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Aquatic Resource Assessment of Fort Necessity National Battlefield and Friendship Hill National Historic Site

Technical Report NPS/NER/NRTR-2006/065

ON THE COVER
Great Meadow Run at Fort Necessity National Battlefield.
Photograph by Caleb Tzilkowski

Aquatic Resource Assessment of Fort Necessity National Battlefield and Friendship Hill National Historic Site

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Abstract

Fish and macroinvertebrate (MI) inventories were conducted during 2005 within two Pennsylvania National Park Service properties: Fort Necessity National Battlefield (FONE) and Friendship Hill National Historic Site (FRHI). Core water chemistry data were also collected at the time of surveys. Nine stream sites and five ponds were sampled at FONE; whereas, seven stream sites and one pond were sampled at FRHI. Ponds are not typically used for biomonitoring, but they were important at both NPS properties because they harbored many MI that were not found in streams. Most FONE stream MI communities were characterized as being at least marginally impaired according to the Macroinvertebrate Biotic Integrity Index (MBII). The three least-impaired MI communities (Great Meadow Run, Indian Run, and Braddock's Run) had nearly identical MBII values (~53.0 out of 100), but all other sites had MBII values less than 50.0. The unnamed tributary to Dunbar Creek had an extremely low MBII value (2.4), indicative of severe impairment. FRHI stream MI communities were, as a group, more impaired than those in FONE streams. Rhododendron Run, near its confluence with the Monongahela River, was the least impaired site based upon most MI community metrics. South Run and Dublin Run had similarly impaired MI communities (MBII ~35.0); whereas, two Ice Pond Run sites and the headwaters of Rhododendron Run all contained severely impaired MI communities based upon the MBII and other metrics. Seven common and native fish species were captured among the pond and three streams sampled at FONE; conversely, only three fish species were found at FRHI, and one species (common carp) was nonnative. Water quality data were limited, but five water bodies among the two properties violated designated use criteria on at least one occasion. FONE and FRHI aquatic communities did not appear to be heavily impacted by current human activities; however, they will likely continue to suffer from historical land uses without implementation of restoration strategies. Baseline assessments from this study provided a reference to: 1) evaluate restoration efforts, and/or 2) detect future degradation of aquatic communities throughout FONE and FRHI.

Introduction

The National Park Service (NPS) mission to preserve, protect, and maintain integrity of park ecosystems for future generations relies upon science-based information regarding the status of ecosystem condition. To aid in the fulfillment of that mission, the NPS implemented a service-wide Inventory and Monitoring Program. The goal of this program is to develop broadly based, scientifically-sound information regarding the current status and long-term trends of the composition, structure, and function of park ecosystems.

Establishing a baseline assessment of biological (and physical) condition is an essential component for monitoring ecosystem condition. The Eastern Rivers and Mountains Network (ERMN) identified the need for fish and aquatic macroinvertebrate (MI) inventories at NPS properties, with specific attention to relating these assemblages to water quality and biological integrity.

Fish and MI inventories were conducted during 2005 within two Pennsylvania NPS properties- Fort Necessity National Battlefield (FONE) and Friendship Hill National Historic Site (FRHI). Prior to the inventories summarized in this report, some historical information was available regarding FONE and FRHI aquatic communities; however, several fish species records in the NPSpecies database were questionable and genus-level MI surveys had not been conducted for either park. A Level I Water Quality Survey was done at FONE (Kimmel and Clark 2000), but limited water quality data were available for FRHI (Cooper et al. 1997; Rocker and Ranson 1998; Lacroix 2001). This research provided the first comprehensive data regarding fish and MI communities, coupled with basic water chemistry data, throughout FONE and FRHI. These baseline assessments will enable the NPS to monitor aquatic communities in both parks to detect future improvement or degradation of aquatic ecosystems.

Aquatic Macroinvertebrates and Biomonitoring

MI are aquatic invertebrate animals larger than microscopic size that are often used as indicators of ecosystem integrity. Freshwater forms used for water quality assessment include arthropods (insects, arachnids, and crustaceans), worms, clams, and snails. Given the increased understanding of MI and their importance to aquatic ecosystems, they are frequently studied in regard to their responsiveness to human-induced environmental perturbations. MI are the most frequently used organisms in water quality assessment because: 1) they are relatively easy to collect; 2) many taxa can be identified to the family level in the field (Barbour et al. 1999); and 3) several MI life history traits (e.g., sedentary, ubiquitous) make them uniquely advantageous for monitoring water quality (Table 1).

The ecosystem is the largest spatial and temporal scale for studying MI (Merritt and Cummins 1996), but studying MI at the ecosystem level is usually impractical with regard to both time and finances. The second largest scale of bioassessment is the community (Merritt and Cummins 1996), and because of its relatively large scale and practicality, the MI community is the most commonly used level for water quality assessment. Biological communities have several attributes (Table 2) that make biological monitoring the "most direct and effective measure of a water body" (Karr and Chu 1999).

Table 1. Advantageous traits of aquatic macroinvertebrates (MI) for water quality assessment (Barbour et al. 1999; Merritt and Cummins 1996).

Trait	Advantage for water quality assessment
Sedentary	Relatively limited migration of MI permits examination of spatial effects from environmental perturbations.
Ubiquitous	MI are affected by stress in a variety of aquatic habitats. Small (1st and 2nd order) streams that may not support fish fauna usually support a diverse MI fauna.
Trophic level	MI form the food base of at least a portion of the life cycle of fishes and other aquatic vertebrates.
Speciose	MI assemblages constitute a wide range of trophic levels, providing information regarding cumulative effects of perturbations.
Complex life cycle	Most MI taxa have a complex life cycle of one year or more and sensitive life stages respond quickly to stress.

Table 2. Attributes of biological communities that have made them useful for monitoring integrity of surface waters (Barbour et al. 1999).

1. Biological communities reflect overall integrity (i.e., chemical, physical, and biological integrity) of aquatic ecosystems.
2. Biological communities integrate and reflect effects of multiple stressors, providing a broad measure of the aggregate impact.
3. Biological communities integrate stresses over time, providing an ecological measure of changing environmental conditions.
4. Monitoring biological communities is cheap compared to other types of testing (e.g., chemical, toxicity).
5. The status of biological communities provides a meaningful measure of pollution to the public.
6. Biological communities may better reflect the impacts of ambient impacts (e.g., nonpoint-source discharges, acid deposition) than other means of evaluation.

Study Area

Both FONE and FRHI properties are in southwestern Pennsylvania in Fayette County. FONE is 18 km (29 mi) east of Uniontown whereas FRHI is 19 km (31 mi) southwest of Uniontown. FONE was established to honor early events of the French and Indian War. Colonel George Washington's defeat at Fort Necessity was the first battle of the seven year war between France and Great Britain. The Main Unit of the park is the largest (364 ha [899 ac]) and contains this battlefield, the reconstructed Fort Necessity, and the Mount Washington Tavern. FRHI was established to commemorate the life of Albert Gallatin, who was best known as Secretary of the Treasury for Presidents Jefferson and Madison (Lacroix, 2001). Gallatin bought the 162 ha (400 ac) Friendship Hill parcel in 1786, and although he believed in responsible stewardship of the land (Lacroix 2001), Gallatin's Friendship Hill property and its natural resources were not immune to effects of human activities after his death.

Sampling Locations

Fishes, MI, and water quality sampling sites at FONE and FRHI were selected based on previous reports (Rocker and Ranson 1998; Kimmel and Clark 2000; Lacroix 2001) and on preliminary site visits conducted on July 21, 2005. Final sampling locations were selected in consultation with the Matthew Marshall, ERMN Coordinator, and Connie Ranson, Natural Resource Management Specialist at FONE and FRHI. Core water quality parameters (temperature, conductivity, DO, pH) were measured at each site on days of fish and/or MI surveys.

Fort Necessity National Battlefield (FONE) Sampling Locations

There are nine streams and eight ponds on FONE property (Figures 1 and 2). Great Meadow Run becomes a third-order stream near the northeastern park boundary and is the largest stream within FONE. Great Meadow Run flows northward and drains much of FONE to the Youghiogheny River. Three intermittent unnamed tributaries to Scott's Run drain the southwest slope of FONE to the Monongahela River. Two small park units, Braddock's Grave and Jumonville Glenn, are 2.4 and 11 km (1.5 and 6.8 mi) west of the park Main Unit, respectively. Braddock's Run is a first-order perennial headwater of Big Sandy Creek in the Monongahela River drainage; whereas, an unnamed intermittent tributary of Dunbar Creek flows through the Jumonville Glen site, ultimately to the Youghiogheny River.

Five ponds and eight stream sites were sampled for MI and core water quality parameters at FONE (Table 3). Great Meadow Run was the only stream large enough to warrant MI sampling at multiple sites and was sampled at two locations. Historical fish sampling records existed for Great Meadow Run and Braddocks Run (Cooper et al. no date provided) in the NPSpecies database, but the accuracy of those records was questionable, given: 1) the nonnative status of several species, and 2) that much of the sampling and analysis was conducted by relatively inexperienced volunteers; therefore, these streams were sampled to verify existing data and to identify potential additional fish species present in these streams. Two other streams (Indian Run and an unnamed tributary to Great Meadow Run) appeared to have sufficient annual flows, based on historical reports (Kimmel and Clark 2000) and preliminary site visits, to warrant fish inventories, but both had very low flows at the time of fish surveys and could not be sampled.

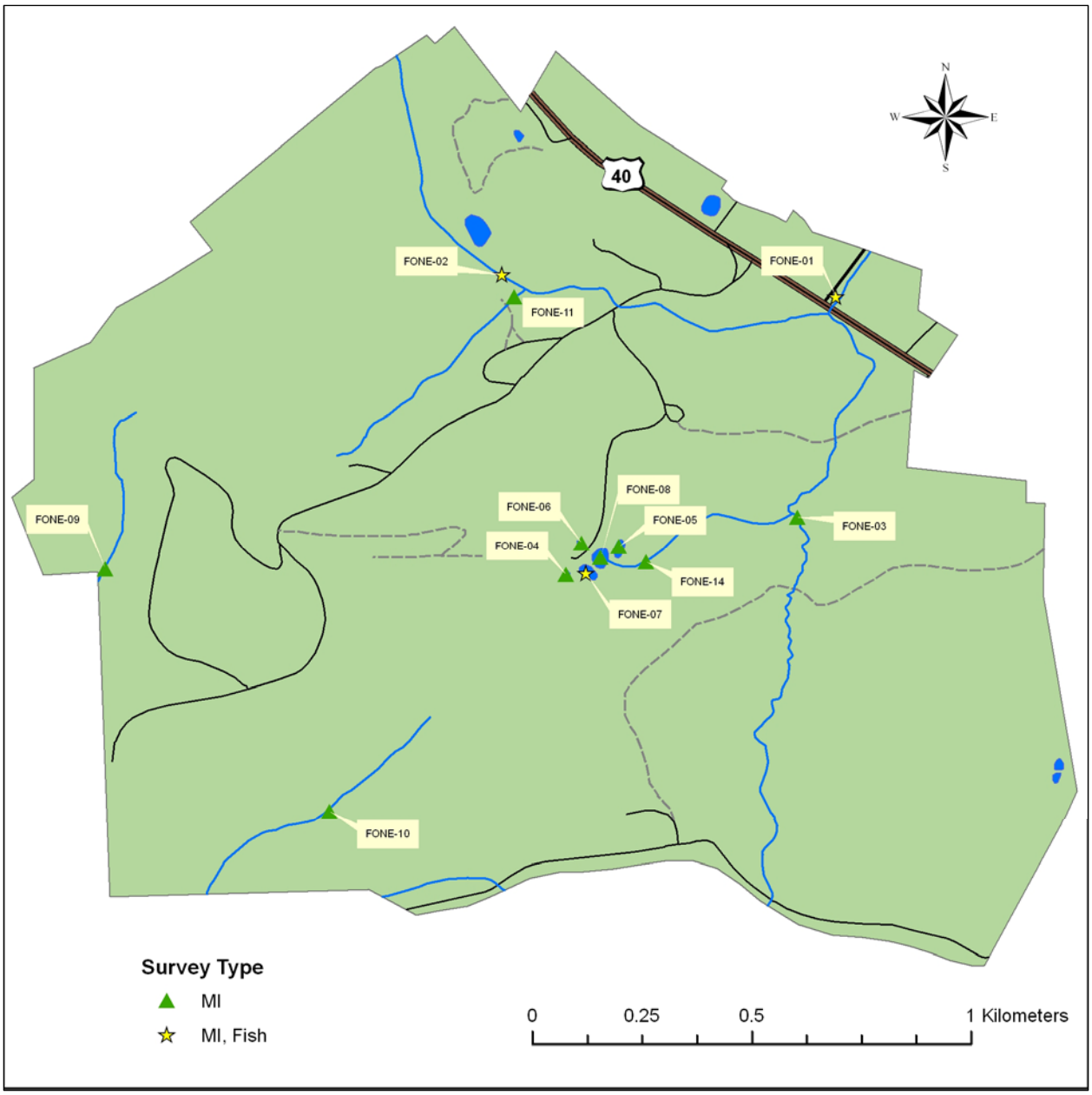

Figure 1. Map of fish, macroinvertebrate (MI), and core water quality parameter sampling sites located at the Main Unit of Fort Necessity National Battlefield. Site descriptions and locations are presented in Table 3.

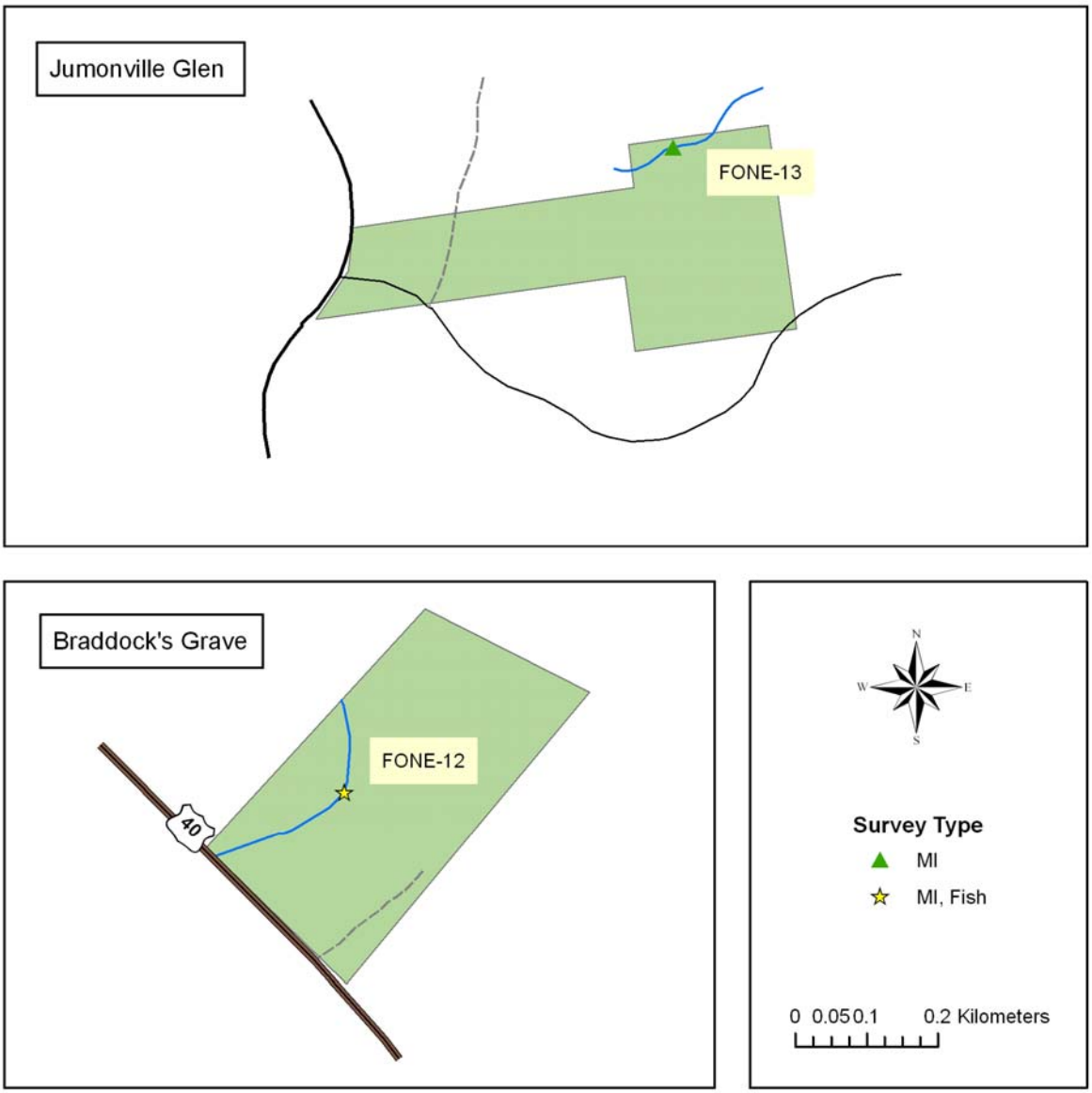

Figure 2. Map of fish, macroinvertebrate (MI), and core water quality parameter sampling sites at Jumonville Glen and Braddock's Grave units of the Fort Necessity National Battlefield. Site descriptions and locations are presented in Table 3.

Table 3. Description, survey type (macroinvertebrates = MI, fishes = F), and location (UTM coordinates) of sampling sites throughout Fort Necessity National Battlefield (FONE) and Friendship Hill National Historic Site (FRHI).

Site	Description	Survey	UTM Coordinates
FONE01	Great Meadow Run, just downstream of I-40	MI, F	621480.3 / 4408167.8
FONE02	Great Meadow Run, upstream of confluence with Indian Run	MI, F	620719.6 / 4408217.9
FONE03	Unnamed tributary to Great Meadow Run	MI	621393.2 / 4407665.5
FONE04	Pond 1, upstream pond	MI	620865.7 / 4407533.6
FONE05	Pond 4, downstream-most pond	MI	620986.6 / 4407599.0
FONE06	Pond 5, pond behind Ranger Annex building	MI	620901.6 / 4407605.5
FONE07	Pond 2, uphill connected pond	MI, F	620911.4 / 4407536.8
FONE08	Pond 3, downstream connected pond,	MI	620944.1 / 4407572.8
FONE09	Northern unnamed tributary to Scott's Run	MI	619816.2 / 4407546.6
FONE10	Southern unnamed tributary to Scott's Run	MI	620326.7 / 4406994.2
FONE11	Indian Run, 100 m upstream of mouth	MI	620748.0 / 4408168.0
FONE12	Braddock's Run at Braddock's Grave Parcel	MI, F	619770.1 / 4410219.7
FONE13	Unnamed tributary to Dunbar Creek (Jumonville Glen Parcel)	MI	616292.8 / 4415431.1
FONE14	Pond outflow, 200 m downstream of ponds	MI	621048.7 / 4407563.4
FRHI01	South Run, upstream of Main Loop Trail	MI	591554.6 / 4402505.6
FRHI02	Rhododendron Run, centered on Main Loop Trail	MI, F	591511.3 / 4402948.9
FRHI03	Rhododendron Run, upstream of downstream-most waterfall	F	591581.3 / 4402959.5
FRHI04	Rhododendron Run, South Branch	MI	591662.7 / 4402959.7
FRHI05	Ice Pond Run, upstream of Main Loop Trail	MI	591538.4 / 4404332.7
FRHI06	Ice Pond Run, upstream of SR 166	MI	592230.3 / 4402911.0
FRHI07	Dublin Run, centered on Main Loop Trail	MI, F	592214.0 / 4404484.1
FRHI08	Sophia's Pond	MI, F	591678.9 / 4403084.0

Friendship Hill National Historic Site (FRHI) Sampling Locations

Sophia's Pond (i.e., the pond at the Rhododendron Run headwaters) and seven sites among four streams were surveyed for MI at FRHI (Table 3, Figure 3). Sophia's Pond and three stream sites were surveyed for fishes. Based on historical reports (Rocker and Ranson 1998; Lacroix 2001) and preliminary surveys, Ice Pond Run and South Run probably do not harbor fish populations due to acid mine drainage and seasonal drying, respectively. Fish were seen in downstream portions of Rhododendron Run and Dublin Run during preliminary site visits and were consequently chosen for sampling. A series of cataracts and waterfalls in the downstream portion of Rhododendron Run likely prohibit upstream movements of fishes from the Monongahela River; therefore, a 100 m (328 ft) reach upstream of the waterfalls was also surveyed to determine whether fishes occur upstream of the barriers, or if fishes seasonally move in and out of the stream from the river. MI were sampled at all water bodies at FRHI despite degraded conditions in Ice Pond Run and the ephemeral nature of South Run.

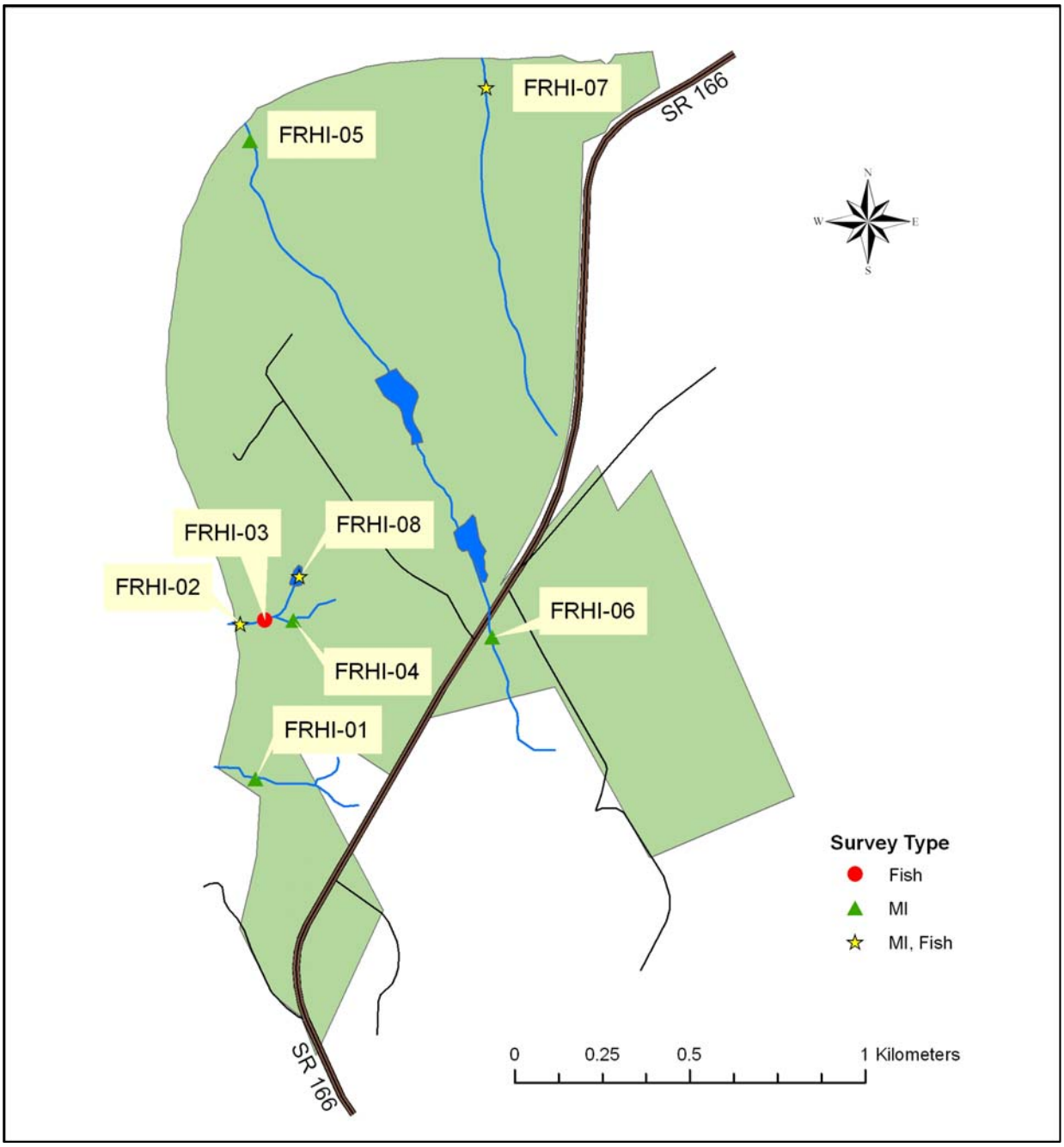

Figure 3. Map of fish, macroinvertebrate (MI), and core water quality parameter sampling sites at Friendship Hill National Historic Site. Site descriptions and locations are presented in Table 3.

Methods

Macroinvertebrate Sampling

MI communities were sampled at FONE and FRHI on December 5, 2005 following protocols outlined by Klemm et al. (2002) and Merritt and Cummins (1996). To adequately characterize stream MI communities, each sample site consisted of a stream reach (i.e., length) 40 times the mean wetted width delineated around a selected midpoint. Eleven evenly spaced transects were established throughout each reach and MI were collected at the inner nine transects with a D-frame kick net (250 µm mesh). D-frame kick nets are the recommended sampling gear for multihabitat bioassessments (Barbour et al. 1999) because they typically collect 95% of the MI taxa present in a stream and can be used in pools, riffles, and runs (Frost et al. 1970). Samples were pooled within sites and preserved in 70% ethyl alcohol. Qualitative MI sampling techniques recommended by Merritt and Cummins (1996) were used in ponds which included replicate D-net dredge or sweep samples within habitat types (i.e., benthos, aquatic vegetation) for a total of nine samples per pond.

Biomonitoring programs often use subsampling to provide a "consistent unit of effort" and to reduce the amount of time, effort, and, ultimately, cost necessary for characterizing MI communities; however, all captured organisms were identified during this study because the primary intent was to inventory as many taxa as possible within the park streams. MI were identified in the laboratory to the lowest practical taxonomic level (usually genus) using standard keys (Peckarsky et al. 1990; Merritt and Cummins 1996) and counted under 60 x-magnification. At least one individual from every taxon was digitally photographed under magnification as a voucher.

Macroinvertebrate Community Data Analysis

Bioassessment protocols advocated by the United States Environmental Protection Agency (USEPA) include Rapid Bioassessment Protocols (Barbour et al. 1999) and the Macroinvertebrate Biotic Integrity Index (MBII [Klemm et al. 2003]). These protocols consist of metrics that describe components of benthic MI community richness or composition using groups of organisms defined by phylogenetic, tolerance, habit, or feeding relationships. The rationale behind these indices is that a suite of metrics representing community structure, pollution tolerance, functional feeding groups and habitat occurrences, life history strategies, disease, and density provide insights regarding how biological communities respond to different natural and anthropogenic stressors (Klemm et al. 2003).

A common stream bioassessment practice is to compare MI community metrics from candidate streams to the same metrics from reference streams. Reference streams are relatively pristine, similarly sized streams within similar geographic and geologic settings as candidate streams that provide an estimate of unimpaired stream communities. Departure of the sampled MI community from expected MI community composition (i.e., reference streams) serves as a measure of stream impairment. The MBII is one such index that uses reference streams to assess stream impairment.

The MBII was used for this study because it was developed for upland and lowland streams dominated by riffle habitat in the Mid-Atlantic Highlands Region (MAHR), which contains Pennsylvania. Moreover, the MBII was based on a large data set of 574 wadeable stream reaches and was thoroughly tested. The MBII is a broadly applicable measure of stream impairment because it is based on several factors that affect aquatic communities throughout the Mid-Atlantic Highlands Region.

Impaired and reference streams for the MBII were identified by Klemm et al. (2003) using water chemistry, qualitative habitat, and minimum organism count criteria. Impaired reaches were defined by meeting any one of the following criteria: pH <5, chloride >1000 µeq/L, sulfate >1000 µg/L, total phosphorous >100 µg/L, total nitrogen >5000 µg/L, or a mean qualitative habitat score <10 (of a possible 20). Reference reaches met all of the following criteria (Klemm et al. 2003): sulfate <400 µg/L, Acid Neutralizing Capacity (ANC) >50 µeq/L, chloride <100 µeq/L, total phosphorous <20 µg/L, total nitrogen <750 µg/L, mean qualitative habitat score >15, and at least 150 organisms.

The MBII uses seven metrics selected from the 100 that are commonly used by governmental agencies throughout the MAHR. The metrics chosen were those that performed best in terms of range, precision, responsiveness to various human-induced disturbances, relationship to catchment area, and redundancy (Table 4 [Klemm et al. 2003]). Most MBII metrics are counts or proportions of taxa in the community that are characterized as tolerant or intolerant to human perturbations; however, one of the metrics (Macroinvertebrate Tolerance Index [MTI]) is more complex because it incorporates ranks (0–10) for each taxon with respect to pollution tolerance, weighted by taxon abundance, and results in higher scores as the proportion of taxa tolerant to general pollution increases (Klemm et al. 2003). Pollution Tolerance Values (PTV) incorporated in the MTI were average organism tolerances to "…various types of stressors" (Klemm et al. 2002).

The MBII was calculated based on floor and ceiling values determined by Klemm et al. (2003) as follows:

> "For positive metrics (i.e., those that increased with improving conditions), the upper expectation (ceiling) was the 75th percentile of the distribution of reference reaches, while the lower expectation (floor) was the 25th percentile of the distribution of impaired reaches. Metrics with a value above the ceiling received a score of 10, while those below the floor scored 0. All other values were linearly scaled along the range between the high and the low. In other words, a raw metric value that was half way between the floor and ceiling values would be scored as 5. For negative metrics, those that decreased with improving condition, the ceiling was the 75th percentile of the distribution of impaired reaches, and the floor was the 25th percentile of the distribution of reference reaches. Negative metrics with a value above the ceiling scored a 0, while those below the floor scored 10. All other values were linearly scaled along the range between the low and high as for positive metrics."

Table 4. Macroinvertebrate Biotic Integrity Index (MBII) metric: descriptions, directions of response to increasing human perturbation, and calculation formulas derived from Klemm et al. (2003).

Metric	Description	Response	Metric Calculation
Ephemeroptera richness	Number of Ephemeroptera (mayfly) taxa	Decrease	1.01 x - 4.25
Plecoptera richness	Number of Plecoptera (stonefly) taxa	Decrease	1.69 x -6.03
Trichoptera richness	Number of Trichoptera (stonefly) taxa	Decrease	1.67 x -1.67
Collector-filterer richness	Number of taxa with a collecting or filtering-feeding strategy	Decrease	1.54 x – 5.98
Percent non-insect individuals	Percent of individuals that are not insects	Increase	-0.56x+10.0
Macroinvertebrate Tolerance Index (MTI)	∑i piti, where pi is the proportion of individuals in taxon i and ti is the pollution tolerance value (PTV) for general pollution	Increase	-5.85+31.34
Percent five dominant taxa	Percentage of individuals in the five numerically dominant taxa	Increase	-0.26+21.21

Metric scores were calculated according to the floor and ceiling values reported by Klemm et al. (2003). To calculate MBII values, metric scores were added together and the sum was scaled by (100/70) which resulted in a range of 0 to 100 for the MBII. Impairment is expected to decrease with increasing MBII score.

Metrics used by the Pennsylvania Department of Environmental Protection (PADEP [Klemm et al. 2002]) were calculated and included: taxa richness, modified Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness (pollution tolerance value, PTV <4), modified % Ephemeroptera (PTV <4), % dominant taxon, and Hilsenhoff Biotic Index (1988).

Physical and chemical characteristics of lentic systems (i.e., lakes and ponds) are very different from those of streams; consequently, lentic MI communities are largely different from those in streams. These differences limit the value of stream indices such as the MBII in ponds. Additionally, lentic MI communities are seldom used for bioassessments in comparison to other assemblages (e.g., plankton) and few indices exist to describe integrity of pond MI communities. Pond MI communities in FONE and FRHI were characterized using other standard descriptors of community structure that provide general information regarding system integrity.

Fish Sampling

Stream fishes were captured by two people from 100 m (328 ft) reaches with gas-powered backpack electrofishing equipment. Water bodies at FONE and FRHI were sampled November 4 and 5, 2005. All fishes were identified, counted, and released after digital images of each species were taken as vouchers.

Sophia's Pond at FRHI was sampled with backpack electrofishing gear. Although electrofishing was attempted at the sampled FONE pond (Pond 2), it was too deep for that sampling gear to be used effectively. Instead, beach seines (12 m, 7 mm mesh) were hauled by rowboat to the middle of the pond then to the shore. Pond 2 and Pond 3 are seasonally connected (personal communication with Connie Ranson); therefore, Pond 2 was the only FONE pond sampled—because the fish species were presumed to be the same in the two ponds. No fish were seen in the nearby, relatively small ponds during preliminary investigations or sampling trips.

Water Quality Sampling

Surface waters located within FONE and FRHI properties were analyzed for chemical and physical constituents, including temperature, pH, dissolved oxygen (DO), and conductivity, termed "core parameters" in the NPS Inventory and Monitoring Program. Each of these parameters is discussed in the following paragraphs.

Core Water Quality Parameters:

Temperature:

Water temperature strongly influences aquatic communities. When the water temperature regime of a system is changed by land cover alterations, reservoir construction, addition of point source discharges, and other human activities, aquatic community composition will change to reflect new conditions. Therefore, temperature measurement can provide information regarding current habitat and serve as a proxy for potential changes in the physical environment.

pH:

Water pH can range from 0–14 on a continuous scale and is the negative logarithm ($-\log_{10}$) of hydrogen-ion activity expressed in moles per liter. Low pH values are acidic; whereas, high values are basic. A pH of 7 is generally considered neutral, though slight variability in the neutral value occurs with changing temperature. Unpolluted river water typically has a pH range from 6.5–8.5, with values outside of this range occurring under certain circumstances (i.e. thermal spring waters can have very low pH). Measurement of pH is a very important component of water quality investigations because pH partly determines solubility of ionic species in solution. For example, different aluminum species predominate under different pH conditions. The cation Al^{3+} predominates when pH is less than 4; whereas, gibbsite is commonly formed by aluminum when the pH is between 4.5 and 6.5. Above neutral pH, the anion $Al(OH)_4^-$ predominates (Hem 1989).

Dissolved Oxygen (DO):

Fishes, MI, and other aquatic organisms require oxygen; therefore, DO concentration is a vital component of aquatic resource investigations. Principal sources of DO include mechanical aeration of the water and photosynthetic output. DO is consumed through respiration, mechanical degassing, and biochemical reactions that occur in the substrate. In unimpaired aquatic ecosystems, DO concentrations are usually sufficient to support aquatic life, but in polluted environments, DO concentrations can be depleted to the extent that many organisms cannot survive.

Conductivity:

Conductivity is the ability of a substance to conduct electrical current. In water, conductivity is related to the concentration of dissolved ionic species in solution, and is therefore useful as a general water quality indicator. The conductance of natural waters has a very wide range depending on geology, soil type, and other sources of solutes. Therefore, conductivity is not a direct indicator of water quality or aquatic system impairment, but it can be used to identify changes in water chemistry. Comparing conductivity at a particular location with upstream locations can often allow inferences regarding groundwater inputs, malfunctioning septic systems, acid mine drainage, and other inputs.

Due to the limited duration of this inventory and the limited number of measurements taken at each site, it was not feasible to conduct statistical analyses. Despite this limitation, water quality data collected were compared to their respective water quality standards where applicable.

Results and Discussion

Fort Necessity National Battlefield (FONE)

Macroinvertebrate Inventories

Sixty-one benthic MI taxa were found throughout FONE (Appendix A). Two salamander species were captured during MI sampling (Northern two-lined salamander *Eurycea bislineata* and Red-spotted newt *Notophthalmus viridescens viridescens*), but because they are vertebrates, they were not included in MI community analyses.

Ponds:

Although ponds are rarely used for biomonitoring, pond MI communities are usually very distinct from those in streams due to the obvious physical and chemical differences between the systems. For example, only nine of the 44 MI taxa captured from FONE ponds were also found in at least one FONE stream. Moreover, despite the close proximity of the FONE ponds, MI communities varied among the ponds.

The small pond (FONE04) uphill of the other ponds had the fewest MI taxa (nine) and was numerically dominated by midges (Chironomidae [Appendix A]). Other taxa found in FONE04 included biting midges (Ceratapogonidae), a cranefly genus (*Limonia* spp.), a waterboatman beetle genus (*Palmacorixa*), aquatic earthworms (Oligochaeta), and two dragonfly genera (*Somatochlora* and *Arigomphus*).

FONE05, the small, downstream-most pond, harbored slightly more taxa (13) than FONE04, but that community was also numerically dominated by midges. Two other true fly (Diptera) families were found in FONE05 in addition to the same waterboatman beetle genus that occurred in FONE04. Unlike FONE04, two caddisfly genera (*Platycentropus*, *Agrypnia*), a hellgrammite (*Chauliodes*), alderfly (*Sialis*), and snail genus (*Planorbella trivolis*) were also collected there.

Fifteen MI taxa were collected from each of the remaining ponds (FONE06, 07, and 08), but there were differences among the three MI samples. The two largest, connected ponds (FONE07 and 08) harbored similar MI families, but there were differences among genera present. For example, four caddisfly genera were collected from both ponds, but only one genus (*Fabria*) was common to both ponds. Similarly, five dragonfly genera were collected from FONE08, but neither of the dragonfly genera collected from FONE07 were found there.

Although the pond (FONE06) behind the ranger annex was small compared to the other ponds, it apparently offered a unique habitat because eight genera found there were not collected from the other ponds. Interestingly, although there were 15 genera found in that pond, one caddisfly genus (*Playcentropus*) constituted 72% of the collected individuals.

Streams:

Based on the suite of metrics typically used by the PADEP, particularly the Hilsenhoff Family-level Biotic Index (HBI; Table 5), water quality at most FONE sampling locations was rated as "excellent, very good, or good" (Table 6). The unnamed tributary to Dunbar Creek (FONE13), located at the Jumonville Glen parcel, contained a MI community indicative of "fair" water quality according to the HBI. Taxa richness at this site was very low (eight) relative to other FONE stream MI communities.

Metrics used by the PADEP rely on MI data collected concurrently from nearby reference (i.e., unimpaired) streams. These data are then compared to MI communities of streams being assessed. Reference streams were not used for this study, but a recent MI survey (Sheeder and Tzilkowski 2006) at the Allegheny Portage Railroad National Historic Site (ALPO) in central Pennsylvania was conducted using the same methods and metrics as in this report. Although not an ideal comparison, Blair Gap Run (BGR) is a relatively unimpaired stream that flows through ALPO. Metrics calculated for MI communities in the BGR watershed reflected the comparatively high degree of biological integrity found there (Sheeder and Tzilkowski 2006). Although taxa richness and HBI values were similar between FONE streams and BGR, there were consistently fewer pollution-intolerant MI taxa (i.e., Ephemeroptera, Plecoptera, Trichoptera) in FONE streams than BGR streams. The relative abundance of pollution-intolerant taxa was also very low in FONE streams compared to BGR. The metric "Modified % Ephemeroptera" (i.e., proportion of pollution-intolerant mayflies in the MI community) is expected to decrease with increasing impairment. Pollution-sensitive mayflies comprised 23±6% of individuals in BGR, but were absent or extremely rare in FONE streams. Impaired MI communities are often dominated by one or a few taxa that typically thrive in a variety of environmental conditions; consequently, the metric "% Dominant taxon" is expected to increase with increasing impairment. Five of the nine MI samples collected from FONE streams had "% Dominant taxon" values that were substantially greater than that of BGR, which indicated considerable impairment.

Most FONE MI communities were characterized as being at least marginally impaired according to the MBII (Table 7, Figure 4). The three least-impaired sites (FONE02, 11, 12) had nearly identical MBII values (~53.0), but all other sites had MBII values less than 50. The site (FONE13) characterized as having "fair" water quality by the HBI had an extremely low MBII value (2.4), which indicated severe impairment.

Although water quality data were limited during the current survey, Kimmel and Clark (2000) did not find evidence of water pollution from mining activity, point source discharges, or development activities in FONE. Instead, behavior of water quality parameters was due to the interaction of precipitation, geology, atmospheric deposition of acids, and wildlife activity. According to Kimmel and Clark (2000), these factors caused most streams to be episodically acidified and the stream in the Jumonville Glen Unit to be chronically acidified. The MI community at Jumonville Glen (FONE13) was severely impaired (MBII =2.4), presumably due to the chronic acidification reported by Kimmel and Clark (2000).

Table 5. Hilsenhoff Biotic Index scores, their water quality characterizations, and associated degrees of organic pollution (Hilsenhoff 1987).

Hilsenhoff Biotic Index Score	Water Quality Rating	Degree of Organic Pollution
0.00– 3.50	Excellent	None
3.51– 4.50	Very good	Possible
4.51– 5.50	Good	Some
5.51– 6.50	Fair	Fairly significant
6.51– 7.50	Fairly poor	Significant
7.51– 8.50	Poor	Very significant
8.51– 10.00	Very poor	Severe

Table 6. Macroinvertebrate (MI) community metrics commonly used by the Pennsylvania Department of Environmental Protection and their values for MI communities sampled throughout Fort Necessity National Battlefield (FONE) streams. Average (±SD) reference values calculated from six sites throughout a relatively unimpaired central Pennsylvania stream (Blair Gap Run[BGR]) are presented for comparison.

		FONE Station								
Metric	BGR	1	2	3	9	10	11	12	13	14
Taxa Richness	26±7	26	21	23	27	20	30	22	8	23
Modified[1] Ephemeroptera, Plecoptera, and Trichoptera Richness	16±6	6	6	5	9	4	10	8	0	3
Modified[1] % Ephemeroptera	23±5	0	1	0	2	1	0	7	0	0
% Dominant Taxon	30±8	35	15	57	58	80	43	22	62	24
Hilsenhoff Family-Level Biotic Index	3.3±0.3	4.30	4.14	3.29	3.14	2.25	3.74	3.65	6.45	4.71

[1]Modified = Pollution Tolerance Value <4.0

Table 7. Macroinvertebrate Biotic Integrity Index (MBII) scores (in bold) and metrics used to calculate the MBII for samples collected throughout Fort Necessity National Battlefield (FONE).

	Sampling Station								
Index or Metric	1	2	3	9	10	11	12	13	14
Epehemeroptera Richness	0	2	1	3	1	2	2	0	0
Plecoptera Richness	3	2	2	4	1	3	4	0	1
Trichoptera Richness	7	6	5	4	4	9	4	2	6
Collector/Filterer Richness	9	10	8	10	9	11	10	3	9
% Noninsect Taxa	3.8	0.4	11.5	1.3	1.5	5.6	1.1	31.0	19.7
Macroinvertebrate Tolerance Index	4.2	4.7	3.4	2.8	1.9	3.7	4.4	6.5	5.7
% 5 Dominant Taxa	84.1	56.8	83.1	87.9	91.7	80.4	52.2	97.4	68.0
MBII Score	46.9	53.3	38.0	49.2	45.8	53.3	53.8	2.4	27.8

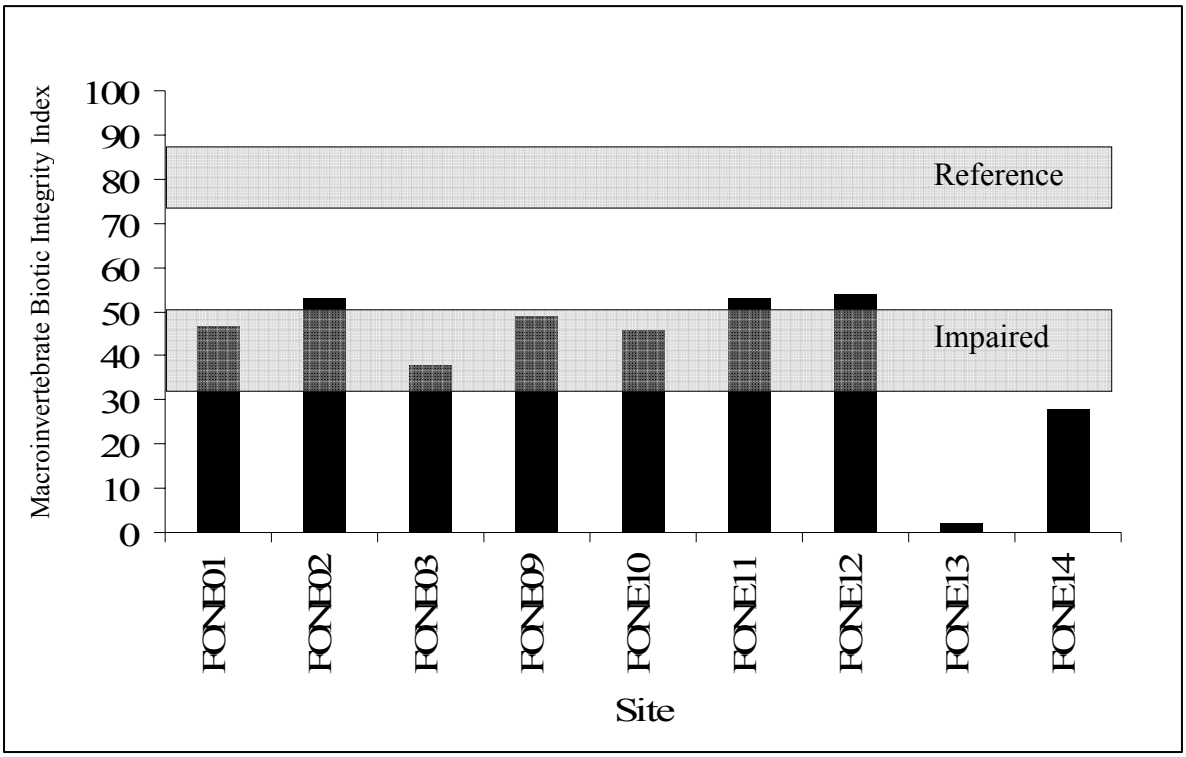

Figure 4. Macroinvertebrate Biotic Integrity Index (MBII) scores for stream stations surveyed in Fort Necessity National Battlefield (FONE). Shaded areas represent middle interquartile range (25–75 %) of MBII values reported for reference and impaired streams in uplands of the Mid-Atlantic Highlands Region.

Episodic water quality impairment still occurs throughout FONE (see Water Quality section below), but that only partly contributes to impairment of stream MI communities. One of the primary advantages of the MBII is that, not only does it incorporate "Core Water Quality Parameters," but it also incorporates other chemical criteria (e.g., nitrates, phosphates) and habitat quality for its calculation. Aquatic organisms not only need suitable water to live in, they also need preferred habitats and, more specifically, microhabitats to exist. Although most FONE streams did not appear to be severely impacted by current local human activities, they have all been subjected to agricultural, mining, and/or point-source impacts in the past. For example, the name of Great Meadow Run (GMR) reflects the historical land use surrounding the largest FONE stream. Although the meadow may have been a naturally occurring one, the stream was channelized and the meadow was tiled, ponded, and filled to dry the meadow and provide additional pasture for livestock and/or crops (Johnson and Cherry 2002). Stream channelization is used to rapidly drain water from a watershed, which it does. Unfortunately, channelization has many negative effects on streams and riparian zones, including increased soil erosion, homogenization of in-stream habitats, and usually increased water temperatures. All of these impacts combine to minimize the quantity and quality of aquatic habitats, which ultimately yields a biological community dominated by pollution-tolerant organisms. Although the degree of impairment varied among FONE streams, it is likely that they are all still responding to human-induced disturbances of the past.

Fish Species Inventories

Seven fish species were captured among the pond and three streams sampled at FONE (Table 8). In addition to bluegill (*Lepomis macrochirus*) and pumpkinseed sunfish (*Lepomis gibbosus*), numerous Red-spotted newts (*Notophthalmus viridescens viridescens*) were found in Pond 2 (FONE07). Mottled sculpin (*Cottus bairdi*), blacknose dace (*Rhinichthys atratulus*), and creek chub (*Semotilus atromaculatus*) were found in Braddock's Run. Those species were also captured from both sites in Great Meadow Run, in addition to white sucker (*Catostomus commersoni*) and johnny darter (*Etheostoma nigrum*).

Prior to these inventories, the NPSpecies database listed seven fish species at FONE (Cooper et al. no date provided), but three of those species (fallfish [*Semotilus corporalis*], slimy sculpin [*Cottus cognatus*], kiamichi shiner [*Notropis ortenburgeri*]) are not native to the Ohio River drainage. Cooper et al. (no date provided) thought that they captured emerald shiners (*Notropis atherinoides*) and assigned the wrong species name in their report; *Notropis ortenburgeri*, which is the Kiamichi Shiner. The name *Notropis ortenburgeri* was entered into the NPSpecies database. It is unlikely, but possible, that Cooper et al. (no date provided) caught emerald shiners from Braddock's Run. Emerald shiners are a mid-water and surface-water swimming species usually found in lakes and large, deep, sluggish rivers (Trautman 1981). In order of decreasing probability, the specimens that Cooper et al. (no date provided) thought they captured were misidentified creek chub, misidentified rosyface shiners (*Notropis rubellus*), misidentified redside dace (*Clinostomus elongatus*), or emerald shiners. Slimy sculpin are not native to western Pennsylvania, but are difficult to tell apart from mottled sculpin in the field; consequently, the slimy sculpin that Cooper et al. (no date provided) thought they found were almost certainly mottled sculpin. Fallfish are not native to the Ohio River drainage but are in the same genus and are similar in appearance to creek chub, which were very abundant in this survey. The fish that Cooper et al. (no date provided) identified as fallfish were likely large creek chub.

All FONE streams currently have the protected use of *High Quality Cold-Water Fishes* (HQ-CWF) designated by the PADEP (Pennsylvania Code, Title 25, Environmental Protection, 1996), which means that they must be suitable for the "maintenance and/or propagation of fish species including the family Salmonidae and additional flora and fauna which are indigenous to cold water habitat". Furthermore, the HQ designation means that these streams fall into the category of "a stream or watershed which has excellent quality waters and environmental or other features that require special water quality protection." Although no trout (family Salmonidae) were captured during these surveys, sculpin, which are also indigenous to cold-water habitat, were captured at the three sampled stream sites. The unnamed tributary to Dunbar Creek at the Jumonville Glen site was not sampled for fishes, but given the poor water quality reported by Kimmel and Clark (2000) and the impaired MI community, that stream probably does not sustain fish populations; consequently, major remediation of that stream would be necessary for it to meet the HQ-CWF designation.

Table 8. Summary of family, species, common name, and number of fishes captured at four Fort Necessity National Battlefield (FONE) locations.

Family and Species		Common Name	Sampling Location 1	2	7	12
Salamandridae	*Notophthalmus* var. *viridescens*	Red Spotted Newt			>200	
Catostomidae	*Catostomus commersoni*	White Sucker	18	3		
Centrarchidae	*Lepomis macrochirus*	Bluegill			>100	
	Lepomis gibbosus	Pumpkinseed			>100	
Cottidae	*Cottus bairdi*	Mottled Sculpin	2	15		35
Cyprinidae	*Rhinichthys atratulus*	Blacknose Dace	14	19		24
	Semotilus atromaculatus	Creek Chub	37	48		40
Percidae	*Etheostoma nigrum*	Johnny Darter	5	5		

Water Quality

Pennsylvania state regulatory criteria exist for stream temperature, pH, and DO. Criteria used in this report have been established for the protection of aquatic life, according to the designated use of the waterbody. Within the FONE and FRHI properties designated uses of surface waters included HQ-CWF and *Warm Water Fishes* (WWF, 25 Pa. Code §93). FONE sampling stations 1–3 and 9–14 are located within stream reaches that currently possess HQ-CWF designations. FONE sampling stations 4–8, located at each of five ponds within the Main Unit of the park are included in the statewide WWF list. Temperature criteria are provided in Table 9. Table 10 provides information regarding established water quality standards for pH and DO.

Specific conductivity is the only parameter included in the NPS list of core water quality parameters that does not have an established water quality standard. There is not a conductivity water quality standard because conductivity is not directly correlated with aquatic health. Nonetheless, conductivity is important for water quality assessment because it provides a measure of dissolved ionic concentration. Therefore, measuring conductivity at points throughout a watershed can provide information on water sources with conductivities that differ from background conditions. In many cases, groundwater inputs, malfunctioning septic systems, mine discharges, or other perturbations can be identified by comparing conductivity measurements at a particular site with upstream and downstream measurements.

Water quality data collected at FONE are presented in Table 11. These limited data suggested that Great Meadow Run (FONE02) and Braddock's Run (FONE12) water temperatures were greater than established criteria for HQ-CWF streams on November 4, 2005. The temperature recorded in the headwaters of Dunbar Creek (FONE13) on December 5, 2005 was also greater than established criteria. Unfortunately, the cause and potential effects of the elevated temperature in these streams could not be determined due to the limited amount of data collected. Stream pH was below established water quality criteria ($6.0<pH<9.0$, inclusive) at FONE06 on December 5, 2005. Again, assessment of the causes and effects of this violation would require further data collection and analysis. DO concentrations at FONE sampling locations were greater than established water quality criteria at all sites. Although DO concentrations were acceptable on the dates sampled, it is important to note that DO concentrations are typically

Table 9. Pennsylvania temperature criteria for the protection of aquatic life (25 Pa. Code §93.7). Time period and maximum temperature criteria for aquatic life high quality-cold water fishes (HQ-CWF) and warm water fishes (WWF) are presented.

	Temperature (°C)	
Time period	HQ-CWF	WWF
January	3.3	4.4
February	3.3	4.4
March	5.6	7.8
April 1-15	8.9	11.1
April 16-30	11.1	14.4
May 1-15	12.2	17.8
May 16-31	14.4	22.2
June 1-15	15.6	26.7
June 16-30	17.8	28.9
July	18.9	30.6
August 1-15	18.9	28.9
August 16-30	18.9	30.6
September 1-15	17.8	28.9
September 16-30	15.6	25.6
October 1-15	12.2	22.2
October 16-31	10.0	18.9
November 1-15	7.8	14.4
November 16-31	5.6	10.0
December	4.4	5.6

Table 10. Pennsylvania dissolved oxygen (DO), and pH criteria for the protection of aquatic life (25 Pa. Code §93.7). Water quality parameter, protected use, and criteria are presented. Aquatic life protected use designations for water bodies within the Fort Necessity National Battlefield (FONE) and Friendship Hill National Historic Site (FRHI) properties include high quality-cold water fishes (HQ-CWF) and warm water fishes (WWF).

Parameter	Protected Use	Criteria
Dissolved Oxygen	HQ-CWF	Minimum of 7 mg DO/L
	WWF – rivers and epilimnion of lakes, ponds, and impoundments	Minimum of 4 mg DO/L
pH	HQ-CWF, WWF	6.0 to 9.0

Table 11. Temperature, pH, dissolved oxygen (DO) and conductivity data collected at Fort Necessity National Battlefield sampling stations. Samples that violated their respective Pennsylvania Department of Environmental Protection aquatic life criteria are in bold.

Site	Date	T	pH	DO %	DO (mg)	Conductivity	Specific Conductivity
FONE01	12/5/2005	0.6	7.23	79.8	11.40	114.6	*
FONE02	11/4/2005	**11.9**	7.28	78.5	8.30	147.2	196.2
	12/5/2005	0.3	7.22	79.8	11.50	101.4	*
FONE03	*	*	*	*	*	*	*
FONE04	12/5/2005	3.5	6.66	72.4	9.40	31.9	53.6
FONE05	12/5/2005	2.6	6.84	77.6	10.50	33.3	59.0
FONE06	12/5/2005	2.8	**5.79**	61.0	8.50	37.7	64.5
FONE07	11/4/2005	7.5	6.95	75.0	8.90	40.9	61.9
	12/5/2005	2.0	6.40	61.9	9.40	28.8	50.1
FONE08	12/5/2005	2.2	6.70	75.0	10.20	31.5	55.6
FONE09	12/5/2005	0.4	7.82	69.0	10.00	37.3	*
FONE10	12/5/2005	0.5	7.47	81.7	11.70	18.8	*
FONE11	12/5/2005	*	*	*	*	*	*
FONE12	11/4/2005	**11.2**	7.14	78.2	8.50	105.8	143.7
	12/5/2005	0.3	7.04	83.0	12.00	51.8	*
FONE13	12/5/2005	**7.2**	6.78	82.2	9.90	28.2	42.6
FONE14	12/5/2005	2.1	6.74	86.3	11.80	33.4	58.9

lowest at night during summer months. Sampling DO concentrations during warm, low water conditions would provide more valuable information regarding DO variability at FONE. Conductivity measurements at FONE01, 02, and 12 were higher than levels detected at other FONE sites. As mentioned previously, high conductivity measurements are not necessarily indicative of aquatic impairment; however, these measurements indicated that the chemical signature of water at these sites was different from the other FONE water bodies. An extensive chemical analysis of water samples would be required to identify causes of the elevated dissolved ion concentrations. Due to the cost associated with extensive water quality analysis, additional collection, and analysis of core water quality parameter data is recommended prior to undertaking any detailed water quality analysis.

Friendship Hill National Historic Site (FRHI)

Macroinvertebrate Inventories

Sophia's Pond (FRHI08):

Sophia's Pond, at the headwaters of Rhododendron Run, contained several MI taxa typically found in ponds (e.g., dragonflies, snails) and was numerically dominated by midges (Chironomidae), but the pond also harbored taxa usually found in streams (Appendix 2); i.e., two mayfly genera (*Caenis*, *Stenonema*) and two caddisfly genera (*Cernotina, Nyctiophylax*), typically found in streams, were abundant in Sophia's Pond. Although not visible at the time of

these samples, the Rhododendron Run headwaters that flow into Sophia's Pond probably provide suitable habitat within the pond for these relatively tolerant MI taxa.

Streams:

FRHI stream MI communities were, as a group, more impaired than those in FONE streams. Although water quality among FRHI sites varied from "excellent" to "fair" based on the HBI (Table 12), they all had MBII values within or below typical values for impaired Pennsylvania streams (Figure 5). Rhododendron Run, near its confluence with the Monongahela River, had the least impaired MI community based upon all but one PADEP metric (Modified % Ephemeroptera). South Run (FRHI01) had substantially more MI taxa (25) than Dublin Run (FRHI07, 13 taxa), but MBII values for the two streams were similar (~35.0, Table 13). Ice Pond Run sites (FRHI05, 06) and the headwaters of Rhododendron Run (FRHI04) all contained severely impaired MI communities based upon the MBII and PADEP metrics. Ice Pond Run is, unfortunately, still impacted from acid mine drainage, but reasons for impairment of the MI community in the headwaters of Rhododendron Run remain unknown and deserve additional attention.

As discussed in the Water Quality section below, most water quality parameters among FRHI stream sites were within acceptable PADEP criteria for the WWF protected use. The most obvious water quality violation was the exceptionally low pH (2.99) in the downstream section of Ice Pond Run (FRHI05) that made conditions inhospitable for all but the most pollution-tolerant MI. Although FRHI streams had water quality generally acceptable for WWF standards, these streams were undoubtedly mostly forested before human disturbance and would have likely harbored MI (and fish) communities typical of coldwater "reference" streams. Similar to FONE streams, the streams and aquatic communities at FRHI are slowly recovering from past land uses (e.g., deforestation, mining).

Fish Species Inventory

Three fish species and three amphibian species were captured at FRHI during electrofishing surveys. One adult and 17 juvenile common carp (*Cyprinus carpio*) were captured from Sophia's Pond (FRHI02). The common carp has been widely introduced throughout North America and can survive, reproduce, and usually become very abundant in a variety of habitats. Three American bullfrogs (*Rana catesbeina*) and one Red-spotted newt were also incidentally captured from Sophia's Pond. Although stream flow was very low at FRHI02, one creek chub and one American bullfrog were captured from an isolated pool located downstream of the first waterfall upstream of the stream mouth. FRHI03, which was from the mouth of Rhododendron Run upstream to the isolated pool (FRHI02), was intended to be sampled but could not be due to the lack of surface flow at the time of inventories. Three blacknose dace and 47 creek chub were captured from Dublin Run (FRHI07).

Water Quality

All FRHI sampling stations were included in the statewide WWF list (25 Pa. Code §93). Water quality data collected at FRHI are presented in Table 14. Temperature and DO were acceptable based upon WWF criteria at all sampling stations on the dates listed. With the exception of

Table 12. Commonly-used Pennsylvania Department of Environmental Protection macroinvertebrate community metrics and their values for streams sampled throughout Friendship Hill National Historic Site (FRHI).

	FRHI Station						
Metric	BGR	1	2	4	5	6	7
Taxa Richness	26 ± 7	25	26	20	7	20	13
Modified[1] Ephemeroptera, Plecoptera, and Trichoptera Richness	16 ± 6	9	11	5	0	5	5
Modified[1] % Ephemeroptera	23 ± 5	9	6	3	0	1	38
% Dominant Taxon	30 ± 8	36	28	25	89	25	38
Hilsenhoff Family-Level Biotic Index	3.3±0.3	4.03	3.48	4.91	5.79	6.40	3.61

[1]Modified = Pollution Tolerance Value <4.0

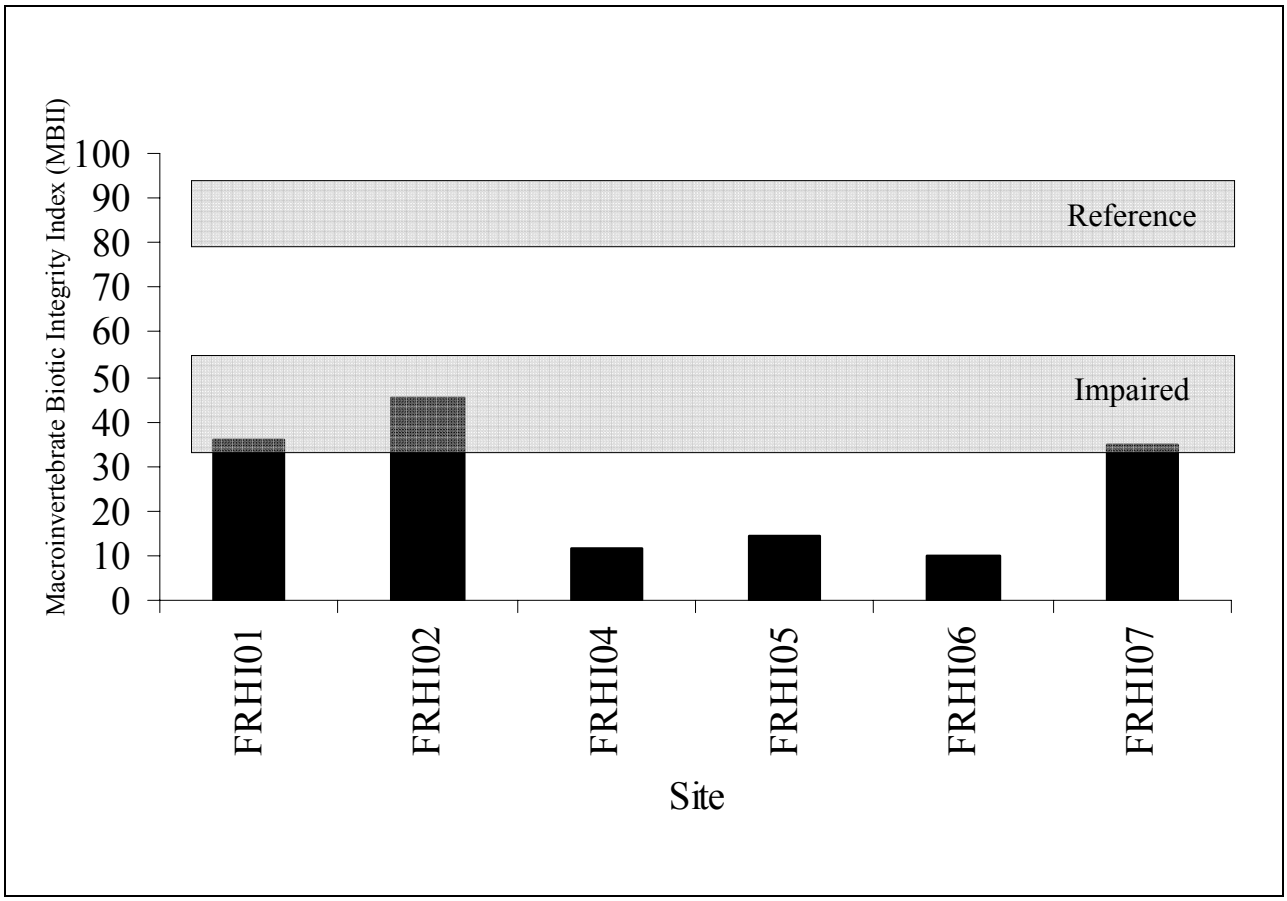

Figure 5. Macroinvertebrate Biotic Integrity Index (MBII) scores for stream stations surveyed in Friendship Hill National Historic Site (FRHI). Shaded areas represent middle interquartile range (25 – 75%) of MBII values reported for reference and impaired streams in uplands of the Mid-Atlantic Highlands Region.

Table 13. Macroinvertebrate Biotic Integrity Index (MBII) scores (in bold) and metrics used to calculate the MBII for samples collected throughout Friendship Hill National Historic Site.

	Sampling Station					
Index or Metric	1	2	4	5	6	7
Epehemeroptera Richness	3	4	2	0	2	1
Plecoptera Richness	4	5	3	0	2	2
Trichoptera Richness	5	4	1	1	2	3
Collector/Filterer Richness	8	10	8	1	7	7
% Noninsect Taxa	14.6	13.9	43.4	0	51.5	6.8
Macroinvertebrate Tolerance Index	4.4	3.5	5.4	5.8	6.5	3.6
% 5 Dominant Taxa	65.2	70.6	74.0	98.6	79.0	90.3
MBII Score	**35.8**	**45.2**	**11.4**	**14.3**	**9.7**	**34.8**

Table 14. Temperature, pH, dissolved oxygen (DO), and conductivity data collected at Friendship Hill National Historic Site (FRHI) sampling stations. Samples that violated the Pennsylvania aquatic life – warm water fish criteria are in bold.

Site	Date	T	pH	DO%	DO (mg)	Conductivity	Specific Conductivity
FRHI01	12/5/2005	3.2	8.70	88.0	11.45	185.5	317.5
FRHI02	11/4/2005	9.1	7.49	91.8	10.56	132.7	190.6
	12/5/2005	2.2	7.48	88.9	12.23	86.2	152.6
FRHI03		*	*	*	*	*	*
FRHI04	12/5/2005	3.7	6.45	71.3	9.17	79.1	132.6
FRHI05	12/5/2005	2.1	**2.99**	86.0	11.73	75.5	132.9
FRHI06	12/5/2005	4.2	7.31	81.3	10.56	118.2	196.3
FRHI07	11/4/2005	10.9	7.40	88.0	9.65	155.6	213.5
	12/5/2005	2.0	7.43	88.0	12.07	114.8	202.9
FRHI08	11/4/2005	8.5	7.19	80.0	9.60	94.0	137.7
	12/5/2005	4.0	7.15	57.0	7.40	84.0	140.5

FRHI05, pH at FRHI sites ranged from slightly acidic at FRHI04 to basic at FRHI01. The pH at each of these sites was within the accepted range (6.0<pH<9.0, inclusive) for the WWF water quality standard. The pH in Ice Pond Run (FRHI05) was extremely acidic (pH=2.99) on December 5, 2005. A pH measurement that low does not occur in surface waters under natural conditions (except in some thermal springs) and indicates that previous efforts to remediate acid mine drainage pollution in Ice Pond Run were unsuccessful. Conductivities of waters located within FRHI were generally greater than those at FONE sites. However, as mentioned above, this does not necessarily indicate a greater level of anthropogenic disturbance. Higher FRHI conductivity measurements may have been due to differences in geology, soil chemistry, or other environmental factors.

Conclusions and Recommendations

Limited information was available regarding FONE and FRHI fish and MI communities prior to this study. Several fish species records for the properties existed in the NPSpecies database, but several of those were almost certainly incorrect. Similarly, although some MI data were available for FONE and FRHI, much of it was questionable and genus-level MI surveys had never been conducted for either property. This study provided the first comprehensive data regarding fish and MI communities throughout FONE and FRHI. It is recommended that the NPS use data from this study as baseline assessments of FONE and FRHI aquatic communities; furthermore, comparisons of future assessments to studies prior to this one should be limited due to considerable errors found in previous reports.

This study demonstrated that all stream communities throughout FONE and FRHI were variably impaired, likely due to either intentional (e.g., channelized) or unintentional (e.g., agriculture, mining, atmospheric deposition) consequences of historical human activities. However, stream communities throughout FONE and FRHI are good examples that, given cessation of intense human impairment, biological communities can respond positively. Although all MI communities were impaired throughout sampled FONE and FRHI streams, they were almost certainly less impaired than they had been in the recent past (e.g., mid-1900's). That being said, recovery of most of these streams is likely to occur at a slower rate in the future unless stream restoration actions are implemented.

On a geologic time scale, stream ecosystems will approach a natural equilibrium after human disturbances cease, but that process takes a very long time. Theoretically, after a stream is channelized it will erode its way through the landscape over hundreds or thousands of years, which will ultimately form a new stream channel. Concurrently, riparian vegetation will colonize areas from where it was removed, water quality will improve, and organisms will colonize areas as habitats become available. For example, it would likely take, minimally, hundreds of years for the currently-channelized Great Meadow Run to naturally revert to a meandering stream channel without deeply incised banks. Consequently, if a biomonitoring program is instituted at either FONE or FRHI, it is likely that most MI and fish communities will remain in their present (impaired) condition for the foreseeable future unless actions are taken to restore stream habitats to a more natural condition. The next step towards rehabilitating these streams is to identify sources of impairment, which was beyond the scope of this study. After sources of impairment are identified, actions can be prioritized and implemented to improve the condition of FONE and FRHI aquatic resources.

Stream corridor restoration techniques are available to accelerate the recovery of stream ecosystems. There is a wide spectrum of passive and active practices to restore stream corridors (FISRWG 1998), and if the NPS decides to proceed with stream restoration projects at FONE and/or FRHI, other agencies (e.g., PADEP, U.S. Department of Agriculture, U.S. Geological Survey) have expertise and should be consulted prior to beginning any projects. Given limited resources, an extremely important decision in the stream restoration process is to prioritize projects based on their potential for completion. For example, because of the nature of AMD at FRHI, resources that would be devoted to mediating AMD effects on Ice Pond Run could probably be better used on smaller, but achievable, restoration projects.

There are passive and aggressive stream restoration methods that vary in cost and time of stream response. A good example of some methods was outlined by Johnson and Cherry (2002) who assessed potential approaches for restoring Great Meadow Run. During the time of Washington's battle (1754), Great Meadow Run meandered through the Great Meadow and overtopped its banks into the floodplain (Johnson and Cherry 2002). This historic, natural stream channel maintained a wetland ecosystem and presumably a much greater variety of in-stream habitats for aquatic organisms. Due to the variety of modifications that the stream has undergone, it no longer floods the meadow with a frequency to maintain wetlands. Johnson and Cherry (2002) examined alternatives for restoring, at a minimum, the function of Great Meadow Run so that native wetland vegetation can survive in at least a portion of the meadow. Four passive options (i.e., that require relatively little earth movement and slow stream channel adjustments) and three aggressive options (i.e., that require significant excavation and construction) were developed and ranged from no cost (no action), to more than $645,000 (full reconstruction of 1754 wetlands; Johnson and Cherry 2002). Instead of using aggressive and expensive reconstruction methods, Johnson and Cherry (2002) recommended that engineered debris jams (cost =$2,500) should be used to restore Great Meadow Run because they will provide a desirable gradual change, have minimal impact on the aesthetics of the park during construction, cause minimal disruption to the current physical system, and produce desired results with the majority of the work being performed by the stream itself. The following paragraphs present general assessments of aquatic resources among FONE and FRHI and potential courses of action to improve the condition of aquatic resources at the properties.

Fort Necessity National Battlefield (FONE)

The unnamed tributary to Dunbar Creek (FONE13) at the Jumonville Glen Unit was severely impaired based upon MI data, and, although Kimmel and Clark (2000) reported that it was chronically acidified, the source of that impairment is unknown and deserves attention. Given the land use history of the area, AMD is a probable cause. The NPS has limited ownership surrounding that stream and would, therefore, have to cooperate with surrounding land owners to determine and mitigate sources of impairment.

The outflow stream from the FONE ponds harbored the second-most impaired MI community, probably due to the influence of the ponds on the chemistry and temperature regime of that stream. No mayflies were found at that site, but several MI typically found in ponds were present. The only way to restore water quality at that site to a more natural condition (for a stream and drainage area of that size) would be to remove the impoundments—which would be logistically and economically prohibitive.

The other FONE sites had MI communities that were similarly impaired, but the sources of impairment remain unknown. Based upon minimal qualitative observations by the authors, most FONE streams no longer have natural stream channels. Given where the FONE property boundaries lie and degrees of impairment among the streams, it is recommended that impairment sources be identified among FONE streams in the following order: mainstem of Great Meadow Run (FONE01, 02); Indian Run (FONE11); unnamed tributary to Great Meadow Run (FONE03); southern unnamed tributary to Scott's Run (FONE10); northern unnamed tributary to Scott's Run (FONE09); Braddock's Run (FONE12); and unnamed tributary to Dunbar Creek

(FONE13). After impairment sources are identified the NPS could prioritize and initiate stream restoration projects at its discretion.

Friendship Hill National Historic Site (FRHI)

Ice Pond Run has a well-documented history of AMD impairment which was confirmed by the low MBII scores and the few MI taxa collected from sites in that stream. As evidenced by past remediation failures in Ice Pond Run, restoring that stream will be a major undertaking and is probably unrealistic until AMD mitigation technologies become more effective and less economically prohibitive. The headwaters of Rhododendron Run had a similarly low MBII value (11.4), but reasons for impairment of that site were not identified and deserve further attention. The remaining three stream sites were less impaired based on MI community data but had similar MBII values. Evaluation of impairment at those sites should be prioritized as follows: Dublin Run (FRHI07); South Run (FRHI01); and Rhododendron Run (FRHI02). Based on those evaluations, stream restoration projects could be initiated.

As stated previously, FONE and FRHI streams do not appear to be heavily impacted by current human activities; however, they will likely continue to suffer from historical land uses without implementation of restoration strategies. If efforts are not made to identify and mitigate the sources of stream impairment, it cannot be expected that fish and MI communities will improve substantially in the near-term. If restoration efforts are not made, it is still recommended that the NPS implement a program to monitor MI communities at as many of the stream sites identified in this study as possible. Comparing those data with the baseline data established in this study will allow detection of future degradation or improvement of aquatic resources throughout FONE and FRHI.

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Appendix A. Benthic organisms captured at sampling sites throughout Fort Necessity National Battlefield on December 5, 2005.

			FONE Site														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	
		Water Body Type	S	S	S	P	P	P	P	P	S	S	S	S	S	S	
		Taxa	26	21	23	9	13	15	15	15	27	20	30	22	8	23	
		Individuals	346	227	610	255	128	591	186	130	461	326	445	92	155	178	
ORDER	FAMILY	GENUS															Individuals
Amphibia	Pleodonthidae	*E. bislineata*			1							3	1	2			7
	Salamandridae	*N. viridescens*					1	2	5	10							3
Bivalvia	Sphaeriidae	*Pisidium*	3		52							1	12	1		14	83
Coleoptera	Dytiscidae	*Agabus*						8									8
		Graphoderus						1									1
		Hydrovatus										1					1
		Laccornis													2		2
	Elmidae	*Dubiraphia*	1	10													11
		Optioservus	1	10							2	1		1			15
		Oulimnius		19								1	3	1			24
		Stenelmis		7										1			8
	Haliplidae	*Haliplus*							1								1
		Peltodytes						2		1							3
	Hydrophilidae	*Hydrochus*												1			1
		Tropisternus														1	1
	Psehenidae	*Ectopria*									4	4		5			13
Decapoda	Cambaridae	*Cambarus* spp.										1					1
		Oronectes spp.		1													1
Diptera	Ceratapogonidae	*Bezzia*							1		1					1	3
		Ceratapogon				3					5						8
		Culicoides														1	1
		Dasyhelea				1			11								12
		Mallochohelea							1								1
		Probezzia							4								4
	Chironomidae	*Chironomidae*	37	30	47	238	83	9	135	31	22	8	84	20	96	31	871
	Muscidae	Unidentifiable					1										1
	Psychodidae	*Pericoma*			1								2				3

			FONE Site														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	
		Water Body Type	S	S	S	P	P	P	P	P	S	S	S	S	S	S	
		Taxa	26	21	23	9	13	15	15	15	27	20	30	22	8	23	
		Individuals	346	227	610	255	128	591	186	130	461	326	445	92	155	178	
ORDER	FAMILY	GENUS															Individuals
		Psychoda														1	1
	Simuliidae	*Prosimulium*	121	34	29						80	5	45	5		3	322
		Stegopterna									3						3
	Tabanidae	*Tabanus*	5		3							1	22				31
		Chrysops		11													11
		Haematopota									3						3
		Hybomitra	2		31						3					17	53
		Merycomyia					4		10	2							16
	Tipulidae	*Brachypremna*		26								2	2				30
		Dicranota	2								1			6			9
		Helius									2	2			1	1	6
		Limnophila	2	18	8						20	3	6	5	3	42	107
		Limonia			2	1							2				5
		Molophilus			9								10	1			20
		Pedicia											1			1	2
		Pseudolimnophila														1	1
		Tipula	7		13								5	9		17	51
Ephemeroptera	Baetidae	*Centroptilium*					1										1
	Caeniidae	*Caenis*								1							1
	Ephemerellidae	*Eurylophella*		1							2	2	1				6
	Ephemeridae	*Ephemera*									4			2			6
	Leptophlebiidae	Unidentifiable		2									1	4			7
	Siphlonuridae	*Ameletus*			1						2						3
Gastropoda	Physidae	*Physella heterostropha*	4														4
		Unidentifiable			1												1
	Planorbidae	*Gyralus parvus*	1														1
		Planorbella trivolis					1										1
Hemiptera	Corixidae	*Hespercorixa*						75									75
		Palmacorixa				1	9										10

			FONE Site														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	
		Water Body Type	S	S	S	P	P	P	P	P	S	S	S	S	S	S	
		Taxa	26	21	23	9	13	15	15	15	27	20	30	22	8	23	
		Individuals	346	227	610	255	128	591	186	130	461	326	445	92	155	178	
ORDER	FAMILY	GENUS															Individuals
		Sigara						1									1
	Notonectidae	*Notonecta*						2									2
Isopoda	Asellidae	*Caecidotea*	3		2							3	9		48	5	70
Lepidoptera	Pyralidae	*Munroessa*						3									3
		Unidentifiable								1					1		2
Megaloptera	Corydalidae	*Chauliodes*					1	2									3
		Nigronia									3						3
	Sialidae	*Sialis*	1		8		1	1	2				1			1	15
Odonata	Coenagrionidae	*Anomalagrion*								1							1
		Chromagrion					3			2							5
		Enallagma					7	22		32							61
		Cordulegaster	1	1	1						1	2	3				9
	Corduliidae	*Neurocordulia*					1										1
		Somatochlora				2			2								4
	Gomphidae	*Arigomphus*				1				2							3
		Gomphus							3								3
		Lanthus									3						3
	Libellulidae	*Libellula*								1							1
Oligochaeta	Lumbricina	Unidentified	2		15	7		39	7	6	6		4			16	102
Plecoptera	Capniidae	*Allocapnia*	79	4	348						266	262	193			3	1155
		Paracapnia												4			4
	Leuctridae	*Leuctra*									4			5			9
	Nemouridae	*Soyedina*									1		2				3
	Perlidae	*Acroneuria*									3						3
		Beloneuria												2			2
	Perlodidae	*Clioperla*	2														2
	Taeniopterygidae	*Taeniopteryx*	28	20	18								14	6			86
Trichoptera	Hydropsychidae	*Cheumatopsyche*		19													19
		Diplectrona	3	2							1	1	2	3		8	20

			FONE Site														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	
		Water Body Type	S	S	S	P	P	P	P	P	S	S	S	S	S	S	
		Taxa	26	21	23	9	13	15	15	15	27	20	30	22	8	23	
		Individuals	346	227	610	255	128	591	186	130	461	326	445	92	155	178	
ORDER	FAMILY	GENUS															Individuals
		Hydropsyche											1				1
	Hydroptilidae	*Agraylea*								1							1
		Ochrotrochia							1								1
	Lepidostomatidae	*Lepidostoma*									1	14	2				17
	Leptoceridae	*Oecetis*							5								5
		Setodes							1								1
	Limnephilidae	*Anabolia*						1									1
		Goera											1				1
		Hydatophylax	5		4								5				14
		Madeophylax													2		2
		Platycentropus	1	1		1	15	424		47							489
		Pycnopsyche	3	4	3						1	2	7	1	2	6	29
	Phryganeidae	*Agrypnia*	3	1	2		1									2	9
		Banksiola						1									1
		Fabria							2	1							3
		Oligostomis	3										1			2	6
		Ptilostomis								1							1
	Rhyachphilidae	*Rhyacophila*			7						17	10	2	2		1	39
	Uenoidae	*Neophylax*	26	6	5								2	7		3	49

Appendix B. Benthic organisms captured at sampling sites throughout Friendship Hill National Historic Site on December 5, 2005.

			FRHI Station								
			1	2	3	4	5	6	7	8	
		Taxa	25	26	-	20	7	20	13	10	
		Individuals	253	575	-	219	141	167	279	107	
ORDER	FAMILY	GENUS									Individuals
Amphibia	Pleodonthidae	*Eurycea bislineata*	6	2		3			1		12
Amphipoda	Crangonyctidae	*Crangonyx*	12	18					5		35
	Gammaridae	*Gammarus*		4							4
Bivalvia	Sphaeriidae	*Pisidium*				4		13			17
Coleoptera	Dytiscidae	*Liodessus*						5			5
	Melyridae	Unidentified	1								1
	Psehenidae	*Ectopria*	2	3				2			7
Decapoda	Cambaridae	*Cambarus* spp.				2			2		4
		Oronectes spp.						1			1
Diptera	Ceratapogonidae	*Atrichopogon*	1								1
		Mallochohelea				1					1
		Probezzia					1				1
	Chironomidae	*Chironomidae*	15	27		15	125	42	25	42	291
	Dixidae	*Dixa*				1					1
	Dolichopodidae			1							1
	Simuliidae	*Prosimulium*						4			4
	Tabanidae	*Chrysops*	1	4				4			9
	Tipulidae	*Brachypremna*	11								11
		Dicranota	1								1
		Limnophila	15	1		16		2			34
		Limonia				2					2
		Pedicia				5					5
		Rhabdomastix	1	2		1					4
		Tipula	2	3		7		5			17
Ephemeroptera	Baetidae	*Baetis*		1							1
		Cloeon						1			1
	Caeniidae	*Caenis*						1		34	35
	Heptageniidae	*Epeorus*	1	21							22

			FRHI Station								
			1	2	3	4	5	6	7	8	
		Taxa	25	26	-	20	7	20	13	10	
		Individuals	253	575	-	219	141	167	279	107	
ORDER	FAMILY	GENUS									Individuals
		Stenonema		3						15	18
	Leptophlebiidae	*Habrophlebioides*	8								8
		Unidentified				1					1
	Siphlonuridae	*Ameletus*	22	10		5			105		142
Gastropoda	Ancylidae	*Ferrissia*								4	4
Hemiptera	Corixidae	*Sigara*				4					4
Isopoda	Asellidae	*Caecidotea*	15	28		35		33	5	1	117
Lepidoptera	Pyralidae	*Acentria*					1				1
Megaloptera	Corydalidae	*Chauliodes*					6	1			7
		Nigronia		4			4	4	5		17
	Sialidae	*Sialis*		2		3	2	2	1		10
Odonata	Coenagrionidae	*Anomalagrion/Ischnura*								3	3
Oligochaeta	Lumbricina	*Oligochaeta*	10	30		54		39	7	5	145
Plecoptera	Capniidae	*Allocapnia*		81				4	59		144
		Capnia	4								4
		Paracapnia		103		33					136
	Leuctridae	*Leuctra*	23	29		24			25		101
	Nemouridae	*Soyedina*		1		5					6
	Peltoperlidae	*Tallaperla*	1	26							27
	Perlodidae	*Diploperla*	2								2
		Diura						2			2
Trichoptera	Glossosomatidae	*Glossosoma*	1								1
	Hydropsychidae	*Diplectrona*	90	163					38		291
		Hydropsyche		2							2
	Limnephilidae	*Pycnopsyche*							1		1
	Philopotamidae	*Wormaldia*	3	6					1		10
	Phryganeidae	*Agrypnia*					2	1		1	4
	Polycentropidae	*Cernotina*								1	1
		Neureclipsis				1					1
		Nyctiophylax								1	1

			FRHI Station								
			1	2	3	4	5	6	7	8	
		Taxa	25	26	-	20	7	20	13	10	
		Individuals	253	575	-	219	141	167	279	107	
ORDER	FAMILY	GENUS									Individuals
		Polycentropus	7								7
	Rhyachphilidae	*Rhyacophila*	4	2							6
	Uenoidae	*Neophylax*						1			1

As the nation's primary conservation agency, the Department of the Interior has responsibility for most of our nationally owned public land and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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