pipestone National Monument	PIPE	Surber	PPS1	Pipestone Creek, riffle 30 m below Winnawassa Falls near large willow tree
			PPS2	Pipestone Creek, riffle 25 m below Lake Hiawatha directly above Circle Trail crossing
Herbert Hoover National Historic Site	HEHO	Surber	HHR	West Branch Wapsinonoc, riffle east of Parkside Drive east of a large cottonwood tree near silver maple tree
George Washington Carver National Monument	GWCA	Surber	CAR	Carver's Branch, riffle 20 m down stream of the visitor's trail crossing
			WIL	William's Branch, riffle between two trail crossings on stream
Wilson's Creek National Battlefield	WICR	Surber	UPPER	Wilson Creek, riffle north of first crossing of visitor's road 0.4 km from creek entrance into park
			LOWER	Wilson's Creek, riffle 25 m south of second crossing of visitor's road
			SKEGGS	Skegg's Branch, riffle 10 m from road ZZ bridge

Table 2. Pearson correlations among community indices; total density, family biotic index (FBI), ratio of EPT taxa

abundance to chironomidae abundance (EPT), family richness (FRCH), family diversity (FDIV), genus richness (GRCH), genus diversity (GDIV), taxa richness (TRCH), taxa diversity (TDIV), Missouri biotic index (MBI), biotic index for Missouri Ozark streams (OBI). Based on calculations with Surber sampler data. See text for description of index calculations.

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	<u>MBI</u>
FBI	0.4987*									
EPT	-0.2696	-0.6107**								
FRCH	0.2309	-0.0602	0.3785*							
FDIV	-0.2126	-0.5344**	0.7891**	0.6126**						
GRCH	0.2614	0.0280	0.3719*	0.9724**	0.6104**					
GDIV	-0.0792	-0.4722**	0.6642**	0.6298**	0.9441**	0.6650**				
TRCH	0.2857	0.0291	0.3541*	0.9470**	0.5981**	0.9804**	0.6762**			
TDIV	-0.0845	-0.3744*	0.6614**	0.6156**	0.9407**	0.6528**	0.9990**	0.6699**		
MBI ^a	0.1694	0.5511**	-0.5261**	-0.5235**	-0.7283**	-0.4924**	-0.6517**	-0.4644**	-0.6446**	
OBI ^a	0.4171*	0.4848**	-0.5215**	-0.3248*	-0.4297**	-0.3115*	-0.3604*	-0.2644	-0.3543*	0.6442**

^a for Missouri streams only

*p<0.05, **p<0.01

Table 3. Principal component loadings of community indices used to assess the biological integrity of Great Plains National Park streams. Data from Surber sampler. Components >3 accounted for < 7 percent of the variation.

<u>Eigenvectors</u>	<u>PC1</u>	<u>PC2</u>	<u>PC3</u>
Genus diversity	0.9239	-0.1962	0.2305
Taxa diversity	0.9142	-0.2282	0.2173
Taxa richness	0.8844	0.4205	0.0025
Family diversity	0.8818	-0.3403	0.2336
Genus richness	0.8638	0.4554	0.0168
Family richness	0.8339	0.4585	-0.0350
EPT/[Chironomidae+EPT]	0.6132	-0.6224	-0.2641
Family biotic index	-0.5699	0.7780	-0.3268
Invertebrate density	0.2753	0.4712	0.5688
Percent of variance explained	62.4	21.6	12.3

Table 4. Sources of variation, expressed as a percentage of the total, and ratio of variation among sampling dates to variation among replicates within a sampling date for community indices. Variance components from mixed model analysis of Surber sample data collected from Great Plains National Park streams during 1989. All components were statistically significant at $p < 0.01$.

<u>Index</u>	<u>Dates</u>	<u>Replicates</u>	<u>Dates/ Replicates</u>
Invertebrate density	85.86	14.14	6.07
Family biotic index	84.99	15.01	5.66
EPT/[Chironomidae+EPT]	84.17	15.83	5.32
Family richness	68.42	31.58	2.17
Family diversity	84.45	15.55	5.43
Genus richness	73.25	26.75	2.74
Genus diversity	81.78	18.22	4.49
Taxa richness	75.40	24.60	3.07
Taxa diversity	83.58	16.42	5.09

Table 5. Sources of variation within a season, expressed as a percentage of the total, and ratio of variation among sampling dates to variation among replicates within a sampling date for community indices. Variance components from mixed model analysis of Surber sample data collected from Wilson's Creek and Skegg's Branch at Wilson's Creek National Battlefield during the summer in 1989.

<u>Index</u>	<u>Dates</u>	<u>Replicates</u>	<u>Dates/ Replicates</u>
Invertebrate density	70.32**	29.68	2.37
Family biotic index	54.48*	45.52	1.20
EPT/[Chironomidae+EPT]	77.54**	22.46	3.45
Family richness	26.83	73.17	0.37
Family diversity	28.18	71.82	0.39
Genus richness	58.60*	41.40	1.42
Genus diversity	73.82**	26.18	2.82
Taxa richness	68.10**	31.90	2.13
Taxa diversity	75.23**	24.77	3.04

*p<0.05, **p<0.01

Table 6. Community index criteria for monitoring Great Plains National Park streams with the Surber sampler.

<u>Index</u>	<u>Exceedance Value</u>
Invertebrate density (m ²)*	-1827.00
Family biotic index	0.74
EPT/[Chironomidae+EPT]**	-0.03
Family richness	-0.75
Family diversity	-0.16
Genus richness*	-1.82
Genus diversity*	-0.23
Taxa richness*	-2.83
Taxa diversity*	-0.38

* not recommended for use.

**excluding West Branch Wapsinonoc Creek at Herbert Hoover National Monument.

Table 7. Water quality ratings using the family biotic index (FBI) from Hilsenhoff (1988).

<u>FBI</u>	<u>Water Quality</u>	<u>Degree of Organic Pollution</u>
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution likely
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

Table 8. Pearson correlations among community indices; total density, family biotic index (FBI), ratio of EPT taxa abundance to chironomidae abundance (EPT), family richness (FRCH), family diversity (FDIV), genus richness (GRCH), genus diversity (GDIV), taxa richness (TRCH), and taxa diversity (TDIV) Based on calculations with Hester-Dendy multiplate sampler data. See text for description of index calculations.

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>
FBI	-0.0777							
EPT	-0.0822	-0.4663**						
FRCH	0.0939	-0.3360*	0.6060**					
FDIV	-0.1415	-0.1546	0.5964**	0.6288**				
GRCH	0.1606	-0.3241*	0.5899**	0.9744**	0.6182**			
GDIV	-0.1928	-0.0937	0.5173**	0.4646**	0.8595**	0.5360**		
TRCH	0.1565	-0.3171*	0.5866**	0.9747**	0.6216**	0.9986**	0.5341**	
TDIV	-0.1931	-0.0942	0.5210**	0.4663**	0.8607**	0.5379**	0.9998**	0.5367**

*p<0.05, **p<0.01

Table 9. Principal component loadings of community indices used to assess the biological integrity of Great Plains National Park streams. Data from Hester-Dendy sampler. Components ≥ 3 accounted for < 5 percent of the variation.

<u>Eigenvectors</u>	<u>PC1</u>	<u>PC2</u>	<u>PC3</u>
Genus richness	0.8974	0.3455	0.1597
Taxa richness	0.8966	0.3422	0.1643
Family richness	0.8759	0.3600	0.0947
Family diversity	0.8625	-0.3401	0.0660
Taxa diversity	0.8116	-0.5090	0.0905
Genus diversity	0.8097	-0.5103	0.0915
EPT/[Chironomidae+EPT]	0.7531	0.0611	-0.4029
Invertebrate density	-0.0246	0.6610	0.4655
Family biotic index	-0.3638	-0.4334	0.7232
Percent of variance explained	57.1	29.2	10.7

Table 10. Sources of variation within a year, expressed as a percentage of the total, and ratio of variation among sampling dates to variation among replicates within a sampling date for community indices. Variance components from mixed model analysis of Hester-Dendy sampler data collected from Cub Creek at Homestead National Monument during 1989.

<u>Index</u>	<u>Dates</u>	<u>Replicates</u>	<u>Dates/ Replicates</u>
Invertebrate density	84.92**	15.08	5.63
Family biotic index	46.60	53.40	0.87
EPT/[Chironomidae+EPT] ¹	0	100.00	-
Family richness	86.29**	13.71	6.29
Family diversity ¹	0	100.00	-
Genus richness	80.43**	19.57	4.11
Genus diversity	56.45*	43.55	1.30
Taxa richness	78.72**	21.28	3.70
Taxa diversity	56.08*	43.92	1.28

* $p < 0.05$, ** $p < 0.01$

¹ variance among dates was negative and was assumed to be negligible.

Table 11. Community index criteria for monitoring Great Plains National
Park streams with the Hester-Dendy sampler.

<u>Index</u>	<u>Exceedance Value</u>
Invertebrate density	-1257.20
Family biotic index	0.74
EPT/[Chironomidae+EPT]*	-0.01
Family richness*	-8.60
Family diversity*	-0.14
Genus richness	-4.60
Genus diversity	-0.23
Taxa richness*	-4.89
Taxa diversity*	-0.23

* not recommended for use.

Table 12. Mean family biotic index (FBI), by sampling site, for the most recent year available.
Water quality ratings from Hilsenhoff (1988).

<u>Park name</u>	<u>Site</u>	<u>Year</u>	<u>Mean FBI</u>	<u>Water Quality Rating</u>
Agate Fossil Beds National- Monument	AFB1	95	6.05	Poor
	AFB3	95	5.82	Fairly poor
Homestead National Monument	HMS1	95	7.13	Poor
	HMS2	95	7.03	Poor
Pipestone National Monument	PPS1	95	4.89	Good
	PPS2	95	4.97	Good
Herbert Hoover National- Historic Site	HHR	90	6.90	Poor
George Washington Carver- National Monument	CAR	95	5.03	Fair
	WIL	95	5.11	Fair
Wilson's Creek National Battlefield	UPPER	94	6.15	Fairly poor
	LOWER	95	6.09	Fairly poor
	SKEGGS	94	6.37	Fairly poor

Table 13. Suggested application of community index criteria for monitoring Great Plains National Park streams. An example is shown using data from Upper Wilsons Creek at Wilson's Creek National Battlefield from the summer in 1993. Reference means are from 1989.

Note inferences should be treated with caution because only August data were collected.

	<u>FBI</u>	<u>EPT ratio</u>	<u>Family richness</u>	<u>Family diversity</u>
June sample				
Replicate 1				
Replicate 2				
Replicate 3				
Replicate 4				
Replicate 5				
July sample				
Replicate 1				
Replicate 2				
Replicate 3				
Replicate 4				
Replicate 5				
August sample				
Replicate 1	5.82	0.00	7.00	0.61
Replicate 2	5.82	0.00	3.00	0.57
Replicate 3	5.82	0.00	2.00	0.65
Replicate 4	5.82	0.00	3.00	0.26
Replicate 5	5.82	0.00	5.00	0.48
Mean	5.82	0.00	4.00	0.51
Reference mean	5.41	0.25	13.60	1.30
Net Change	0.41	-0.25	-9.60	-0.79
Criteria	0.74	-0.03	-0.75	-0.16
Exceedance (Y or N)	N	Y	Y	Y

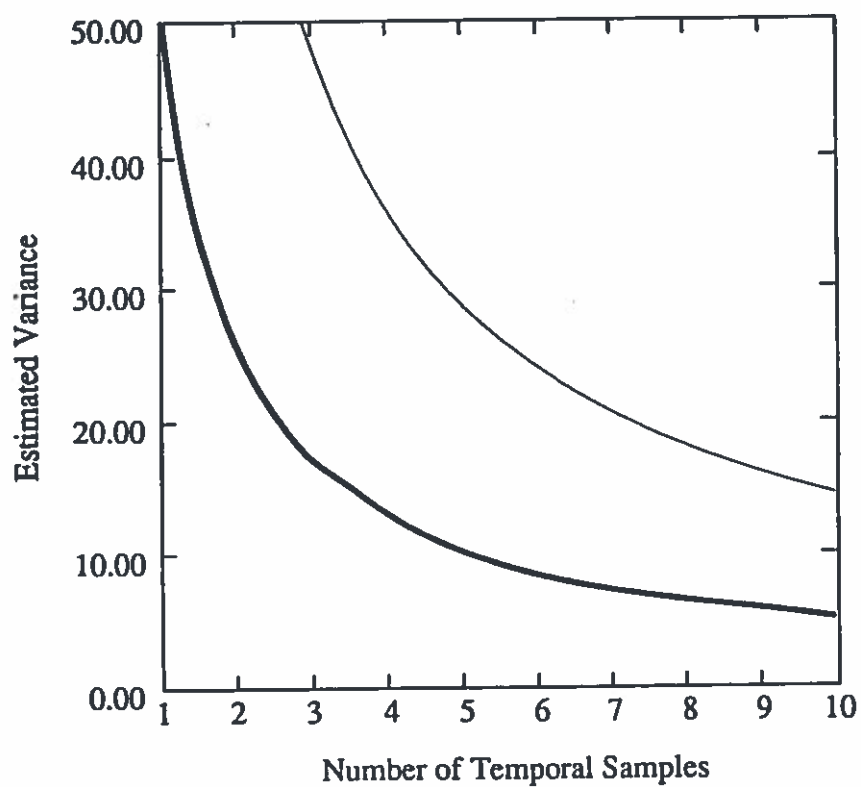


Figure 1. Estimated variance of invertebrate density estimates from Surber samples collected during days within a year, fine line, and at different days within the summer, heavy line. Estimates assume 5 sub-samples within a site during sampling day. Note: estimated variance has been square root transformed.

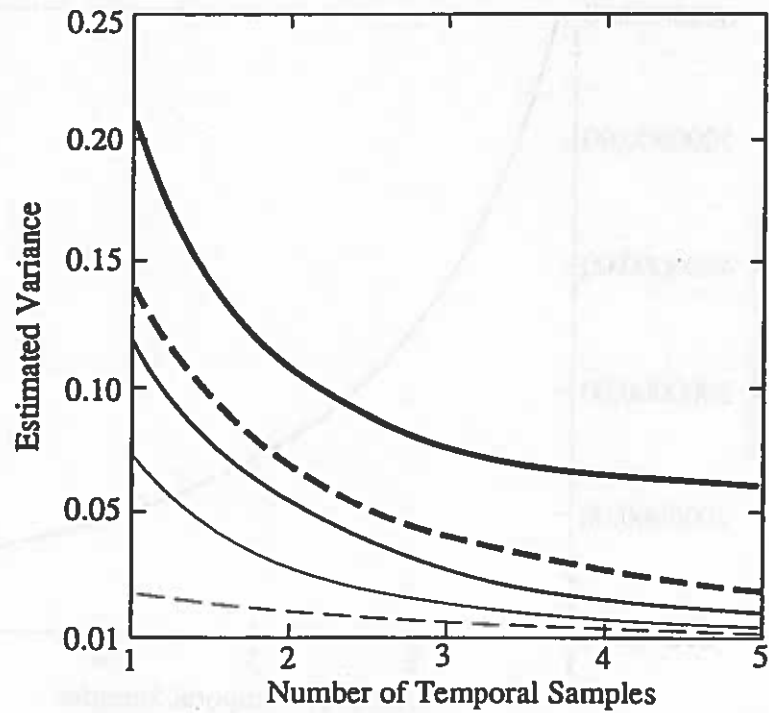


Figure 2. Estimated variance of the family biotic index (heavy solid line), taxa diversity (heavy broken line), genus diversity (medium solid line), family diversity (fine broken line), and EPT/[EPT+Chironomidae] (fine solid line) estimates from Surber samples collected during different days within summer. Estimates assume 5 sub-samples within a site during each time period.

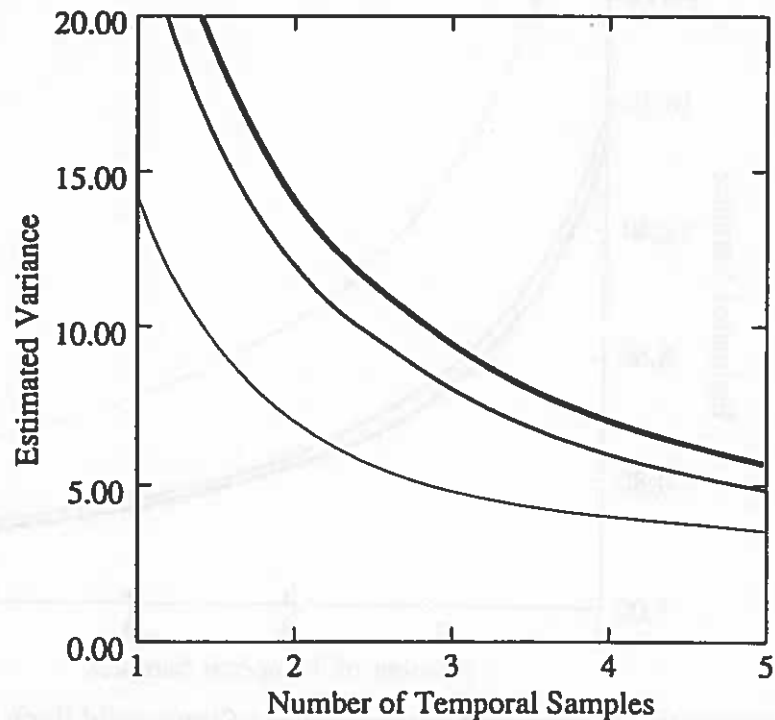


Figure 3. Estimated variance of the taxa richness (heavy solid line), genus richness (medium solid line), and family richness (fine solid line) estimates from Surber samples collected during different days within summer. Estimates assume 5 sub-samples within a site during each time period.

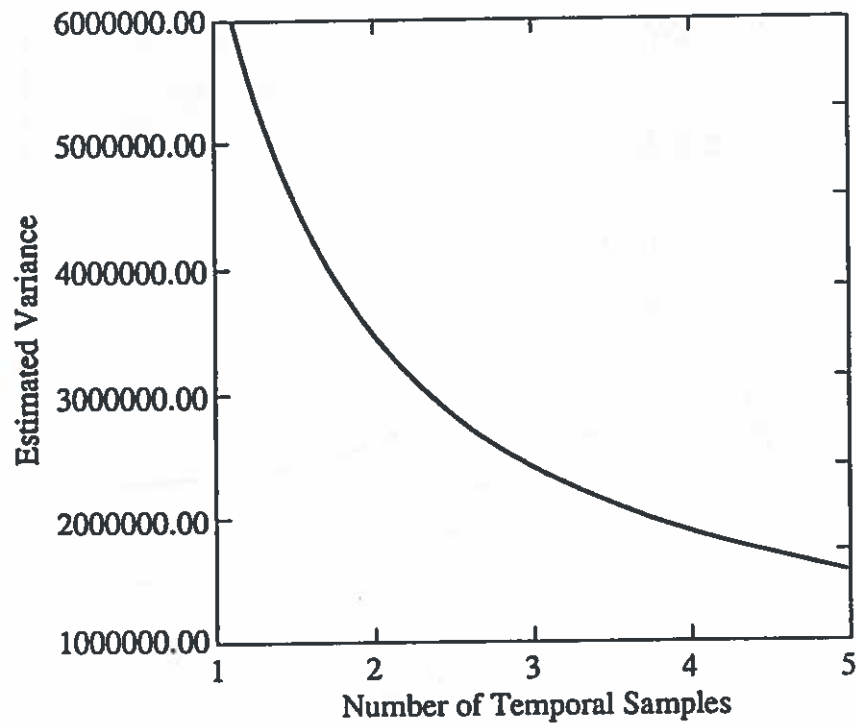


Figure 4. Estimated variance of the invertebrate densities from Hester-Dendy samples collected during different colonization periods within a year. Estimates assume 5 sub-samples (i.e., samplers) within a site during each colonization period.

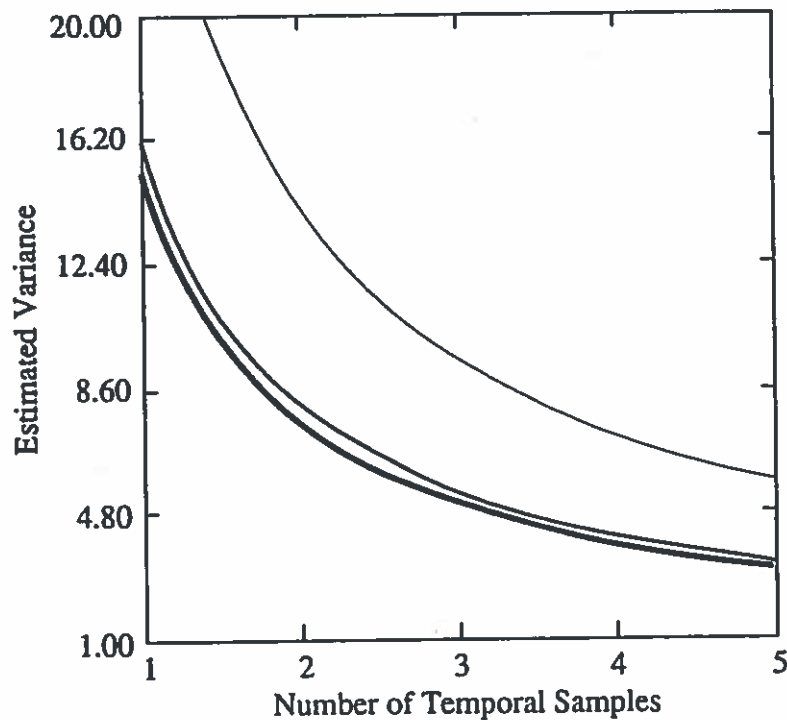


Figure 5. Estimated variance of the genus richness (heavy solid line), taxa richness (medium solid line), and family richness (fine solid line) from Hester-Dendy samples collected during different colonization periods within a year. Estimates assume 5 sub-samples (i.e., samplers) within a site during each colonization period.

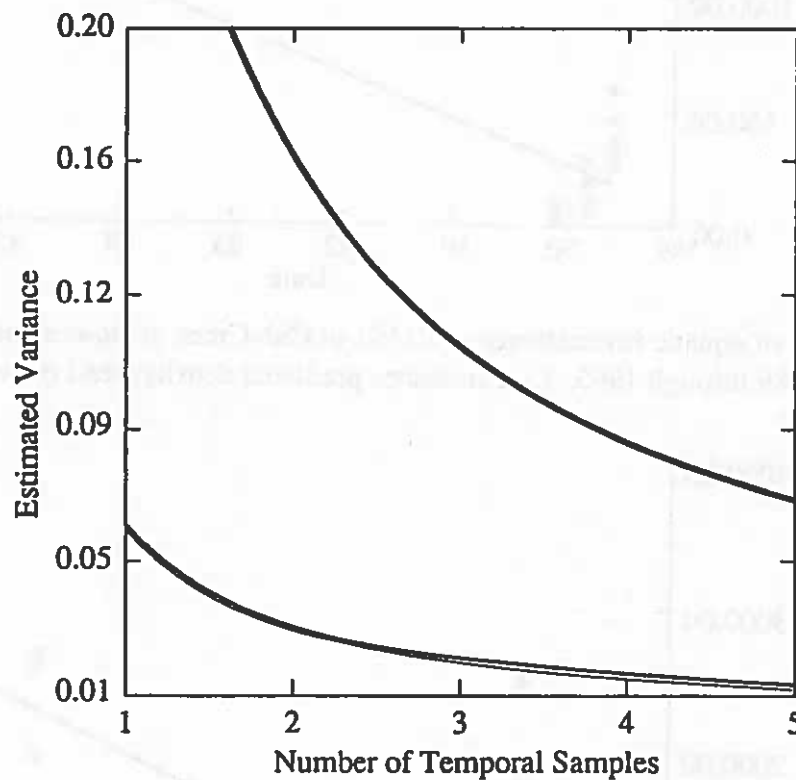


Figure 6. Estimated variance of the family biotic index (heavy solid line), taxa diversity (medium solid line), and genus diversity (fine solid line) from Hester-Dendy samples collected during different colonization periods within a year. Estimates assume 5 sub-samples (i.e., samplers) within a site during each colonization period.

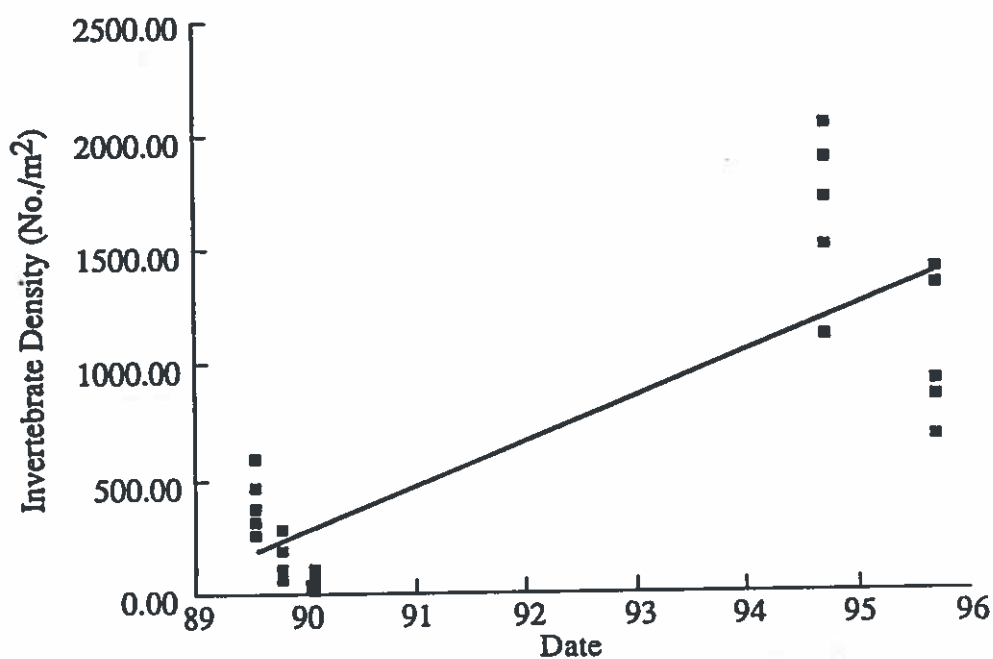


Figure 7. Density of aquatic invertebrates at HMS1 in Cub Creek at Homestead National Monument from 1989 through 1995. Line indicates predicted density trend ($r^2 = 0.673$, $P < 0.0001$).

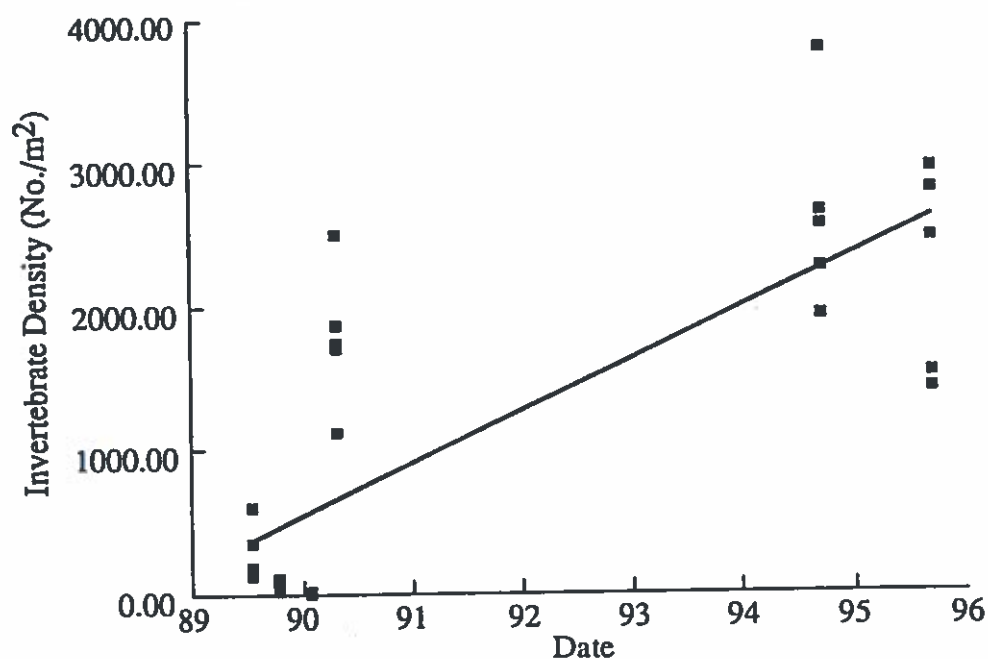


Figure 8. Density of aquatic invertebrates at HMS2 in Cub Creek at Homestead National Monument from 1989 through 1995. Line indicates predicted density trend ($r^2 = 0.621$, $P < 0.0001$).

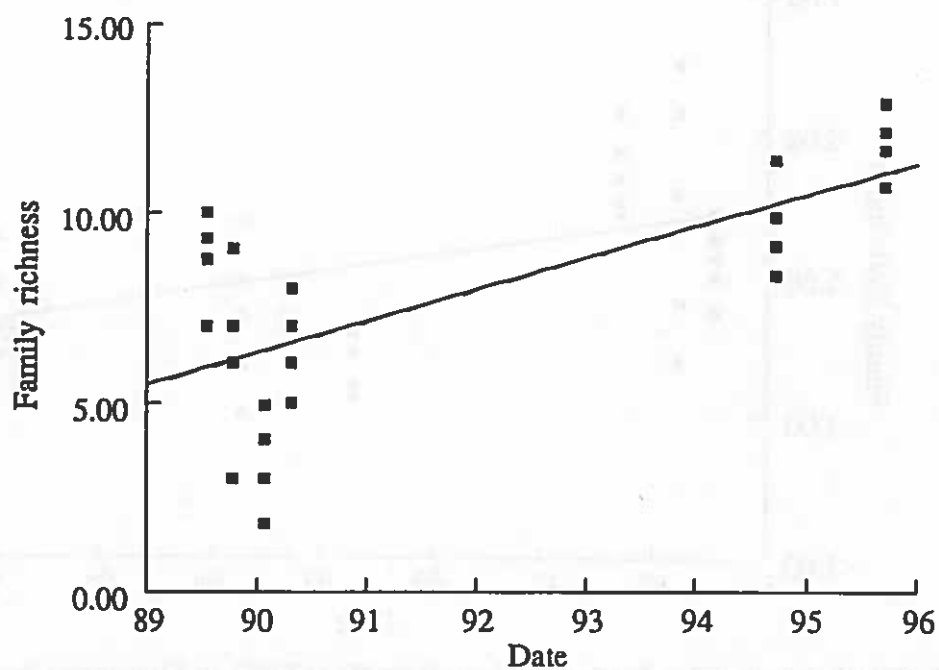


Figure 9. Family richness of aquatic invertebrates at HMS2 in Cub Creek at Homestead National Monument from 1989 through 1995. Line indicates predicted family diversity trend ($r^2 = 0.619$, $P=0.0004$).

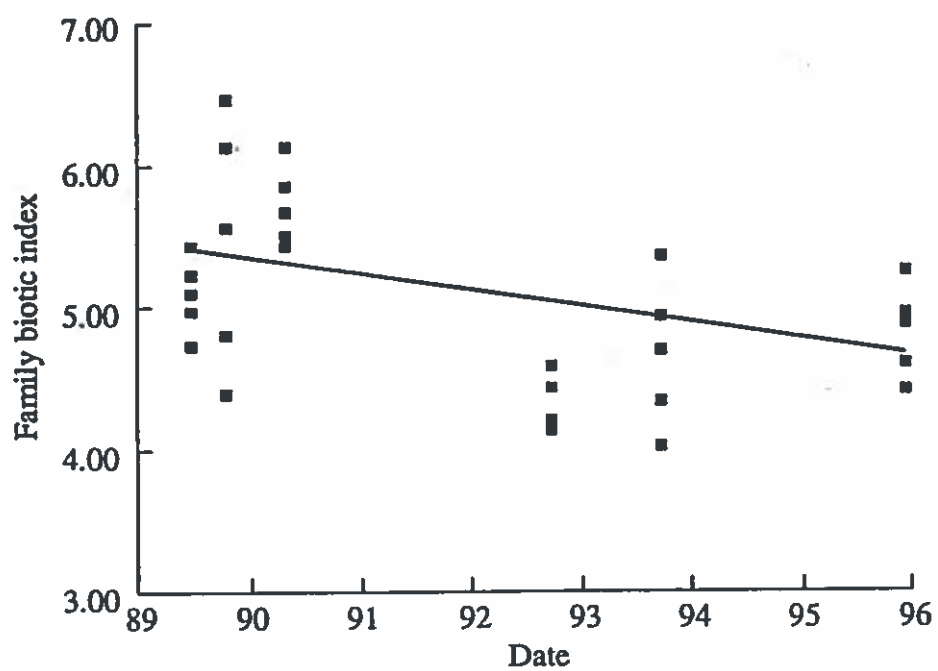
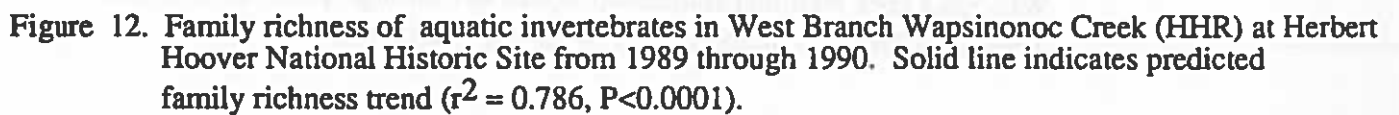
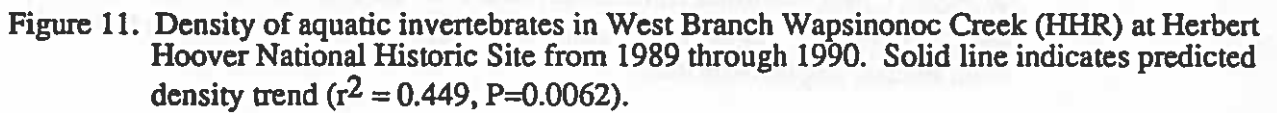


Figure 10. Family biotic index for aquatic invertebrates at PPS1 in Pipestone Creek at Pipestone National Monument from 1989 through 1995. Line indicates predicted family biotic index trend ($r^2 = 0.396$, $P=0.0029$).



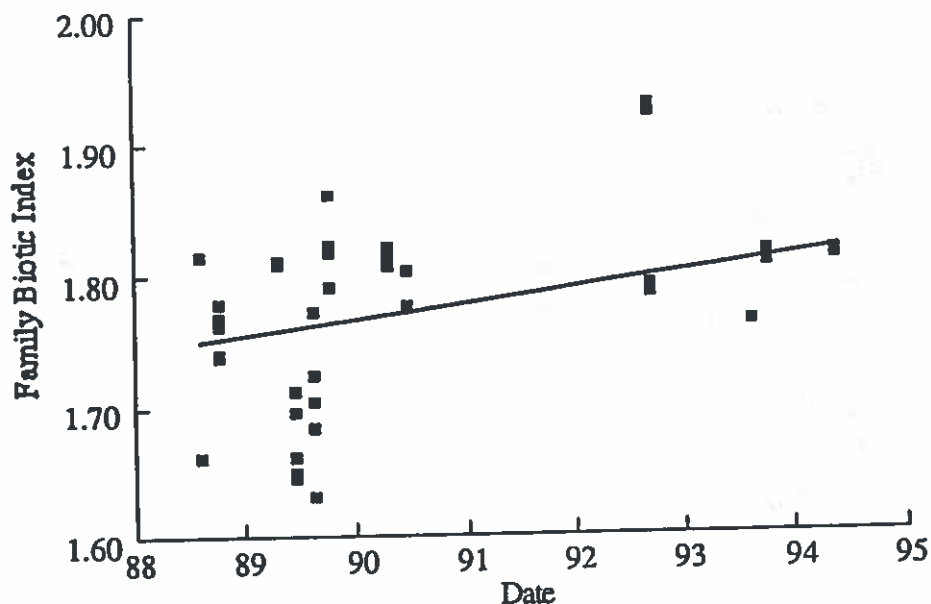


Figure 13. Family biotic index for aquatic invertebrates in UPPER Wilson's Creek at Wilson's Creek National Battlefield from 1989 through 1994. Line indicates predicted Family Biotic Index trend ($r^2 = 0.171$, $P=0.0028$). Note: index has been natural log transformed.

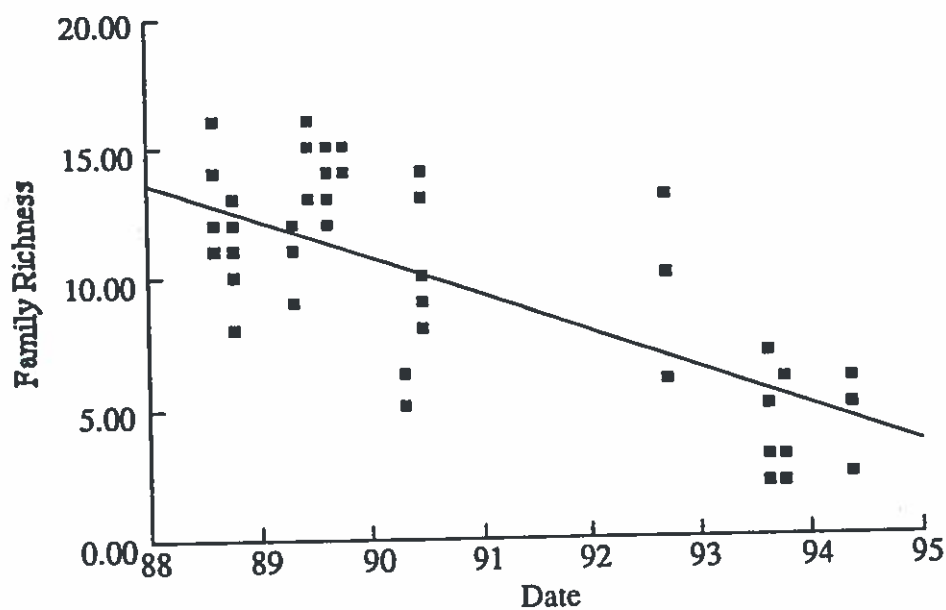


Figure 14. Family richness of aquatic invertebrates in UPPER Wilson's Creek at Wilson's Creek National Battlefield from 1989 through 1994. Line indicates predicted family richness trend ($r^2 = 0.413$, $P<0.0001$).

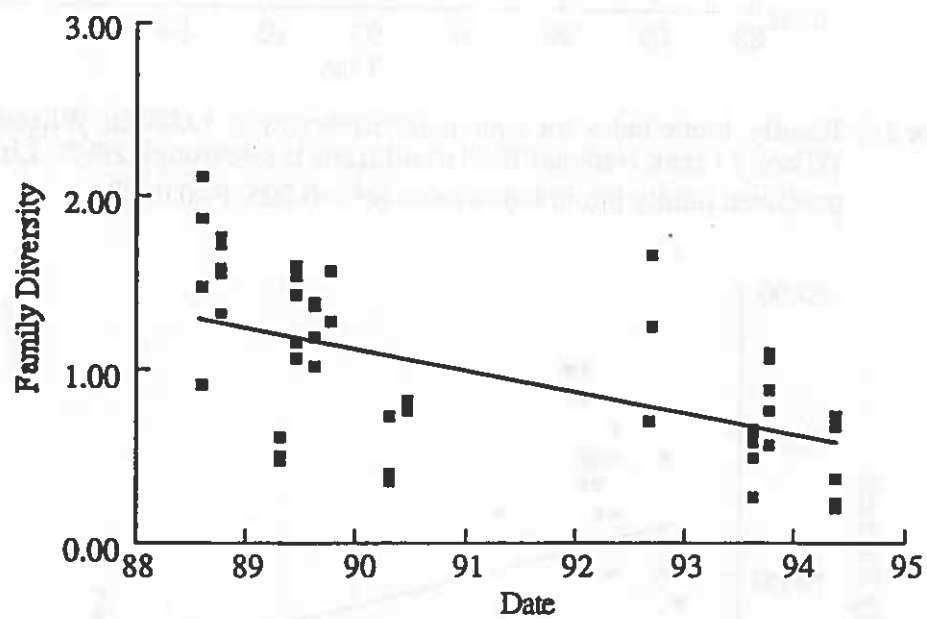


Figure 15. Family diversity of aquatic invertebrates in UPPER Wilson's Creek at Wilson's Creek National Battlefield from 1989 through 1994. Line indicates predicted family diversity trend ($r^2 = 0.413$, $P < 0.0001$).

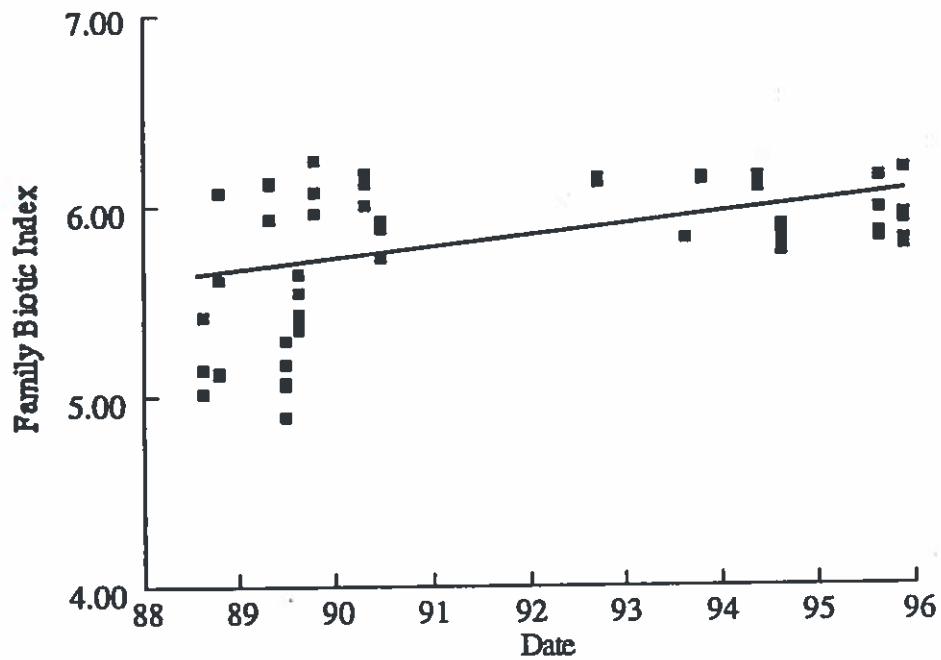


Figure 16. Family biotic index for aquatic invertebrates in LOWER Wilson's Creek at Wilson's Creek National Battlefield from 1989 through 1995. Line indicates predicted family biotic index trend ($r^2 = 0.205$, $P=0.0009$).

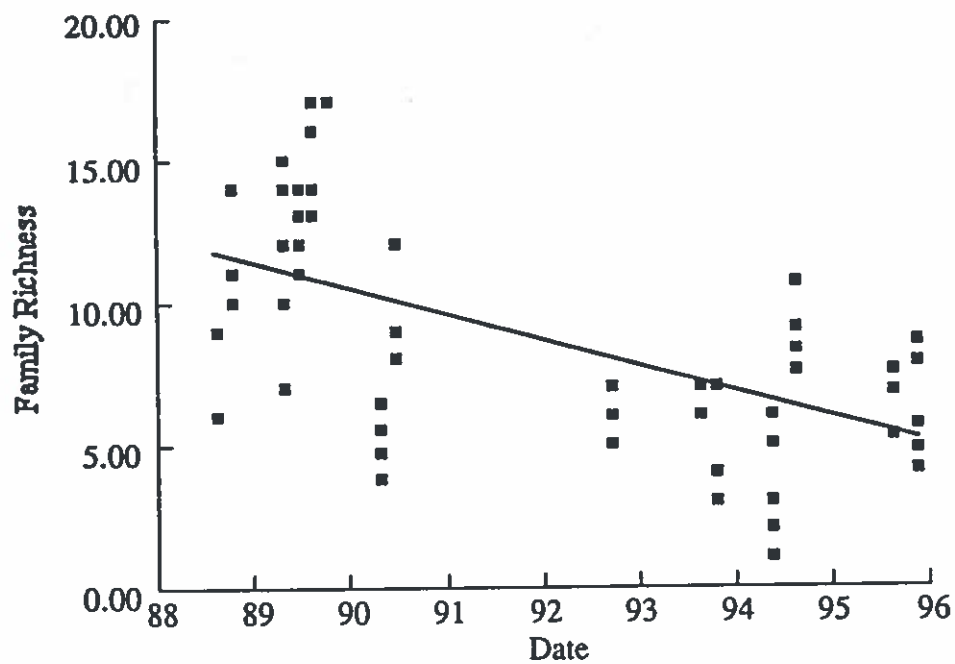


Figure 17. Family richness of aquatic invertebrates in LOWER Wilson's Creek at Wilson's Creek National Battlefield from 1989 through 1995. Line indicates predicted family richness trend ($r^2 = 0.351$, $P<0.0001$).

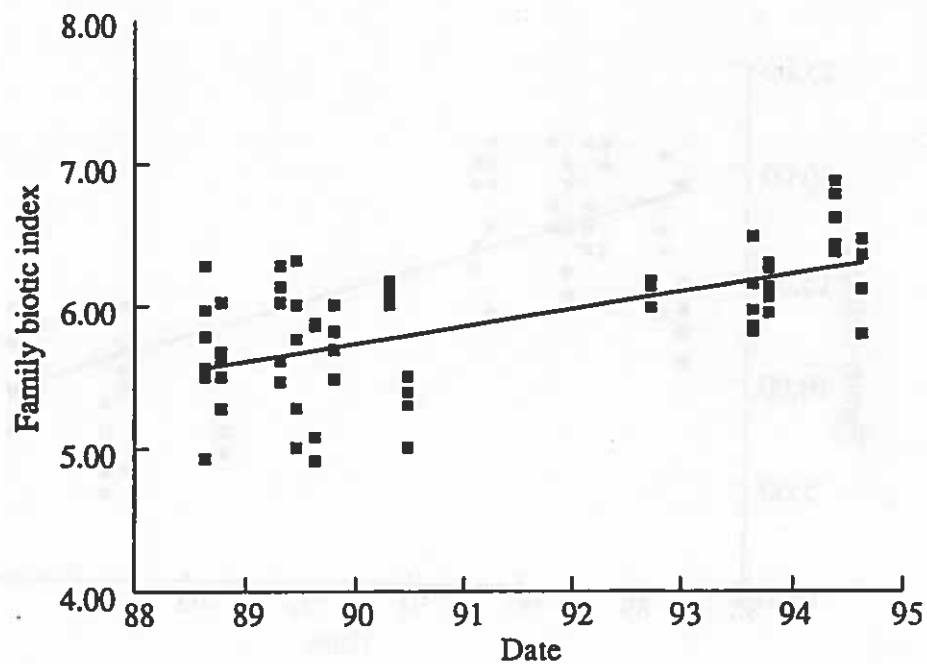


Figure 18. Family biotic index for aquatic invertebrates in SKEGGS Branch at Wilson's Creek National Battlefield from 1989 through 1994. Line indicates predicted family biotic index trend ($r^2 = 0.314$, $P < 0.0001$).

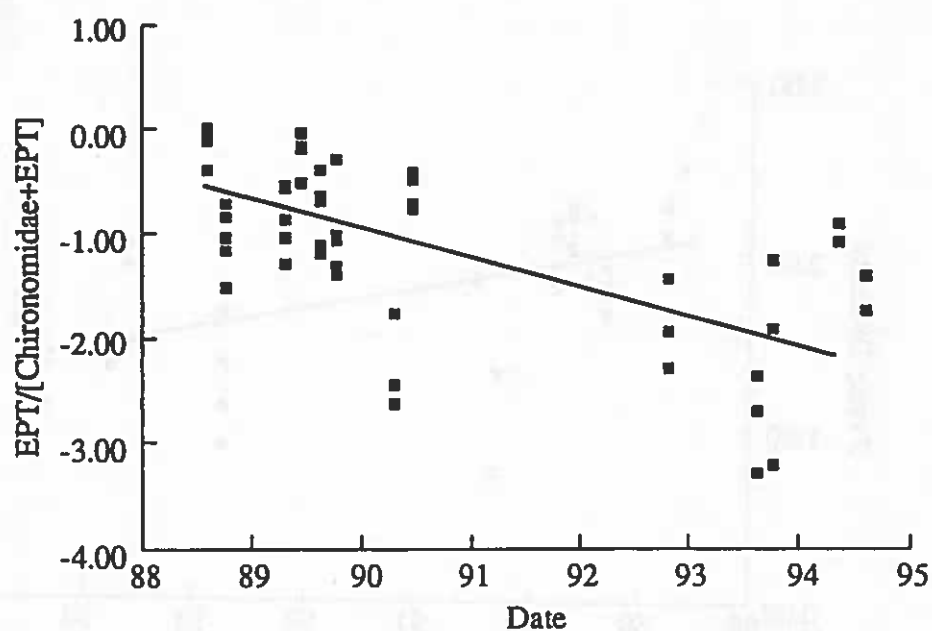


Figure 19. EPT/[Chironomidae+EPT] ratio for aquatic invertebrates in SKEGGS Branch at Wilson's Creek National Battlefield from 1989 through 1995. Line indicates predicted EPT/[Chironomidae+EPT] ratio trend ($r^2 = 0.263$, $P < 0.0001$). Note: index has been natural log transformed.

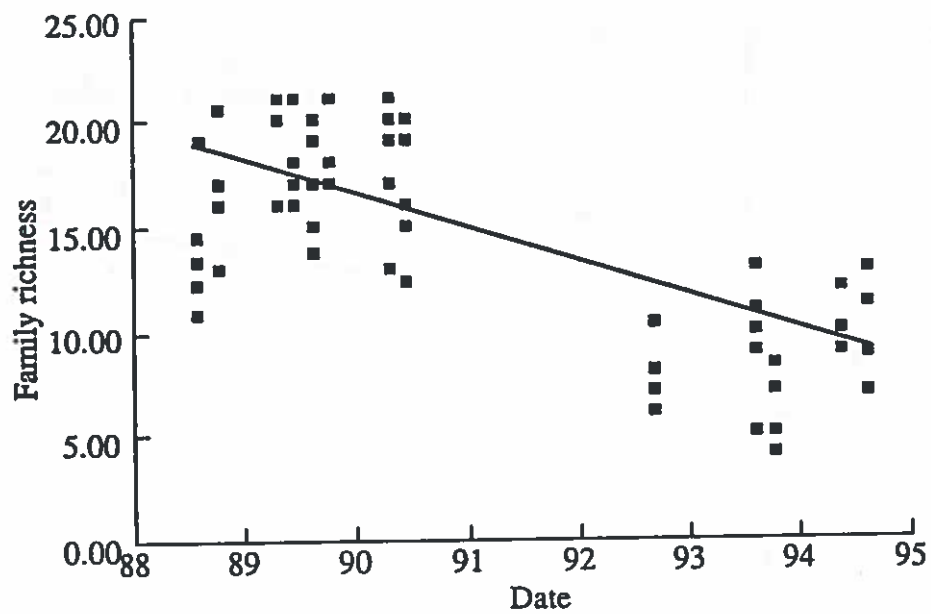


Figure 20. Family richness of aquatic invertebrates in SKEGGS Branch at Wilson's Creek National Battlefield from 1989 through 1994. Line indicates predicted family richness trend ($r^2 = 0.424$, $P < 0.0001$).

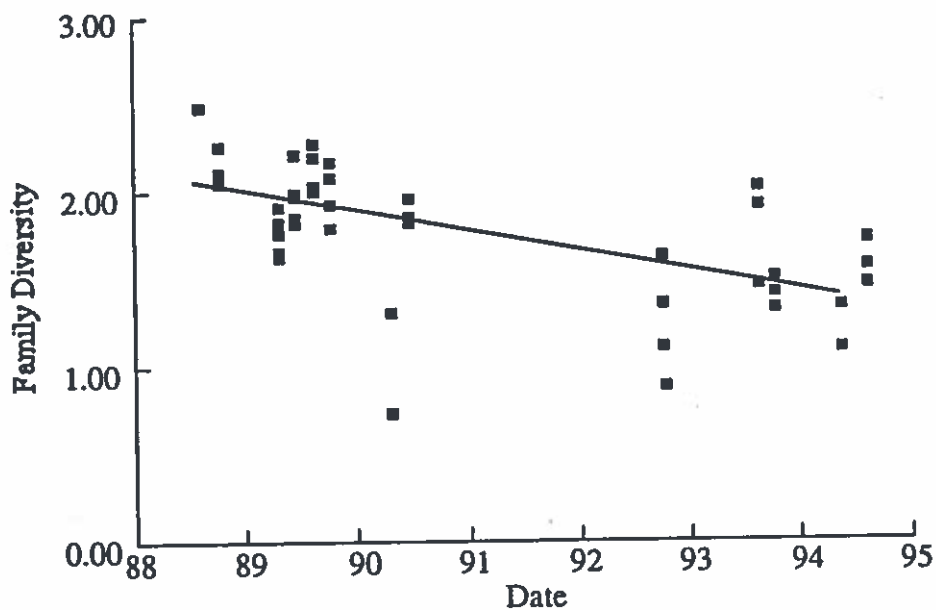


Figure 21. Family diversity of aquatic invertebrates in SKEGGS Branch at Wilson's Creek National Battlefield from 1989 through 1994. Line indicates predicted family diversity trend ($r^2 = 0.258$, $P < 0.0001$).

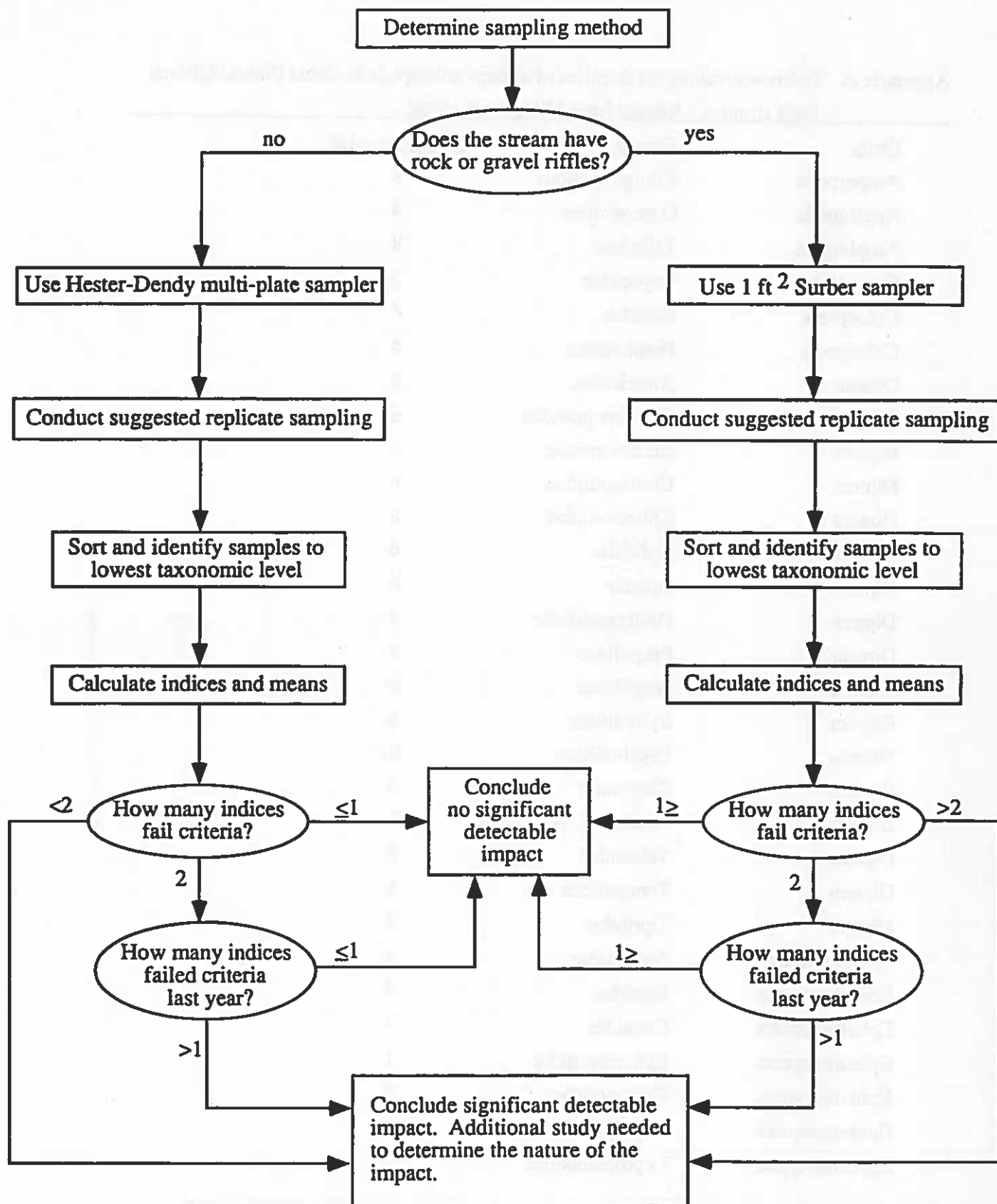


Figure 22. Suggested protocol for monitoring Great Plains National Park streams. Index criteria given in tables 6 and 11.

Appendix A. Tolerance values for families of stream arthropods in Great Plains National
Park streams. Values from Hilsenhoff (1988).

<u>Order</u>	<u>Family</u>	<u>Tolerance value</u>
Amphipoda	Crangonyctidae	8
Amphipoda	Gammaridae	4
Amphipoda	Talitridae	8
Coleoptera	Dryopidae	5
Coleoptera	Elmidae	4
Coleoptera	Psephenidae	4
Diptera	Athericidae	2
Diptera	Ceratopogonidae	6
Diptera	Chironomidae	2
Diptera	Chironomidae	6
Diptera	Chironomidae	8
Diptera	Culicidae	6
Diptera	Dixidae	6
Diptera	Dolichopodidae	4
Diptera	Empididae	4
Diptera	Empididae	6
Diptera	Ephydriidae	6
Diptera	Psychodidae	10
Diptera	Simuliidae	6
Diptera	Stratiomyidae	6
Diptera	Tabanidae	6
Diptera	Tenipedidae	6
Diptera	Tipulidae	3
Ephemeroptera	Ameletidae	4
Ephemeroptera	Baetidae	4
Ephemeroptera	Caenidae	7
Ephemeroptera	Ephemerellidae	1
Ephemeroptera	Ephemeridae	4
Ephemeroptera	Heptageniidae	4
Ephemeroptera	Leptophlebiidae	2

Appendix A. (continued)

<u>Order</u>	<u>Family</u>	<u>Tolerance value</u>
Ephemeroptera	Oligoneuriidae	2
Ephemeroptera	Tricorythidae	4
Isopoda	-	8
Isopoda	Asellidae	8
Lepidoptera	Pyrilidae	5
Lepidoptera	Tortricidae	5
Megaloptera	Chauliodinae	4
Megaloptera	Corydalidae	0
Megaloptera	Sialidae	4
Odonata	Aeshnidae	3
Odonata	Calopterygidae	5
Odonata	Coenagrionidae	5
Odonata	Corduliidae	5
Odonata	Gomphidae	1
Odonata	Lestidae	9
Odonata	Libellulidae	9
Plecoptera	Leuctridae	0
Plecoptera	Nemouridae	2
Plecoptera	Perlidae	1
Plecoptera	Perlodidae	2
Plecoptera	Taeniopterygidae	2
Trichoptera	Glossosomatidae	0
Trichoptera	Helicopsychidae	3
Trichoptera	Hydropsychidae	4
Trichoptera	Hydroptilidae	4
Trichoptera	Leptoceridae	4
Trichoptera	Limnephilidae	4
Trichoptera	Philopotamidae	3
Trichoptera	Phryganeidae	4
Trichoptera	Polycentropodidae	6
Trichoptera	Psychomyiidae	2

Appendix B. Means, ranges, and standard errors (SE) of community indices; total density, family biotic index (FBI), ratio of

EPT taxa abundance to chironomidae abundance (EPT), family richness (FRCH), family diversity (FDIV), genus richness (GRCH), genus diversity (GDIV), taxa richness (TRCH), taxa diversity (TDIV), Missouri biotic index (MBI), biotic index for Missouri Ozark streams (OBI), by site and season in 1989. See text for description of index calculations.

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	<u>MBI</u>	<u>OBI</u>
Agate Fossil Beds National Monument- AFB1											
<u>Summer</u>											
Mean	3487.62	4.27	0.81	19.1	1.81	21.2	1.88	21.2	1.88		
<u>Fall</u>											
Mean	4047.36	5.26	0.47	16.4	1.88	17.0	1.90	17.0	1.90		
<u>All seasons</u>											
Mean	3767.49	4.77	0.64	17.8	1.84	19.1	1.89	19.1	1.89		
Agate Fossil Beds National Monument-AFB3											
<u>Summer</u>											
Mean	1743.81	4.39	0.76	20.7	2.10	22.7	2.27	22.7	2.27		
<u>Fall</u>											
Mean	7319.70	5.77	0.41	18.3	1.06	20.5	1.08	20.5	1.08		
<u>All seasons</u>											
Mean	4531.76	5.08	0.58	19.5	1.58	21.6	1.68	21.6	1.68		

Appendix B. (continued)

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	<u>MBI</u>	<u>OBI</u>
Homestead National Monument- HMS1											
<u>Summer: n=5</u>											
Mean	4305.7	7.06	0.02	12	1.03	13.20	1.05	13.40	1.05		
Range	2723-6361	6.30-7.48	0-0.05	9-16	0.73-1.27	11-16	0.75-1.29	11-16	0.75-1.29		
SE	640.94	0.22	0.01	1.30	0.10	0.97	0.10	1.08	0.10		
<u>Fall: n=5</u>											
Mean	1571.6	7.35	0.01	6	1.10	8.60	1.37	8.60	1.37		
Range	689-2938	6.88-7.90	0-0.05	4-7	0.98-1.27	6-10	1.17-1.62	6-10	1.62		
SE	407.77	0.18	0.01	0.55	0.05	0.75	0.08	0.75	0.08		
<u>All seasons: n=10</u>											
Mean	2938.6	7.21	0.01	9	1.06	10.90	1.21	11	1.21		
Range	689-6361	6.30-7.90	0-0.05	4-16	0.73-1.27	6-16	0.75-1.62	6-16	0.75-1.62		
SE	579.56	0.14	0.01	1.20	0.06	0.96	0.08	1.01	0.08		

Appendix B. (continued)

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	<u>MBI</u>	<u>OBI</u>
Homestead National Monument- HMS2											
<u>Summer: n=5</u>											
Mean	2290.6	6.63	0	9.80	1.30	10.60	1.34	10.80	1.34		
Range	1410-3810	5.26-7.64	0-0.02	7-11	1.08-1.55	8-12	1.09-1.55	8-12	1.10-1.55		
SE	412.42	0.39	-	0.73	0.08	0.68	0.08	0.73	0.08		
<u>Fall: n=5</u>											
Mean	861.1	7.40	0	6.40	1.23	8.40	1.43	8.60	1.43		
Range	301-1302	7.13-7.82	-	3-9	1-1.49	5-10	1.20-1.70	5-11	1.20-1.70		
SE	171.00	0.12	-	0.98	0.09	0.93	0.09	1.03	0.09		
<u>All seasons: n=10</u>											
Mean	1575.9	7.02	0	8.10	1.27	9.50	1.38	9.70	1.39		
Range	301-3810	5.26-7.82	0-0.02	3-11	1-1.55	5-12	1.09-1.70	5-12	1.10-1.70		
SE	317.89	0.23	-	0.81	0.06	0.65	0.06	0.70	0.06		

Appendix B. (continued)

<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	<u>MBI</u>	<u>OBI</u>
Pipestone National Monument- PPS1										
<u>Summer, n=5</u>										
Mean	2600.6	5.09	0.70	9.40	1.75	12.80	2.01	15.40	2.21	
Range	1227-5306	4.73-5.42	0.61-0.78	7-11	1.47-2.11	11-15	1.78-2.29	14-18	2.06-2.43	
SE	719.04	0.12	0.03	0.75	0.12	0.66	0.10	0.75	0.07	
<u>Fall, n=5</u>										
Mean	755.6	5.47	0.43	6	1.38	7.40	1.65	7.60	1.65	
Range	54-3348	4.38-6.46	0-0.86	3-11	1.06-1.59	3-14	1.06-2.13	3-15	1.06-2.14	
SE	648.35	0.39	0.15	1.41	0.11	1.91	0.20	2.09	0.20	
<u>All seasons: n=10</u>										
Mean	1678.1	5.28	0.57	7.70	1.57	10.10	1.83	11.50	1.93	
Range	54-5307	4.38-6.46	0-0.86	3-11	1.06-2.11	3-15	1.06-2.29	3-18	1.06-2.43	
SE	550.33	0.20	0.09	0.94	0.10	1.31	0.12	1.67	0.14	

Appendix B. (continued)

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	<u>MBI</u>	<u>OBI</u>
Pipestone National Monument- PPS2											
<u>Summer: n=5</u>											
Mean	5227.1	5.22	0.58	9.20	1.64	12.20	1.91	15.80	2.10		
Range	2917-8095	4.70-5.80	0.46-0.70	7-11	1.36-1.83	11-13	1.55-2.01	14-17	1.91-2.22		
SE	1063.76	0.20	0.04	0.80	0.08	0.37	0.09	0.58	0.05		
<u>Fall: n=4</u>											
Mean	83.4	5.51	0.16	3	0.56	3.50	0.70	3.50	0.70		
Range	11-269	5.38-5.63	0-0.40	1-8	0-1.67	1-9	0-1.75	1-9	0-1.75		
SE	62.36	0.13	0.10	1.68	0.39	1.89	0.43	1.89	0.43		
<u>All seasons: n=9</u>											
Mean	2941.0	5.30	0.40	6.44	1.16	8.33	1.37	10.33	1.47		
Range	11-8095	4.70-5.80	0-0.70	1-11	0-1.83	1-13	0-2.01	1-17	0-2.22		
SE	1063.7	0.15	0.09	1.36	0.25	1.72	0.28	2.32	0.30		

Appendix B. (continued)

TOTAL	FBI	EPT	FRCH	FDIV	GRCH	GDIV	TRCH	TDIV	MBI	OBI
Herbert Hoover National Historic Site- HHR										
<u>Summer, n=5</u>										
Mean	3997.8	6.20	0.02	9	1.48	11.40	1.56	11.40	1.56	
Range	1518-8471	5.97-6.35	0-0.03	8-10	0.97-1.69	11-12	1.03-1.76	11-12	1.76	
SE	1181.08	0.07	0.01	0.45	0.13	0.24	0.13	0.24	0.13	
<u>Fall, n=5</u>										
Mean	2124.9	6.65	0.02	7.40	1.11	8.40	1.17	8.60	1.18	
Range	517-4575	6.13-7.25	0-0.09	5-9	0.42-1.55	6-10	0.47-1.68	6-10	0.47-1.73	
SE	758.74	0.21	0.02	0.81	0.21	0.81	0.22	0.75	0.22	
<u>All seasons: n=10</u>										
Mean	3061.3	6.43	0.02	8.20	1.29	9.90	1.37	10	1.37	
Range	517-8471	5.97-7.25	0-0.09	5-10	0.42-1.69	6-12	0.47-1.76	6-12	0.47-1.76	
SE	731.69	0.13	0.01	0.51	0.13	0.64	0.14	0.60	0.14	

Appendix B. (continued)

<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	<u>MBI</u>	<u>OBI</u>
George Washington Carver National Monument- CAR										
<u>Summer: n=5</u>										
Mean	1257.3	3.19	0.85	15.20	2.16	16.80	2.22	17.20	2.23	2.16
Range	431-3122	2.93-3.78	0.79-0.96	10-20	1.61-2.44	10-23	1.61-2.57	10-24	1.61-2.60	2.10-2.20
SE	500.36	0.16	0.03	1.77	0.14	2.35	0.16	2.58	0.17	0.02
<u>Fall: n=5</u>										
Mean	2669.5	6.10	0.10	9.80	0.83	12.80	1.42	13.40	1.43	2.50
Range	775-6533	5.78-6.37	0.03-0.25	9-11	0.34-1.44	12-14	0.71-1.97	12-16	0.71-2.00	2.26-2.88
SE	1010.51	0.09	0.04	0.49	0.19	0.49	0.23	0.75	0.23	0.10
<u>Winter: n=5</u>										
Mean	7821.3	5.25	0.31	18.60	1.93	22.00	2.26	22.60	2.27	2.64
Range	4887-12249	4.40-5.76	0.10-0.58	15-21	1.43-2.33	18-25	1.88-2.58	18-26	1.88-2.58	2.28-2.84
SE	1394.7	0.26	0.09	1.03	0.17	1.22	0.13	1.40	0.13	0.09
<u>All seasons: n=15</u>										
Mean	3916.0	4.85	0.42	14.53	1.64	17.20	1.97	17.73	1.98	2.43
Range	431-12249	2.93-6.37	0.03-0.96	9-21	0.34-2.44	10-25	0.71-2.58	10-26	0.71-2.60	2.10-2.88
SE	935.30	0.34	0.09	1.17	0.18	1.31	0.14	1.37	0.14	0.07

Appendix B. (continued)

<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	<u>MBI</u>	<u>OBI</u>
George Washington Carver National Monument- WIL										
<u>Summer, n=5</u>										
Mean	5916.0	5.03	0.64	17	2.04	20.60	2.31	23	2.36	2.49
Range	3552-8783	4.61-5.34	0.60-0.80	16-18	1.96-2.11	20-22	2.31-2.46	21-25	2.24-2.55	2.73-2.73
SE	991.68	0.14	0.04	0.45	0.02	0.40	0.04	0.89	0.05	0.07
<u>Fall, n=5</u>										
Mean	3987.1	5.49	0.37	14.40	1.75	19	2.28	21.60	2.35	2.50
Range	1905-8353	5.19-5.95	0.19-0.59	12-17	1.33-1.98	17-22	2.03-2.38	19-25	2.07-2.49	2.38-2.68
SE	1161.22	0.14	0.08	0.87	0.11	0.95	0.06	1.08	0.08	0.05
<u>Winter, n=5</u>										
Mean	11380.0	5.64	0.17	17.40	0.96	21.20	1.44	22	1.44	2.43
Range	3842-21851	5.36-5.80	0.07-0.30	12-23	0.76-1.26	15-28	1.15-1.74	15-31	1.15-1.74	2.31-2.55
SE	3006.48	0.08	0.04	2.18	0.10	2.65	0.11	3.16	0.12	0.04
<u>All seasons, n=15</u>										
Mean	7094.4	5.38	0.39	16.27	1.58	20.27	2.01	22.20	2.05	2.47
Range	1905-21851	4.61-5.95	0.07-0.80	12-23	0.76-2.11	15-28	1.15-2.46	15-31	1.15-2.55	2.31-2.73
SE	1335.35	0.10	0.06	0.82	0.13	0.91	0.12	1.08	0.12	0.03

Appendix B. (continued)

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	<u>MBI</u>	<u>OBI</u>
Wilson's Creek National Battlefield- UPPER											
<u>spring: n=5</u>											
Mean	13153.9	6.11	0.01	10.40	0.47	12.60	0.81	13.20	0.81	3.05	2.80
Range	8912-20947	6.10-6.12	0-0.01	9-12	0.30-0.61	11-14	0.52-1.04	12-14	0.52-1.04	2.75-3.37	2.71-2.88
SE	2240.82	0.01	0	0.60	0.05	0.60	0.09	0.37	0.09	0.11	0.03
<u>Summer: n=10</u>											
Mean	9312.2	5.41	0.25	13.60	1.30	16.20	1.64	17.50	1.65	2.57	2.89
Range	6146-14391	5.10-5.88	0.14-0.34	12-16	1.02-1.58	14-18	1.64-1.88	15-21	1.27-1.91	3.19-3.19	2.95-2.95
SE	909.49	0.07	0.02	0.43	0.06	0.49	0.08	0.69	0.08	0.10	0.02
<u>Fall: n=5</u>											
Mean	22176.5	6.18	0.17	16.40	1.44	20.40	2	21.80	2.01	2.30	2.82
Range	15069-27674	5.98-6.43	0.13-0.21	14-18	1.27-1.55	18-22	1.86-2.09	19-24	1.87-2.09	2.15-2.51	2.74-2.85
SE	2736.68	0.07	0.02	0.81	0.05	0.81	0.04	0.97	0.04	0.06	0.02
<u>All seasons: n=20</u>											
Mean	13488.7	5.78	0.17	13.50	1.13	16.35	1.52	17.50	1.53	2.62	2.85
Range	6146-27674	5.10-6.43	0-0.34	9-18	0.30-1.58	11-22	0.52-2.09	12-24	0.52-2.09	2.15-3.37	2.71-2.95
SE	1519.22	0.09	0.02	0.58	0.09	0.72	0.11	0.81	0.11	0.08	0.02

Appendix B. (continued)

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	<u>MBI</u>	<u>OBI</u>
Wilson's Creek National Battlefield- LOWER											
<u>Spring: n=5</u>											
Mean	14361.7	6.09	0.01	11.60	0.72	13.20	0.98	13.80	0.98	2.41	2.77
Range	11162-20915	6.06-6.12	0-0.01	7-15	0.62-0.86	9-16	0.89-1.05	9-17	0.89-1.07	2.09-3.31	2.68-2.84
SE	1726.97	0.01	0	1.44	0.05	1.39	0.03	1.62	0.03	0.23	0.03
<u>Summer: n=10</u>											
Mean	8040.9	5.26	0.35	13.40	1.47	16.60	1.86	17.50	1.90	2.49	2.75
Range	2906-19225	4.71-5.64	0.25-0.62	11-17	1.08-1.64	13-21	1.32-2.13	14-22	1.33-2.21	2.11-2.99	2.58-2.87
SE	1498.8	0.09	0.03	0.62	0.05	0.82	0.09	0.83	0.10	0.09	0.03
<u>Fall: n=5</u>											
Mean	33392.9	6.27	0.44	17.60	1.55	22.60	2.12	24.20	2.14	2.45	2.84
Range	28493-37750	6.07-6.46	0.34-0.55	17-19	1.47-1.70	22-24	1.94-2.20	23-25	1.97-2.21	2.04-2.73	2.78-2.90
SE	1531.31	0.08	0.04	0.40	0.04	0.40	0.05	0.37	0.05	0.12	0.02
<u>All seasons: n=20</u>											
Mean	15959.1	5.72	0.28	14	1.30	17.25	1.70	18.25	1.73	2.46	2.78
Range	2906-37750	4.71-6.46	0-0.62	7-19	0.62-1.70	9-24	0.89-2.20	9-25	0.89-2.21	2.04-3.31	2.58-2.90
SE	2548.55	0.12	0.04	0.68	0.08	0.93	0.11	1.03	0.11	0.08	0.02

Appendix B. (continued)

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	<u>MBI</u>	<u>OBI</u>
Wilson's Creek National Battlefield- SKEGGS											
<u>Spring: n=5</u>											
Mean	10254.0	5.90	0.44	19.80	1.75	24.80	2.13	25	2.13	1.32	2.19
Range	6265-15252	5.47-6.27	0.28-0.57	16-21	1.62-1.91	19-28	1.99-2.24	19-28	1.99-2.24	0.89-1.72	2.11-2.29
SE	1821.10	0.15	0.06	0.97	0.05	1.53	0.04	1.58	0.04	0.16	0.03
<u>Summer: n=10</u>											
Mean	6552.2	5.47	0.64	18.30	2.03	23.50	2.27	24.10	2.28	1.69	2.45
Range	3757-11313	4.60-6.56	0.30-0.96	15-22	1.81-2.28	20-28	1.97-2.50	20-28	1.97-2.52	1.05-2.70	2.27-2.55
SE	719.77	0.20	0.07	0.70	0.05	0.75	0.06	0.78	0.06	0.20	0.03
<u>Fall: n=5</u>											
Mean	10779.3	5.69	0.39	19.60	2	24.80	2.37	25.40	2.37	1.45	2.50
Range	4629-14812	5.48-6.01	0.25-0.75	17-24	1.78-2.17	22-30	2.12-2.63	22-31	2.12-2.63	1.06-2.14	2.39-2.65
SE	1773.6	0.10	0.09	1.29	0.07	1.50	0.10	1.63	0.10	0.19	0.05
<u>All seasons: n=20</u>											
Mean	8534.4	5.63	0.53	19	1.95	24.15	2.26	24.65	2.26	1.54	2.40
Range	3757-15253	4.60-6.56	0.25-0.96	15-24	1.62-2.28	19-30	1.97-2.63	19-31	1.97-2.63	0.89-2.70	2.11-2.65
SE	819.41	0.11	0.05	0.53	0.04	0.63	0.04	0.66	0.04	0.12	0.03

Appendix C. Means, ranges, and standard errors (SE) of community indices; total density, family biotic index (FBI), ratio of

EPT taxa abundance to chironomidae abundance (EPT), family richness (FRCH), family diversity (FDIV), genus richness (GRCH), genus diversity (GDIV), taxa richness (TRCH), and taxa diversity (TDIV), by site and season from 1992-1995.

See text for description of index calculations.

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>
Agate Fossil Beds National Monument- AFB1									
<u>Spring: n=5</u>									
Mean	357.4	6.02	0.21	6.91	1.26	7.53	1.35	8.2	1.58
Range	151-710	5.72-6.25	0.21-0.32	5-9	1.26-1.47	5-11	1.27-1.49	7-12	1.15-1.82
SE	106.54	0.23	0.04	0.78	0.13	1.02	0.19	1.02	0.14
<u>Fall: n=15</u>									
Mean	435.9	5.90	0.31	7.81	1.29	8.42	1.39	9.8	1.54
Range	94-1162	5.13-6.37	0.11-0.72	4-15	0.62-1.90	6-11	1.27-1.65	5-17	1.62-2.04
SE	65.05	0.09	0.05	0.84	0.08	0.54	0.09	0.94	0.08
<u>All seasons: n=10</u>									
Mean	416.3	5.93	0.29	7.40	1.28	7.93	1.21	9.4	1.55
Range	94-1162	5.13-6.37	0.11-0.72	4-15	0.62-1.90	5-11	1.27-1.65	5-17	1.15-2.04
SE	579.56	0.06	0.04	0.67	0.07	0.56	0.13	0.75	0.07

Appendix C. (continued)

Agate Fossil Beds National Monument-AFB3									
<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	
<u>Spring: n=5</u>									
Mean	725.2	6.02	0.21	6.19	1.17	7.91	1.25	8.20	1.49
Range	323-1011	5.71-6.26	0.14-0.21	5-8	0.96-1.35	6-9	1.05-1.39	6-11	1.26-1.70
SE	128.20	0.11	0.03	0.77	0.08	0.92	0.10	1.02	0.09
<u>Fall: n=10</u>									
Mean	1131.0	5.77	0.28	7.94	1.20	8.60	1.37	10.5	1.53
Range	301-1969	5.50-6.26	0.13-0.36	4-10	0.71-1.86	6-10	1.22-1.63	6-13	0.96-2.24
SE	223.94	0.18	0.03	0.59	0.10	0.75	0.09	0.78	0.08
<u>All seasons: n=15</u>									
Mean	995.7	5.85	0.26	7.36	1.20	8.12	1.29	9.73	1.51
Range	301-1969	5.50-6.26	0.13-0.36	4-10	0.71-1.86	6-10	1.05-1.63	6-13	0.96-2.24
SE	579.56	0.07	0.02	0.52	0.07	1.00	0.11	0.69	0.08

Appendix C. (continued)

<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>
Homestead National Monument- HMS1								
<u>Summer: n=10</u>								
Mean	1328.8	7.18	0.02	8.56	1.18	10.32	1.28	1.50
Range	667-2034	7.10-7.30	0.01-0.02	6-11	0.79-1.64	9-12	0.82-1.74	0.96-1.89
SE	144.58	0.04	0.01	1.30	0.10	0.91	0.11	0.10
Homestead National Monument- HMS2								
<u>Summer: n=10</u>								
Mean	2424.2	7.09	0.01	10.75	1.33	12.51	1.48	1.67
Range	1410-3766	6.99-7.19	0-0.03	8-13	0.84-1.73	10-15	1.04-1.59	1.12-2.10
SE	221.07	0.20	0.01	0.54	0.12	0.65	0.10	0.11

Appendix C. (continued)

<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>
Pipestone National Monument- PPS1								
<u>Summer: n=5</u>								
Mean	24.0	4.65	0.61	6	1.27	8.84	1.73	9.20
Range	14-34	3.82-5.51	0.18-1.00	3-9	0.85-1.82	5-13	1.07-2.32	5-14
SE	3.48	0.28	0.13	1	0.21	1.56	0.22	1.66
<u>Winter: n=5</u>								
Mean	260.4	5.07	0.47	5.74	1.37	7.33	1.66	7.60
Range	43-527	4.82-5.24	0.33-0.68	3-10	1.00-1.82	4-12	1.26-2.16	4-13
SE	88.37	0.07	0.06	1.14	0.15	1.42	0.17	1.50
<u>All seasons: n=10</u>								
Mean	142.2	4.86	0.54	5.87	1.32	8.09	1.70	8.40
Range	14-527	3.82-5.51	0.18-1.00	3-10	0.85-1.82	4-13	10.7-2.32	4-14
SE	57.36	0.15	0.07	0.72	0.12	1.03	0.13	1.09

Appendix C. (continued)

<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>
Pipestone National Monument- PPS2								
<u>Summer, n=5</u>								
Mean	73.4	4.74	0.60	6.20	1.20	8.47	1.54	8.80
Range	10-196	3.82-5.82	0-0.71	4-13	0.61-1.60	4-18	0.86-2.12	6-19
SE	37.54	0.32	0.16	1.98	0.19	2.75	0.25	2.91
<u>Winter, n=5</u>								
Mean	245.4	5.07	0.47	5.74	1.42	7.33	1.71	7.60
Range	108-355	4.96-5.20	0.37-0.56	4-8	1.18-1.67	5-10	1.45-1.99	6-11
SE	47.19	0.04	0.04	0.71	0.09	0.88	0.10	0.93
<u>All seasons; n=10</u>								
Mean	159.4	4.91	0.53	5.97	1.31	7.90	1.63	8.20
Range	11-355	3.82-5.82	0-0.71	4-13	0.61-1.67	4-18	0.86-2.12	6-19
SE	40.37	0.16	0.08	1	0.11	1.37	0.13	1.45

Appendix C. (continued)

George Washington Carver National Monument- CAR									
<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>	
<u>Spring: n=5</u>									
Mean	762.0	5.09	0.45	13.34	1.99	16.78	2.35	17.60	2.39
Range	387-958	4.93-5.26	0.44-0.46	10-17	1.75-2.17	12-21	2.08-2.55	13-23	2.13-2.59
SE	97.48	0.06	0	1.31	0.07	1.63	0.08	1.72	0.08
<u>Summer: n=2</u>									
Mean	1264.6	5.05	0.45	12.51	1.79	15.74	2.13	16.50	2.17
Range	624-1905	5.00-5.10	0.31-0.45	11-13	1.50-2.09	14-17	1.80-2.45	15-18	1.85-2.50
SE	640.45	0.05	0	1.14	0.29	1.42	0.32	1.50	0.32
<u>All seasons: n=7</u>									
Mean	905.6	5.08	0.45	13.10	1.93	16.49	2.29	17.29	2.33
Range	387-1905	4.93-5.26	0.31-0.46	10-17	1.50-2.17	12-21	1.80-2.55	13-23	1.85-2.59
SE	180.69	0.04	0	0.95	0.09	1.18	0.10	1.25	0.10

Appendix C. (continued)

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>
George Washington Carver National Monument- WIL									
<u>Spring: n=5</u>									
Mean	1002.8	5.05	0.45	12.43	1.67	15.65	2	16.40	2.04
Range	377-2098	4.93-5.16	0.28-0.45	10-15	1.29-1.92	12-19	1.58-2.26	13-20	1.62-2.31
SE	296.88	0.05	0.04	1.12	0.11	1.39	0.12	1.47	0.12
<u>Summer: n=4</u>									
Mean	1573.7	5.11	0.45	13.84	1.85	17.40	2.19	18.25	2.23
Range	646-2722	4.99-5.23	0.34-0.45	11-16	1.61-2.07	14-20	1.93-2.44	15-22	1.97-2.48
SE	483.50	0.05	0.03	1.26	0.09	1.56	0.10	1.65	0.10
<u>All seasons: n=9</u>									
Mean	1256.6	5.07	0.45	13.06	1.75	16.43	2.08	17.22	2.12
Range	377-2722	4.93-5.23	0.28-0.45	10-16	1.29-2.07	12-20	1.58-2.44	13-22	1.62-2.48
SE	271.12	0.04	0.01	0.82	0.08	1.02	0.08	1.08	0.08

Appendix C. (continued)

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>
Wilson's Creek National Battlefield- UPPER									
<u>Spring: n=5</u>									
Mean	131.2	6.12	0.01	5.00	0.44	5.20	0.45	6.20	0.96
Range	46-242	6.11-6.13	0-0.07	3-6	0.20-0.73	3-6	0.20-0.78	4-7	0.75-1.20
SE	32.22	0.00	0.01	0.55	0.11	0.58	0.12	0.58	0.09
<u>Summer: n=5</u>									
Mean	1155.6	5.82	0.00	4.00	0.51	6.00	0.68	6.60	0.73
Range	53-2344	5.72-5.82	-	2-7	0.26-0.65	4-9	0.36-0.96	4-10	0.36-1.11
SE	411.48	0.00	-	0.89	0.07	1.05	0.10	1.21	0.12
<u>Fall: n=10</u>									
Mean	328.1	6.34	0.25	7.60	1.22	11.50	1.62	12.30	1.76
Range	16-808	5.96-7.19	0-0.79	2-14	0.56-1.88	6-20	1.26-1.98	6-20	1.38-2.00
SE	88.17	0.14	0.09	1.27	0.14	1.53	0.08	1.41	0.07
<u>All seasons: n=20</u>									
Mean	485.8	6.15	0.13	6.05	0.85	8.55	1.09	9.35	1.30
Range	16-2344	5.72-7.19	0-0.79	2-14	0.20-1.88	3-20	0.20-1.98	4-20	0.36-2.00
SE	137.91	0.08	0.05	0.76	0.11	1.04	0.13	1.01	0.12

Appendix C. (continued)

TOTAL	FBI	EPT	FRCH	FDIV	GRCH	GDIV	TRCH	TDIV
Wilson's Creek National Battlefield- LOWER								
<u>Spring: n=5</u>								
Mean	114.4	6.12	0.06	3.40	0.36	5.25	0.92	0.96
Range	27-187	6.08-6.13	0-0.18	1-6	0-0.87	2-10	0.53-1.58	0.57-1.63
SE	26.25	0.01	0.04	0.93	0.15	1.36	0.18	0.18
<u>Summer: n=15</u>								
Mean	840.1	5.83	0.09	7.39	1.29	9.66	1.62	1.66
Range	355-1632	5.82-5.89	0-0.21	6-10	0.81-1.65	8-13	1.11-1.98	1.15-2.02
SE	81.96	0.01	0.02	0.35	0.08	0.40	0.08	0.08
<u>Fall: n=10</u>								
Mean	849.9	5.99	0.06	5.91	1.01	9.88	1.61	1.65
Range	108-2733	5.77-6.13	0-0.19	3-10	0.73-1.44	7-13	0.99-2.22	1.03-2.27
SE	275.21	0.05	0.02	0.73	0.07	0.66	0.11	0.11
<u>All seasons: n=30</u>								
Mean	722.4	5.93	0.07	6.23	1.04	9	1.50	1.54
Range	27-2733	5.77-6.13	0-0.21	1-10	0-1.65	2-13	0.53-2.22	0.57-2.27
SE	109.65	0.03	0.01	0.42	0.08	0.47	0.08	0.08

Appendix C. (continued)

	<u>TOTAL</u>	<u>FBI</u>	<u>EPT</u>	<u>FRCH</u>	<u>FDIV</u>	<u>GRCH</u>	<u>GDIV</u>	<u>TRCH</u>	<u>TDIV</u>
Wilson's Creek National Battlefield- SKEGGS									
<u>Spring: n=5</u>									
Mean	397.2	6.69	0.52	10.40	1.32	12.81	1.53	13.40	1.57
Range	209-826	6.36-7.06	0.36-0.71	9-12	1.08-1.69	9-15	1.15-1.93	10-16	1.20-1.98
SE	111.68	0.13	0.07	0.68	0.11	1.18	0.15	1.25	0.15
<u>Summer: n=9</u>									
Mean	575.3	6.00	0.05	10.72	1.72	13.28	2.09	13.89	2.13
Range	7-1700	5.79-6.47	0-0.11	5-16	1.29-2.02	5-20	1.56-2.72	6-21	1.60-2.76
SE	216.20	0.07	0.01	1.03	0.09	1.34	0.12	1.42	0.12
<u>Fall: n=5</u>									
Mean	33.0	6.14	0.09	4.60	1.21	8.09	1.71	8.40	1.76
Range	5-70	5.95-6.30	0-0.28	2-7	0.68-1.49	3-10	0.91-2.17	3-11	0.96-2.22
SE	13.29	0.06	0.05	0.81	0.14	1.36	0.22	1.44	0.22
<u>All seasons: n=19</u>									
Mean	385.7	6.22	0.18	9.03	1.48	11.79	1.84	12.32	1.89
Range	5-1700	5.79-7.06	0-0.71	2-16	0.68-2.02	3-20	0.91-2.72	3-21	0.96-2.76
SE	115.53	0.08	0.05	0.82	0.08	0.92	0.10	0.97	0.10