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Aquatic Invertebrate Monitoring at George Washington Carver National Monument

2005-2007 Report

Natural Resource Technical Report NPS/HTLN/NRTR—2009

ON THE COVER
Caver Creek, George Washington Carver National Monument, Missouri
Photo from The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program files.

Aquatic Invertebrate Monitoring at George Washington Carver National Monument

2005-2007 Report

Natural Resource Technical Report NPS/HTLN/NRTR—2009/243

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Table of Contents

Figures

Page

Tables

Page

Abstract

In the late 1980’s, the National Park Service (NPS) began an intensive program to monitor water quality and invertebrate community structure in prairie streams at several midwestern parks. Included in this baseline study was George Washington Carver National Monument (GWCA). Some preliminary monitoring was conducted at GWCA in 1988 and 1996, but monitoring was discontinued thereafter. These previous sampling efforts suggested that stream condition at gwca was not impaired. Monitoring was re-initiated at GWCA in 2005 based on a monitoring protocol developed by the heartland network using revised methodology from previous protocols. The objectives of current monitoring are to: 1) determine the status and trends of invertebrate species diversity, abundance, and community metrics, and 2) relate the invertebrate community to overall water quality through quantification of metrics related to species richness, abundance, diversity, and region-specific multi-metric indices as indicators of water quality and habitat condition.water quality, habitat, and invertebrate community metrics were generally consistent among sampling years and streams sampled. Although some minor differences were observed, they most likely are not biologically important. The data currently are insufficient to determine trends in the resource although they suggest that stream condition at GWCA is relatively unimpaired. Additional monitoring data will allow a more extensive analysis for trends. Based on the calculated invertebrate metrics as a whole and supporting habitat and water quality information, it appears that stream condition at GWCA is generally good, although there may be some mild impairment attributed to activities in the watersheds outside the park boundaries.

Acknowledgements

I thank David Peitz, Tyler Cribbs, Hope Dodd, Jan Hinsey, Jake Waters, Angela Bandy, Greg Wallace, and Lloyd Morrison for assisting with this project.

Introduction

In the late 1980's, the National Park Service (NPS) began an intensive program to monitor water quality and invertebrate community structure in prairie streams at several midwestern parks (Harris et al. 1991). Included in this baseline study was George Washington Carver National Monument (GWCA). Based on the study of Harris et al. (1991), a preliminary protocol was suggested by Peterson (1996), in which data dating back to 1988 and collected under the guidance described in Boyle et al. (1990) were analyzed. An official invertebrate biomonitoring protocol, drawing heavily on Peterson's (1996) results, was published in 1999 (Peterson et al., 1999). GWCA, however, was not included in this original protocol. Subsequent to the publication of the original protocol, Peterson (1997) collected stream invertebrates at GWCA in 1996 using methods similar to those described in the 1999 protocol, but no further monitoring was continued at GWCA until 2005. The monitoring data presented in Harris et al. (1991) and Peterson (1997) suggest the streams at GWCA were not impaired at the time of sampling. A revised monitoring protocol (Bowles et al. 2008) included invertebrate monitoring at GWCA using revised methodology from Peterson et al. (1999). The findings of this report are based on the revised protocol.

Aquatic invertebrates are an important biomonitoring tool for understanding and detecting changes in ecosystem integrity over time. The monitoring objectives of this study, as described by Debacker et al. (2005), are:

1) Determine the status and trends of invertebrate species diversity, abundance, and community metrics.
2) Relate the invertebrate community to overall water quality through quantification of metrics related to species richness, abundance, diversity, and region-specific multi-metric indices as indicators of water quality and habitat condition.

Methods

Methods and procedures used in this report follow Bowles *et al*. (2008), Monitoring Protocol for Aquatic Invertebrates of Small Streams in the Heartland Inventory & Monitoring Network. Three benthic invertebrate samples were collected from each of three successive riffles in each stream sampled using a Surber stream bottom sampler (500 µm mesh, 0.093 m^2). For each sample, current velocity (meters/second) and depth (cm) were recorded directly in front of the sampling net frame. Qualitative habitat variables (percent embeddedness, periphyton, filamentous algae, aquatic vegetation, deposition, and organic material) were estimated within the sampling net frame as percentage categories (0, <10, 10-40, 40-75, >75). Habitat data were analyzed as midpoints of each category. Dominant substrate size from the area within the sampling net frame was visually assessed based on the Wentworth scale (Wentworth 1922). Stream discharge was measured upstream of each sampling site after invertebrate collections were completed. Hourly readings of water quality parameters (temperature, dissolved oxygen, specific conductance, pH, turbidity) were recorded continuously at least 24 hours prior to sampling for each stream using data loggers or sondes. Samples were sorted in the laboratory following a subsampling routine described in Bowles *et al*. (2008), and taxa were identified to the lowest practical taxonomic level (usually genus) and counted.

The primary interest in the analysis and interpretation of the data presented in this report is the magnitude of change rather than change *per se* (Bowles *et al*. 2008), and whether it represents something biologically important. Null hypothesis significance testing in the strict sense may not be the best approach given these goals (Morrison 2007). Therefore, univariate control charts were established to illustrate the general trend of invertebrate community metrics and provide a visual tool for managers to determine which variables may require more in-depth analyses or management action in the future. Control charts plot a characteristic through time with reference to its expected value. Upper or lower thresholds specify amounts of variability beyond what would normally be expected and indicate when a system is going 'out of control' (Morrison 2008). Control charts as used here contain a control limit of (mean ± 1.86 standard deviations) for those community metrics that respectively decrease or increase due to stressors. This specified threshold serves as an indicator to suggest a biologically important change may be occurring. Setting a control chart threshold equal to 1.86 standard deviations is analogous to significance tests at a critical value of 0.05 for one-tailed tests (since we are only interested in change in one direction). The student's *t*-distribution (df = 8) was used to determine the one-tailed area because of the relatively small sample size. A critical value of 0.05 is widely accepted as the 'standard' in significance testing approaches. Control limits may need to be reset after more data are accumulated.

Data from 2005-2007 serve as a baseline and were used to construct thresholds based on standard deviations of the mean of these data points. The data addressed in this report are only those collected during the May-June index period from the general sampling reach described in Bowles *et al*. (2008). A critical value of 0.05 indicates that one out of every 20 data points will exceed this limit if the population is not changing, which is our assumption. Thus, the primary purpose of sampling to date with respect to control chart construction has been to establish a baseline and evaluate natural variability. The primary value of the selected thresholds is for the evaluation of future data points.

The Missouri Stream Condition Index (SCI) was also calculated for each site and year. This multimetric index is described in Sarver *et al*. (2002). This SCI is based on four metrics—Taxa Richness, EPT richness, Shannon's Diversity Index, and Hilsenhoff Biotic Index (HBI)—that are considered sufficiently sensitive to detect a variety of potential pollution problems in Missouri streams (see Bowles *et al*. 2007 for discussion). Because taxa richness, EPT richness, and the Shannon Index all decrease with increased impairment, any values above the lower quartile (25%) of the reference distribution receive the highest score of five. Values between the 25% quartile and the 1% quartile receive a score of 3 and values below the 1% quartile receive a score of 1. The Biotic Index increases with increased impairment, so any value below the upper quartile (75%) of the reference distribution receives the highest score of 5. Values between the 75% quartile and the 99% quartile receive a score of 3, and values above the 99% quartile receive a score of 1. Each metric score is determined by averaging the metric values from the 9 samples collected. Individual scores are summed to generate the SCI score. Scores range from >16 for fully biological supporting (i.e., not impaired), 10-14 for partially biologically supporting (impaired), and <8 for non-biologically supporting (i.e., very impaired).

Results

Water Quality

Core 5 water quality measurements (Figures 1-5) were generally consistent, although there was modest variation among years. Observed differences among streams are likely a result of their individual specific physical characteristics and other undetermined factors. However, the parameter values generally are typical for regional streams and do not suggest impairment (Brown and Czarnezki undated). Acceptable ranges for water quality data in southwestern Missouri streams are presented in Table 1. The observed variation among years is likely due to a number of factors chief among them being the month the samples were taken; samples in 2005-2006 data were collected nearly one month later (June) than the 2007 data (May). Also, measurements taken in 2005 were recorded as static measurement using hand-held meters while those in 2006-2007 were collected continuously with dataloggers. Discharge (Table 2) for the respective streams was higher in 2007 compared to 2006. Discharge estimates reported here are intended to illustrate the general flow tendencies for the respective streams for a given sampling year and are not intended to be precise measurements. Discharge was not measured in 2005.

Habitat

Habitat measurements associated with invertebrate collections as reported here were collected only during 2006-2007 (Figures 6-13). Sampling sites were generally shallow and with relatively low current velocity. Substrate embeddedness was moderate and generally less than 30% with the exception of Williams Branch (33-50%), owing to the smaller range of substrate sizes in that stream (Fig. 14). Percent vegetation (primarily mosses) and filamentous algae were generally poorly represented in the three streams (≤5%). Percent periphyton and organic material were moderate (≤30%) for all three streams. Percent deposition varied widely between years and among streams with the highest mean deposition being in Williams Branch (45-54%), likely owing to the small substrate and low gradient of that stream (it issues from an impounded spring source). Substrate size was largest in Harkins Branch and smallest in Williams Branch, although the range of substrate sizes overlapped broadly among the three streams (Fig. 14).

Invertebrate Community Metrics

Invertebrate metrics were consistent among years and streams sampled (Tables 3-5, Figs. 15-21). The number of invertebrate families represented in samples was about 15 for each stream, while the number of genera represented in samples ranged from a low of 12 in Harkins Creek to a high of 17 in Carver Creek. Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness was generally consistent among years and streams sampled and ranged from about 5-7 taxa per stream. The EPT ratio, a metric that decreases with increasing number of undesirable Chironomidae, likewise remained relatively consistent among all sites and years sampled and ranged from 0.38 to 0.79. Although the Shannon index scores reported here are relatively low (~1.8-2.3), they are comparable with those of other regional systems (Jones *et al*. 1981, Bowles *et al*. 2008), and they were broadly consistent among years and streams sampled. Shannon diversity increases as richness increases and as all taxa approach equal abundances. Low Shannon values reflect low species richness and communities dominated by one or a few taxa. A similar pattern was observed for the Shannon Evenness scores that ranged from 0.64 to 0.83 among streams. Because lower evenness indicates that a stream may have been subjected to disturbance and is being populated by fewer, pollution tolerant genera, the relatively high evenness scores reported here suggest minimal disturbance. Mean HBI scores were consistently below 5.5, indicating that taxa represented in samples were, on average, only moderately tolerant of pollution.

SCI scores calculated for the three streams at GWCA ranged from a low of 8 for Williams Branch in 2005, to a high of 14 at Carver Creek in 2006-2007 and Williams Branch in 2007 (Table 6). Williams Branch and Harkins Branch had the lowest SCI scores in 2005 of 8 and 10, respectively. In general these scores suggest mild to moderate impairment of the three streams.

Figure 1. Map showing the approximate lower sampling reach boundaries for Carver Creek, Williams Branch and Harkins Branch, George Washington Carver National Monument.

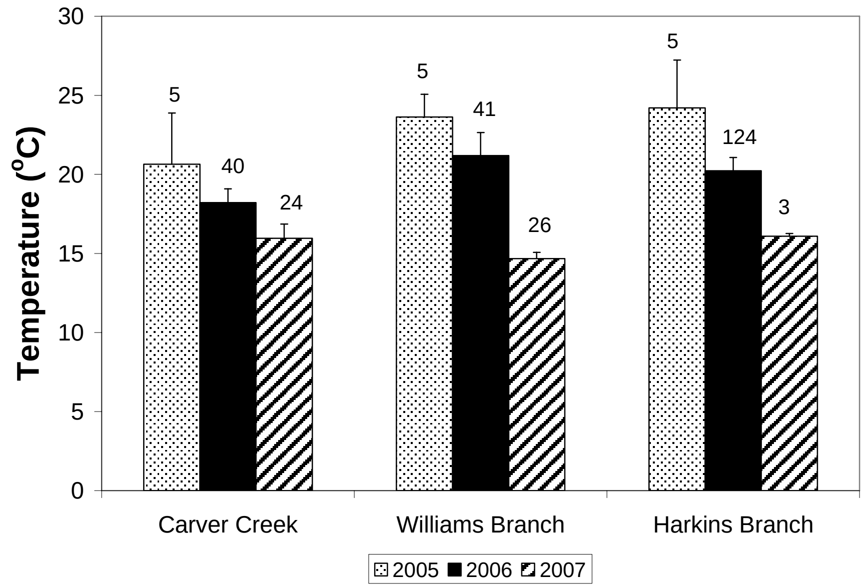

Figure 2. Mean temperature (^{o}C) and standard errors for streams at George Washington Carver National Monument, 2005-2007. Data in 2005 represent static readings taken with hand-held meters and data for 2006-2007 were collected continuously with data-loggers. Numbers above bars represent the number of measurements taken.

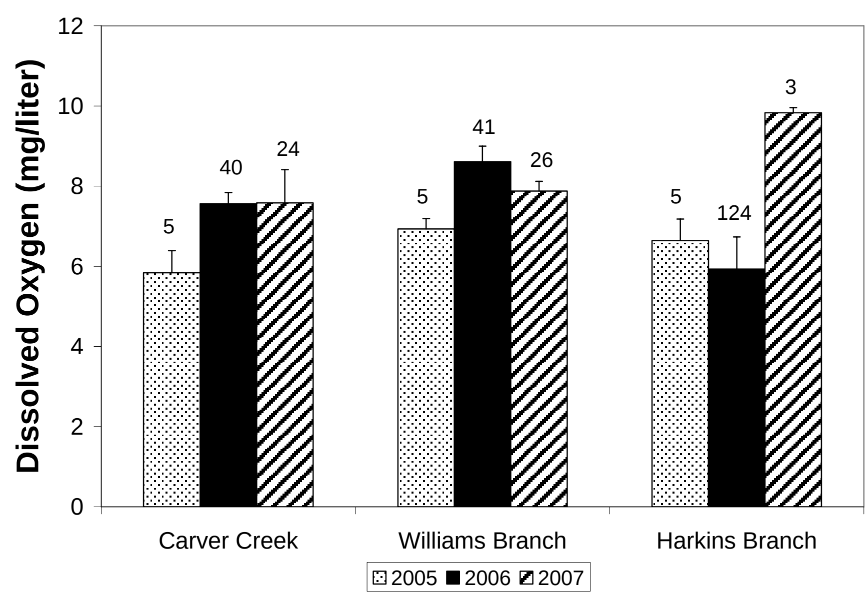

Figure 3. Mean dissolved oxygen concentration (mg/liter) and standard erros for streams at George Washington Carver National Monument, 2005-2007. Data in 2005 represent static readings taken with hand-held meters and data for 2006-2007 were collected continuously with data-loggers. Numbers above bars represent the number of measurements taken.

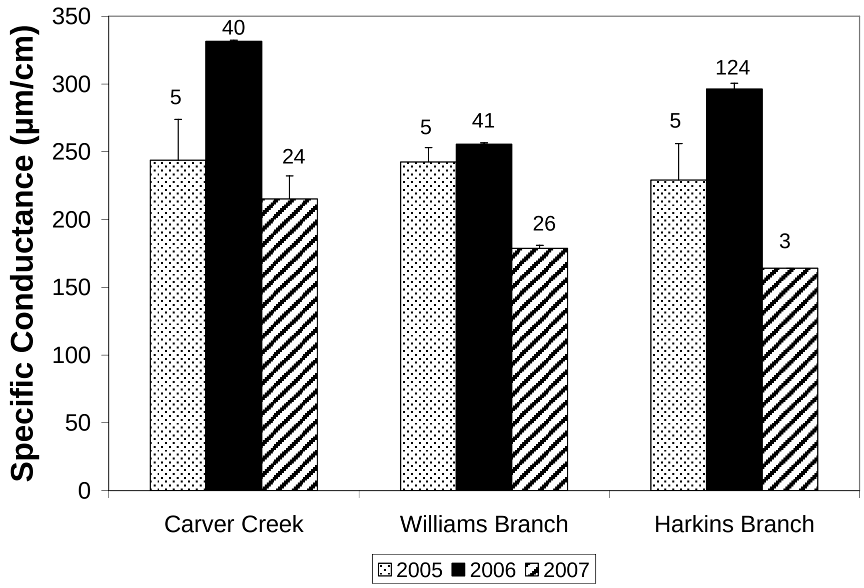

Figure 4. Mean specific conductance and standard errors for streams at George Washington Carver National Monument, 2005-2007. Data in 2005 represent static readings taken with hand-held meters and data for 2006-2007 were collected continuously with data-loggers. Numbers above bars represent the number of measurements taken.

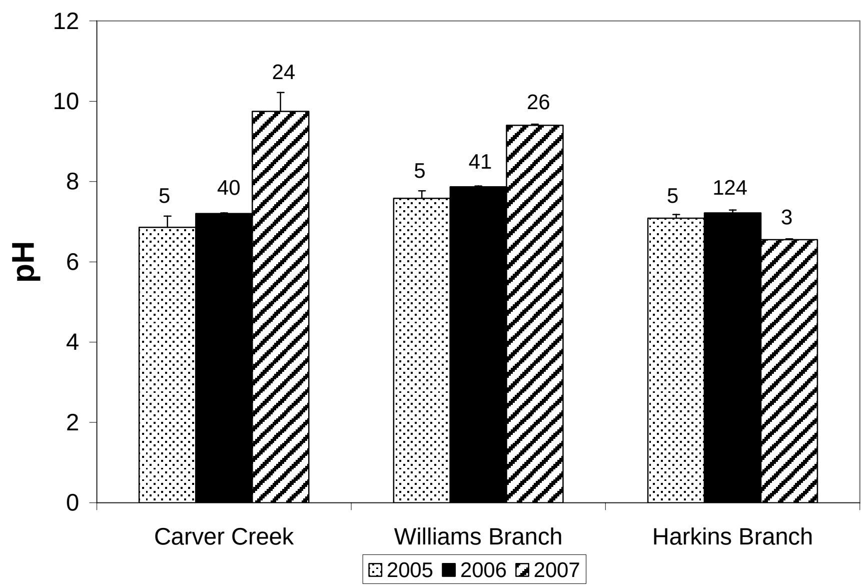

Figure 5. Mean pH and standard errors for streams at George Washington Carver National Monument, 2005-2007. Data in 2005 represent static readings taken with hand-held meters and data for 2006-2007 were collected continuously with data-loggers. Numbers above bars represent the number of measurements taken.

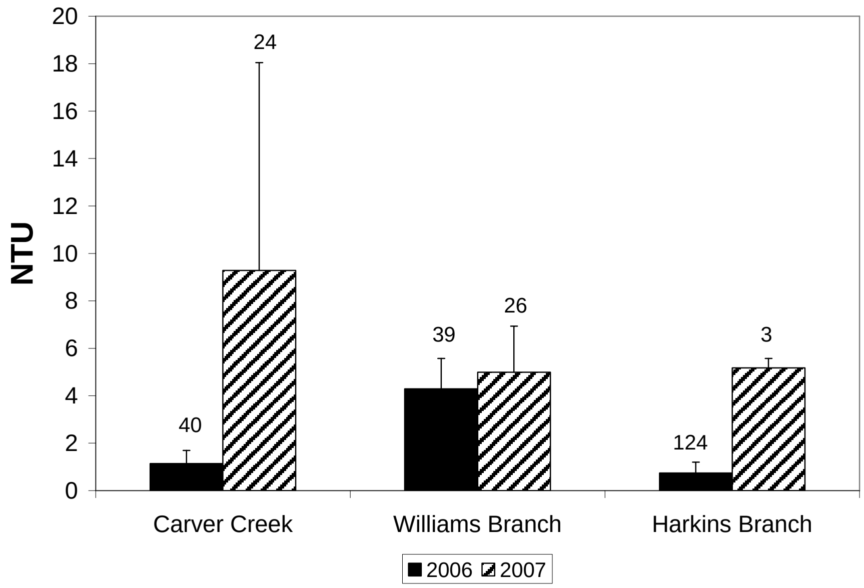

Figure 6. Mean turbidity (NTU) and standard errors for streams at George Washington Carver National Monument, 2005-2007. Data were collected continuously with data-loggers. Numbers above bars represent the number of measurements taken.

Table 1. Acceptable ranges for water quality parameters in southwestern Missouri streams. Adapted from Brown and Czarnezki (undated).

Water Quality Parameter	**Acceptable Range**
Temperature	0-34 ^{o}C
Dissolved Oxygen	5-15 mg/liter
Specific Conductance	100-400 μS/cm
pH	6.5-9.0
Turbidity	Variable, but generally <10 NTU dry weather

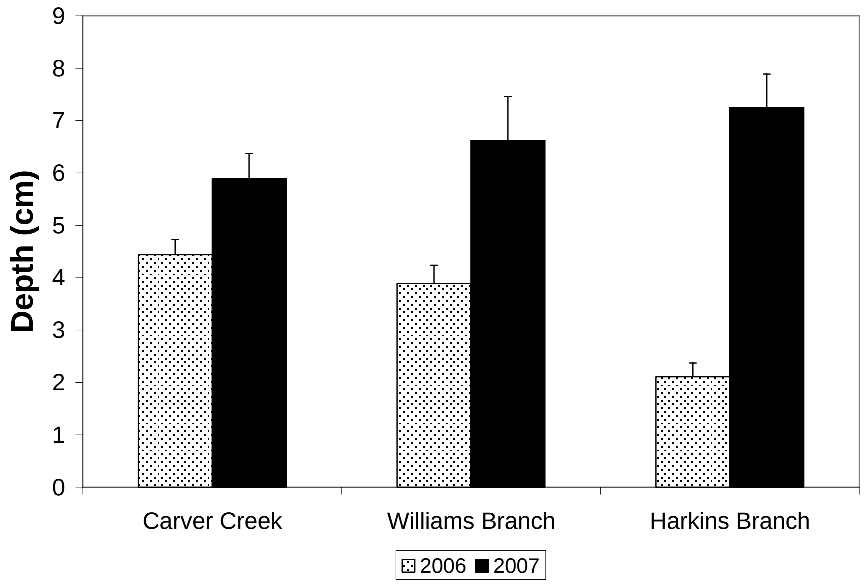

Figure 7. Mean depth (cm) and standard errors of riffles where benthic samples were collected.

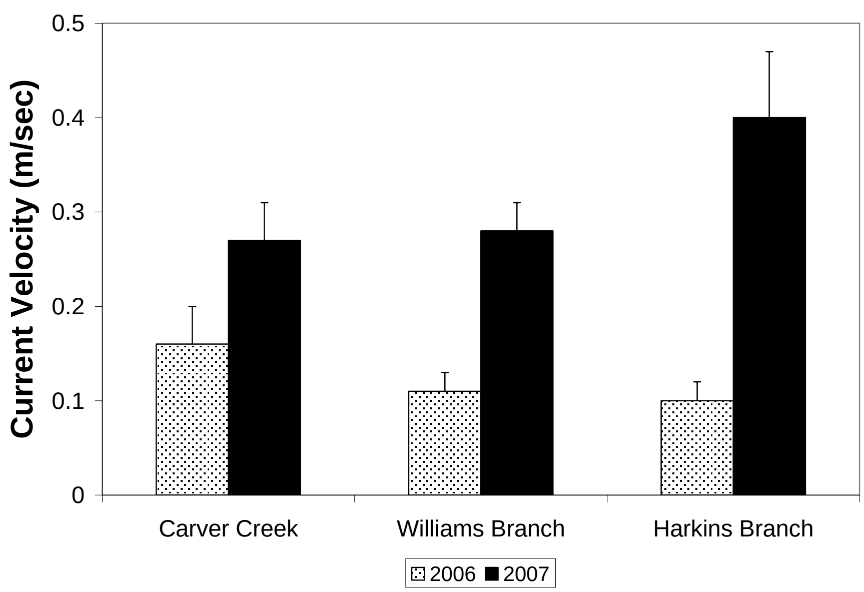

Figure 8. Mean current velocity (m/sec) and standard errors of riffles where benthic samples were collected.

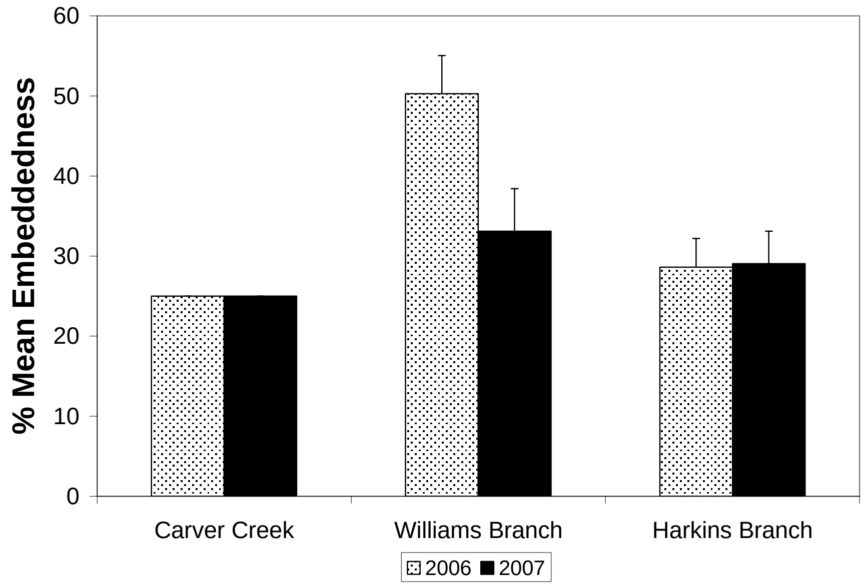

Figure 9. Mean percent embeddedness and standard errors of riffles where benthic samples were collected.

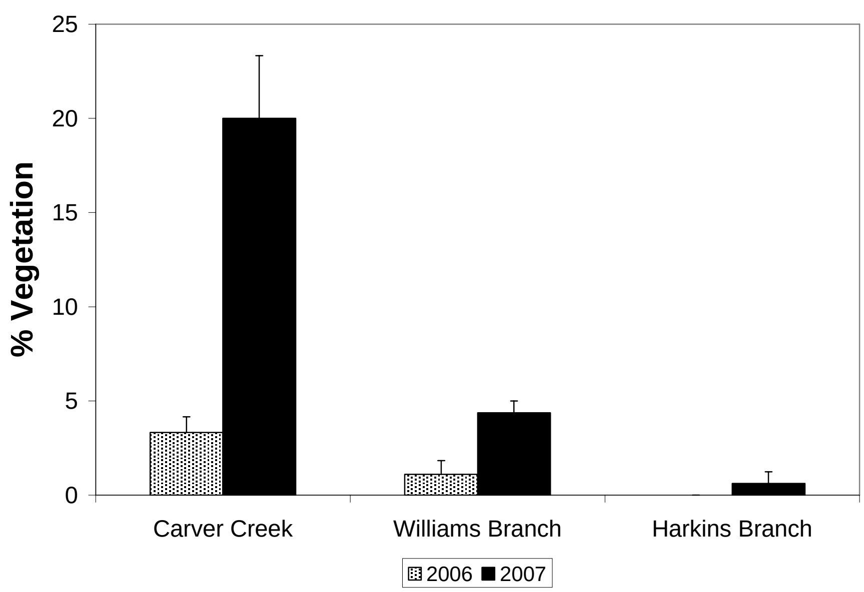

Figure 10. Mean percent vegetation and standard errors of riffles where benthic samples were collected.

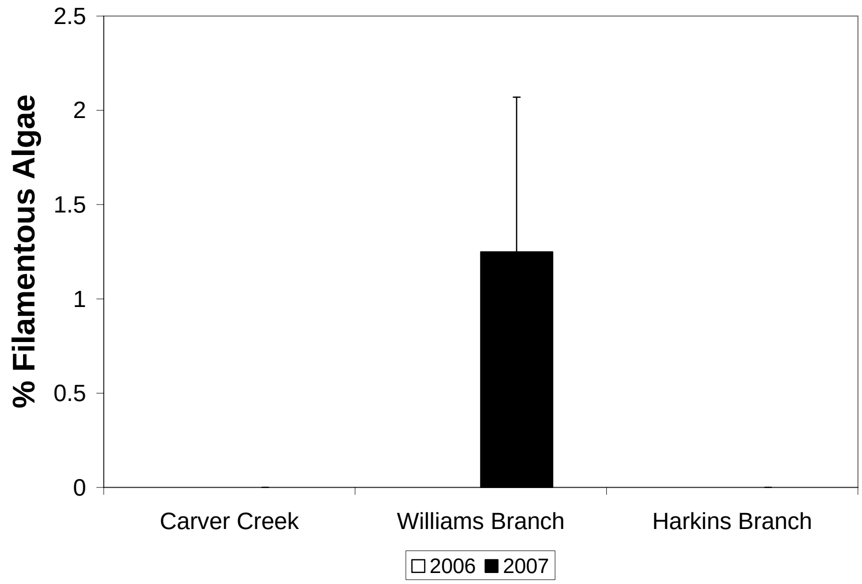

Figure 11. Mean percent filamentous algae and standard errors for riffles where benthic samples were collected.

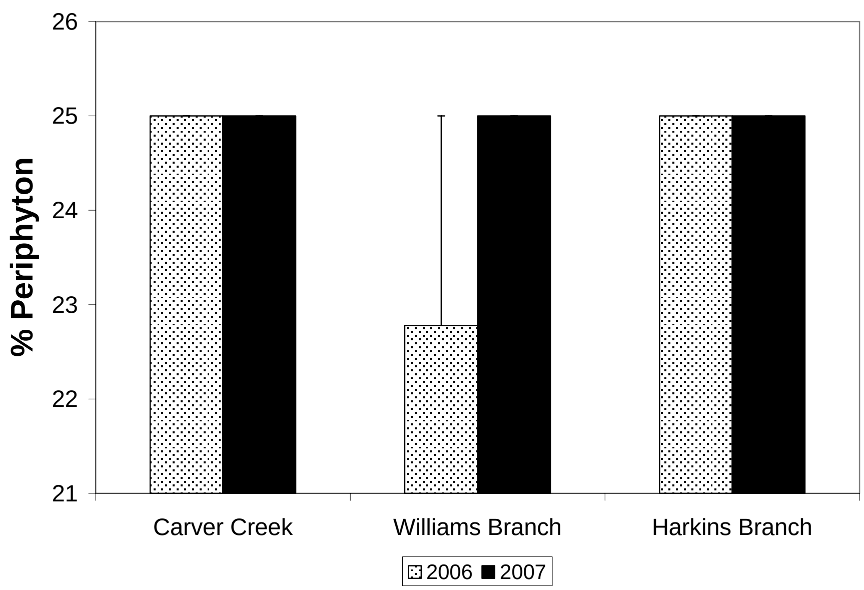

Figure 12. Mean percent periphyton and standard errors for riffles where benthic samples were collected.

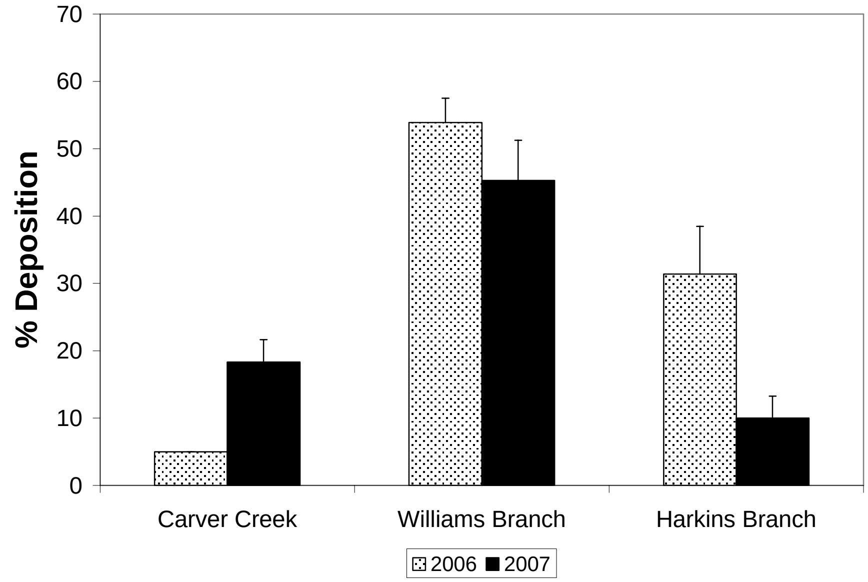

Figure 13. Mean percent deposition and standard errors for riffles where benthic samples were collected.

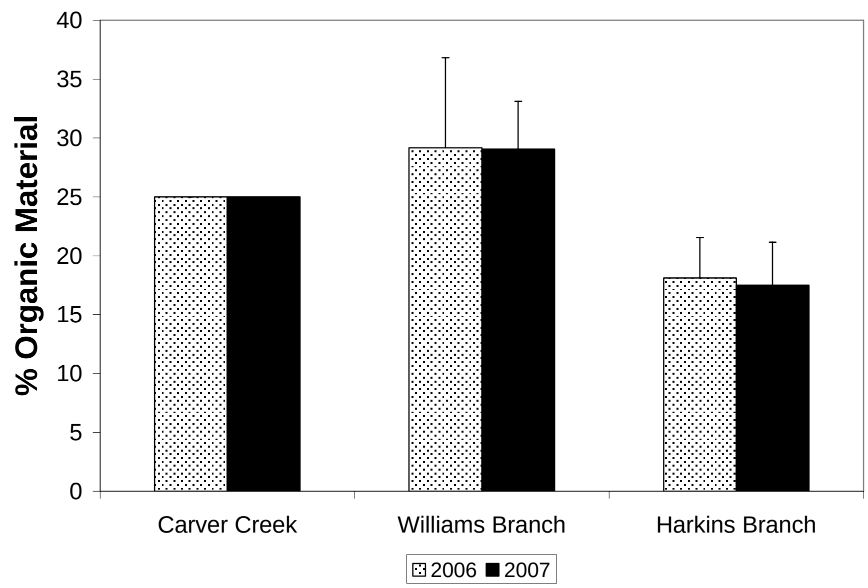

Figure 14. Mean percent organic material and standard errors for riffles where benthic samples were collected.

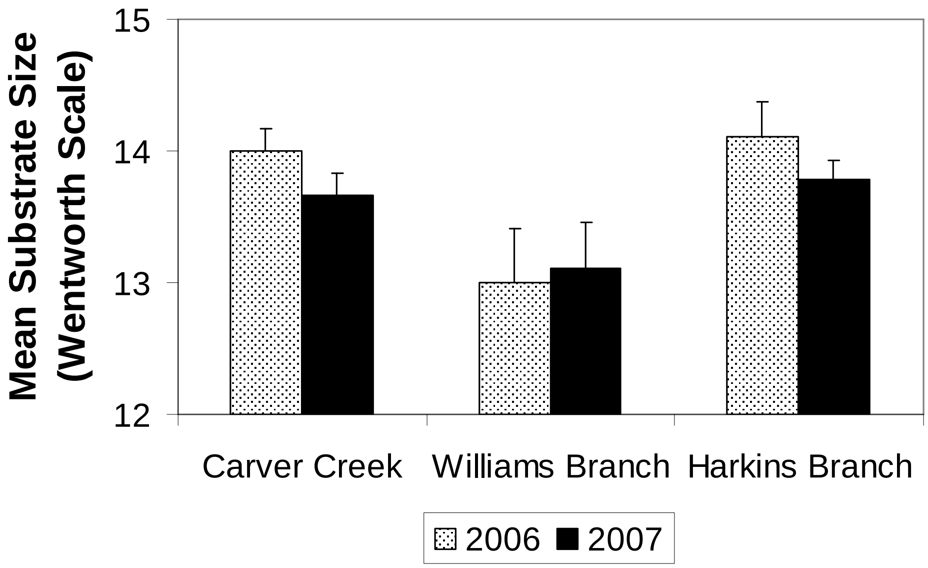

Figure 15. Mean substrate size and standard errors for stream riffles where benthic samples were collected.

Table 2. Discharge measurements for streams at George Washington Carver National Monument.

Discharge (m^3/sec)			
Stream	2005	2006	2007
Carver Creek	n/a	0.01	0.13
Williams Branch	n/a	0.02	0.11
Harkins Branch	n/a	0.01	0.15

Table 3. Mean invertebrate metrics for Carver Creek, George Washington Carver National Monument, 1989-2007. Data for 1989 and 1996 are from Harris *et al*. (1991) and Peterson (1997), respectively. Hilsenhoff Biotic Index was based on family-level scores prior to 2005. Standard error is indicated in parenthesis below the mean. N= number of samples collected.

Carver Creek					
Metric	**1989**	**1996**	**2005**	**2006**	**2007**
N	15	5	15	9	9
Family Richness	n/a	14.60 (1.78)	14.2 (1.09)	15.33 (0.5)	16 (1.12)
Genus Richness	33	n/a	15.87 (1.17)	17 (0.68)	17.56 (1.12)
EPT Richness	11	n/a	7.4 (0.40)	6.89 (0.56)	6.89 (0.56)
EPT Ratio	n/a	0.48 (0.07)	0.38 (0.04)	0.48 (0.05)	0.68 (0.06)
Shannon Index	2.14	1.84 (0.12)	1.74 (0.8)	2.11 (0.07)	2.26 (0.08)
Shannon Evenness Index	n/a	n/a	0.64 (0.03)	0.74 (0.02)	0.79 (0.02)
Hilsenhoff Biotic Index	n/a	4.75 (0.09)	5.23 (0.99)	4.23 (0.12)	4.62 (0.13)

Table 4. Mean invertebrate metrics for Williams Branch, George Washington Carver National Monument, 1989-2007. Data for 1989 are from Harris *et al*. (1991). Hilsenhoff Biotic Index was based on family-level scores prior to 2005. N= number of samples collected.

Williams Branch				
Metric	**1989**	**2005**	**2006**	**2007**
N	15	15	9	9
Family Richness	n/a	11.8 (0.62)	15.33 (0.85)	14 (0.62)
Genus Richness	37	13.87 (0.69)	17 (1.03)	15.44 (0.85)
EPT Richness	15	5.33 (0.39)	5.89 (0.42)	6 (0.37)
EPT Ratio	n/a	0.48 (0.07)	0.52 (0.05)	0.68 (0.05)
Shannon Index	2.29	1.80 (0.07)	2.04 (0.08)	2.03 (0.08)
Shannon Evenness Index	n/a	0.74 (0.04)	0.72 (0.02)	0.79 (0.01)
Hilsenhoff Biotic Index	n/a	5.54 (0.11)	4.30 (0.5)	4.44 (0.17)

Table 5. Mean invertebrate metrics for Harkins Branch, George Washington Carver National Monument, 1989-2007. Data for 1996 are from Peterson (1997). Hilsenhoff Biotic Index was based on family-level scores prior to 2005. N= number of samples collected.

Harkins Branch				
Metric	**1996**	**2005**	**2006**	**2007**
N	5	10	9	9
Family Richness	17.80 (2.03)	10.6 (0.87)	14 (1.28)	15.11 (1.12)
Genus Richness	n/a	12.1 (0.87)	15.11 (1.44)	16.11 (1.21)
EPT Richness	n/a	6.4 (0.43)	7.33 (0.94)	7.56 (0.58)
EPT Ratio	0.51 (0.05)	0.51 (0.06)	0.65 (0.08)	0.79 (0.02)
Shannon Diversity Index	2.03 (0.08)	1.88 (0.12)	1.99 (0.09)	2.27 (0.06)
Shannon Evenness Index	n/a	0.74 (0.04)	0.74 (0.02)	0.83 (0.01)
Hilsenhoff Biotic Index	4.87 (0.12)	5.04 (0.14)	4.82 (0.32)	4.30 (0.50)

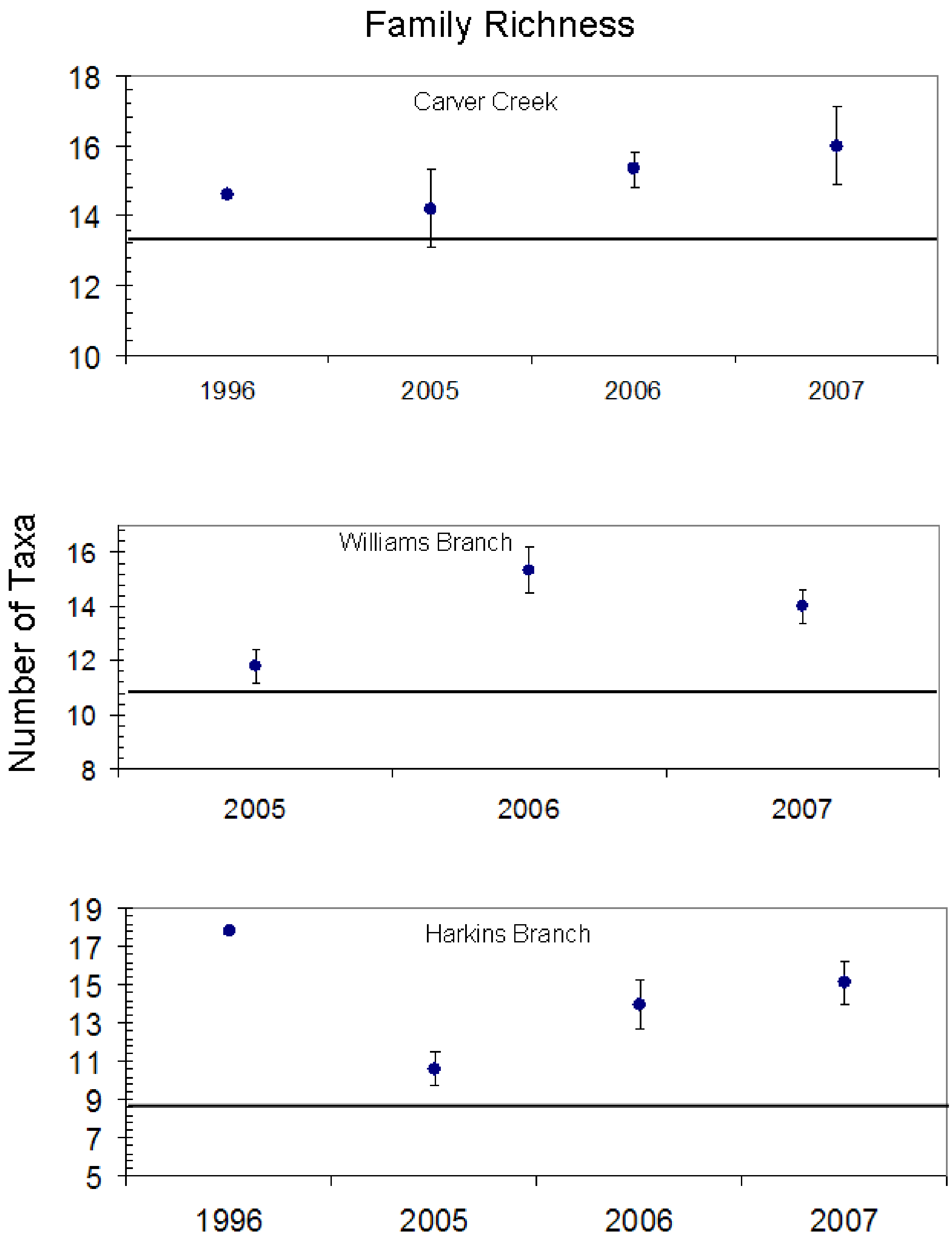

Figure 16. Control charts for family richness for streams at George Washington Carver National Monument. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to the Type I error rate of 0.05.
Data for 1996 are from Peterson (1997).

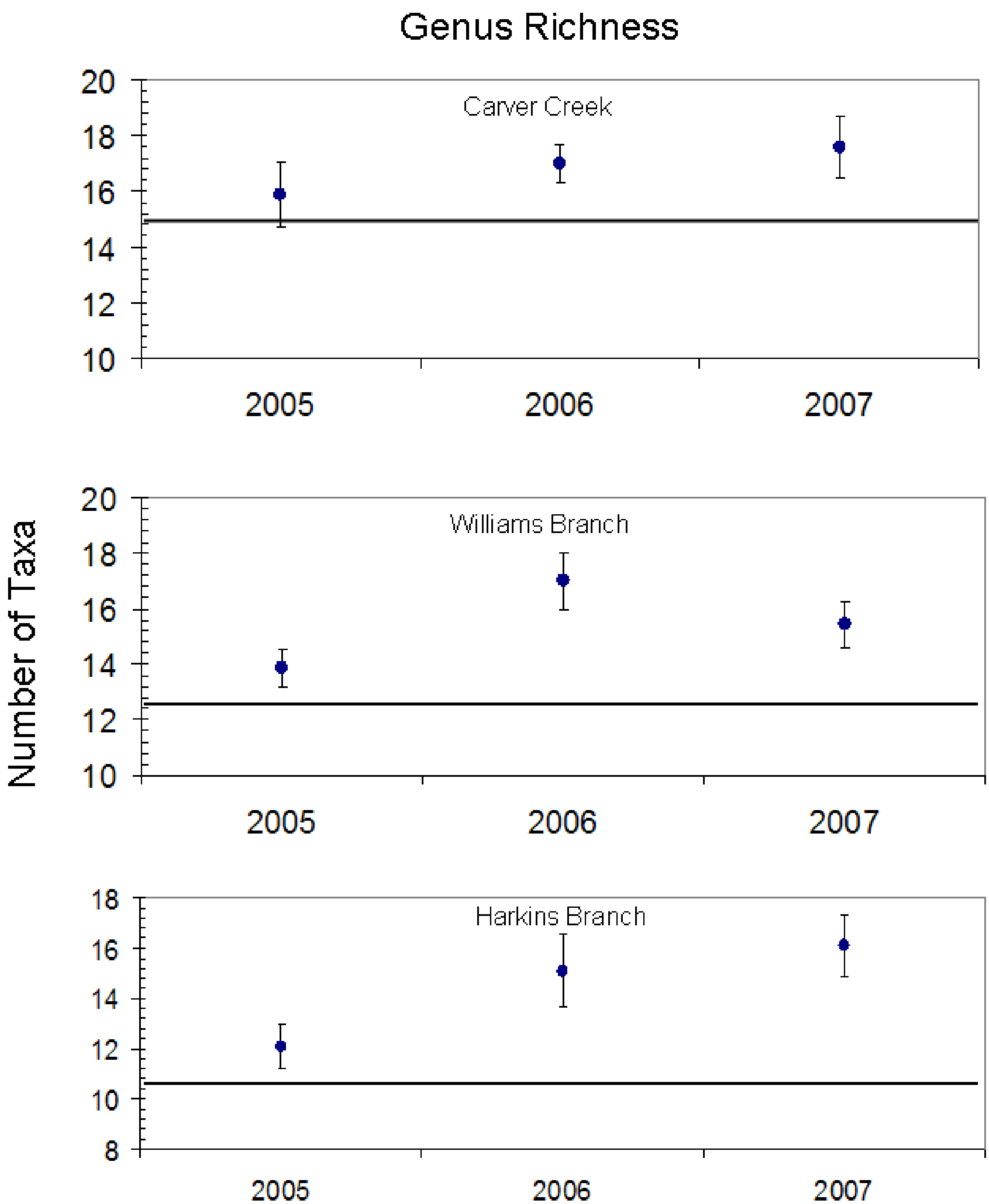

Figure 17. Control charts for genus richness for streams at George Washington Carver National Monument. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to the Type I error rate of 0.05.

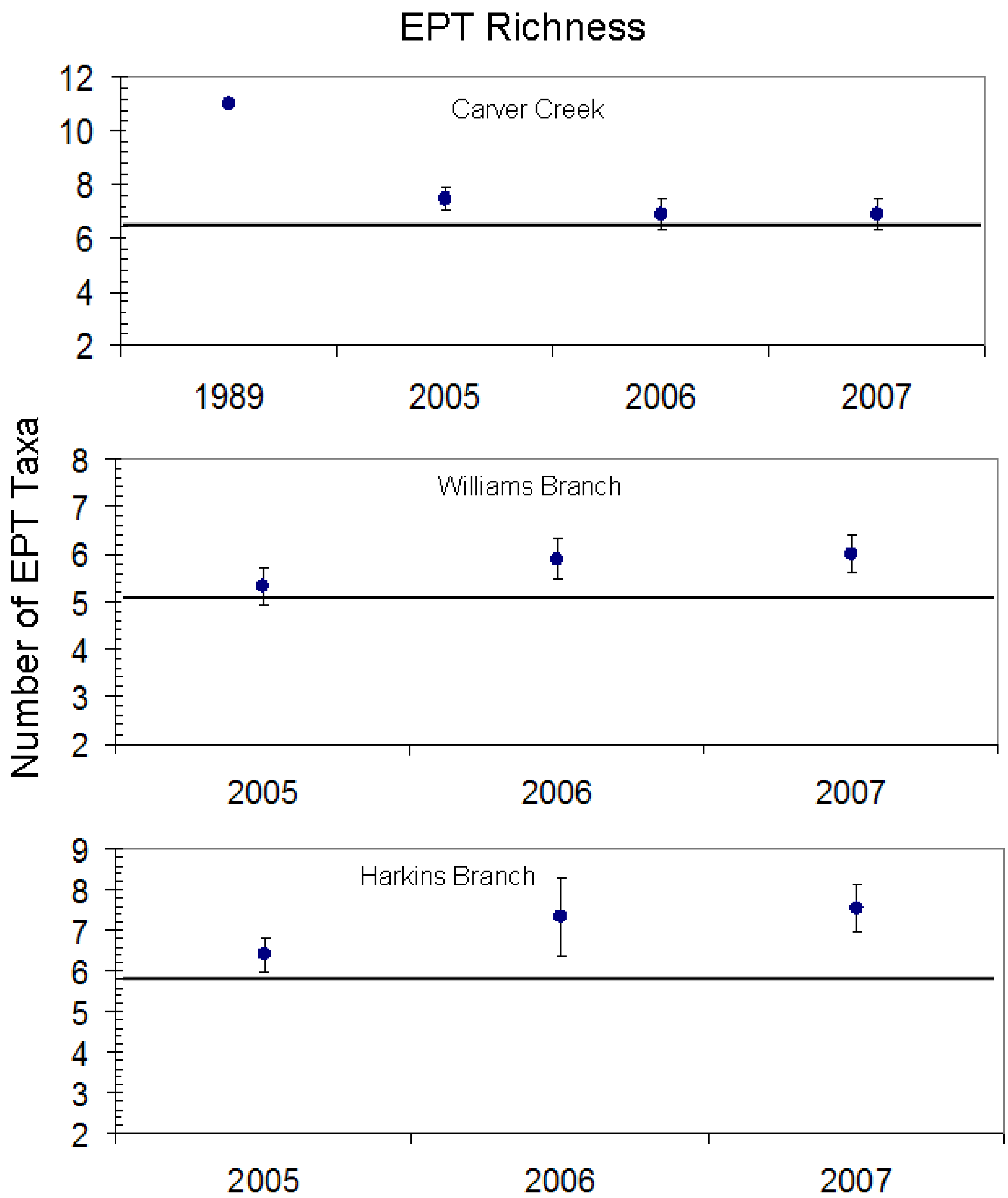

Figure 18. Control charts for Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness for streams at George Washington Carver National Monument. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to the Type I error rate of 0.05. Data for 1989 are from Harris *et al*. (1991).

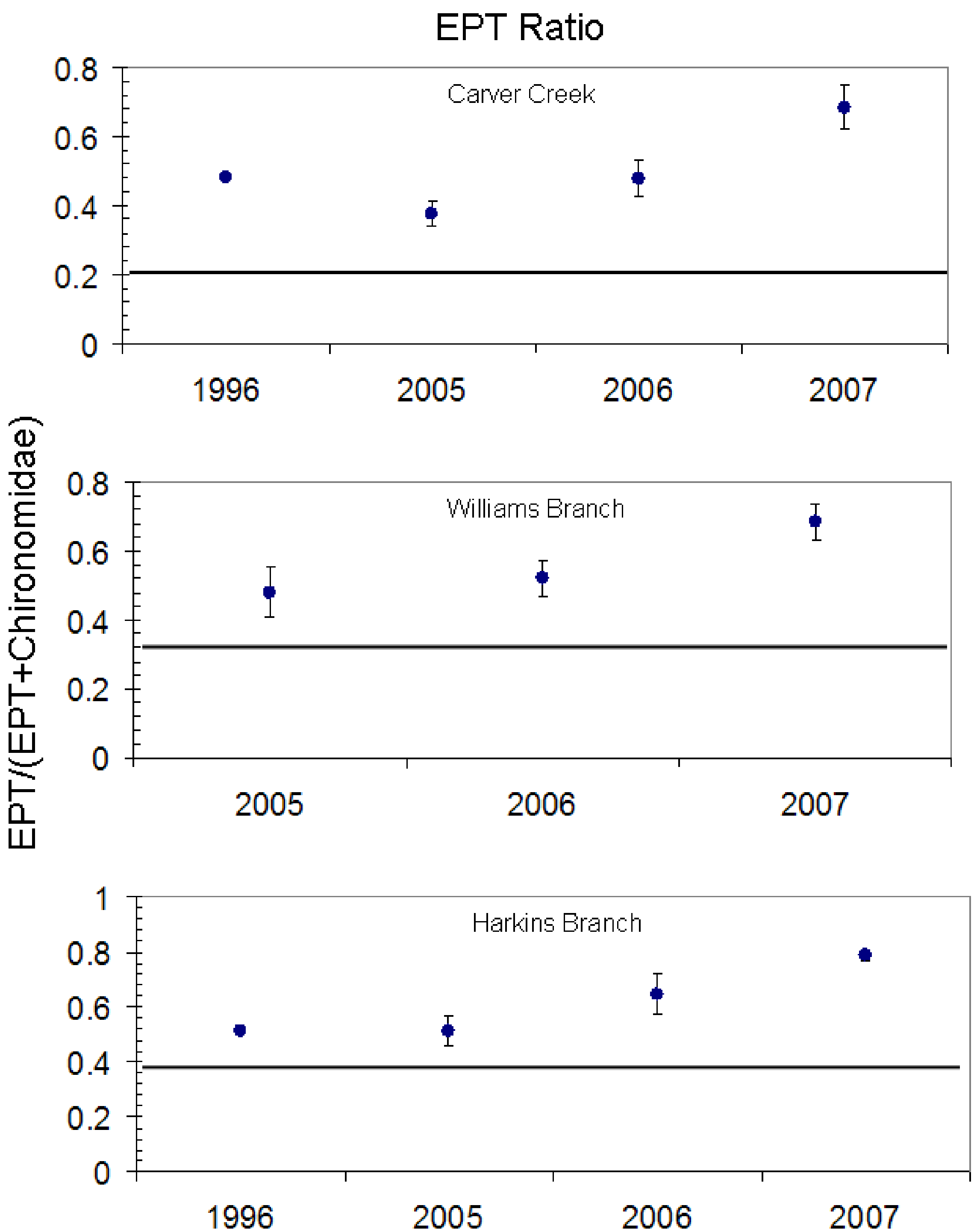

Figure 19. Control charts for Ephemeroptera, Plecoptera, and Trichoptera (EPT) to Chironomidae ratio for streams at George Washington Carver National Monument. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to the Type I error rate of 0.05. Data for 1996 are from Peterson (1997).

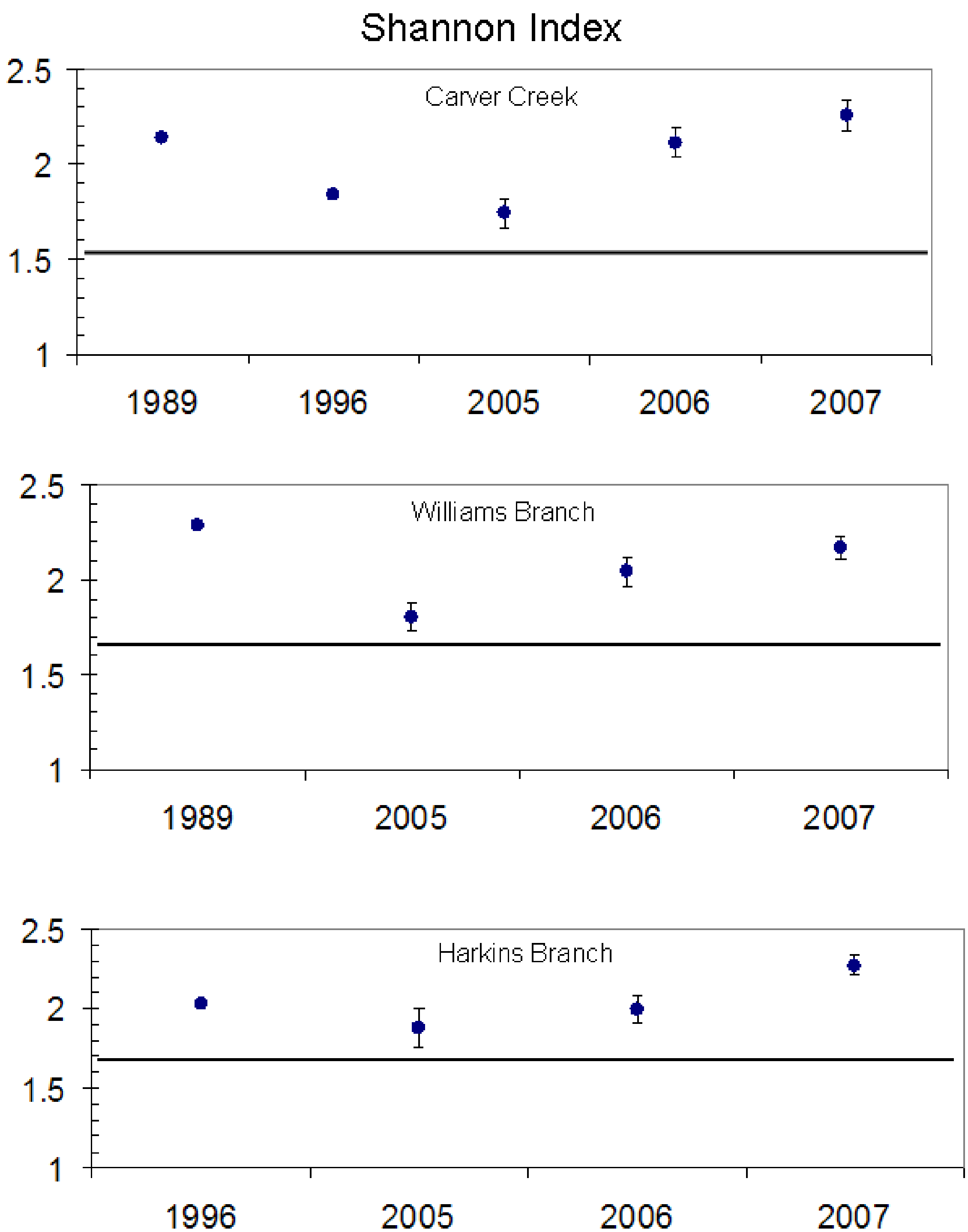

Figure 20. Control charts for Shannon Diversity index for streams at George Washington Carver National Monument. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to the Type I error rate of 0.05. Data for 1989 and 1996 are from Harris et al. (1989) and Peterson (1997), respectively.

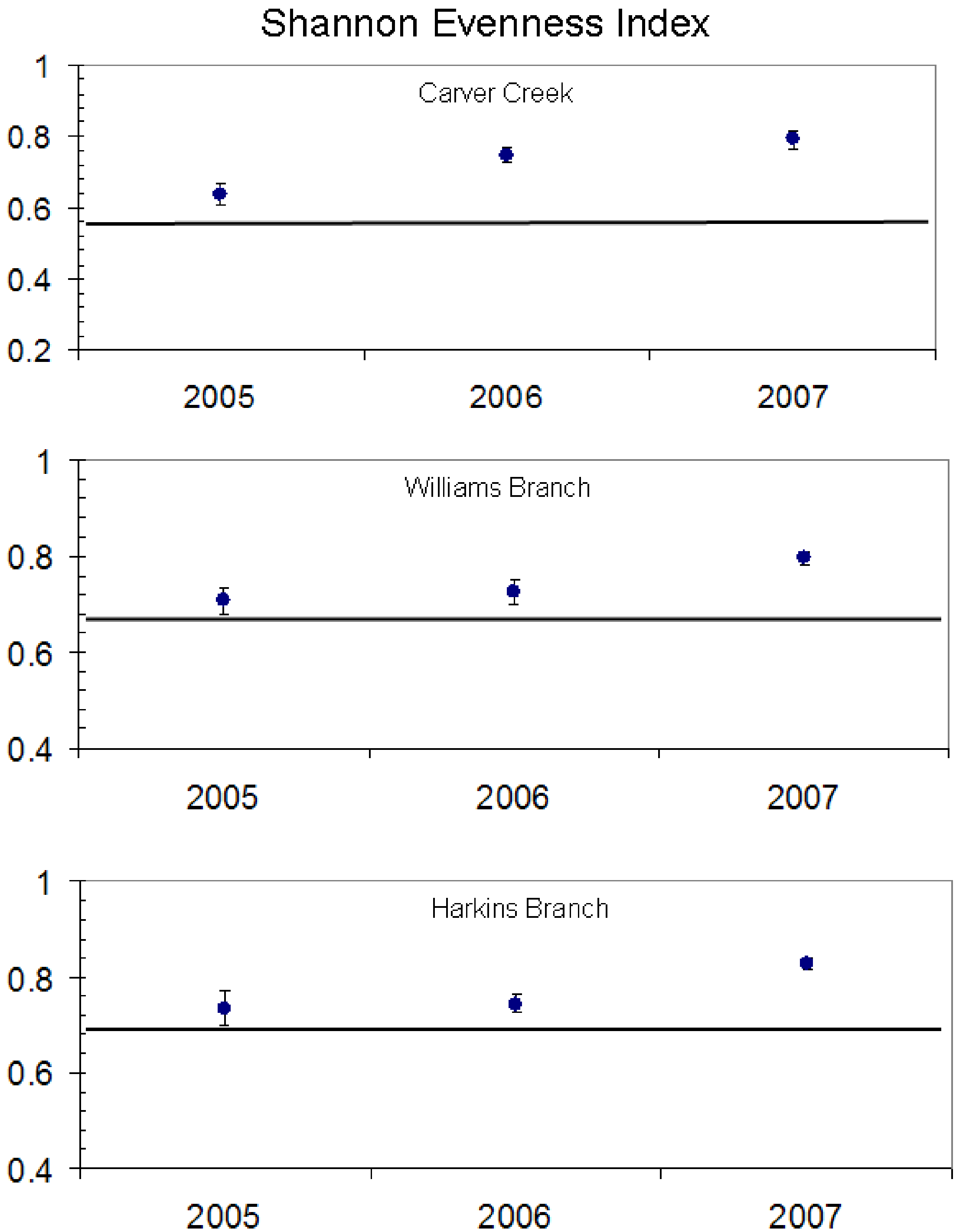

Figure 21. Control charts for Shannon Evenness Index for streams at George Washington National Monument. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to the Type I error rate of 0.05.

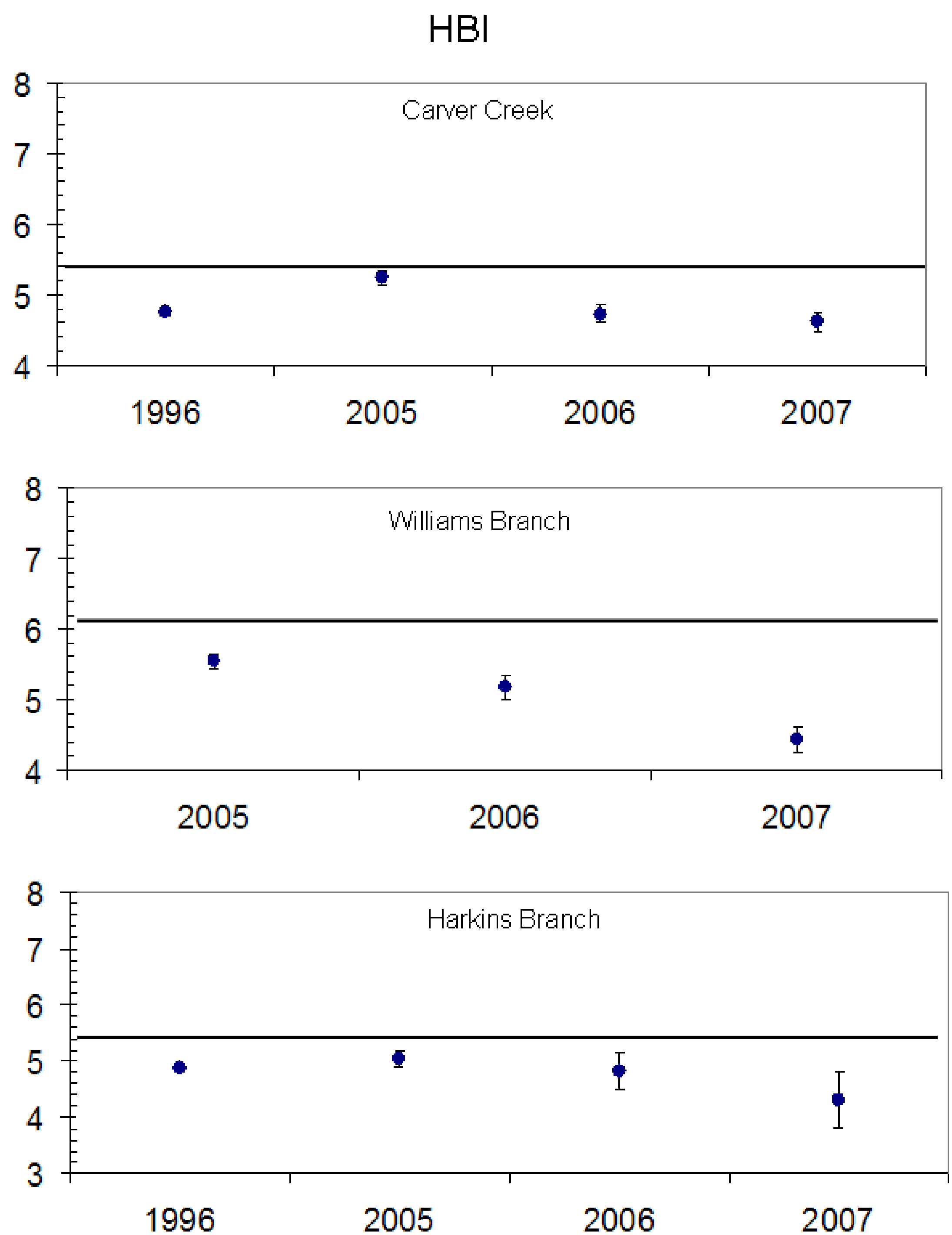

Figure 22. Control charts for Hilsenhoff Biotic Index (HBI) for streams at George Washington Carver National Monument. Points are means for a given sampling date, and the vertical bars are standard errors. The horizontal line represents the control limit corresponding to the Type I error rate of 0.05. Data for 1996 are from Peterson (1997).

Table 6. Missouri Stream Condition Index (SCI) for streams at George Washington Carver National Monument, 2005-2007.

Stream	2005	2006	2007
Carver Creek	12	14	14
Williams Branch	8	12	14
Harkins Branch	10	12	12

Discussion

Based on the calculated invertebrate metrics as a whole and supporting habitat and water quality information, it appears that stream condition at GWCA is generally good, although there may be some mild impairment attributable to activities in the watersheds outside the park boundaries. Water quality, habitat, and invertebrate community metrics were generally consistent among sampling years and streams sampled, and were well within the range for unimpaired streams in the region (Brown and Czarnezki undated; Jones *et al*. 1981, Sarver *et al*. 2002). Aquatic invertebrates have evolved to survive a fairly wide range in water quality variables as a function of the dynamic nature of streams. Although some minor differences were observed, they most likely are not biologically important. The data currently are insufficient to determine trends in the resource, although they suggest that stream condition at GWCA is at best unimpaired and at worst mildly impaired. Furthermore, the preliminary control charts included in this report suggest that stream quality, as estimated by the invertebrate community, has not degraded appreciably since monitoring began—all mean metric values were at or above the warning threshold. However, the control charts presented here are only preliminary and based on a limited amount of data, and are only meant to serve as a visual tool for comparing data among years. Additional monitoring will provide data for comparison to the baseline in control charts and aid managers in deciding if additional monitoring or management action is warranted.

The SCI values consistently rated as mildly impaired for all three streams, although these relatively low index values may reflect the relatively small sample size for each stream (n=9). However, the relatively low SCI scores calculated for GWCA may be a reflection of the index period chosen for sampling (i.e., late spring-early summer). Sampling during this time period may have the effect of lowering SCI scores because some key drivers of this index (such as EPT) may be lower, due to life history mechanisms such as peak emergence of stoneflies (Plecoptera) and many sensitive Trichoptera. Because of this constraint, management focus should be directed at ensuring the SCI scores for the respective streams do not drop below the warning thresholds depicted above rather than the values themselves.

Literature Cited

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The NPS has organized its parks with significant natural resources into 32 networks linked by geography and shared natural resource characteristics. HTLN is composed of 15 National Park Service (NPS) units in eight Midwestern states. These parks contain a wide variety of natural and cultural resources including sites focused on commemorating civil war battlefields, Native American heritage, westward expansion, and our U.S. Presidents. The Network is charged with creating inventories of its species and natural features as well as monitoring trends and issues in order to make sound management decisions. Critical inventories help park managers understand the natural resources in their care while monitoring programs help them understand meaningful change in natural systems and to respond accordingly. The Heartland Network helps to link natural and cultural resources by protecting the habitat of our history.

The I&M program bridges the gap between science and management with a third of its efforts aimed at making information accessible. Each network of parks, such as Heartland, has its own multi-disciplinary team of scientists, support personnel, and seasonal field technicians whose system of online databases and reports make information and research results available to all. Greater efficiency is achieved through shared staff and funding as these core groups of professionals augment work done by individual park staff. Through this type of integration and partnership, network parks are able to accomplish more than a single park could on its own.

The mission of the Heartland Network is to collaboratively develop and conduct scientifically credible inventories and long-term monitoring of park "vital signs" and to distribute this information for use by park staff, partners, and the public, thus enhancing understanding which leads to sound decision making in the preservation of natural resources and cultural history held in trust by the National Park Service.

www.nature.nps.gov/im/units/htln/

Heartland Network

Natural Resource Monitoring

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