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System-Wide Water Resources Program

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Abstract: Rapid Bioassessment Protocols (RBP's) were used in combination with geospatial techniques to elucidate spatial variability in ecological quality among streams at Fort Benning Military Installation, Georgia. The installation includes portions of several physiographic landforms, which results in substantial differences in geomorphology, water chemistry, and instream cover among streams. In an effort to characterize this variability, 23 streams were sampled during fall each year from 2002-2005. Data describing biological, water quality, and physical habitat conditions were collected and analyzed following general RBP methods. Geospatial mapping techniques were used to demonstrate spatial trends in habitat variability. Specific variables that best demonstrated variability in stream conditions included pH, physical habitat score (HI), Hilsenhoff Index of Biotic Integrity (HIBI), and percent Ephemeroptera, Plecotera, and Tricoptera (%EPT). In general, upland streams were shallow and contained unstable substratum of mostly sand with very little cover and normal pH. Coastal plain streams in the eastern and southeastern portion of the base had suitable stable substratum and cover, although water chemistry results indicated very acidic conditions (pH often < 5.0). Coastal plain streams in the southern portion of the base contained more instream stable habitat and organic debris but demonstrated a more moderate pH than in the eastern portion of the base. The use of RBP's allows standard evaluation, characterization, and monitoring of stream quality at military bases. Growing need for environmental inventories, management plans, and impact analyses on military lands could make the proactive incorporation of RBP's into basewide stream monitoring advantageous as the preferred approach for natural resource managers.

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Preface

This report was prepared by Mark D. Farr, Mark D. Antwine, and Dr. Barry S. Payne, Aquatic Ecology and Invasive Species Branch (EE-A), Environmental Laboratory (EL), U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS.

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The report was prepared under the general supervision of Dr. Timothy Lewis, Chief, EE-A; Dr. Michael Passmore, Deputy Director, EL; and Dr. Beth Fleming, Director, EL.

The Commander and Executive Director of ERDC is COL Gary E. Johnston. Dr. Jeffery P. Holland is ERDC Director.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
angstroms	0.1	nanometers
atmosphere (standard)	101.325	kilopascals
bars	100	kilopascals
British thermal units (International Table)	1,055.056	joules
centipoises	0.001	pascal seconds
centistokes	1.0 E-06	square meters per second
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
fathoms	1.8288	meters
feet	0.3048	meters
foot-pounds force	1.355818	joules
gallons (U.S. liquid)	3.785412 E-03	cubic meters
hectares	1.0 E+04	square meters
horsepower (550 foot-pounds force per second)	745.6999	watts
inches	0.0254	meters
inch-pounds (force)	0.1129848	newton meters
kilotons (nuclear equivalent of TNT)	4.184	terajoules
knots	0.5144444	meters per second
microinches	0.0254	micrometers
microns	1.0 E-06	meters
miles (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
mils	0.0254	millimeters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters

Multiply	By	To Obtain
pints (U.S. liquid)	4.73176 E-04	cubic meters
pints (U.S. liquid)	0.473176	liters
pounds (force)	4.448222	newtons
pounds (force) per foot	14.59390	newtons per meter
pounds (force) per inch	175.1268	newtons per meter
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
quarts (U.S. liquid)	9.463529 E-04	cubic meters
slugs	14.59390	kilograms
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (force)	8,896.443	newtons
tons (force) per square foot	95.76052	kilopascals
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (nuclear equivalent of TNT)	4.184 E+09	joules
tons (2,000 pounds, mass)	907.1847	kilograms
tons (2,000 pounds, mass) per square foot	9,764.856	kilograms per square meter
yards	0.9144	meters

1 Introduction

Purpose

Rapid Bioassessment Protocols (RBP's) were used as part of a landscape-level examination of stream quality at Fort Benning Military Installation, Georgia. The primary objective was to use a multimetric approach to characterize stream quality by describing spatial variability of biotic and abiotic conditions among military base streams. Long-term goals were to provide military base personnel with baseline information describing stream condition and quality to aid in development of an adaptive management plan.

Background

Rapid Bioassessment Protocols (RBP's) were developed to characterize and monitor quality of wadeable streams in relation to ecosystem management. Ecological conditions within a stream are often directly influenced by changes in natural conditions or other perturbations occurring within the watershed. For this reason, streams have been referred to as "sentinels" of ecosystem health (Karr 1998) and often receive a great deal of focus when designing a long-term watershed monitoring plan. For example, training exercises and resource management on military bases are often organized by land "compartments," the boundaries for which often coincide with those of particular watersheds. A relatively simple multimetric approach, such as RBP, can be used to evaluate potential impacts of training or environmental restoration on ecosystem health among watersheds at military bases.

Rapid Bioassessment Protocols were originally developed in the mid-1980s as a cost-effective alternative to more intensive quantitative techniques used for investigating abiotic and biotic properties of streams (Plafkin et al. 1989). Subsequent refinement of RBP has resulted in a simple and flexible set of standard methods for evaluating environmental, biological, and physical habitat characteristics of streams (Barbour et al. 1999). This report discusses application of RBP techniques to characterize and describe baseline ecological conditions of 23 first- to fifth-order streams on Fort Benning Military Reservation (FBMR) during each fall 2002-2005 (explained in "Data Collection" in Chapter 2). Drawing on this specific experience, the choices that were made concerning site selection, methods of sampling, simple analytical procedures, and interpretations of results that are likely to be made in similar efforts to establish practical, cost-effective baseline stream-monitoring programs at similar landscape scales are described.

2 Methods

Study area

Fort Benning Military Reservation occupies 764 km^2 in west central Georgia just south of Columbus. This area is a transitional zone between the lower Piedmont and upper Coastal Plain ecoregions comprising evergreen, deciduous, and mixed forests. For this reason, there is great potential for fundamental differences in habitat conditions among streams. The largest stream is Upatoi Creek, a sixth-order stream that generally runs from northeast to southwest before flowing into the Chattahoochee River. A well-developed and diverse system of first- to fifth-order streams channel flow into Upatoi Creek (Figure 1).

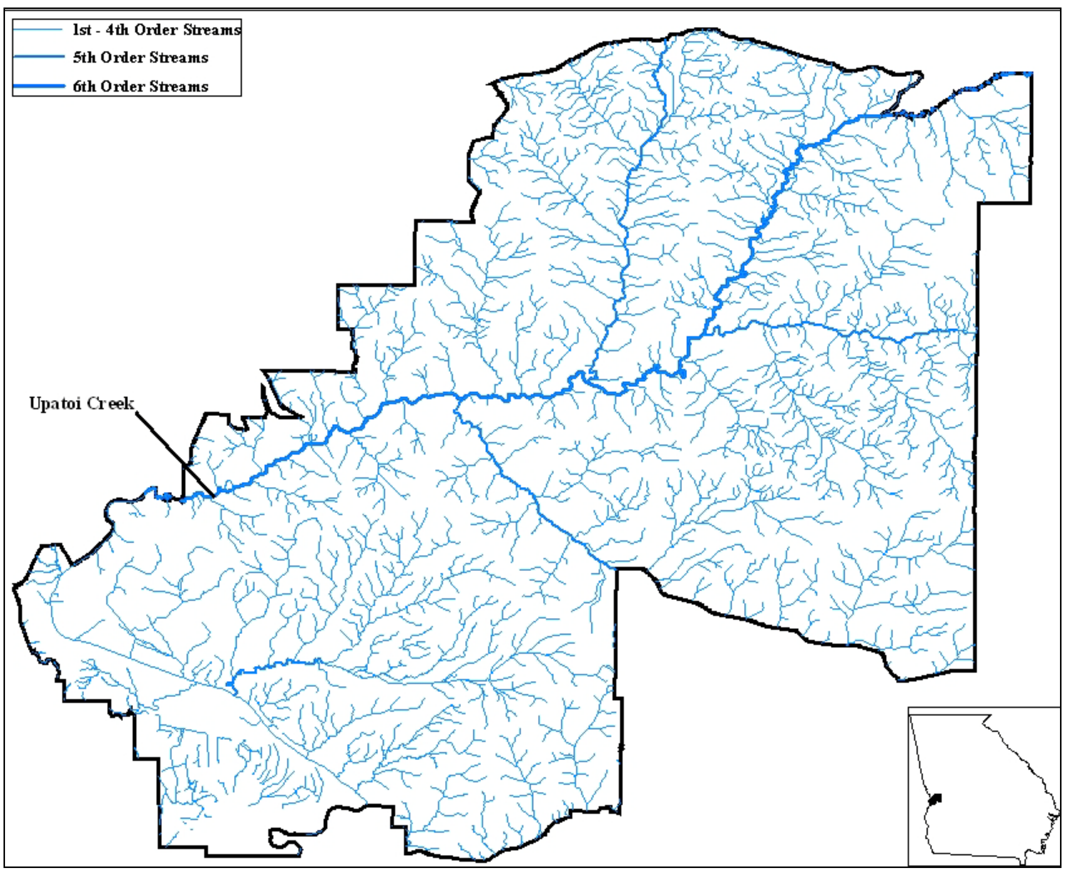

Figure 1. Stream network at Fort Benning Military Installation, near Columbus, Georgia.

Factors to consider before designing a long-term monitoring plan

Rapid Bioassessment Protocols represent a suite of acceptable methods for field sampling, laboratory processing of samples, and data analysis. Decisions regarding the number of sites to be monitored, frequency of sampling, level of taxonomic identification, and sophistication of data analyses are influenced in large part by available resources and the intended use of survey results by resource managers. Each of these decisions affects costs. The following sections provide a brief discussion of factors that influence the design of RBP-based long-term monitoring programs and how similar decisions were made as part of the Fort Benning stream characterization effort.

Site selection

One of the most important decisions in the initial phase of designing a monitoring plan involves determining the number, size, and locations of sites to be sampled. The number of sites is most often either limited by available resources (e.g., funding, time constraints, and labor requirements) or the scope of a particular project (e.g., single or multiple streams to be sampled). At FBMR, the purpose of the stream monitoring effort was to use simple sampling and analytical techniques to describe and contrast common physical, water quality, and biological factors of streams throughout the entire base to inform the development of an adaptive management plan. Restricted access to cantonment, headquarters, live training activities, and unexploded ordnance precluded sampling all streams (Figure 2). Instead, 23 streams of various stream-orders within each physiographic sub-ecoregion were sampled (Figure 3).

Site size and length can vary substantially depending on stream order, habitat diversity, and extent of access. A preliminary visual survey was conducted by walking along each stream to observe the abundance and diversity of specific habitat types (e.g., riffles, pools, root wads, leaf-packs, undercut banks). The primary concern was to establish sites of sufficient size to adequately represent major habitats prevalent throughout the local stream reach. Standard 100-m sites were established at each FBMR stream sampled. This “fixed length” approach is acceptable for small streams, although many studies use variable-length sites based on a multiple of wetted-width (i.e., 40 times wetted width; Lazorchak et al. 1998).

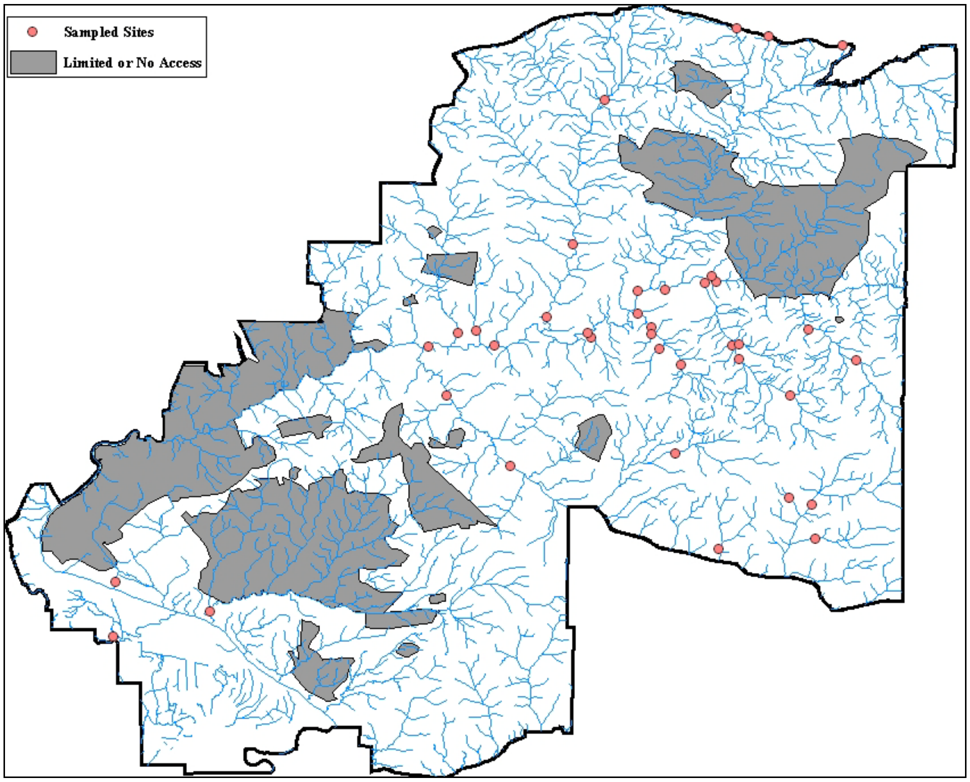

Figure 2. Sampling sites were precluded from limited or no access zones.

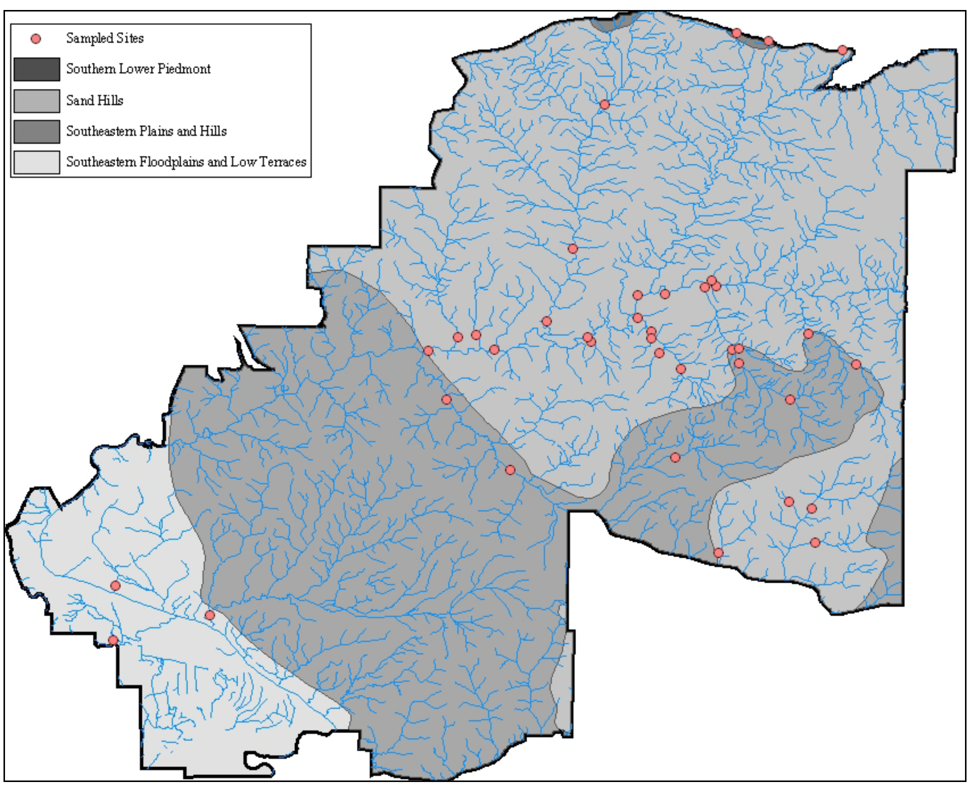

Figure 3. Physiographic complexity at Fort Benning Military Reservation results in a diverse range of soil types, flora, and fauna.

The specific section of stream designated for data collection was representative of general habitat conditions within the drainage. Sites were primarily limited by physical access and safety constraints. Anomalous habitat features (e.g., roads, low-water bridges, isolated areas of heavy erosion) were not included within site boundaries. Although most sites were accessible from nearby roads or trails, care was taken to establish sites upstream and approximately 100 m from road crossings to minimize potential effects of these structures.

Data collection

Sampling frequency. Monitoring programs that use seasonal sampling regimes are ideal for detecting variability in stream quality indicators over the course of a year (Gibson et al. 1996). This type of approach is particularly useful for tracking changes in biological assemblages composed of organisms with short life spans or multiple life-history stages (e.g., periphyton and benthic macroinvertebrate assemblages). Results often convey valuable information regarding resiliency and stability of assemblage composition and structure. However, multiple sampling events directly increase project costs and were prohibitive in the present study.

Instead, the sampling regime at FBMR involved annual winter sampling. Life-history processes and species composition of benthic macroinvertebrates are most stable during late fall and winter months. Therefore, annual winter sampling of streams both minimizes the potential for data variability caused by natural biological processes and provides results that integrate cumulative effects of ecosystem stressors throughout the year (Gibson et al. 1996).

Water quality. Water quality factors can be an important component of a stream monitoring program because they can indicate natural geochemical properties as well as unnatural levels of pollution or contamination (e.g., point and non-point pollution, erosion, elevated nutrient levels, etc.). Variables such as water temperature, conductivity, dissolved oxygen, pH, and turbidity typically are measured at each monitoring site and were assessed in studying baseline conditions at FBMR.

Chemical analyses of water samples can be included from each site, particularly if a specific problem is suspected for which an analytical test can be targeted. However, water chemistry analyses can be costly, often requiring special collection and storage methods, and sometimes involving time-sensitive analytical techniques.

Physical habitat index (HI). RBP's utilize a visual habitat assessment system where 10 habitat features are scored from 0-20 (0 = very degraded; 20 = pristine) to qualitatively describe fundamental habitat conditions both within and outside the stream channel. Scores are then summed to calculate a habitat index value (HI) reflecting overall habitat quality at a site. Habitat features used to estimate HI are described below:

1. *Epifaunal substrate.* How much cover/surface area is provided by the substratum (cobble, large rocks, logs and woody debris, and undercut banks) as refugia for macroinvertebrates and fish.

2. *Embeddedness*. The depth that rocks or logs are embedded in sand, silt, or mud can be correlated with erosion within a watershed and subsequent sedimentation within a stream; low embeddedness indicates better habitat conditions.

3. *Velocity and depth*. Stream reaches with slow-deep, slow-shallow, fast-deep, and fast-shallow velocity depth regimes were given the highest scores, whereas reaches with only one or two of these habitat regimes were given lower scores.

4. *Sediment deposition*. Excessive deposition occurring throughout a reach can result in the formation of point bars or the filling of pools and runs with sand, silt, or mud; heavy levels of deposition indicate poor habitat quality.

5. *Channel flow status*. The amount of the stream channel covered by water. A low percentage of substrate covered by water represents limited habitat availability to instream organisms.

6. *Channel alteration*. The presence of unnatural stream conditions, such as riprap, bridges, or sections of channelized (straightened) stream can indicate low habitat quality.

7. *Frequency of riffles*. The presence of typical riffle/pool habitats at a site. Riffles occurring less than seven stream widths from one another are considered optimal. For example, if a stream is 5 m wide, then riffles

should be no more than 35 m from the end of one to the beginning of the next to be considered optimal.

8. *Bank stability*. Amount of erosion or potential for erosion in a reach. Unprotected steep banks with exposed soils receive the lowest scores, whereas gently sloping banks covered with rooted vegetation are given higher scores.

9. *Bank vegetative protection*. Amount of coverage/protection from erosion afforded streambanks by plants; plants influence nutrient uptake and hydrology as well as provide allochthonous organic material for detritivores.

10. *Riparian vegetative zone width*. The width of mature vegetation within 18 m of the streambank. Roads, agriculture, and other human developments are assumed to decrease stream quality (e.g., increased water temperature, runoff, nutrient loads, and sedimentation rates).

The HI scoring system is effective for quickly assessing general stream habitat conditions. However, the subjective nature of the scoring method requires that persons using the system receive training and practice to produce consistent and reliable results. Prior to initiating work at FBMR, appropriate conditions for assigning habitat parameter scores were discussed and preliminary exercises were conducted to compare scores from multiple persons for several streams and thus minimize variability in habitat scores.

Data were also collected to describe several other physical habitat variables often included as part of an RBP assessment. These data are typically used to describe or estimate the prevalence of large woody debris, coarse particulate organic matter (CPOM), fine particulate organic matter (FPOM), percent riffle/pool/run habitat, substratum composition, and canopy coverage. Large woody debris provides cover and habitat stability for both fishes and benthic macroinvertebrates (Dolloff 1986, Lemly and Hilderbrand 2000). Increased retention times of CPOM and FPOM, important energy sources for macroinvertebrates, have also been linked to increased stability of pool habitats associated with large woody debris (Lemly and Hilderbrand 2000). Canopy cover limits exposure of the stream to sunlight, thus potentially limiting primary production (Minshall et al. 1983, Feminella et al. 1989) as an important energy source.

Biological assemblages.Periphyton, benthic macroinvertebrates, and fishes are all considered appropriate for conducting biological assessments as part of RBP (Plafkin et al. 1989). Many different types of biological metrics and indices have been developed for use as ecological indicators of stream condition (Barbour et al. 1999). However, data describing environmental tolerances for specific fish and macroinvertebrate taxa are more common than for periphyton. Similarly, efforts to develop, calibrate, and implement multimetric biological indices have focused more on fishes and macroinvertebrates rather than periphyton. Nonetheless, each type of assemblage offers advantages and disadvantages that should be evaluated before deciding what types of organisms to use for biological assessments.

Periphyton taxa are most appropriate for studying acute stress in aquatic systems because they are short-lived and probably respond more directly to physico-chemical changes than benthic macroinvertebrates and fishes (Patrick 1973, 1977; Rodgers et al. 1979). Sampling is relatively simple, requires very few resources, and well-established standard methods are available for laboratory processing. However, as mentioned above, the absence of many well-developed multimetric indices for periphyton can be problematic.

Most fish species are mobile and have life spans of a few to several years (Karr et al. 1986). This presents a potential dynamic quality to fish distributions that can fluctuate rapidly with changes in stream conditions. For this reason, biological assessments using fishes are particularly appropriate for studying potential changes in stream quality over larger temporal and spatial scales. Life-history and ecological information is available for most freshwater fish species including a large number of sensitive threatened or endangered species (Warren and Burr 1994). Although fishes can usually be enumerated and identified quickly in the field, resources required to effectively sample fishes are often large compared with periphyton and benthic macroinvertebrates.

Benthic macroinvertebrates are the most common group of organisms used for biological assessments in streams due to their ubiquitous nature and their taxonomic and functional diversity (Merritt and Cummins 1996). The nearly sessile nature of benthic macroinvertebrates makes them particularly useful in monitoring stream conditions at small scales (i.e., stream reach or macrohabitats). Relatively easy standard methods also have been developed for sampling benthic macroinvertebrates; these methods are not as expensive or labor-intensive as those required for sampling fishes. Many ecological metrics and indices have been developed to evaluate stream quality using benthic macroinvertebrates (Hilsenhoff 1988, Barbour et al. 1999). Because many states use benthic macroinvertebrate sampling as part of their statewide stream monitoring programs, reference data and regional tolerance values are often readily available. For these reasons, benthic macroinvertebrates at each of the sites in this study were sampled for the biological component of the RBP.

Sampling macroinvertebrates at each site. A variety of methods have been adopted for sampling benthic macroinvertebrates as part of RBP-type monitoring studies. The three most common approaches involve the use of artificial substrata, a 1-m kicknet sample, and the D-net "jab method." Aspects of each of these methods are sometimes mixed and varied, but the fundamental difference between these three approaches is the type and variety of habitats sampled.

Artificial substrates provide a "passive" standard sampling unit that can be deployed and retrieved with very little training (Cairns 1982). By providing a homogenous sampling surface, artificial substrates might also minimize the confounding effects of comparing results from multiple stream sites with inherent differences in substratum composition. However, artificial substratum represents only one type of "habitat" and may greatly limit sensitivity to effects associated with diverse groups of taxa occupying heterogeneous habitats.

The original RBP (Plafkin et al. 1989) suggested that only riffle habitats be sampled since diversity and abundance of benthic macroinvertebrates is usually greater in these areas. The single-habitat approach works well in streams with well-defined riffle habitat comprising larger substrata (e.g., large gravel and cobble). However, riffles in many low-gradient streams often contain more sand and small gravel with limited amounts of cobble and other large substratum; methods for sampling in these streams usually include a multiple-habitat approach.

Streams at FBMR were all low-gradient with a dominant substratum of sand. Riffle habitat was often limited and contained very small portions of small gravel and coarse sand. Other major habitat types included large woody debris, rootwads, undercut banks, leaf packs, and pools.

A multiple-habitat sampling approach was used in which 20 "jab" samples were taken at each 100-m sampling reach. A visual survey was initially used to identify the types and relative amounts of major habitats present within each site. This allowed the 20 samples to be collected in a stratified manner among major habitats weighted by relative abundance.

For each sample, a D-net was swiftly "jabbed" into an area to be sampled, agitated to collect organisms, and then withdrawn. To sample organisms associated with root wads and large woody debris, the net was positioned immediately behind and downstream of the object to be sampled. Organisms were then dislodged by scrubbing and agitating the sampled surface by hand. After collecting each sample, all organisms and debris were removed from the net and combined into a composite sample. This material was then preserved in a 10% formalin solution and transported to the laboratory for processing.

Laboratory processing of samples – Considerable debate has occurred over how benthic macroinvertebrate samples should be processed in the laboratory. One of the fundamental reasons for developing RBP was to minimize the costs and labor required to evaluate stream quality. As a result, Plafkin et al. (1989) supported the use of sub-sampling techniques during sample processing. The "fixed count" method is most commonly used, where a pre-determined number of organisms are randomly removed from a sample and used for subsequent analyses. A few researchers have raised concerns over the effects that sub-sampling techniques (Courtemanch 1996) and inclusion of rare taxa (Cao et al. 1998, 2001; Marchant 2002; and Cao and Williams 1999) may have on subsequent results and conclusions. However, the most recent revised version of US EPA RBP (Barbour et al. 1999) still suggests that sub-sampling techniques are a valid cost-effective approach for assessing stream quality. In fact many state environmental assessment programs still employ the "fixed count" method.

The "fixed count" method was used during laboratory processing of FBMR samples. Composite sample material from each site was spread evenly throughout a shallow, flat sub-sampling tray. A small random sub-sample of the material was then removed from the tray and examined under a dissecting microscope. All organisms were removed and stored in 70% ethanol. Additional sub-samples were similarly processed until a random subset of 250 $\pm$ 25 organisms had been removed from the sample material.

All subsampled organisms were then identified to genus or lowest practical taxonomic level. This process was then repeated for each site sampled.

Data analysis. The specific objectives of stream assessment projects determine what types of data analyses are most appropriate. The level of statistical analyses can vary from very simple subjective comparisons of calculated metrics among sites to more sophisticated hypothesis testing and multivariate analyses designed to elucidate how variables differ among sites. Basic environmental monitoring programs usually involve comparisons of baseline sampling results with set standards determined by state agencies; site-specific results can be used to detect changes in stream quality in response to both natural perturbations as well as planned management techniques.

The objective at FBMR was to characterize basic habitat conditions of accessible and free-flowing streams. A statewide system of standard stream assessment protocols was under development but not available at the time of this study. Objectives did not include identifying specific mechanisms affecting stream quality; nor was hypothesis testing used to statistically discriminate among stream types. Instead, simple comparisons of metric values were used to indicate how general stream conditions varied across the entire FBMR.

3 Results

Four specific variables were particularly useful indicators of stream condition at Fort Benning: pH, HI, HIBI, and %EPT. For each variable, median values from each sampling site were used to estimate conditions throughout the entire drainage (Table 1). Based on this approach, the sampling sites represent approximately 58.3% of the military base. Error in estimating conditions throughout an entire basin obviously can be correlated with basin size, sampling frequency, and other factors. Therefore it is suggested that these results be viewed as rough estimates of stream conditions at the installation.

Table 1. Median estimates of environmental, physical, and biological factors describing stream conditions at Fort Benning Military Installation during 2002-2005.

Stream	pH	Conductivity (uS/cm)	Turbidity (NTU)	Temp (°C)	DO (mg/L)	HI	HIBI	%EPT
Baker Cr	7.2	0.07	19.8	20.7	9.4	130	6.3	8
Bonham Cr	4.8	0.02	24.5	19.2	8.0	148	5.4	22
Cox Cr	7.0	0.09	13.0	21.8	7.4	173	5.1	10
Dstr Trib Bon Cr	5.2	0.02	2.8	19.6	6.5	156	5.2	27
Halaca Cr	5.4	0.04	17.5	17.6	8.2	143	6.5	3
Hollis Br	5.3	0.03	22.0	24.6	4.8	158	5.9	0
Hollis Cr	5.3	0.02	12.1	19.6	8.2	150	5.9	9
Hollis Cr Trib	5.1	0.02	12.0	20.8	7.8	165	5.1	5
Laundry Crk	5.6	0.06	3.7	16.2	8.5	148	5.3	30
Little Pine Knot	4.5	0.02	11.7	15.0	6.7	159	5.5	34
Long Br	5.3	0.02	7.5	22.0	8.6	152	5.2	15
Ochillee Cr	6.2	0.03	23.8	16.9	8.9	162	5.5	28
Oswitchee Cr	5.8	0.03	22.1	15.2	9.2	154	6.1	13
Pine Knot Cr (PKC)	4.5	0.02	7.1	19.3	8.6	160	5.4	11
Randall Cr	7.2	0.06	10.0	21.6	8.6	118	5.7	49
Sally Br	4.8	0.03	14.0	16.1	7.3	146	5.9	6
Sally Br Trib	4.3	0.03	5.1	21.4	6.7	167	5.8	36
Tar Cr	7.4	0.10	24.0	21.7	9.1	115	5.8	9
Trib to Och Cr	6.1	0.05	19.5	17.3	9.3	137	6.1	7
Trib to PKC	6.1	0.02	6.3	19.8	6.4	147	6.5	9
Trib Upatio Cr	5.0	0.01	12.5	23.0	7.3	144	5.9	41
Upstr Trib Bon Cr	5.0	0.02	11.6	19.6	7.2	158	4.3	40
Wolf Cr	4.5	0.02	7.5	17.4	7.8	153	5.6	13

pH. The rate at which enzyme-mediated biochemical reactions occur can be influenced by the pH of an organism's environment. Therefore, the range and variability of pH as well as the buffering capacity of the environment can affect overall habitat suitability for aquatic macroinvertebrates in streams.

Stream pH varied substantially among streams depending on physiographic conditions (Figure 4). Although acidic conditions persisted in most streams (pH < 7.0 in 79.8% of sampled basin area - SBA), streams in the upland portion of the base (e.g., Randall and Cox Creeks, Tar River) had pH values greater than 7.0. Streams in the eastern portion of the base as well as Wolf Creek were very acidic (pH < 5.0) and represented ~26.9% SBA.

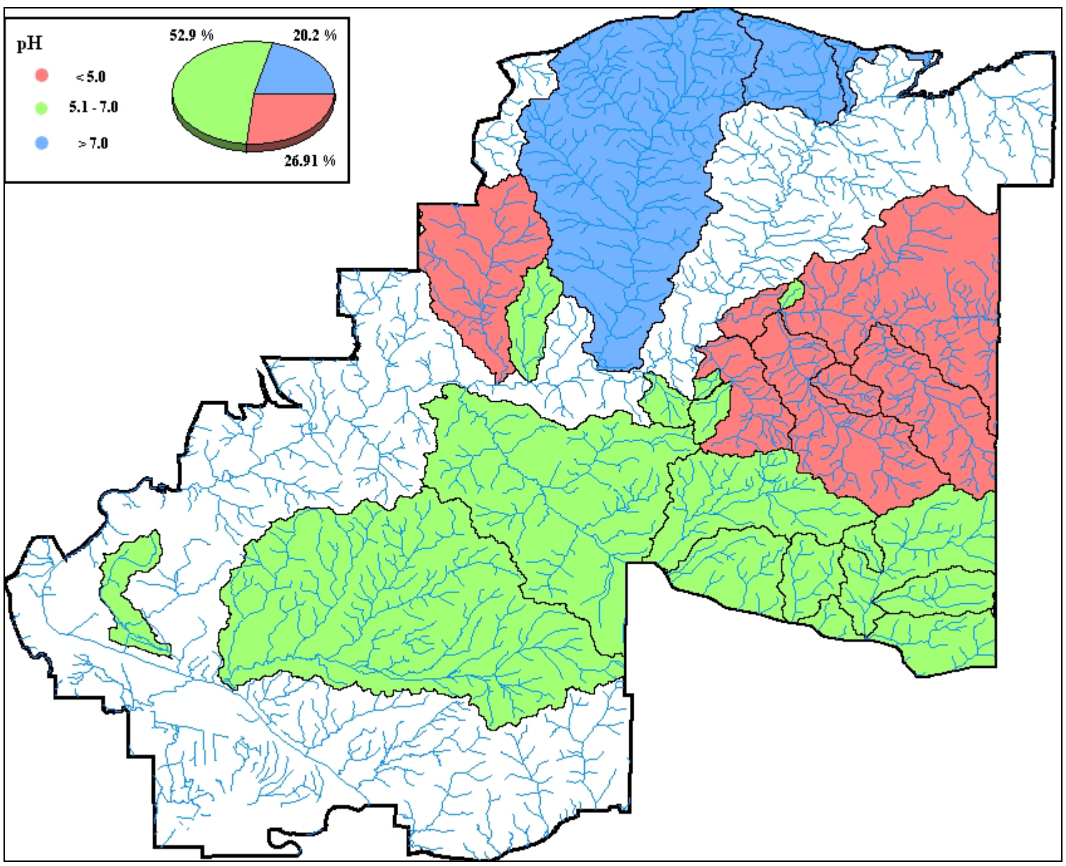

Figure 4. Estimated pH within sampled basins at Fort Benning, 2002-2005.

HI. Scores indicated moderate (HI = 130-149; ~16% SBA) to good (HI >150; ~67% SBA) habitat quality among most sampled streams (Figure 5). Scores from two upland streams (Randall Creek and Tar River – HI < 130; ~18% SBA) indicated relatively low habitat quality. These two systems can be characterized as shallow with very little depth diversity, almost devoid of instream stable substratum, and comprising a loose, shifting sand substratum. All of these conditions indicate poor stream habitat throughout the upland sand-hills portion of the base.

HIBI. Median HIBI estimates indicated moderate stream quality among most streams; estimates ranged from 5.1-6.0 for streams representing ~74% SBA (Figure 6). One stream, Bonham Creek, had a median HIBI estimate below 5.0 (4.3; ~0.5% SAB). Although streams with HIBI > 6.0 represented ~26% SBA, the largest basin in this group (Oswitchee Creek) was only sampled once and comprises streams draining a DUD area (no access due to unexploded ordinates). Furthermore, no HIBI scores exceeded 7.0 or indicated "poor" habitat quality.

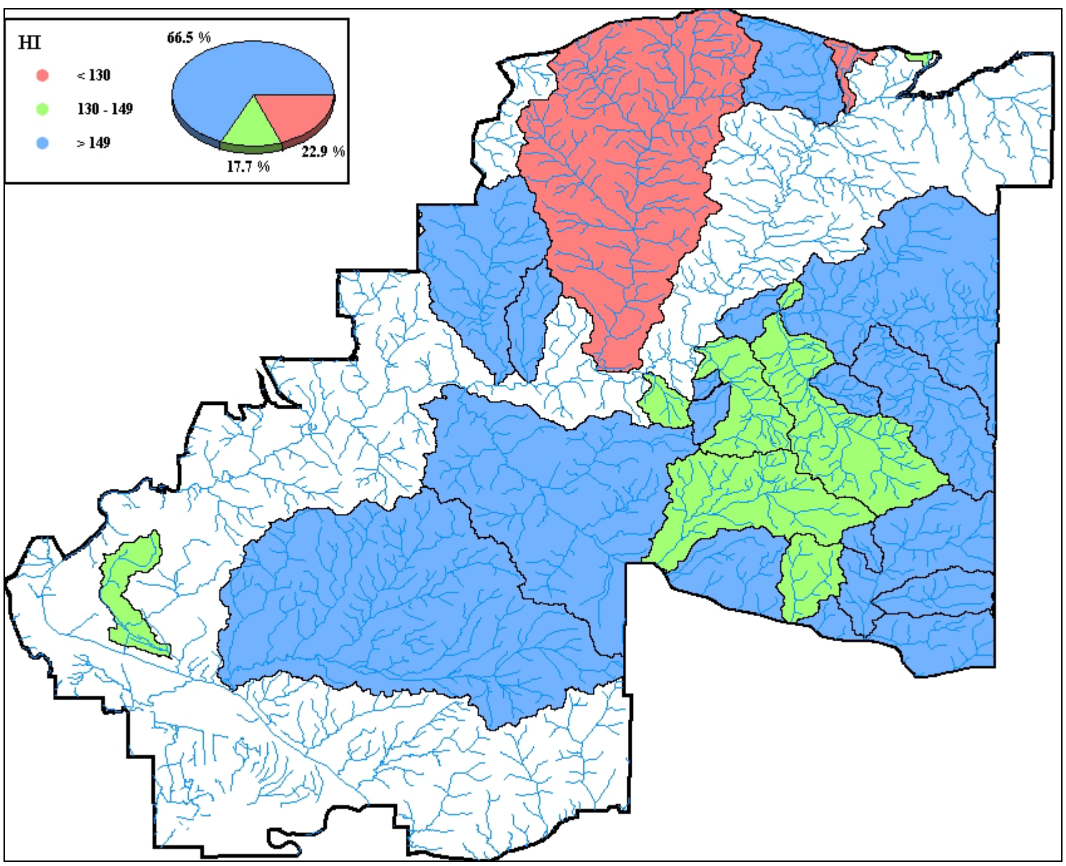

Figure 5. Estimated HI (index of habitat quality) scores within sampled basins at Fort Benning, 2002-2005. Higher HI scores indicate greater stream habitat quality.

%EPT. Median %EPT varied greatly among streams at Fort Benning (Table 1). Several streams contained fewer than 10% EPT organisms (e.g., Hollis Branch – 0%; Halaca Creek – 3%; Table 1), and over half SBA had %EPT less than 17% (Figure 7). Samples from other streams contained over 30% EPT organisms (e.g., Randall and Little Pine Knot; ~23% SBA - Figure 7, Table 1).

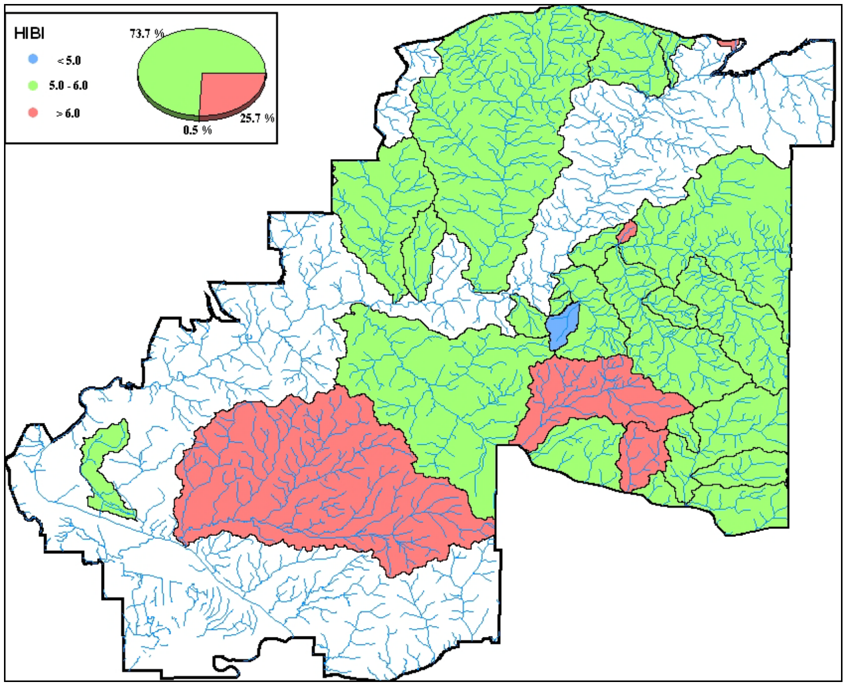

Figure 6. Estimated HIBI (Hilsenhoff Index of Biotic Integrity) scores within sampled basins at Fort Benning, 2002-2005. Low HIBI scores indicate greater stream quality.

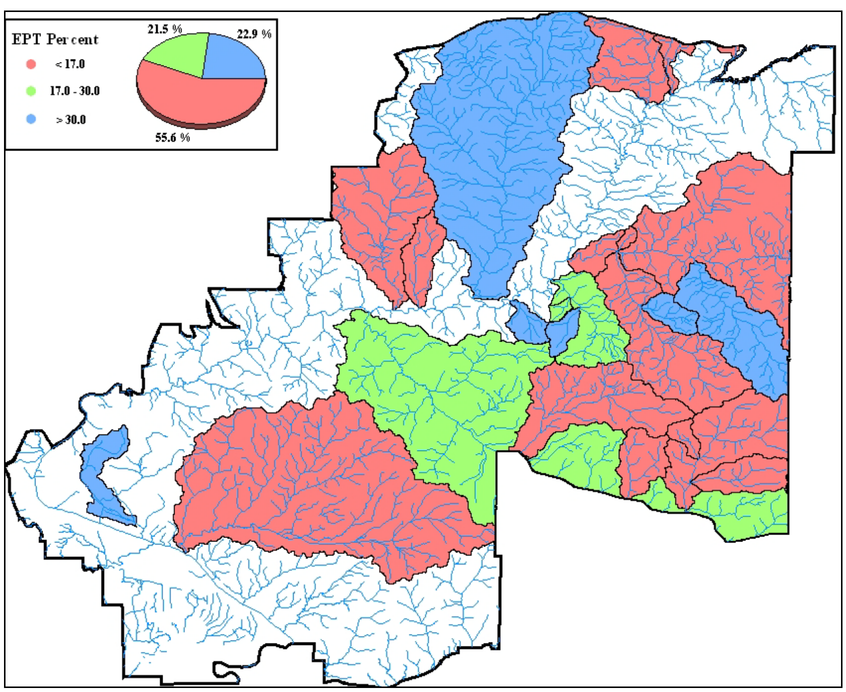

Figure 7. Percent EPT (Ephemeroptera, Plecoptera, and Trichoptera) within sampled basins at Fort Benning, 2002-2005; greater %EPT is often associated with better quality habitats.

4 Discussion

Streams at Fort Benning are diverse in both habitat quality and condition. The confluence of multiple physiographic regions has resulted in both diverse chemical and physical habitat conditions among streams. Such distinct fundamental differences in stream types within FBMR boundaries represent natural conditions and should be considered when developing natural resource management plans. Ecological responses to management techniques may vary among physiographic regions based on subtle differences in community composition, natural resilience properties, or legacy effects from past land-use practices.

Rapid stream assessment techniques can be useful in the development of an environmental management or rehabilitation plan by identifying variability in general habitat conditions and stream quality at different spatial scales. Since stream quality often reflects integration of all watershed impacts, RBP allows identification and prioritization of high-value habitat with great diversity or sensitive species. This approach often involves elucidating specific factors or mechanisms driving general trends in stream quality. Results from Fort Benning indicate that these factors can vary among streams in relative close proximity based on physiography, land use, and resource management patterns. For this reason, RBP can help inform development of management plans designed to incorporate various management techniques for individual streams or watersheds. Two streams may have similar HIBI scores (biological quality), although the mechanisms responsible for these results can differ substantially.

Upland streams at Fort Benning (e.g., Randall, Tar) are characterized as shallow, clear-flowing streams with very little pool development or instream stable substratum such as woody debris. Streams in the eastern portion of the military base (e.g., Sally, Bonham, Little Pine Knot, Pine Knot) typically have very low pH but more depth diversity, variability in current velocity, and more stable substratum than the upland streams. Streams in the lower portion of the military base have moderately low pH with more diversity in depth and substratum; stable substratum and pool development is more prevalent in these streams. Despite obvious differences in physical habitat and pH, several streams from among these three areas of the base had HIBI scores of 5.0 to 6.0. These results indicate that different management actions might be necessary in each of the three areas of the base, if improving HIBI scores is a main goal of the overall environmental management plan.

Basic RBP monitoring elucidated similarities and differences among streams at Fort Benning. Identification of such basic characteristics is fundamental to understanding implications of natural resource management strategies when designing and implementing an ecologically sound adaptive management strategy. Stream monitoring programs based on RBP principles can provide a relatively inexpensive, yet very useful, component of basewide resource management plans.

5 Summary

There are many benefits associated with implementing a basic RBP stream monitoring program. Landscape level RBP programs can be used to establish initial large-scale baseline conditions and then monitor subsequent changes in ecological conditions. Baseline data are often needed to obtain regulatory permits for construction, operations, or maintenance of basic infrastructure, recreational, and industrial facilities. Standard RBP protocols can be particularly useful for monitoring potential effects of point-source perturbations or improvements associated with environmental rehabilitation efforts (Herbst and Silldorff 2006).

Legacy effects from past land use practices at Fort Benning (e.g., soil erosion from heavy agricultural usage) have influenced current stream conditions. Although negative aspects of historical land use may constrain the current potential for rehabilitation, the stream monitoring program has helped establish benchmarks for comparison to future changes in stream conditions.

One of the long-term objectives of the environmental program at Fort Benning is to develop adaptive management tools to learn how management actions can impact environments at the ecosystem level. The use of refined RBP methods, along with the continued development of a standard statewide stream assessment protocol, should result in a system helpful for both characterizing current reference conditions as well as managing potential environmental quality impacts associated with resource management decisions at Fort Benning.

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14. ABSTRACT
Rapid Bioassessment Protocols (RBP's) were used in combination with geospatial techniques to elucidate spatial variability in ecological quality among streams at Fort Benning Military Installation, Georgia. The installation includes portions of several physiographic landforms, which results in substantial differences in geomorphology, water chemistry, and instream cover among streams. In an effort to characterize this variability, 23 streams were sampled during fall each year from 2002-2005. Data describing biological, water quality, and physical habitat conditions were collected and analyzed following general RBP methods. Geospatial mapping techniques were used to demonstrate spatial trends in habitat variability. Specific variables that best demonstrated variability in stream conditions included pH, physical habitat score (HI), Hilsenhoff Index of Biotic Integrity (HIBI), and percent Ephemeroptera, Plecotera, and Tricoptera (%EPT). In general, upland streams were shallow and contained unstable substratum of mostly sand with very little cover and normal pH. Coastal plain streams in the eastern and southeastern portion of the base had suitable stable substratum and cover, although water chemistry results indicated very acidic conditions (pH often < 5.0). Coastal plain streams in the southern portion of the base contained more instream stable habitat and organic debris but demonstrated a more moderate pH than in the eastern portion of the base. The use of RBP's allows standard evaluation, characterization, and monitoring of stream quality at military bases. Growing need for environmental inventories, management plans, and impact analyses on military lands could make the proactive incorporation of RBP's into basewide stream monitoring advantageous as the preferred approach for natural resource managers.

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