# Macroinvertebrate Monitoring as an Indicator of Water Quality: Status Report for Cub Creek, Homestead National Monument of America, 1989-2002


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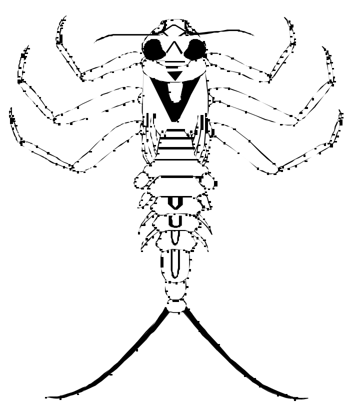


**March 18, 2003**

**ACKNOWLEDGEMENTS**

We would like to thank all of those who have contributed to macroinvertebrate monitoring at Homestead National Monument of America, Nebraska over the years. In particular, we would like to thank the numerous permanent and seasonal employees of Homestead National Monument of America who assisted with macroinvertebrate sample collections. Also, a debt of thanks is owed Lisa Thomas and Daren Carlisle, both have assisted in numerous ways to keep this monitoring focused and the results of highest quality.

## INTRODUCTION

The National Park Service (NPS) began monitoring the aquatic macroinvertebrates of Cub Creek in 1989 (Harris et al. 1991). However, sampling was sporadic and mostly outside the collection season of interest (summer) for this report. During the period 1992-1995, the Midwest Regional Office of NPS funded macroinvertebrate sampling. Concerted monitoring efforts began again in 1996-1997, following creation of the Prairie Cluster Prototype Long-term Ecological Monitoring Program (Prairie Cluster LTEM) – a base-funded science program to monitor natural resources at Homestead National Monument of America and five other Midwestern NPS units. The purpose of this report is to summarize macroinvertebrate monitoring data collected in 1996 through 2002, and to assess changes in community structure through time, especially since the 1989 baseline year.

Benthic macroinvertebrates are the most common group of organisms used to assess water quality (Rosenberg and Resh 1993). They are attractive as indicators because they represent a diverse group of long-lived, sedentary species that react strongly and often predictably to human influences on aquatic systems (Cairns and Pratt 1993). The objectives of this biomonitoring program are to determine the annual status of stream macroinvertebrate communities in order to assess the water quality of Cub Creek and to detect changes through time in macroinvertebrate communities.

## BACKGROUND

The Cub Creek basin is located in the loess plains of southeastern Nebraska and encompasses 374 $km^2$ of area (Harris et al. 1991). Cub Creek meanders through the western half of Homestead National Monument of America, exiting and reentering the park twice before leaving the park and joining the Big Blue River 3-km below it. Flood control and sediment dams have been constructed upstream of the park.

Homestead National Monument of America is located in Omernick's (1987) Central Great Plains ecoregion. Natural vegetation of the park is bluestem prairie (Kuchler 1964, Stubbendieck and Willson 1986). Restored tallgrass prairie covers approximately 40 ha of the park. Twenty-five hectares of hardwood forest border Cub Creek within park boundaries. The primary land use in the watershed surrounding the park is agriculture.

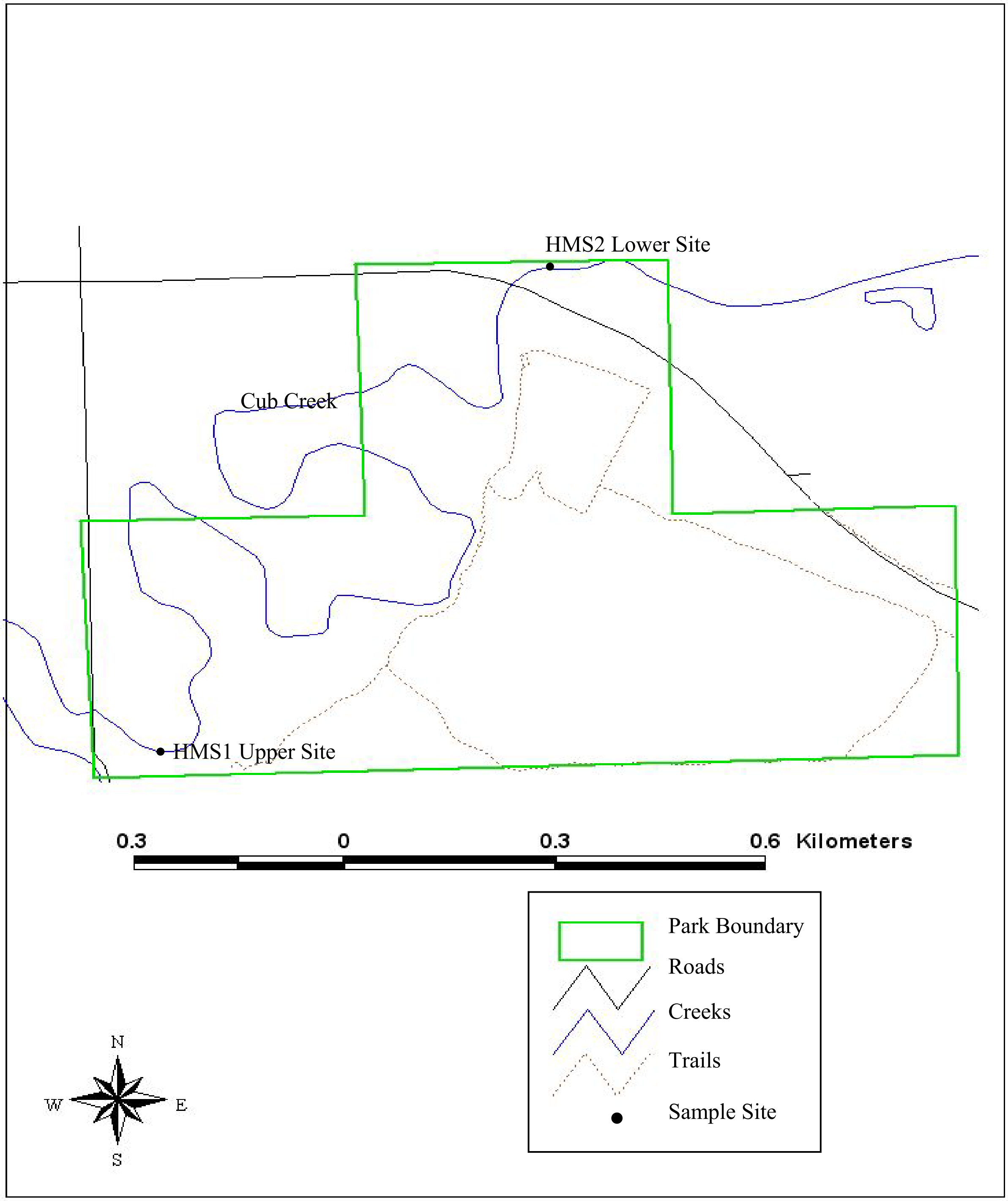
**Pollution history.** Water Resources Division (WRD), National Park Service conducted an extensive review of historic water quality data (1960 - 1997) for an area along Cub Creek three miles upstream and one mile downstream of Homestead National Monument of America (Water Resources Division 1999). Water Resources Division found surface water quality to have been impacted adversely by human activities. Potential anthropogenic sources of pollutants include municipal and industrial wastewater discharge (11 sites identified), agriculture, quarrying, stormwater runoff, and recreational use. Dissolved oxygen, pH, cadmium, copper, lead, and zinc all exceeded their respective EPA criteria for the protection of freshwater aquatic life one or more times during WRD review period. Nitrite plus nitrate, beryllium, cadmium, chromium, lead, nickel, bis (2-ethylhexyl) phthalate, and atrazine exceeded their respective EPA drinking water criteria one to many times also. Fecal-indicator bacteria concentrations and turbidity exceeded the WRD screening limits for freshwater bathing and aquatic life, respectively.

## SAMPLING METHODS

The details of field and laboratory procedures are described in Peterson et al. (1999), and summarized below.

**Monitoring Sites.** Harris et al. (1991) established two monitoring sites within the park, along Cub Creek (Figure 1). Five replicate Hester-Dendy samples were collected at each site during each sampling event.

**Figure 1. Macroinvertebrate monitoring sites at Homestead National Monument of America, Nebraska.**



**Sampling Frequency And Timing.** The monitoring protocol calls for the collection of three samples, with five replicates per sample, at approximate monthly intervals during a summer sampling window defined by growing degree days (i.e. days with average daily temperature above 10°C). For Homestead National Monument of America, normal average daily temperatures fall within this range for the period 18 June through 19 September (National Weather Service). The samples included in this report were collected between 23 July and 28 September, samplers were deployed one month prior to collection dates.

**Field Sampling.** Benthic macroinvertebrate samples were collected from the stream with Hester-Dendy samplers following methods outlined by Peterson et al. (1999). Macroinvertebrates were carefully removed from the sampler and placed in labeled jars containing 80 % ethyl alcohol. Samples were then prepared for shipping and sent to a lab for species identification and enumeration.

Colorado State University investigators collected macroinvertebrate samples in 1989 (Harris et al. 1991). Park staff collected macroinvertebrate samples for the period 1996-2002.

Macroinvertebrates were identified and enumerated by Dr. Boris Kondratieff's lab, Colorado State University for the year 1989 (Harris et al. 1991); and by Dr. Charles Rabeni's lab, Missouri Cooperative Fish and Wildlife Research Unit, University of Missouri-Columbia for 1996-2002. Macroinvertebrates were identified to the lowest taxonomic level possible, which was generally to genus.

To insure the consistency of data collected in the future, Dr. Charles Rabeni's lab has agreed to process annually collected macroinvertebrate samples for the next five years with contract extensions possible thereafter. NPS personnel at Homestead National Monument of America will continue to collect five replicate macroinvertebrate samples from each of two sites, three times annually. Additional physical and chemical parameters will be measured each time a sample is collected.

**Community Indices.** The monitoring protocol recommended using a suite of four community indices to describe changes in community structure (Table 1; Peterson et al. 1999). Peterson (1996) identified four metrics to be the least redundant and most indicative of water quality from a list of nine possible metrics using Pearson correlation comparisons and a Principal Components Analysis of the correlation matrix. Additionally, we have included Genus Evenness and EPT Richness in this report for the purpose of comparison with macroinvertebrate monitoring data from other sources.

**Table 1. Metrics used to characterize the aquatic macroinvertebrate communities of Cub Creek, Homestead National Monument of America, Nebraska and chosen as indicative of changing water quality through time. An asterisk indicates metrics originally selected by Peterson (1996).**

| Metric (Reference) | Definition | Expected Response |
|---|---|---|
| Density* (Plafkin et al. 1989) | Number of all individuals present per sample. Reported as individuals per $m^2$ | Lower macroinvertebrate densities indicate that a stream may have been subjected to one or more stresses. |
| Family Biotic Index* (Hilsenhoff 1988) | $FBI = \Sigma n_i a_i / N$ N is the total number of individuals in a sample, $n_i$ is the total number of individuals in a family, and $a_I$ the tolerance value for the *i*th family. | Higher FBI indicates that a stream may have been subjected to one or more stresses. This index weights the relative abundance of each family by its relative pollution tolerance value to determine a community score. Therefore, pollution-tolerant species are weighted heavier than pollution-sensitive species in the index. |
| Genus Diversity* (Shannon-Wiener 1949) | $H' = -\Sigma(n_i / N)*\ln(n_i / N)$ N is the total number of individuals in a sample and $n_i$ is the total number of individuals in the *i*th genus. | Lower diversity indicates that a stream may have been subjected to one or more stresses. |
| Genus Richness* (Resh and Grodhaus 1983) | Number of genus present per sample. | Lower richness indicates that a stream may have been subjected to one or more stresses. |
| Genus Evenness (Pielou 1966) | A measure of how evenly the total number of individuals are distributed across the genus's. $J' = H'/\ln(\text{genus richness})$ | Lower evenness indicates that a stream may have been subjected to one or more stresses and is being populated disproportionately by a few genus's, usually pollution tolerant genus's. |
| EPT Richness (Resh and Grodhaus 1983) | Number of Ephemeroptera, Plecoptera, and Trichoptera taxa present per sample. | Lower richness indicates that a stream may have been subjected to one or more pollution stresses. In general, the majority of taxa in these three orders are pollution sensitive. |

**Statistical Analysis Methods.** The macroinvertebrate indices for Cub Creek were compared graphically using means and an estimate of variance. This analysis approach was chosen over other statistical analysis options given there was an imbalance among years in the number of samples. Specifically, in 1989 and 1996 samples were collected on only one date. During 1997–2002 samples were collected on two different dates within each year, exception being 2000 and 2002 when samples were collected on three dates at site two. Also, at each site on various sample dates, less than five hester-dendy samplers were recovered after being deployed (Appendix A). Spring flooding often washed samplers down stream and late season droughts often resulted in samplers resting in the mud on the bottom.

Annual means and standard errors were calculated from means for each sample site and date. These means and standard errors, when graphed were used to make annual water quality comparisons for Cub Creek within the monument. As more data is collected, annual variations in the water quality of Cub Creek will be investigated using more rigorous statistical methods. The U.S. Geological Survey has agreed to undertake a project to design a statistical analysis of trends in the water quality of Cub Creek based on collected data. Both, the correlation of data collected at the same site through time, and the lack of independence of samples collected at a site on any given date, will be considered in this future design.

## RESULTS AND DISCUSSION

The macroinvertebrate indices for Cub Creek across years are reported in Table 2 and Figure 2. The data are also reported by date and sampling site in Appendix A.

**Table 2. Cub Creek, Homestead National Monument of America, Nebraska macroinvertebrate indices; least square means and standard errors.**

| | Mean (SE) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Macroinvertebrate Index** | **1989 n = 2** | **1996 n = 2** | **1997 n = 4** | **1998 n = 4** | **1999 n = 4** | **2000 n = 5** | **2001 n = 4** | **2002 n = 6** |
| Density | 3298.17 | 1421.96 | 3231.97 | 4947.26 | 3805.71 | 2414.21 | 2651.23 | 2872.20 |
| | (1005.38) | (33.37) | (967.89) | (979.78) | (794.98) | (380.05) | (921.96) | (220.82) |
| Family Biotic Index | 7.75 | 4.27 | 5.81 | 5.76 | 4.60 | 4.57 | 4.91 | 4.92 |
| | (0.04) | (0.02) | (0.50) | (0.35) | (0.09) | (0.14) | (0.35) | (0.18) |
| Genus Diversity | 1.20 | 1.00 | 2.07 | 1.84 | 1.84 | 1.45 | 1.81 | 1.50 |
| | (0.15) | (0.05) | (0.14) | (0.15) | (0.19) | (0.06) | (0.29) | (0.12) |
| Genus Richness | 11.90 | 12.00 | 20.40 | 15.6 | 19.88 | 14.00 | 13.18 | 13.26 |
| | (1.30) | (1.60) | (1.93) | (1.39) | (3.10) | (0.57) | (2.56) | (0.84) |
| Genus Evenness | 0.49 | 0.40 | 0.69 | 0.68 | 0.62 | 0.55 | 0.72 | 0.60 |
| | (0.08) | (0.00) | (0.04) | (0.04) | (0.05) | (0.03) | (0.07) | (0.03) |
| EPT Richness | 0.40 | 5.30 | 5.10 | 2.85 | 7.15 | 4.84 | 5.13 | 4.62 |
| | (0.20) | (0.30) | (0.95) | (0.29) | (0.83) | (0.69) | (0.53) | (0.68) |

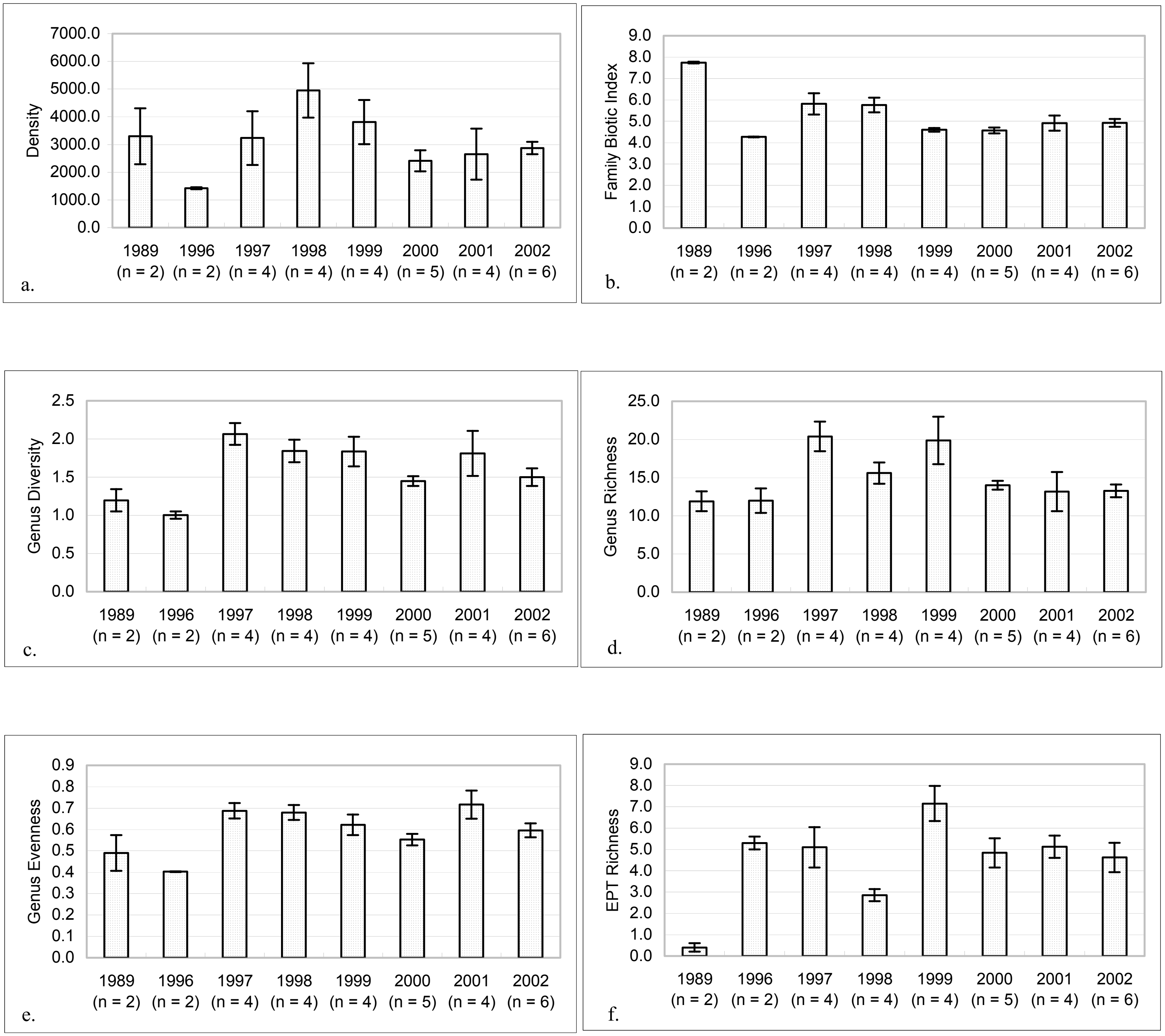
Density (Fig. 2a), the number of individuals present per sample, reported as individuals per $m^2$ has not changed significantly over time based on means and overlapping standard errors, with two exceptions. Year 1998 samples contained significantly more individuals than other years and 1996 contained significantly fewer. Consistent densities suggest that there has not been a significant shift in individual numbers within any one species and water quality has remained relatively unchanged. The higher density in 1998 may be the result of samplers being deployed at later dates when compared to other years (see Appendix A), rather than representative of any changes in water quality. The opposite could explain the 1996 anomaly as samplers were deployed early in the summer. Colonization of samplers can be greater in late summer as waters begin to cool and a mix of summer and fall colonizing macroinvertebrates are present.

The Family Biotic Index (Fig. 2b) indicates that water quality has remained relatively unchanged since an improvement in 1996 over the baseline year. EPT Richness values (Fig. 2f) provide a mirror image of Family Biotic Index values. As pollution tolerant chironomidae declined so did the Family Biotic Index. Simultaneously, the number of pollution intolerant species increased resulting in higher EPT Richness. Therefore, both Family Biotic Index and EPT Richness suggest that water quality in Cub Creek has improved over the baseline and has remained relatively constant since 1996.

Genus Diversity (Fig. 2c), Richness (Fig. 2d) and Evenness (Fig. 2e) all suggest that water quality improved from baseline conditions and have remained relatively unchanged since 1996. However, Genus Richness suggests that water quality of Cub Creek within the Monument may be declining slightly since 2000, based on means and overlapping standard errors.

In summary, it appears that water quality has improved over baseline conditions and is remaining relatively constant in quality. It is important to keep in mind that data from Cub Creek has not been compared to a high quality reference stream in the region, and the noted improvement is only relative to our baseline conditions. Despite the observed improvements, Cub Creek may still be considered a heavily impacted stream when compared to regional reference streams. Results do suggest that water quality may be starting to decline; however, most are not significant. An expansion of the water quality monitoring within the Monument to include chemical and physical measures, as well as the biotic measure, seems warranted at this time to help identify and document the decline in water quality if it is real. Both chemical and physical measures will help identify potential cause for changes in the biotic community, as well as serve as indicator of changing water conditions themselves. The addition of both chemical and physical measures to our macroinvertebrate monitoring effort will also allow us to more readily compare our data with regionally collected water quality data.

**Figure 2. Cub Creek, Homestead National Monument of America, Nebraska macroinvertebrate index means (standard error) by sample year.**



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**Appendix A. Cub Creek, Homestead National Monument of America, Nebraska macroinvertebrate index means (standard error) by sample date and sample site.**

| Sample Date | N | Density | Total Taxa Diversity | Total Taxa Richness | Total Taxa Evenness | FBI | Genus Diversity | Genus Richness | Genus Evenness | EPT Richness |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | HOME 1 | | | | | |
| 7/24/89 | 5 | 4303.55 (641.17) | 1.05 (0.10) | 13.40 (1.08) | 0.41 (0.03) | 7.79(0.02) | 1.05 (0.10) | 13.20 (0.97) | 0.41 (0.03) | 0.60 (0.60) |
| 7/30/96 | 5 | 1388.59 (199.85) | 0.96 (0.24) | 10.80 (0.66) | 0.40 (0.09) | 4.25 (0.10) | 0.96 (0.24) | 10.40 (0.75) | 0.40 (0.09) | 5.00 (0.63) |
| 7/23/97 | 1 | 2561.89 (0.00) | 1.67 (0.00) | 18.00 (0.00) | 0.58 (0.00) | 5.12 (0.00) | 1.67 (0.00) | 18.00 (0.00) | 0.58 (0.00) | 4.00 (0.00) |
| 9/23/97 | 5 | 6071.04 (1091.46) | 2.05 (0.11) | 17.00 (1.30) | 0.72 (0.03) | 6.89 (0.21) | 2.05 (0.11) | 17.00 (1.30) | 0.72 (0.03) | 3.60 (0.68) |
| 9/10/98 | 5 | 2815.93 (315.42) | 1.40 (0.13) | 11.80 (1.50) | 0.57 (0.04) | 4.84 (0.12) | 1.40 (0.13) | 11.80 (1.50) | 0.57 (0.04) | 2.20 (0.49) |
| 9/28/98 | 5 | 4150.70 (516.92) | 1.96 (0.07) | 15.40 (1.44) | 0.72 (0.02) | 6.25 (0.10) | 1.96 (0.07) | 15.40 (1.44) | 0.72 (0.02) | 2.80 (0.66) |
| 8/22/99 | 5 | 3016.15 (697.40) | 1.99 (0.03) | 17.00 (1.05) | 0.71 (0.03) | 4.74 (0.20) | 1.99 (0.03) | 17.00 (1.05) | 0.71 (0.03) | 6.80 (0.80) |
| 9/24/99* | 5 | 5190.53 (1024.44) | 1.72 (0.22) | 24.80 (1.62) | 0.54 (0.07) | 4.74 (0.25) | 1.72 (0.22) | 24.80 (1.62) | 0.54 (0.07) | 8.00 (0.45) |
| 8/23/00 | 5 | 1453.18 (257.65) | 1.64 (0.16) | 15.00 (1.10) | 0.61 (0.06) | 4.78 (0.19) | 1.64 (0.16) | 15.00 (1.10) | 0.61 (0.06) | 5.00 (1.05) |
| 9/25/00 | 5 | 1715.82 (250.64) | 1.51 (0.14) | 14.20 (1.28) | 0.57 (0.03) | 4.94 (0.23) | 1.51 (0.14) | 14.20 (1.28) | 0.57 (0.03) | 3.00 (0.45) |
| 8/2/01 | 5 | 1268.03 (363.29) | 1.09 (0.15) | 9.00 (1.79) | 0.52 (0.07) | 4.97 (0.73) | 1.09 (0.15) | 9.00 (1.79) | 0.52 (0.07) | 4.60 (1.17) |
| 8/30/01 | 5 | 1603.88 (343.14) | 2.26 (0.07) | 17.20 (1.36) | 0.80 (0.02) | 5.72 (0.35) | 2.26 (0.07) | 17.20 (1.36) | 0.80 (0.02) | 4.00 (0.84) |
| 7/28/02 | 5 | 1948.33 (996.20) | 1.16 (0.27) | 12.60 (4.04) | 0.47 (0.09) | 4.82 (0.55) | 1.16 (0.27) | 12.60 (4.04) | 0.47 (0.09) | 3.40 (1.14) |
| 8/23/02 | 4 | 2637.24 (738.59) | 1.62 (0.20) | 13.00 (3.37) | 0.64 (0.05) | 4.70 (0.22) | 1.62 (0.20) | 13.00 (3.37) | 0.64 (0.05) | 5.50 (1.00) |
| 9/24/02 | 5 | 3240.04 (1664.32) | 1.79 (0.45) | 15.40 (3.65) | 0.65 (0.11) | 5.43 (1.10) | 1.79 (0.45) | 15.4 (3.65) | 0.65 (0.11) | 3.60 (0.89) |
| | | | | | HOME 2 | | | | | |
| 7/24/89 | 5 | 2292.79 (414.40) | 1.34 (0.08) | 10.80 (0.73) | 0.57 (0.04) | 7.70 (0.05) | 1.34 (0.08) | 10.60 (0.68) | 0.57 (0.04) | 0.20 (0.20) |
| 7/30/96 | 5 | 1455.33 (178.29) | 1.05 (0.08) | 13.60 (0.68) | 0.40 (0.04) | 4.28 (0.04) | 1.05 (0.08) | 13.60 (0.68) | 0.40 (0.04) | 5.60 (0.93) |
| 7/23/97 | 1 | 1711.52 (0.00) | 2.21 (0.00) | 21.00 (0.00) | 0.73 (0.00) | 6.40 (0.00) | 2.21 (0.00) | 21.00 (0.00) | 0.73 (0.00) | 5.00 (0.00) |
| 9/23/97 | 5 | 2583.42 (214.94) | 2.34 (0.05) | 25.60 (0.81) | 0.72 (0.02) | 4.84 (0.17) | 2.34 (0.05) | 25.60 (0.81) | 0.72 (0.02) | 7.80 (0.37) |
| 9/10/98 | 5 | 7425.19 (870.46) | 2.02 (0.15) | 18.20 (3.12) | 0.71 (0.03) | 5.61 (0.19) | 2.02 (0.15) | 18.20 (3.12) | 0.71 (0.03) | 3.60 (0.51) |
| 9/28/98 | 5 | 5397.20 (1383.76) | 1.99 (0.11) | 17.00 (1.90) | 0.71 (0.03) | 6.35 (0.19) | 1.99 (0.11) | 17.00 (1.90) | 0.71 (0.03) | 2.80 (0.58) |
| 8/22/99 | 2 | 1948.33 (204.52) | 1.37 (0.05) | 12.50 (0.50) | 0.54 (0.03) | 4.38 (0.23) | 1.37 (0.05) | 12.50 (0.50) | 0.54 (0.03) | 5.00 (1.00) |
| 9/24/99 | 5 | 5067.81 (802.81) | 2.27 (0.10) | 25.20 (1.46) | 0.70 (0.02) | 4.54 (0.11) | 2.27 (0.10) | 25.20 (1.46) | 0.70 (0.02) | 8.80 (1.39) |
| 7/20/00 | 5 | 2402.58 (178.65) | 1.46 (0.09) | 11.80 (1.46) | 0.60 (0.03) | 4.36 (0.09) | 1.46 (0.09) | 11.80 (1.46) | 0.60 (0.03) | 5.40 (0.68) |
| 8/23/00 | 5 | 3451.02 (472.10) | 1.39 (0.15) | 14.20 (1.53) | 0.52 (0.04) | 4.17 (0.06) | 1.39 (0.15) | 14.20 (1.53) | 0.52 (0.04) | 7.00 (0.71) |
| 9/25/00 | 5 | 3048.44 (436.85) | 1.25 (0.07) | 14.80 (0.58) | 0.46 (0.02) | 4.58 (0.05) | 1.25 (0.07) | 14.80 (0.58) | 0.46 (0.02) | 3.80 (0.20) |
| 8/2/01 | 2 | 2411.19 (473.63) | 1.57 (0.18) | 8.50 (1.50) | 0.74 (0.02) | 4.00 (0.06) | 1.57 (0.18) | 8.50 (1.50) | 0.74 (0.02) | 5.50 (0.50) |
| 8/31/01 | 5 | 5321.85 (554.85) | 2.32 (0.07) | 18.00 (1.00) | 0.80 (0.02) | 4.95 (0.20) | 2.32 (0.07) | 18.00 (1.00) | 0.80 (0.02) | 6.40 (0.75) |
| 7/28/02 | 5 | 2839.61 (2077.26) | 1.29 (0.23) | 10.80 (5.07) | 0.61 (0.23) | 5.51 (1.19) | 1.29 (0.23) | 10.80 (5.07) | 0.61 (0.23) | 3.80 (2.39) |

**Appendix A. continued.**

| Sample Date | N | Density | Total Taxa Diversity | Total Taxa Richness | Total Taxa Evenness | FBI | Genus Diversity | Genus Richness | Genus Evenness | EPT Richness |
|---|---|---|---|---|---|---|---|---|---|---|
| 8/23/02 | 3 | 3085.76 (928.81) | 1.83 (0.21) | 16.00 (4.58) | 0.67 (0.08) | 4.52 (0.11) | 1.83 (0.21) | 16.00 (4.58) | 0.67 (0.08) | 7.67 (1.15) |
| 9/24/02 | 4 | 3482.24 (1411.98) | 1.30 (0.25) | 11.75 (1.71) | 0.53 (0.11) | 4.56 (0.18) | 1.30 (0.25) | 11.75 (1.71) | 0.53 (0.11) | 3.75 (0.50) |

* Replicates were in mud when they were recovered for analysis.