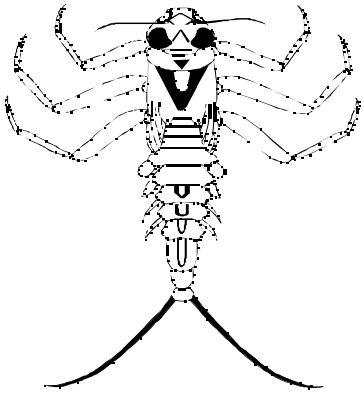
Bio-monitoring of Water Quality Using Aquatic Invertebrates and In-stream Habitat and Riparian Condition Assessments: Status Report for Cub Creek, Homestead National Monument of America, Nebraska 1989-2004



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1.0 INTRODUCTION

The National Park Service (NPS) began monitoring the aquatic invertebrates of Cub Creek within Homestead National Monument of America, Nebraska in 1989 (Harris et al. 1991). During the period 1992-1995, the Midwest Regional Office of NPS funded the aquatic invertebrate sampling effort within the creek. However, sampling was sporadic and mostly outside the collection season of interest (summer) for this report. Concerted monitoring efforts began in 1996-1997, following creation of the Prairie Cluster Prototype Long-term Ecological Monitoring Program, now known as the Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program – a base-funded science program to monitor natural resources at Homestead National Monument of America and sixteen other Midwestern NPS units. The purpose of this report is to summarize aquatic invertebrate monitoring data collected from 1989 through 2004, and to assess changes in community structure through time. In-stream habitat and riparian assessments were conducted in 2002 and 2003 to document habitat conditions of Cub Creek where the aquatic invertebrate communities evolved. Results of this effort are reported as well.

Benthic invertebrates are the most common group of organisms used to assess water quality (Rosenberg and Resh 1993). They are useful as indicators because they represent a diverse group of relatively long-lived, sedentary species that react strongly and often predictably to human influences on their aquatic environment (Cairns and Pratt 1993). The objectives of this bio-monitoring program are to determine the annual status of stream invertebrate communities and their habitat in order to assess the overall biotic integrity of water in Cub Creek and to detect changes through time in these communities, thus water quality. The in-stream habitat and riparian condition assessments will give us a better understanding of the environment in which the aquatic communities have evolved.

1.1 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 downstream. 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 row crop 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 four point eight kilometers upstream and one point six kilometers downstream of Homestead National Monument of America (Water Resources Division 1999). The study by the Water Resources Division found surface water quality had been impacted adversely by human activities. Potential anthropogenic sources of pollutants include municipal and industrial wastewater discharge (11 sites identified), agriculture, quarrying, storm-water 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 have also exceeded the WRD screening limits for freshwater bathing and aquatic life, respectively.

2.0 METHODS

2.1 Aquatic Invertebrate Sampling

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.

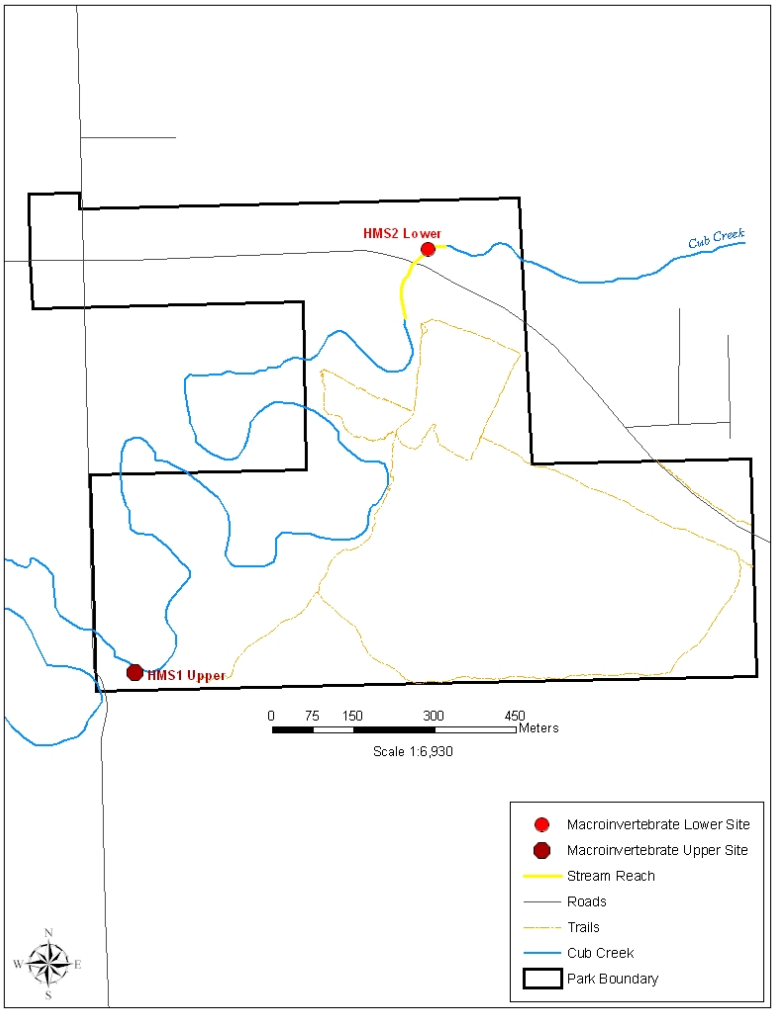

Figure 1. Aquatic Invertebrate monitoring sites at Homestead National Monument of America, Nebraska.

Sampling Frequency And Timing.--The monitoring protocol calls for the collection of three samples at each sample site, 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 20 July and 1 October, samplers were deployed one month prior to collection dates.

Field Sampling.--Benthic invertebrate samples were collected from Cub Creek with Hester-Dendy samplers following methods outlined by Peterson et al. (1999). Invertebrates 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 aquatic invertebrate samples in 1989 (Harris et al. 1991). Park staff collected aquatic invertebrate samples for the period 1996-2004.

Aquatic invertebrates 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 1996-2004. Invertebrates were identified to the lowest taxonomic level possible, which was generally to genus.

To insure the consistency of data collected in the future, NPS personnel at Homestead National Monument of America will continue to collect five replicate invertebrate 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 aquatic invertebrate monitoring data from other sources.

Table 1. Metrics used to characterize the aquatic invertebrate 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 invertebrate 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 Index: Shannon and Weaver 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 genera 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 genera. $J' = H'/\ln(\text{genus richness})$	Lower evenness indicates that a stream may have been subjected to one or more stresses and is being populated disproportionately by a few genera, usually pollution tolerant genera.
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.

2.2 In-stream Habitat and Riparian Condition Assessment

Details on procedures for assessing in-stream habitat and riparian condition are described in Peitz (draft), and summarized here. Eleven transects spaced equal distances apart along a 200 m reach, were used to assess in-stream habitat and riparian condition. The first two transects

were located downstream of the invertebrate sample site. The third transect was located at the sample site with the remaining eight upstream at 20 m intervals. Water quality measurements, dissolved oxygen, conductivity, pH, temperature and water clarity were taken at a representative location along the reach before entry into the stream to complete other assessment work. This kept observers from impacting water quality results. Dissolved oxygen (DO) and temperature were measured using a YSI 55 meter. Conductivity, relative conductivity and pH were measured using a YSI 63 meter. Water clarity or cloudiness caused by suspended or dissolved materials in the water was measured using a 120 cm Secchi tube.

In-stream discharge, flow stage, fluctuation rating and channel morphology were assessed and recorded for the stream reach at the completion of all in-stream habitat and riparian condition assessments. The presence and type of channel alterations as well as sedimentation and excessive algae problems were noted. Also noted was the amount and date of all recent rains if any. Pools located within the reach were recorded as belonging to one of four classes depending on depth: class 1, pool > 3 ft; class 2, pool > 2 ft; class 3, pool >1 ft; and class 4, pool is shallow and pool/riffle/run/bend ratio determined. Channel sinuosity and a stream degradation rating were determined for the reach.

In-stream habitat and riparian condition parameter were assessed at each transect and results recorded in one of three categories; in-stream, stream bank or riparian zone. Stream bank and riparian zones were assessed on the left and right side of the stream separately. Right and left banks were determined when looking downstream. Both in-stream habitat and stream bank assessments were done for an area five meters on either side of each transect. Stream bank was the area between the wetted edge of the stream and point of bank full (the point were the stream would leave its banks at flood stage). The riparian zone was assessed for an area 10 m^2 centered on each transect and starting at the bank full mark of the stream. Coverage of vegetation, woody debris and other structures were determined for in-stream, stream bank and riparian areas. Substrate type and embeddedness were determined and recorded for both in-stream and stream bank areas. The occurrence of filamentous algae, floating vegetation, rooted vascular plants and large woody debris were recorded. Upper and lower bank stability, severity of grazing damage if any, and overall assessment of buffer zone condition was also made for each side of a transect. The depth of the Thalweg and substrate present at the point of the Thalweg were recorded during the 2003 survey.

2.3 Statistical Analysis Methods.

Aquatic Invertebrate Analysis.--The invertebrate indices for Cub Creek were compared graphically using means and an estimate of variance. This analytical approach was chosen over other statistical analysis options because of the imbalance among years in the number of samples collected. Specifically, in 1989 and 1996 when samples were collected on only one date. During 1997, 1998, 1999 and 2001 samples were collected on two different dates within each year. During 2000, 2002, 2003 and 2004 samples were collected on three dates. Also, at each site during various sampling events, 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 for Cub Creek were calculated from means for each sample site and date. These means and standard errors were graphed and used to make annual water quality comparisons for Cub Creek within the monument. As more data is collected, annual variations and trends in the water quality of Cub Creek will be investigated using more

rigorous statistical methods. 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 future analysis.

In-stream Habitat and Riparian Condition Assessment Analysis.--Annual means were calculated for parameters measured within the stream reach. Using these means an overall mean and standard error for each parameter was calculated. Mean parameter values provide a baseline from which we can assess the influences of the physical and chemical environment on the invertebrate communities within Cub Creek. As more data is collected, the relationship between in-stream habitat and riparian conditions with invertebrate communities in Cub Creek will be investigated using more rigorous correlation analysis.

3.0 RESULTS

Aquatic Invertebrates.--The annual aquatic invertebrate indices calculated for Cub Creek at Homestead National Monument of America, Nebraska are reported on Table 2 and displayed in Figure 2. The raw data are reported by sampling event and site in Appendix A as well.

Table 2. Mean (± SE) metric values for the aquatic invertebrate communities in Cub Creek at Homestead National Monument of America, Nebraska from 1989 to 2004.

	Mean (SE)									
Aquatic Invertebrate 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	2003 n = 6	2004 n = 6
Density	3298.17 (1005.38)	1421.96 (33.37)	3231.97 (967.89)	4947.26 (979.78)	3805.71 (794.98)	2414.21 (380.05)	2651.23 (921.96)	2872.20 (220.82)	2773.95 (412.89)	3414.69 (937.31)
Family Biotic Index	7.75 (0.04)	4.27 (0.02)	5.81 (0.50)	5.76 (0.35)	4.60 (0.09)	4.57 (0.14)	4.91 (0.35)	4.92 (0.18)	5.02 (0.15)	5.62 (0.27)
Genus Diversity	1.20 (0.15)	1.00 (0.05)	2.07 (0.14)	1.84 (0.15)	1.84 (0.19)	1.45 (0.06)	1.81 (0.29)	1.50 (0.12)	1.73 (0.14)	1.99 (0.11
Genus Richness	11.90 (1.30)	12.00 (1.60)	20.40 (1.93)	15.6 (1.39)	19.88 (3.10)	14.00 (0.57)	13.18 (2.56)	13.26 (0.84)	15.29 (1.24)	15.45 (0.76)
Genus Evenness	0.49 (0.08)	0.40 (0.00)	0.69 (0.04)	0.68 (0.04)	0.62 (0.05)	0.55 (0.03)	0.72 (0.07)	0.60 (0.03)	0.63 (0.04)	0.73 (0.03)
EPT Richness	0.40 (0.20)	5.30 (0.30)	5.10 (0.95)	2.85 (0.29)	7.15 (0.83)	4.84 (0.69)	5.13 (0.53)	4.62 (0.68)	5.02 (0.71)	3.10 (0.26)

Average annual invertebrate densities (Fig. 2a) or 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 1996 samples contained significantly fewer individuals than all other years. However, 1996 was represented by only two sampling events which may have depressed the mean density value and standard error. Year 1998 samples contained more individuals than all other year samples. However, 1998 invertebrate densities were only significantly greater than densities in five of the remaining nine years. Relatively 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 invertebrates are present.

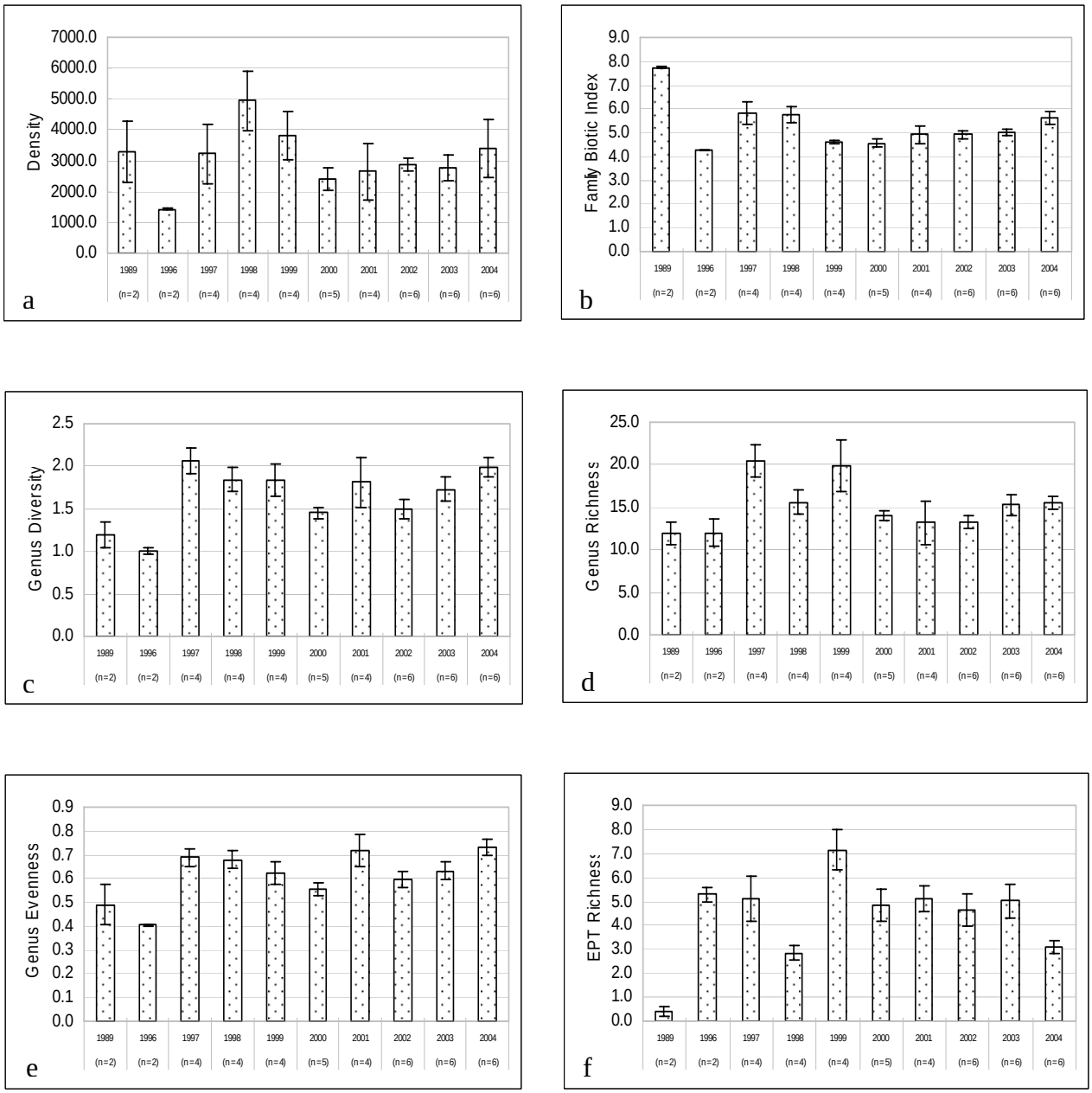

Figure 2. Mean (± SE) metric values for the aquatic invertebrate communities in Cub Creek at Homestead National Monument of America, Nebraska from 1989 to 2004.

The Family Biotic Index (Fig. 2b) indicates that water quality has remained relatively unchanged since improving in 1996 over the baseline year (1989). EPT Richness (Fig. 2f) provides us with a mirror image of Family Biotic Index values. As pollution tolerant chironomidae are replaced by pollution intolerant EPT taxa the Family Biotic Index declines and

EPT Richness increase. Therefore, both Family Biotic Index and EPT Richness values suggest that water quality in Cub Creek has improved over baseline measures 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 with slight annual improvements occurring since 2000.

In-stream Habitat and Riparian Condition Assessment.—Average habitat conditions for our assessment reach in Cub Creek at Homestead National Monument of America, Nebraska during 2002-2003 are shown in Table 3. Flow of Cub Creek was determined to be low to moderate with no recent rain events recorded. The fluctuation rating for Cub Creek was determined to be moderate and sinuosity low. Excessive algae growth in the creek was not noted, however, sedimentation

Table 3. Mean (± SE) values for habitat parameters measured in Cub Creek at Homestead National Monument of America, Nebraska in 2002 and 2003.

	Mean	Std. Err	Minimum	Maximum	Range
	Water chemistry parameter				
Water temperature (C^o)	25.80	0.60	25.50	26.40	0.90
Dissolved oxygen (mg/l)	8.35	0.20	8.15	8.55	0.40
Conductivity (uS/cm)	407.50	152.50	255.00	560.00	305.00
pH	8.22	0.21	8.01	8.42	0.41
Water clarity (cm)	18.00	5.00	13.00	23.00	10.00
	In-stream habitat parameter				
Stream width (m)	4.70	0.80	1.40	7.80	6.40
Thalweg depth (m)—2003 only	0.28	--	0.07	0.69	0.62
Canopy cover (%)	74.25	3.37	70.89	77.62	6.73
In-stream vegetation cover (%)	1.26	0.92	0.00	15.00	15.00
Small woody debris cover (%)	7.29	6.12	0.00	37.50	37.50
Overhanging vegetation cover (%)	12.48	12.48	0.00	62.50	62.50
Undercut bank (%)	2.74	2.30	0.00	37.50	37.50
Boulder cover (%)	0.21	0.10	0.00	3.50	3.50
Artificial structure cover (%)	5.28	5.17	0.00	62.50	62.50
	Stream bank parameter				
Height (m)	4.15	0.33	1.60	7.50	5.90
Slope (^{o})	37.23	1.36	23.00	57.00	34.00
Grass/forb cover (%)	30.79	5.96	1.00	85.00	84.00
Shrub/Vine cover (%)	4.29	3.03	0.00	37.50	37.50
Understory trees cover (%)	7.51	2.47	0.00	37.50	37.50
Overstory tree cover (%)	33.86	7.84	0.00	85.00	85.00
Bare soil cover (%)	67.35	0.08	3.50	97.50	94.00
Bare rock cover (%)	8.53	0.09	0.00	85.00	85.00
Woody debris cover (%)	4.11	2.44	0.00	37.50	37.50
	Riparian parameter				
Grass/forb cover (%)	59.08	23.69	1.00	97.50	96.50
Shrub/vine cover (%)	6.89	0.39	0.00	62.50	62.50
Tree seedling cover (%)	1.44	1.44	0.00	15.00	15.00
Understory tree cover (%)	37.03	10.85	0.00	97.50	97.50
Overstory tree cover (%)	51.60	4.88	0.00	85.00	85.00

representative of a stream surrounded by row crop agriculture was noted. The creek was channelized within the reach to accommodate a highway bridge. Riffles were rare within the reach. Therefore, the pool/riffle/run/bend ratio was high, greater than 26. Class 3 and class 4 pools were observed in the reach in 2002 and Class 2 through Class 4 pools were observed in

2003, a year of higher rain fall. Stream degradation was assessed as moderate for the reach. The condition of the buffer zone along the assessment reach ranged from poor to good but most of the reach length was recorded as being in fair condition. Grazing damage along the reach was minor and was only recorded in one small section where horses are tied.

Average water quality measurements taken at a representative location along the assessment reach are given in Table 3. These measurements were not effected by runoff from recent rain events or return flow. Stream discharge within the reach averaged 0.14 m^3/s and average stream depth at the point of discharge was 0.16 m. Average Thalweg depth for the total reach was 0.28 m. Sand made up over 55 % of the substrate within the reach followed by gravel (26%), silt (8%), clay (7%) and cobble (4%). With only a small percentage (4%) of the substrate materials greater than 64.0 mm in diameter we were precluded from effectively measuring substrate embeddedness. However, embeddedness for the few large substrate particles present from the sand, gravel, silt and clay was high. Figure 3 illustrates the average depth and flow at ¼, ½ and ¾ of the distance across the creek.

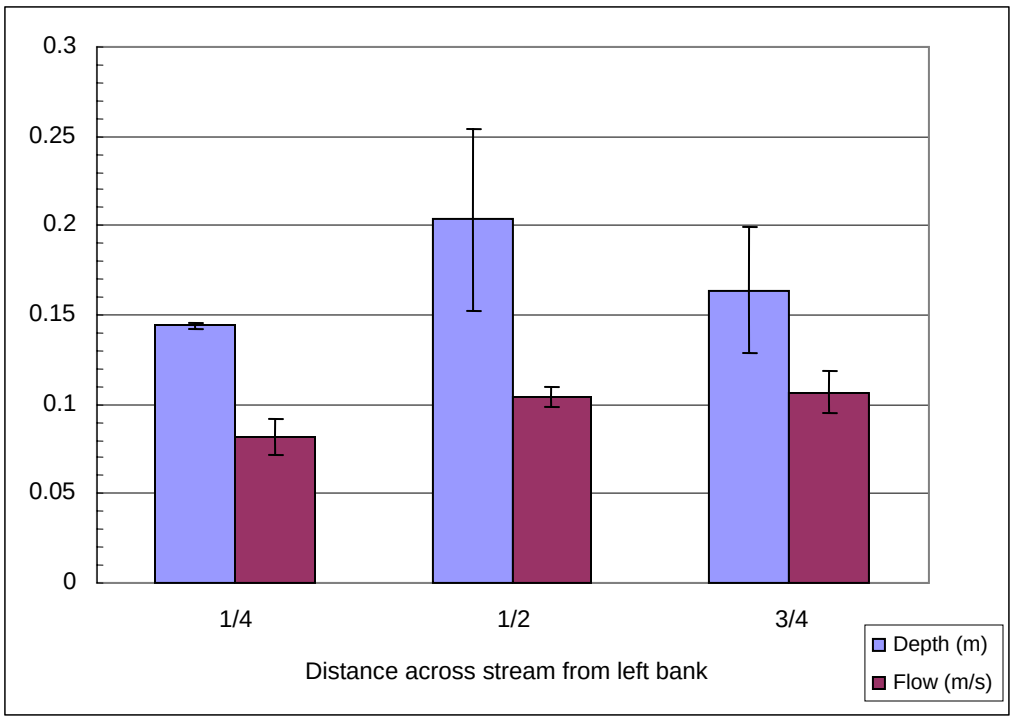

Figure 3.0. Mean (± SE) stream depth and flow at ¼, ½ and ¾ of the way across Cub Creek from left bank. Measurements were taken within Homestead National Monument of America, Nebraska in 2002-2003.

Average cover of vegetation, brush and small woody debris, overhanging vegetation, undercut banks, boulders and artificial structures in Cub Creek within our assessment reach are given in Table 3. Within the reach, canopy cover averaged 74% above the creek. Large wood debris was common in the creek in 2002. However, one or more flooding events moved the large woody debris downstream resulting in about 1/8th of the material remaining in 2003. Rooted vascular plants were encountered only rarely within the reach, floating vegetation occasionally and filamentous algae were rare to common. Although filamentous algae was recorded as occurring commonly, it was only common on a couple of transects.

Lower stream bank stability along the reach ranged from poor to good, but most was recorded as being poor. Upper stream bank stability ranged from poor to excellent, but it was mostly fair along the reach. The dominant bank substrate was silt and clay with the dominant cover type bare soil (Table 3). The riparian area along the stream bank was dominated by mowed lawn/trails/hard surfaces (45%), forest/woodland (32%), upland-prairie (19%) and riparian-prairie (3%).

4.0 DISCUSSION

In summary, it appears that water quality of Cub Creek within Homestead National Monument of America improved sharply over baseline conditions and is remaining constant or improving slightly with time. However, 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 improvements are only relative to baseline conditions. That being said and the fact Cub Creek may still be a heavily impacted stream (Water Resources Division1999), efforts by the Monument to work with land owners upstream in establishing buffer zones has helped water quality. Increases in genus diversity, richness and evenness while density and Family Biotic Index values remain constant suggest that pollution intolerant species are not being replaced by tolerant species. Increases in the presence of more pollution tolerant species would suggest water quality is in decline. Buffer zones help to filter out chemical runoff from agriculture and reduce sedimentation entering the stream. Both chemical runoff and sedimentation have detrimental effects on less pollution tolerant aquatic invertebrate species.

An expansion of the water quality monitoring within the Monument to include chemical and physical measures in 2002-2003 has allowed us the opportunity to establish a baseline on which to measure changes in in-stream habitat conditions and the effects these have on the invertebrate communities and water quality. The true influence of improved buffer zones on water quality will be noted in improved in-stream substrate composition and structure (invertebrate habitat). We are scheduled to reassess in-stream habitat and riparian conditions in 2007-2008.

5. 0 MANAGEMENT IMPLICATIONS

The suppressed aquatic invertebrate communities in Cub Creek within Homestead National Monument of America, Nebraska suggest that active management could improve water quality and in-stream habitat and riparian zone conditions. Continued establishment and widening of riparian buffer zones along Cub Creek above the park will protect aquatic life as well as in-stream habitat from chemical runoff and sedimentation. Improved buffer zones will also reduce bank erosion within the Monument by reducing stream velocity and the amount of water entering Cub Creek. A reduction in the Monuments impervious surfaces (sidewalks, trails and parking lot) and mowing in the riparian buffer along Cub Creek would also help to stabilize the riparian zone and in-stream habitat. This in turn will have a positive benefit on the aquatic life of Cub Creek. Even with improved in-stream habitat it should be remembered that the diversity of aquatic invertebrates that utilize Cub Creek may appear low when compared to other systems. With the majority of the stream bed consisting of sand, gravel, silt and clay, a suppressed aquatic invertebrate community should be expected and considered a natural condition of Cub Creek, a prairie stream system. The long history and continuing efforts with

water quality monitoring in Cub Creek provides a sound tool to recognize both a rapid deterioration of water quality as well as a chronic decline.

6.0 ACKNOWLEDGEMENTS

We would like to thank all of those who have contributed to invertebrate monitoring at Homestead National Monument of America, Nebraska over the years. In particular, we would like to thank Michael Stansberry, Jesse Bolli and the numerous permanent and seasonal employees of Homestead National Monument of America who assisted with invertebrate sample collections. Also, a debt of thanks is owed the Senior Ranger Corp. who voluntarily assists with water quality monitoring efforts year in and year out.

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Appendix A. Mean (± Std Dev) values for the aquatic invertebrate metrics calculated for Cub Creek, Homestead National Monument of America, Nebraska 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)
7/21/03	5	3683.53 (2756.43)	1.17 (0.56)	11.20 (3.63)	0.47 (0.18)	4.73 (0.51)	1.17 (0.56)	11.20 (3.63)	0.47 (0.18)	2.80 (0.45)
8/22/03	5	1959.10 (495.45)	2.12 (0.40)	19.60 (3.91)	0.71 (0.12)	5.56 (0.77)	2.12 (0.40)	19.60 (3.91)	0.71 (0.12)	6.80 (0.84)
10/01/03	5	1832.08 (462.58)	1.86 (0.33)	15.60 (2.97)	0.68 (0.08)	4.83 (0.39)	1.86 (0.33)	15.60 (2.97)	0.68 (0.08)	4.60 (0.55)
7/21/04	5	2811.63 (914.09)	1.81 (0.45)	15.60 (4.10)	0.66 (0.11)	5.34 (0.73)	1.79 (0.43)	14.80 (3.42)	0.66 (0.11)	4.00 (1.22)
8/26/04	4	2037.14 (915.97)	1.97 (0.14)	18.75 (3.40)	0.68 (0.03)	4.81 (0.08)	1.96 (0.13)	18.25 (2.87)	0.68 (0.03)	3.00 (2.16)
9/30/04	5	7737.35 (871.25)	2.29 (0.13)	17.60 (1.82)	0.80 (0.02)	6.64 (0.26)	2.24 (0.10)	16.00 (1.00)	0.81 (0.02)	2.20 (0.84)
						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)

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
8/22/99	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)
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)
7/21/03	5	4210.98 (709.72)	1.49 (0.43)	12.60 (3.29)	0.59 (0.11)	5.04 (0.29)	1.49 (0.43)	12.60 (3.29)	0.59 (0.11)	3.40 (0.89)
8/22/03	5	2977.40 (604.79)	1.88 (0.31)	17.00 (4.18)	0.67 (0.06)	4.64 (0.31)	1.88 (0.31)	17.00 (4.18)	0.67 (0.06)	7.00 (2.74)
10/01/03	4	1980.62 (991.40)	1.85 (0.14)	15.75 (1.89)	0.67 (0.05)	5.30 (0.65)	1.85 (0.14)	15.75 (1.89)	0.67 (0.05)	5.50 (1.29)
7/21/04	4	2567.28 (997.06)	1.63 (0.49)	13.75 (2.63)	0.62 (0.15)	5.11 (0.47)	1.58 (0.44)	12.50 (1.73)	0.62 (0.15)	2.75 (0.96)
8/26/04	3	4004.31 (2297.41)	2.23 (0.20)	16.00 (2.65)	0.81 (0.05)	5.85 (0.53)	2.21 (0.19)	15.33 (2.89)	0.81 (0.05)	3.67 (1.15)
9/30/04	5	1330.46 (627.36)	2.19 (0.08)	16.40 (2.07)	0.79 (0.05)	5.94 (0.10)	2.18 (0.08)	15.80 (1.30)	0.79 (0.05)	3.00 (0.71)

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