Field and Laboratory Methods for Macroinvertebrate and Habitat Assessment of Low Gradient, Nontidal Streams

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Preface

The methods presented in this document were developed by a workgroup of State and USEPA biologists called the Mid-Atlantic Coastal Streams (MACS) Workgroup. They were developed for coastal plain streams from New Jersey to South Carolina to promote the transfer of data and knowledge between State and Federal agencies in this region. The methods may also be applicable to other regions that have low gradient streams. Testing is encouraged in the application of these methods to areas outside this region.

This document establishes standard procedures for collecting biological and physical habitat data in low gradient nontidal streams of the Middle Atlantic Coastal Plain ecoregion (Figure 1). It includes standard methods for collecting and processing macroinvertebrate samples and for quantifying habitat quality. The methods developed by the US Environmental Protection Agency (USEPA) (Plafkin et al. 1989) for high gradient streams (i.e., piedmont, mountain) were modified for use in low gradient streams (i.e., coastal, valley bottom, swamp). Modifications were made to address the unique characteristics of these streams while retaining the basic assessment approaches the States have used for many years in high gradient streams.

Low gradient streams typically have velocities less than 0.5 fps and lack riffle habitats. Therefore, the kick-net developed for high gradient streams has been replaced by the dip-net, and a variety of habitats are sampled rather than a single habitat. The coastal plain is a region where alluvial sediments are deposited. Those habitat parameters that address excessive sediment deposition in the piedmont region (e.g., embeddedness) would assess all coastal plain streams in "poor" condition. The twelve habitat parameters commonly used in the piedmont region were reduced to seven parameters through the elimination of those that addressed sediment deposition.

This document provides standard methods for producing quantitative measures (i.e., metrics) of biological and physical habitat quality. It includes methods for sample collection, sample processing, data management, calculation of metrics, and quality assurance (QA). Standardized procedures include the use of the 100-organism subsample, a standard sample size of 100-120 organisms for the calculation of metrics, a minimum of genus level taxonomy, and a set of QA objectives. The Workgroup States presently use a variety of biological metrics and assessment thresholds in the coastal plain. Future efforts of the Workgroup will focus on the analysis of biological metrics to determine those best suited to the Mid-Atlantic Coastal Plain region.

The technical basis for these methods is provided in Appendix B, and includes summaries of the literature and field testing completed by the Workgroup. The estimated variability associated with the metric data produced using these methods is also presented in Appendix B. Appendix A provides sample Habitat Assessment Field Data Sheets.

Acknowledgments

This document was a collaborative effort of the Mid-Atlantic Coastal Streams (MACS) Workgroup. The following Workgroup members provided technical direction, review, and testing of these procedures. The document was written by John Maxted. Mike Barbour of Tetra Tech, Inc. and Len Smock of Virginia Commonwealth University also provided helpful guidance and review. Maggie Passmore of the US Environmental Protection Agency (USEPA) Region 3 in Philadelphia and Susan Jackson of the USEPA in Washington DC provided technical support and funding for Workgroup activities.

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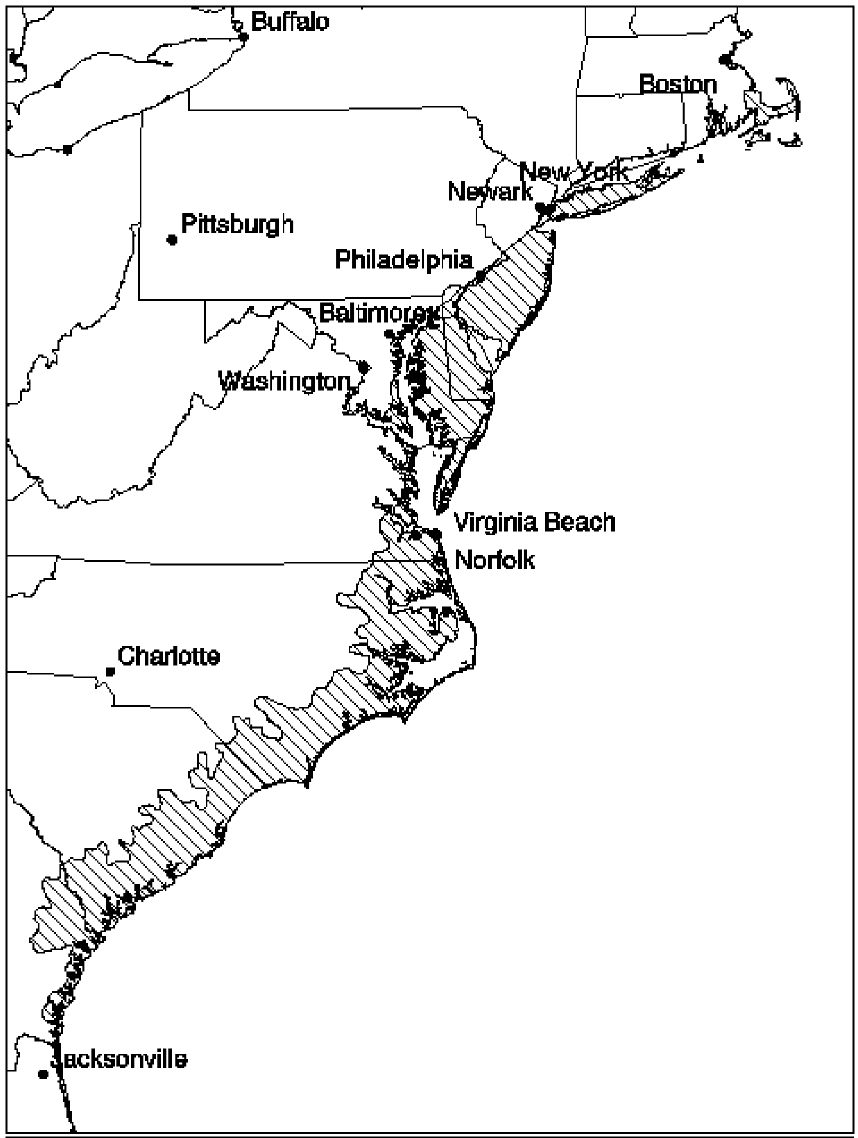
Figure 1: Middle Atlantic Coastal Plain Ecoregion (Omernik 1987).



1.0 Introduction

A variety of techniques have been developed for sampling macroinvertebrates and assessing the habitat quality of nontidal streams. This has made it difficult to compare results between investigators and between States and regions. To facilitate the transfer of data and information between States, the Environmental Protection Agency (EPA) developed the "Rapid Bioassessment Protocols for Use in Streams and Rivers - Benthic Macroinvertebrates and Fish" (RBP) (Plafkin et al. 1989). The RBPs are recommended methods for sampling macroinvertebrates, fish, and habitat quality in nontidal streams. All of the MACS Workgroup States use these methods to varying degrees in their biological monitoring programs.

The Atlantic coast from Massachusetts to Georgia contains portions of the Middle Atlantic Coastal Plain Ecoregion (Omernik 1987) (Figure 1). This ecoregion is characterized by flat terrain, nontidal wetlands, agricultural land use, and scattered small (< 10,000 people) to medium (10,000-100,000 people) sized towns and cities. The RBP sampling methods were developed for streams with a sufficient gradient to produce shallow riffles. In contrast, streams of the coastal plain typically have velocities less than 0.5 fps, sandy or muddy substrates, and few riffle areas. In a Statewide survey in Delaware, 5 percent of 116 sites surveyed in the coastal plain had riffle habitats. Thus, a large proportion of these streams cannot be assessed using the RBP methods. An alternative approach to macroinvertebrate sample collection and habitat assessment was needed.

Coastal plain streams have received relatively little attention from scientists, the public, and government agencies. For two centuries, ditches have been constructed throughout the region to drain freshwater wetlands and promote development. Understanding the ecological condition of these systems has been secondary to their continued use as drainage systems. Further, most major point sources in the region discharge to tidal waters and large rivers. Thus, the attention placed on the control of point sources by the Clean Water Act has directed attention away from nontidal streams.

It is difficult to draw attention to an aquatic resource with limited direct human use. Swimming and fishing are obviously limited, especially in the small headwater streams that dominate the resource, and nontidal streams are not used extensively as a drinking water source in the coastal plain. The value of coastal plain streams and adjacent wetlands to downstream water quality (e.g., ponds, estuaries) and groundwater quality are not easily quantified by scientific research or understood by the general public. Lastly, coastal plain streams are difficult to access and use for recreation and scientific study. They often have soft muddy bottoms and are surrounded by wetlands making them difficult to traverse on foot. Abundant snags make even larger streams difficult to canoe or kayak and they often have braided channels or lack a defined channel altogether.

Coastal plain streams have extensive riparian wetlands and contain a diverse community of aquatic and terrestrial organisms. These forested wetlands provide additional habitat for aquatic life during high flow periods and benefit water quality by attenuating flood flows and removing suspended and dissolved contaminants. These stream and wetland complexes often constitute the largest contiguous natural areas that remain relatively undisturbed in the region. Mitsch and Gosselink (1993) have prepared a summary of the physical, chemical, and biological functions of riparian and forested wetlands and associated nontidal streams. Becker and Neitzel (1990), Hackney, Adams, and Martin (1992), and Rosenberg and Resh (1993) have prepared contemporary summaries of the physical, chemical, and biological characteristics of coastal plain streams.

Coastal plain streams have undergone and will continue to undergo changes that profoundly affect their ecological condition. Standardizing sampling methods and data reporting will promote the collection of data to better understand these streams. The data will be used to better manage the many land use activities that affect these important and little understood aquatic resources.

1.1 Mid-Atlantic Coastal Streams (MACS) Workgroup

The MACS Workgroup was established to promote the transfer of data and information on coastal plain streams between biologists of the Mid-Atlantic region. The MACS Workgroup first met in November 1990, and currently meets approximately once per year. The responsibility for managing Workgroup activities is shared by different Workgroup members depending on interest and expertise. The MACS Workgroup has identified the following priority subject areas:

- macroinvertebrate collection procedures
- habitat assessment procedures
- macroinvertebrate sample processing
- macroinvertebrate data analysis (i.e., metrics)
- reference site selection
- fish assessment procedures
- database management
- quality assurance

The development of standard methods for the collection of macroinvertebrate and habitat data was selected as the Workgroup's highest priorities, and are the subject of this document. This document also provides standard procedures for producing quantitative measures (i.e., metrics) of the macroinvertebrate community and habitat quality. Fish assessment procedures will follow the implementation of procedures for macroinvertebrates and physical habitat. The Workgroup determined that habitat assessment procedures should include criteria for assessing overall habitat conditions to support both macroinvertebrates and fish.

The MACS Workgroup concluded that procedures should build upon existing protocols and should involve as many States, EPA Regions, and other government agencies as possible. This effort focused on the modification of established procedures. Procedures developed by EPA (Plafkin et al. 1989) were first modified for use in the coastal plain and then tested by the Workgroup through targeted studies. The technical basis for these methods and the results of Workgroup testing efforts are presented in Appendix B.

1.2 Uses of these Methods

The methods described in this document are designed for wadable nontidal streams of the Middle Atlantic Coastal Plain ecoregion (Figure 1). These stream typically have velocities less than 0.5 fps and lack riffles. The methods are best suited for perennial streams with a confined channel although braided channels or wetland areas may also be assessed using these methods. They are applicable to the wide range of habitat conditions found in coastal plain streams from undisturbed streams in wooded floodplain areas to channelized streams with little or no riparian buffer zone.

These methods produce data and information on overall biological and habitat conditions. They are most applicable where semi-quantitative information on biological and physical habitat condition is desired. Because the methods are relatively rapid, they allow for the collection of information in a short period of time, usually less than 1 hour per site. They are generally used (1) to assess overall ecological condition and (2) as a screening tool to determine the need for more detailed information. These methods are designed to address the following assessment objectives:

- regional assessment
- status and trends assessment
- assessment of diffuse pollution sources (e.g., nonpoint sources)
- preliminary assessment (screening) of specific pollution sources (e.g., point sources)

The results of these assessments support a wide range of regulatory and non-regulatory activities. They provide the basis for (1) assessing and reporting aquatic life use support under Sections 303(d) and

305(b) of the CWA, (2) the impacts of nonpoint source pollution under Section 319 of the CWA, and (3) the review of permit requirements under the National Pollution Discharge Elimination System (NPDES). Section 303(d) requires States to prepare total maximum daily loads (TMDL) for waters that do not meet water quality standards. EPA guidance recommends the use of both chemical and non-chemical stressors as the basis for 303(d) listing of waters (USEPA 1994). Hydromodification, such as stream channelization and the degradation of physical habitat, is an example of a non-chemical stressor specified in EPA guidance. The habitat data produced with these methods can be used to prepare “habitat TMDLs” for specific waterbodies or watersheds.

Additional information on the uses of biological and physical habitat assessments are contained in EPA guidance (USEPA 1996; Barbour and Stribling 1991; USEPA 1991; Plafkin et al. 1989).

2.0 General Provisions

2.1 Assessment Area (AA)

The assessment area (AA) for sampling macroinvertebrates and collecting habitat data is a discrete 100 meter segment of a stream channel. This distance is estimated visually, although specific gear may be used to precisely measure channel length (e.g., tape measure, hip-chain). Macroinvertebrates are collected throughout the 100 meter AA while habitat measurements are taken for the assessment area as a whole. The 100 meter AA should contain no major tributaries and should be homogeneous with regard to habitat conditions.

The AA is visually inspected before sampling to ensure that land use and hydrologic conditions exist to meet the study objectives. Watershed land use (e.g., agriculture, urban, forest, wetlands) and human activities immediately adjacent to or upstream of the assessment area (e.g., industrial/commercial operations, feedlots, disposal sites, power lines) are useful in site selection and data analysis. Separate collections are taken above and below point sources, bridges, or major tributaries if the study objective is to evaluate their affect on stream conditions. Information is often available from files, GIS databases, reports, aerial photos, or maps before visual inspection in the field.

2.2 Site Selection and Sampling Period

These methods are best suited to wadable streams with a defined channel. Coastal plain streams are often surrounded by extensive wetland areas and have braided channels particularly during high flow conditions. The movement of water out of the main channel and into the floodplain during rainfall events is characteristic of these streams. Sampling in the main channel reduces data variability associated with fluctuating water levels. Sampling during low flow conditions facilitates the identification of the main channel and maximizes the abundance of organisms collected.

Access to these streams is often difficult. There are often long distances between access points (e.g., roads and bridges) in this sparsely populated region. There are often extensive wetlands adjacent to these streams making the main channel difficult to access. For these reasons, road crossings are often used as the primary access point. Because roads are often public property, they provide legal access to the streams. It is advisable to inform nearby residents before entering these streams.

The following factors are considered when using road crossings as the point of access for coastal plain stream assessments. Vegetation is often cleared along roadways. Therefore, habitat and biological conditions adjacent to roads may be different than conditions 50-100 meters from roads. Cultural practices along roadways (houses, yards, commercial operations, etc.) and the road itself (e.g., stormwater, illicit discharges) may adversely impact stream quality. Road crossings often direct flow into a defined channel downstream and impound water upstream. When sampling below a road, collections should begin far enough downstream to ensure completion of the assessment before reaching the road.

Beaver activity is common in coastal plain streams. Areas immediately above beaver dams may be difficult to sample due to deep water. The assessment area should be homogeneous with regard to beaver activity and its effect on stream flow and depth. Evidence of beaver activity (lodges, cuttings) is recorded on the Habitat Assessment Field Data Sheet.

2.3 Sampling Reference Sites

The sampling of least impaired reference sites provides the basis for comparison with test sites, and is used to prepare percent of reference estimates using EPA methods (Plafkin et al. 1989). To minimize temporal variability, assessments at reference sites are completed during the same period that collections are made at test sites. To minimize the variability associated with any one reference site, at least three reference sites are sampled from which mean metric values are determined.

2.4 Natural Acidity

Coastal plain streams are often naturally acidic due to the high concentration of humic and fulvic acids found in the water draining swamp soils. The pH of these streams most often ranges from 3.5 to 7.5. Macroinvertebrates begin to show the adverse effects of low pH at pH 5.5. Rosenberg and Resh (1993) have assembled pH tolerance data on over 300 macroinvertebrate species found in North America. Table 1 summarized the number of species within each of the major Phyla that are tolerant at four levels of pH. The true flies (Diptera) are the most sensitive to extremely low pH levels (below 5.0) while the mayflies (Ephemeroptera) are the most sensitive to moderately low pH levels (5.0-6.0). The caddisflies (Trichoptera) and stoneflies (Plecoptera) are also sensitive to low pH. The pH of coastal plain streams should be considered in both study design and data analysis.

Table 1. Number of macroinvertebrate species, by Phylum, in North American streams sensitive within four pH categories (modified from Rosenberg and Resh 1993).

Phylum	> 5.5	5.5-5.0	5.0-4.7	< 4.7	Totals
Diptera	9	3	34	41	87
Ephemeroptera	21	20	9	13	63
Trichoptera	1	10	7	33	51
Mollusca	8	5	11	0	24
Plecoptera	0	8	0	14	22
Oligochaeta	0	0	7	5	12
Hirudinea	4	1	6	0	11
Crustacea	3	3	2	1	9
Odonata	0	0	5	2	7
Megaloptera	0	0	1	2	3
Turbellaria	0	2	0	0	2
Hemiptera	0	0	2	0	2
Coleoptera	0	0	1	0	1
Other Phyla	0	1	2	1	4
Totals	46	53	87	112	298

2.5 Flow Regime

These methods are designed for use in perennial streams with persistent base flow to support aquatic organisms. They should not be used for intermittent streams that experience regular desiccation during part of the year.

The movement of water is an important physical factor affecting the macroinvertebrate community in nontidal streams. The velocity of these streams is typically low (< 0.5 fps) or non-detectable (< 0.05 fps) and varies spatially and temporally. The flow regime is often spatially diverse as water moves around snags and aquatic plants. Macroinvertebrate collections are made in both slow and fast moving areas. A flow measurement is taken to provide standardized measures of channel width, depth, and flow. The flow data assists in the interpretation of the macroinvertebrate and habitat data. These methods are most suitable to coastal plain streams that have a defined channel indicating that there has been sufficient flow and velocity to maintain a permanent channel.

2.6 Tidal Influence

Aerial photos and USGS topographic maps (1:24,000 scale) are useful in determining the proximity of sampling locations to tidal waters. However, it is difficult to determine the extent to which sampling sites located near tidal waters are affected by fluctuating water and chloride levels. Dams or other structures that control the movement of tidal water are common in the region and can be used to determine that areas upstream of these structures are nontidal. Long-term chloride or conductivity data may be available on larger streams but are generally lacking on smaller tributaries. High conductivity readings (e.g., > 1000 umhos) taken during biological surveys may indicate tidal influence. Wetland maps (e.g., National Wetland Inventory, US Fish and Wildlife Service) provide an estimate of the location of the head-of-tide using the wetland classification (e.g., tidal vs. nontidal) information.

2.7 Replication

Replicates should be collected periodically to define site variability and refine collection techniques. At least three separate macroinvertebrate collections should be made while moving progressively upstream. Habitat quality should be similar for each replicate sample. Replicate habitat assessments by different investigators should be done periodically to identify inconsistencies in scoring and to define data variability. Where two or more investigators are assessing a particular site, each investigator should record habitat scores separately. It is recommended that 5-10 percent of the assessments completed using the MACS Workgroup method include replicate collections.

Additional 100-organism subsamples (i.e., subsampling replicates) are recommended to build a data set on the effect of subsample size on biological metrics and RBP scores. It is recommended that a second 100-organism subsample be processed for 5-10 percent of samples collected in a survey.

2.8 Sampling Season

No single season for sampling was selected by the Workgroup. Delaware prefers the Fall season, North Carolina prefers the Winter and Spring seasons, while Maryland prefers the Fall and Spring seasons. Summer is the least desirable season due to a lower diversity of aquatic invertebrates. Summer sampling is also more difficult than other seasons due to the abundance of algae at sites that lack canopy (algae makes sample processing more difficult, time consuming, and variable) and due to the heat in the Southern portions of the ecoregion (daytime air temperatures often exceed 35 degrees C, 95 degrees F). Fall, Winter, and Spring are the preferred seasons for sampling in the Mid-Atlantic Coastal Plain region.

3.0 Macroinvertebrate Assessment

3.1 Field Collection

3.1.1 Equipment

The 1-foot wide D-frame dip net (Forestry Suppliers, Inc., item #53755) is the recommended collection device. This net has a mesh size of 650 µm and has heavy canvas sides to protect the mesh from tearing when jabbed in snags. A 600 µm sieve bucket (Wildco, Inc., wash bucket for littoral samples, item # 190) is also recommended. The smaller sieve size for the bucket is used to ensure that animals are not lost in the bucket during sample cleaning. Other dip-nets with similar dimensions and mesh sizes may also be used. Users should document the exact sieve sizes of their dip net and sieve bucket.

The 600 µm sieve is traditionally used by freshwater biologists interested in macrobenthos. Smaller sieve sizes are used for more intensive surveys where there is interest in collecting early instars and members of the Diptera and Oligochaeta groups. These groups require significantly greater effort and expertise in sorting and taxonomic identification and are subject to data quality problems. While these groups are an important and often dominant component of the overall community, the larger representatives within these groups provide sufficient information on community composition.

The following equipment is required for the collection of macroinvertebrates in the field:

- aquatic dip net: D-frame; 0.3 meter width (1 foot); 650 µm mesh
- sieve bucket; 600 µm mesh
- 90 percent ethanol
- rose bengal dye (optional)
- forceps
- storage container (1 liter)

3.1.2 Sampling Technique and Level of Effort

Macroinvertebrate collection consists of jabbing the D-net 20 times in productive habitats. A single jab consists of aggressively thrusting the net into the target habitat for a distance of approximately 1 meter; i.e. the distance the net can be swept while standing in one place. This initial "jab" is followed by 2-3 sweeps of the same area to collect dislodged organisms. This level of effort represents a sample area of approximately 6.2 meters^2. The following techniques are recommended for sampling the three major productive habitats in coastal plain streams.

<u>woody snags</u> - Snags, or submerged woody debris, are sampled by jabbing in medium sized snag material (sticks and branches). Large material (e.g., logs) may be sampled by scraping the net along the surface. The snag habitat may be kicked first to dislodge organisms.

<u>banks</u> - Stream banks with roots and snag material are sampled similar to snags. Vegetated banks are preferred over unvegetated banks. The bank habitat may be kicked first to dislodge organisms.

<u>submerged macrophytes</u> - Submerged macrophytes are sampled in deep water by drawing the net through the vegetation from the bottom to the surface of the water. Macrophytes in shallow water are sampled by bumping the net along the bottom in the macrophyte bed.

Macroinvertebrate collections are made while moving progressively upstream to avoid low visibility caused by sediment resuspension. Collections are made in all available velocity conditions and stable habitats found in the AA. Streams with hard substrates are easily sampled by wading throughout the stream. Streams with soft substrates may be sampled by wading along the shallow edge of the stream or by standing on the bank out of the stream channel. The collection method is not designed to be used from a boat.

Sampling of the channel bottom (sand, mud, and detritus) should be avoided as much as possible. These habitats are relatively unproductive, and sampling them often results in large quantities of fine material in the sample that adds considerably to processing time and expense. For the same reason, the collection of algae should be minimized. Productive habitats along muddy bottoms can be effectively sampled by bumping the net along the bottom rather than dragging the net through the substrate.

The sample is transferred to the sieve bucket by banging the net over the bucket opening or by inverting the net into a partially submerged bucket. Samples are transferred from the net to the sieve bucket after each jab. Clogging results in diversion of water and sample material around the net rather than through the net. If clogging occurs, the sample in the net is discarded and collection for that portion of the sample redone.

After the 20 jabs are transferred to the sieve bucket, the sample is "cleaned" in undisturbed stream water to remove fine material and large debris. The bucket is allowed to fill with water and the sample gently mixed by hand and sieve several times to remove fine sediment. Large debris (e.g., sticks and leaves) are collected, swirled in the bucket, and inspected. Animals on the debris are placed back into the bucket and the debris is discarded. Small pieces of debris are not inspected. The sample is transferred to a labeled storage container and preserve in 90-100 percent ethanol. (The water in the sample will dilute the ethanol concentration to the desired level of 70-80 percent.) Forceps may be used to remove animals from the sieve bucket screen. The collection should result in no more than 1 liter of sample; animals and detritus.

3.1.3 Proportional Sampling of Productive Habitats

Collections are made in the following three target habitats. These habitat were selected because they are the most productive for macroinvertebrates and are common in the coastal plain streams. No single habitat was selected because no one habitat is found at all sites. Unshaded channelized streams have no woody snags while wooded reference sites have few macrophytes.

- banks
- woody snags (branches and sticks)
- submerged macrophytes (all species)

The locations of the 20 jabs are selected according to the proportion of these habitats present in the assessment area. This standardizes the selection of habitats to be sampled. For example, if the site is wooded and 50 percent of the stable habitat is along the banks and 50 percent is in the snags, then 10 jabs (50 percent) are located in the banks and 10 jabs (50 percent) are located in the snags. If the site is adjacent to an open field and 50 percent of the productive habitat is along the banks and 50 percent is in submerged macrophytes, then 10 jabs are located in the banks and 10 jabs are located in the macrophytes. If the site is wooded along one side and open on the other, 10 jabs are located in the snags along the wooded side and 10 jabs are located in the macrophytes along the open side. The investigator records the proportion of stable habitats sampled on the Habitat Assessment Field Data Sheet (Appendix A).

Relatively unproductive habitats such as sand, mud, and filamentous algae are not sampled. Riffles may be found in the assessment area but are also not sampled due to their rarity throughout the coastal plain region. The sampling of rare habitats, such as riffles, would confound the comparison of the results with sites that do not contain these rare habitats. Where there is interest in assessing the community of rare habitats, these habitats should be sampled and processed separately from those collected using the Workgroup method.

3.1.4 Quality Assurance

Investigators using these methods must be trained field biologists and must be experienced in nontidal stream assessments and stream ecology. Investigators must have been trained by a Workgroup member to draw direct comparisons between their data and data collected by the Workgroup. At least one person in each field crew must be trained in these methods. These methods are not designed for use by non-biologists. Methods for sampling macroinvertebrates by non-biologist and citizen monitoring groups have been developed by USEPA (USEPA 1995a).

It may be desirable to conduct more intensive collections including (1) additional levels of effort, (2) the use of other collection techniques and equipment, and (3) the evaluation of rare habitats. In these cases, collections using the MACS Workgroup method are preserved and processed separately from more detailed collections to ensure data quality. Investigators are encouraged to conduct more detailed collections in order to evaluate results using the MACS Workgroup methods.

3.2 Sample Processing

Specific procedures for sample processing vary between the States and are not presented here. The following is a summary of the important elements of sample processing and quality assurance adopted by the States to ensure data quality and comparability. A single 100-organism subsamples is produced for each sample and processed to the genus level of taxonomy. Where additional levels of subsampling effort (e.g., 200, 300, etc.) are required, the results are reported separately for each 100-organism subsample.

3.2.1 Sorting

Sample sorting is done in the laboratory. The content of the sample is transferred to a No.30 sieve (600 micron) to wash the sample to remove fine sediment, dehydrate the organisms, and remove large debris (e.g., sticks, leaves, and pebbles). The cleaned sample is then distributed evenly in one or more gridded sorting pans. Grids are randomly selected and sorted using standard procedures generally following those described by USEPA (Plafkin et al. 1989). This process is repeated until at least 100 animals have been removed from the sample. Organisms are stored in glass vial preserve in 70-80% ethanol. Sorted detritus and the remaining unsorted material are stored in 70-80% ethanol for QA analysis.

The sorting is done without the aid of magnification. Empty shell, cast skins, colonial groups (Bryozoans and Porifera), vertebrates, terrestrial organisms, and semiaquatic invertebrates are not removed. Both larvae and pupae are removed. The organisms sorted are whole organisms of sufficient size and condition to allow for taxonomic identification to the genus level.

3.2.2 Taxonomic Identification

Organisms are identified to lowest practicable taxonomic level, generally species for most groups, and counted. The Workgroup has established the genus level as the minimum level of taxonomy for MACS Workgroup projects, although this level may not be achievable on selected organisms due to size and condition. Metric calculations are made at the genus level to minimize data variability due to taxonomy. Midges (family Chironomidae) and Oligochaetes are mounted on slides for identification. A confidence code (e.g., A, B, C) using EPA’s BIOS database system is recorded for each identification. The taxonomic keys used by each State are listed in Table 2.

Table 2. Taxonomic keys used by the Workgroup States, by taxonomic group; Insecta (I), other Arthropoda (A), Chironomidae (C), Mollusca (M), and Oligochaeta (O); principle (1) and secondary (2) keys (citations, page 24).

	DE	MD	SC	NC	NJ	VA
Brigham et al. 1982			I-2	I-1		
Brinkhurst 1986			O-1	O-1		
Epler 1992			C-1			
Hilsenhoff 1975 (revised)	I-2					
Merritt and Cummins 1996	I-1	I-1	I-1		I-1	I-1
Mozley 1980 (revised)				C-2		
Needham and Westfall 1954				I-2		
Peckarsky et al. 1990		A,M,O-1				
Pennak 1989	A,M,O-1		A,M-1		A,M,O-1 I-2	A,M,O-1 I-2
Schuster and Etnier 1978				I-2		
Simpson and Bode 1980	C-1					
Stewart and Stark 1988				I-2		
USEPA (Burch) 1982	M-2		M-2	M-1		
USEPA (Brown) 1976				I-2		
USEPA (Hobbs) 1976				A-1		
USEPA (Williams) 1976				A-1		
USEPA (Burch) 1973				M-1		
USEPA (Mason) 1973					C-1	
Ward and Whipple 1966					A,M,O-2 I-2	
Wiederholm 1983		C-1	C-2	C-1		
Wiggins 1977		I-2		I-2		

3.2.3 Quality Assurance

The following is a summary of QA objectives used by the Workgroup States. Specific QA procedures and thresholds are defined by each State and are not summarized here.

QA Objective #1 - Sorting

Procedures are established to ensure that all of the proper organisms have been removed for identification. This QA check is performed by a second sorter using one of three options.

Option 1 - Sorted grids are checked by a second sorter immediately after sorting to ensure that a prescribed level of quality (e.g., # of organisms, % of total, etc.) has been achieved. At least three grids in each sample are checked by the second sorter. QA is determined by counting the number of animals found by the second sorter. The principle limitation of this option is that the sorting cannot be checked again after the sample processing is completed.

Option 2 - A grid separator (e.g., open-ended box the size of a grid square) is used to remove all of the material from a selected grid without disturbing the rest of the sample. These "subsamples" are selected randomly, removed, and sorted until at least 100 organisms have been counted. The remaining detritus from the sorted subsamples is retained and checked by the QA sorter. QA involves resorting the sorted detritus to determine whether a prescribed threshold (number or percent of organisms missed) has been achieved. A subsampling device has been designed for this purpose (Larry Caton, Oregon Department of Environmental Protection, Portland, OR).

Option 3 - All the organisms are removed from the sample. The random selection process is then performed using the sorted animals. The remaining detritus is retained for QA analysis. QA involves resorting the remaining detritus to determine whether a prescribed threshold (e.g., number or percent of organisms missed) has been achieved. The principle limitation of this option is that this "whole picking" of samples is time consuming since samples often contain over 1000 organisms.

QA Objective #2 - Enumeration

The number of organisms identified by the taxonomist is compared to the number of organisms sorted by the sorter. The sample passes this QA check if the two numbers are within a prescribed threshold (e.g., 5 percent) of each other. This QA procedure ensures that organisms sorted are not lost and that each sample contains at least 100 organisms. This QA check is performed by the taxonomist.

QA Objective #3 - Nontarget Material

The taxonomist records and discards pieces of nontarget material in the sorted sample. The sample passes this QA check if the sorted sample contains fewer than a prescribed threshold (e.g., 5 percent) of nontarget material. This QA procedures ensures that the sorted sample does not include a large amount of nontarget material (e.g., empty shells, seeds, other detritus).

QA Objective #4 - Taxonomy

Procedures are established to evaluate the quality of the taxonomy. This QA check is performed by a second taxonomist. Taxonomy is checked using one of the following two options. Option 2 is preferred, particularly for large numbers of samples in a survey. For both options, the taxonomy passes the QA check if a prescribed percentage (e.g., 90%) of the identifications are the same at the genus level between the original taxonomist and the QA taxonomist.

Option 1 - At least 10% of the samples are identified again by the QA taxonomist. Samples selected for QA should include at least 25% of the taxa identified in the study.

Option 2 - The original taxonomist prepares a reference (i.e., voucher) collection for all of the samples processed for a particular survey. The reference collection will contain at least one representative of each taxon identified. The collection is then identified by the QA taxonomist. Where errors are identified, corrections are made to the reference collection and to the sample data.

3.3 Data Management

3.3.1 Sample Size

The data are evaluated to ensure that each sample contains a minimum of 100 organisms. Every attempt is made to sort at least 100 organisms from each sample. Samples with a high abundance of organisms in the final sorted sample (e.g., 150-200 organisms) have a higher incidence of rare taxa than samples with the target abundance (e.g., 100 organisms). This could produce differences in metric values due to differences in abundance rather than differences in community structure and composition. A random number generator is used to eliminate organisms from the taxa list down to 120 organisms before calculating metrics. Therefore, all samples will have 100-120 organisms before calculating metrics.

3.3.2 Metrics

Metric calculations are made on samples with 100-120 organisms. Metrics are not calculated on samples with fewer than 100 organisms. The raw biological data are reported in standard spreadsheet format with the organism names listed in rows and the number of individuals in each sample listed in columns. The data are then reduced to metrics using the following procedures. Table 3 summarizes the metrics used by the MACS Workgroup States in the coastal plain.

<u>Taxonomic Richness</u> - The total number of unique taxa in the sample. Metric values decrease as water quality and habitat quality decrease. Values have no limits.

<u>EPT Richness</u> - The total number of unique taxa in the Ephemeroptera, Plecoptera, and Trichoptera orders. Metric values decrease as water quality and habitat quality decrease. Values have no limits.

<u>% EPT Abundance</u> - The percent of the organisms in the sample that are EPTs. Metric values decrease as water quality and habitat quality decrease. Values range from 0 to 100.

<u>% Chironomidae</u> - The percent of the organisms in the sample that are in the family Chironomidae. Metric values increase as water quality and habitat quality decrease. Organic pollution results in a loss of EPTs and an increase in the abundance of these organisms. Values range from 0 to 100.

<u>% Dominant Taxon</u> - The percent of the total abundance that is a single taxon. Metric values increase as water quality and habitat quality decrease. A community dominated by a single taxon is indicative of anthropogenic stress. Values range from 0 to 100.

<u>Hilsenhoff Biotic Index (HBI)</u> - A tolerance value is given to each genera and summed for the assemblage as a whole using the following equation. Metric values increase as organic pollution increase. Values range from 0 to 10. The USEPA has prepared a list of tolerance values for calculating the HBI (USEPA 1990).

$$HBI = x_i t_i / n$$

where:
x_i = number of individuals within genera i
t_i = tolerance value for genera i
n = total number of organisms in the sample

<u>North Carolina Biotic Index</u> - Same as HBI above using tolerance values developed by the North Carolina Department of Environmental Management.

<u>Community Loss Index (CLI)</u> - A measure of the dissimilarity between a test site and a reference site (Plafkin et al. 1989). Metric values increase as biological impairment (i.e., dissimilarity with the reference) increase. Values have no limits.

$$CLI = a - c / b$$

where:

a = number of genera in reference sample
b = number of genera in test sample
c = number of genera common to both samples

% Non-Insect - The percent of the organisms in the sample which are not insects. Assemblage dominated by snails, worms, leeches, water mites, and other non-insects are generally more pollution tolerant than assemblage dominated by insects. Used principally to assess severe impairment. Values range from 0-100.

The MACS Workgroup is presently evaluating these and other metrics for use in the coastal plain. coastal plain streams naturally have a lower richness and abundance of EPTs than steeper gradient streams with riffle habitats. In addition, the tolerance values used to calculate the HBI may be inappropriate for streams that are naturally depositional and high in particulate and dissolved organic matter. Future updates of these methods will include the results of this analysis.

Table 3. Biological metrics used by the Workgroup States in the coastal plain.

Metric	DE	MD	SC	NC	NJ	VA
Taxonomic Richness (TR)	X	X	X	X	X	X
EPT Richness (EPT)	X	X			X	X
% EPT Abundance (%EPT)	X	X			X	
% Chironomidae (%C)	X					
% Dominant Taxon (%DT)	X	X			X	X
Hilsenhoff Biotic Index (HBI)	X	X			X	X
North Carolina Biotic Index (NCBI)			X	X		
Community Loss Index (CLI)		X				X
% non-insect (%NI)		X				

4.0 Habitat Assessment

The habitat assessment is done after the macroinvertebrate collections have been made so that the investigator can consider the knowledge gained during the macroinvertebrate collection in the habitat assessment. If a macroinvertebrate collection is not made, the investigator walks the entire 100 meter assessment area (AA) to characterize the instream and shorezone habitat conditions.

4.1 Field Collection

4.1.1 Equipment

The following equipment is required:

- dissolved oxygen meter
- pH meter
- conductivity meter
- thermometer
- Habitat Assessment Field Data Sheets (Appendix A)
- velocity meter
- tape measure
- camera (35 mm) and slide film

4.1.2 Visual Scoring of Habitat Quality

The seven parameters used to score habitat quality are described below. The data sheet used to score each parameter in the field is presented in Appendix A. Each parameter has a maximum of 20 points. The total score for each site is determined by adding the points for all parameters; maximum total score possible is 140 points. For selected parameters, left and right banks are scored separately. The parameters are divided into the following groups.

<u>General Characteristics</u> - the overall physical configuration of the stream with regard to the degree of channelization and frequency of bends. One parameter, total of 20 points.

<u>Instream Measures</u> - habitat conditions within the water column. Two parameters, total of 40 points.

<u>Stream Bank Measures</u> - habitat conditions along the stream bank where the water surface meets land. Two parameters, total of 40 points.

<u>Riparian Zone Measures</u> - habitat conditions next to the stream within a distance of 18 meters (60 feet). Two parameters, total of 40 points.

Scoring is done for each parameter by first selecting one of four assessment categories ("excellent, "good", "fair", "poor") using the scoring criteria. A specific numerical score within the category is then selected using best professional judgment. The range of scores for each parameter are summarized in Table 4. Guidance on the scoring of each habitat parameter follows. A summary of the habitat assessment scoring criteria appears in Table 5.

Table 4. Habitat parameter scoring ranges; (L) left and (R) right bank while looking downstream; N/A - not applicable, no scoring in this category.

	Excellent	Good	Fair	Poor
General Characteristics				
1. channel modification	20-16	15-11	10-6	5-0
Instream Measures				
2. instream habitat	20-16	15-11	10-6	5-0
3. pools	20-16	15-11	10-6	5-0
Stream Bank Measures				
4. bank stability (L)	10-9	8-6	5-3	2-0
bank stability (R)	10-9	8-6	5-3	2-0
5. bank vegetative type (L)	10-9	8-6	5-3	2-0
bank vegetative type (R)	10-9	8-6	5-3	2-0
Riparian Zone Measures				
6. shading	20-16	15-11	N/A	5-0
7. riparian zone width (L)	10-9	8-6	5-3	2-0
riparian zone width (R)	10-9	8-6	5-3	2-0

1. Channel Modification

This parameter is a measure of the degree to which the stream channel has been modified or engineered by man. Scoring is based upon the extent of channelization and the frequency of bends. Sites are first separated into two groups, "excellent/good" or "fair/poor", based upon the degree of channelization. The category is then determined by the frequency of bends. Each assessment category is described below.

"Excellent" - natural channel, bends frequent, good diversity of runs and bends
"Good" - natural channel, bends infrequent, mostly straight channel
"Fair" - channelized, bends present or stream meanders within a defined channel
"Poor" - channelized, bends absent, straight channel

Natural channels in the coastal plain include both streams that show no evidence of channelization as well as old channelized streams that have not been reconstructed or substantially altered in the last 30-50 years. Judgment is used to determine if the channel has recently been channelized. The height of the trees along the stream bank may be used to estimate the length of time since channelization. Channels with trees greater than 30-40 feet in height generally have undergone limited alteration in the last 30-50 years. The presence of large trees along the stream bank is not, by itself, an indicator of the degree of channel modification. Some natural channels do not have large trees (e.g., emergent wetland area or mowed yards) while recently channelized streams may have large trees (e.g., selected cutting). The determining factor for scoring this parameter is evidence of recent (within the last 30-50 years) alteration.

For example, a stream that shows evidence of channelization but has reverted to a natural condition with mature trees is scored in either the "excellent" or "good” category. A channelized stream with water meandering through vegetation is scored in the "fair" category. A channelized stream with little or no meandering through vegetation is scored in the “poor” category.

2. Instream Habitat

This parameter is scored based upon the diversity and abundance of stable habitats available to the aquatic community. Sites are first separated into two groups, "excellent/good" and "fair/poor", based upon the number of types of stable habitats present in the assessment area (diversity), then separated within each group based upon the percentage of the channel that contains stable habitats (abundance). Each assessment category is described below.

"Excellent" - 3-4 habitat types, > 50% coverage
"Good" - 3-4 habitat types, < 50% coverage
"Fair" - 1-2 habitat types, > 50% coverage
"Poor" - 1-2 habitat types, < 50% coverage

Habitat diversity is measured by counting the number of stable habitat types present in the assessment area. Stable habitats include snags, riffles, vegetated banks, and macrophytes. Both common and rare habitats are included. Habitat abundance is then determined by estimating whether less than or more than 50 percent of the stream channel is covered by all stable habitats.

For example, a channel with a sand or mud bottom and only stable habitats along the bank would have less than 50 percent stable habitats. This site would be scored "good" if there were 3-4 habitat types present and "poor" if there were 1-2 types present. A site with snags (wooded) or macrophytes (open) throughout the channel would have greater than 50 percent stable habitat. This site would be scored in the "fair" category if there were 1-2 stable habitat types and "excellent" if there were 3-4 types. Sites with 1-2 stable habitat types and less than 50 percent coverage in the channel would be scored in the "poor" category.

3. Pools

This parameter is scored based upon the diversity and abundance of pools present in the AA. Sites are first separated into two groups, "excellent/good" and "fair/poor", based upon the variety of pool depths, then separated within each group based upon the abundance of pools. Each assessment category is described below.

"Excellent" - deep and shallow pools, > 5 pools
"Good" - deep and shallow pools, < 5 pools
"Fair" - only shallow pools, > 5 pools
"Poor" - only shallow pools, < 5 pools

A pool is defined as any area that is at least one foot deeper than the prevailing depth. A "deep" pool is more than 2-3 feet deeper than the prevailing depth while a "shallow" pool is 1 foot deeper than the prevailing depth. Pools are abundant if there are more than 5 pools within the assessment area while pools are rare if there are fewer than 5 pools. Pool diversity and abundance are estimated based upon the knowledge gained while collecting macroinvertebrates.

For example, a site with a mixture of deep and shallow pools would be scored in either the “excellent” or “good” categories. Sites with an abundance of shallow pools would be scored in the “fair” category while sites which are uniformly shallow are classified in the "poor" category. Streams which are uniformly deep (>3-4 feet) are generally not wadable but would be scored in the “good” category if sampled for macroinvertebrates along the stream edge or bank.

4. Bank Stability

This parameter is scored by estimating the percentage of the stream bank that shows evidence of recent erosion or bank failure. Left and right banks are scored separately. Each assessment category is described below.

"Excellent" - very stable, no evidence of erosion
"Good" - stable, areas of erosion mostly healed over
"Fair" - unstable, 5-10% bank shows erosion
"Poor" - very unstable, > 10% bank shows erosion

Evidence of erosion is indicated by exposed soil that shows recent scouring, disturbance, or failure. Exposed unvegetated stream banks during low flow conditions or hard packed mud banks in heavily wooded sites are considered stable. The percentage of stream bank eroded is estimated by visual inspection of both banks.

For example, wooded sites with exposed mud banks at low flow and no active erosion are scored in the "excellent" category. Sites that show evidence of erosion that has mostly healed over with vegetation are scored in the "good" category. Banks hardened with rocks or concrete are considered stable and in the "excellent" category although they may show evidence of erosion at the edges of these areas. A stream with more than 10 percent of the banks showing evidence of active erosion (bare soil) is scored in the "poor" category.

5. Bank Vegetative Type

This parameter is scored by determining the dominant type of vegetation along the stream bank. Left and right banks are scored separately. Each assessment category is described below.

"Excellent" - dominant vegetation is shrubs
"Good" - dominant vegetation is trees
"Fair" - dominant vegetation is grasses and herbaceous plants
"Poor" - < 25% of the bank vegetated

The dominant type of vegetation is determined by the area of the stream bank covered by one of three types of vegetation; trees, woody shrubs, and herbaceous plants. Herbaceous plants include grasses and other vegetation that exist only during the growing season. Each stream bank is scored separately; left and right banks are determined while looking downstream.

For example, streams with large mature trees along the bank and a thin understory (i.e., few shrubs) are scored in the "good" category. Sites with a thick growth of shrubs along the bank and scattered trees are scored in the "excellent" category. Open channels with little or no canopy and a thin covering of herbaceous vegetation are scored in the "fair" category. Channels that have more than 50 percent of the bank with exposed soil, rip-rap, concrete, or gabions are scored in the "poor" category.

6. Shading

This parameter is scored by estimating the percent of the water surface that is shaded. Each assessment category is described below.

"Excellent" - 25-90% of the water surface shaded, mixture of conditions
"Good" - > 90% shaded, full canopy
"Fair" - no scoring in this category
"Poor" - < 25% shaded

Time of year, time of day, and weather can affect the measurement of shading. Therefore, percent shade is estimated by assuming that the sun is directly overhead and the vegetation is in full leaf-out. There is no scoring in the "fair" category for this parameter.

For example, a mature forested floodplain with an extensive and undisturbed riparian zone generally has greater than 90 percent of the water surface shaded and would be scored in the “good” category. Streams flowing through a scrub/shrub wetland often have greater than 90 percent of the water surface shaded and are scored in the “good” category as well. Forested streams with large gaps in the canopy (e.g., around fallen trees) are scored in the “excellent” category. “Excellent” scores are also given to streams with extensive shade trees along the bank. Open channels are scored in the “poor” category.

Table 5. Summary of habitat parameter scoring criteria and definitions; (L) left and (R) right banks.

Parameter	Criteria	Definitions
channel modification	degree of channelization frequency of bends	channelized: recent maintenance recent: within 30-50 years
instream habitat	diversity abundance	high diversity: 3-4 types low diversity: 1-2 types high abundance: > 50% channel low abundance: < 50% channel
pools	diversity abundance	high diversity: deep and shallow low diversity: shallow only shallow pool: 1 foot deeper deep pool: 2-3 feet deeper high abundance: > 5 per 100 m low abundance: < 5 per 100 m
bank stability (L&R)	evidence of bank erosion % of bank eroded	stable: 0% eroded moderately unstable: 5-10% eroded very unstable: > 10% eroded
bank vegetative type (L&R)	dominant vegetation type (trees, shrubs, grasses/herbs)	dominance: proportion (%) by area
shading	% water surface shaded	full leaf-out sun directly overhead
riparian zone width (L&R)	width of riparian zone with no evidence of human activity	human activities: crops, feedlots, lawns, parks, structures, ditch maintenance (mowing, spraying)

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7. Riparian Zone Width

This parameter is scored by estimating the width of the riparian zone that shows no evidence of human activity. Left and right banks are scored separately. Each assessment category is described below.

"Excellent" - no human activity within 18 meters (60 ft)
"Good" - no human activity within 12 meters (40-60 ft)
"Fair" - no human activity within 6 meters (20-40 ft)
"Poor" - human activity within 6 meters (20 ft)

The riparian zone is the area on either side of the stream channel. Human activities include the cultivation of crops, livestock and poultry operations, the mowing of grass or lawns, the control of vegetation either through spraying or cutting, and the construction of buildings, roads, or other structures. The degree, extent, or types of human activities are not considered in the selection of categories but may be considered in the selection of numerical scores within categories. Measurement begins at the point where the water meets the bank.

The age and height of trees in the riparian zone is an indicator of recent human activity. Riparian areas show evidence of human activity if the trees are less than 30-40 feet in height. Larger trees would indicate minimal human alteration of the riparian zone. Mature trees along the sides of a channelized stream are considered part of a riparian zone with no human activity. Mowed banks along channelized streams indicate human activity.

For example, a wooded riparian zone with extensive wetlands in the floodplain would be classified in the "excellent" category. Channelized stream through a farm field with mowed banks are scored in the "poor" category. A 6 meter band of mature tree along a channelized stream through a farm field is scored in the "fair" category. A wooded floodplain with a residential lot with grass up to the edge of the bank is scored in the "poor" category.

4.1.3 Physicochemical Measurements

Measurements of air and water temperature, dissolved oxygen, pH, and specific conductance are made at the time that habitat data and macroinvertebrate samples are collected. Standard procedures are followed according to manufacturer specifications.

4.1.4 Other Information

Additional information on the physical characteristics of the stream and surrounding area are recorded on the Habitat Assessment Field Data Sheet (Appendix A). Flow measurements are recorded along with a more detailed description of the land use and vegetation in the riparian zone. The proportion and condition of stable habitats sampled for macroinvertebrates are recorded. The following provides clarification of the some of the information requested.

<u>location:</u> The location of the assessment area (lat/long, road crossing, above or below road, etc.).

<u>time on/off:</u> The time the crew arrived at the AA and the time the crew left the AA.

<u>photos taken</u>: Photos taken of the AA and the riparian zone (slide film).

<u>flow:</u> At least 10 depth and velocity measurements taken along a single transect to estimate flow. Channel width, mean depth, mean velocity, and maximum velocity determined from the flow data. Additional velocity measurements also required if the maximum velocity occurs outside the area where the flow measurements were taken.

<u>high water mk:</u> The height that the water has risen above the present water surface as evidenced by stained leaves and debris on vegetation along the banks.

<u>channel type:</u> The type of channel.

<u>bottom type:</u> The type of substrate.

<u>upstream:</u> The land use (e.g., wooded, open, urban, agriculture) and habitat condition that can be seen immediately upstream of the AA.

<u>sampling:</u> Macroinvertebrate sample collected and how it was collected.

<u>habitats:</u> The number, proportion (%), and condition (e.g., algae, accumulation of silt, macrophytes species, etc.) of stable habitats sampled for macroinvertebrates.

riparian: The land use (e.g., crops, woods, wetlands, yards) and the type of vegetation (trees, shrubs, grass) within 1-2 meters, 2-10 meters, and 10-20 meters from the channel; text or drawing (plan view); left and right riparian areas (while looking downstream) described separately.

comments: Important information and observations not recorded elsewhere on the Field Data Sheets (e.g., unique features, water clarity, trash, evidence of beaver, dominant aquatic organisms, macrophyte species, fish, amphibians, difficulties, nearby property owners, etc.).

4.1.5 Quality Assurance

Investigators using these methods must be trained field biologists and must be experienced in nontidal stream assessments and stream ecology. Investigators must have been trained by a Workgroup member to draw direct comparisons between their data and data collected by the Workgroup. At least one person in each field crew must be trained in these methods. These methods are not designed for use by non-biologists. Methods for conducting habitat assessments by non-biologist and citizen monitoring groups have been developed by USEPA (USEPA 1995a).

The evaluation of data quality for habitat data is complicated by the visual nature of these measurements. The following procedures are recommended where multiple investigators or survey crews are involved in a survey. These procedures reduce data variability between investigators.

The habitat assessment scores are evaluated by all of the investigators while reviewing the slides, field notes, and other descriptions of each site. The slides taken at each site are particularly helpful in recalling the characteristics of each site, and provide a visual representation of the site to those investigators not familiar with the site. A group discussion of each score in relation to the scoring criteria is conducted to identify discrepancies. Changes are made to an original score only if the following two criteria are met; (1) there is agreement that the original score was incorrect and (2) the change in numerical score would result in a change in category (e.g., change from "good" to "fair"). Score discrepancies within an assessment category are not changed.

4.2 Data Management

The habitat, water quality, and other physical data are reported in standard spreadsheet format, with each measurement listed in columns and the station numbers listed in rows. The seven habitat metrics are totaled for each site and listed in a separate column.

5.0 Literature Cited

Ball, J.; 1982; "Stream classification guidelines for Wisconsin"; Wisconsin Department of Natural Resources, Madison, Wisconsin; technical bulletin.

Barbour, M.T. and J.B. Stribling; 1993; "An evaluation of visual-based techniques for assessing stream habitat structure"; In proceedings of "Riparian ecosystems of the humid United States", USEPA, Office of Water, Washington, D.C.

Barbour, M.T. and J.B. Stribling; 1991; "Use of habitat assessment in evaluating the biological integrity of stream communities"; Proceedings of a symposium - biological criteria research and regulation; Office of Water, Washington, D.C.; EPA 440/5-91-005.

Barclay, J.S.; 1980; "Impact of stream alterations on riparian communities in south-central Oklahoma"; U.S. Fish and Wildlife Service, Albuquerque, NM; FWS/OBS-80/17.

Bartholow, J.M.; 1989; "Water temperature investigations: field and analytic methods"; U.S. Fish and Wildlife Service, Fort Collins, CO.

Barton, D.R. and W.D. Taylor; 1985; "Dimensions of riparian buffer strips required to maintain trout habitat in southern Ontario streams"; North American Journal of Fisheries Management 5, pp. 364-378.

Becker, C.D. and D.A. Neitzel; 1992; Water quality of north American river systems; Battelle Press, 304 pages.

Benke, A.C. and K.A. Parsons; 1990; "Modelling blackfly production dynamics in blackwater streams"; Freshwater Biology 24, pp. 167-180.

Benke, A.C. and J.L. Meyer; 1988; "Structure and function of a blackwater river in the southeastern USA."; International Association of Theoretical and Applied Limnology 23, pp. 1209-1218.

Benke, A.C., R.L. Henry, III, D.M. Gillespie, and R.J. Hunter; 1985; "Importance of snag habitat for animal production in southeastern streams"; Fisheries 10(5).

Benke, A.C., T.C. Van Arsdall, Jr., D. M. Gillespie, and F. K. Parrish; 1984; "Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history"; Ecological Monographs 54(1), pp. 25-63.

Boward, D.; 1992; personal communication; Maryland Department of Natural Resources, Annapolis, MD.

Brazier, J.R., and G.W. Brown; 1973; "Buffer strips for stream temperature control"; research paper no. 15; Forest Research Laboratory, Oregon State University, Corvallis, OR.

Brinson, M.M., B.L. Swift, R.C. Plantico, and J.S. Barclay; 1981; "Riparian ecosystems: their ecology and status"; U.S. Fish and Wildlife Service; FWS/OBS-81/17.

Bulkley, R.V.; 1975; "A study of the effects of stream channelization and bank stability on warm water sport fish in Iowa, subproject no. 1, Inventory of major stream alterations in Iowa"; U.S. Fish and Wildlife Service, Washington, D.C.; FWS/OBS-76/16.

Campbell, C.J.; 1970; "Ecological implications of riparian vegetation management"; Journal of Soil and Water Conservation 25, p. 49.

Cooper, J.R., R.B. Daniels, and W.P. Robarge; 1987; "Riparian areas as filters for agricultural sediment"; Soil Science Society of America Journal 51(6), pp. 416-240.

Gorman, O.T. and J.R. Karr; 1978; “Habitat structure and stream fish communities”; Ecology 59, p. 507.

Hackney, C.T., S.M. Adams, and W.A. Martin; 1992; Biodiversity of southeastern United States aquatic communities; John Wiley and Sons, Inc.; 794 pages.

Hewlett, J.D. and J.C. Fortson; 1982; "Stream temperature under an inadequate buffer strip in the southeast piedmont”; Water Resources Bulletin 18, pp. 983-988.

Jacobi, D.I. and A.C. Benke; 1991; "Life histories and abundance patterns of snag-dwelling mayflies in a blackwater coastal plain river"; Journal of the North American Benthological Society 10(4), pp. 374-387.

Johnston, C.A.; 1991; "Sediment and nutrient retention by freshwater wetlands: effects on surface water quality"; Critical Reviews in Environmental Control 21(5,6), pp. 491-565.

Johnston, C.J., Johnson, T., Kuehl, M., Taylor, D., and Westman, J.; 1990; "The effects of freshwater wetlands on water quality: a compilation of literature values"; prepared for USEPA, Office of Research and Development, Duluth, MN; internal report; 178 pp.

Karr, J.R. and I.J Schlosser; 1978; "Water resources and the land-water interface"; Science 201, pp. 229-234.

Karr, J.R. and I.J. Schlosser; 1976; "Impact of nearstream vegetation and stream morphology on water quality and stream biota"; Ecological Research Series; EPA-600/3-77-097; USEPA, Washington, D.C.

Kohnke, H. and A.R. Bertrand; 1959; Soil conservation; McGraw-Hill; 298 pages.

Kuenzler, E.J.; 1989; "Value of forested wetlands as filters for sediment and nutrients"; proceedings of the symposium - the forested wetlands of the southern United States, July 12-14, 1988, Orlando, FL; U.S. Department of Agriculture, Forest Service, Ashville, NC; report SE-50, 168 pp.

Lowrance, R.R., J.K. Sharpe, and J.M. Sheridan; 1986; "Long-term sediment deposition in a riparian zone of a coastal plain watershed"; Journal of Soil and Water Conservation, 41(4), pp. 266-270.

Lowrance, R.R., R. Leonard, and J. Sheridan; 1985; "Managing riparian ecosystems to control nonpoint pollution"; Journal of Soil and Water Conservation 40(1), pp. 87-91.

Lowrance, R.R., R.L. Todd, and L.E. Asmussen; 1984a; "Nutrient cycling in an agricultural watershed: I. phreatic movement"; Journal of Environmental Quality 13, pp. 22-27.

Lowrance, R.R., R. Todd, J. Fail Jr., O. Hendrickson, Jr., R. Leonard, and L. Asmussen; 1984b; "Riparian forests as nutrient filters in agricultural watersheds"; Bioscience 34(6), pp. 374-377.

Maxted, J.R., E.L. Dickey, and G.M. Mitchell; 1995; “The water quality effects of channelization in coastal plain streams of Delaware”; Delaware DNREC, Dover, DE; 21 pages.

Maxted, J.R., E.L. Dickey, and G.M. Mitchell; 1992; "Level of effort evaluation and analysis of variance of an invertebrate collection method developed for the coastal plain"; technical report no.1-02; Delaware DNREC, Dover, DE.

Maxted, J.R. and E.L. Dickey; 1990; "Invertebrate community of coastal stream habitats"; technical report no. 1-01; Delaware DNREC, Dover, DE.

Medlin, N.; 1992; "Swamp and nonflowing stream sampling method evaluations"; memo dated April 29, 1992 and draft technical report, North Carolina Department of Environment, Health, and Natural Resources, Raleigh, NC.

Mid-Atlantic Coastal Streams (MACS) Workgroup;1995; “Field testing of methods - data report”; USEPA Region III, Wheeling Field Office, Wheeling WV.

Mid-Atlantic Coastal Streams (MACS) Workgroup; 1993a; "Comparison of invertebrate collection methods applicable to low velocity streams of the mid-atlantic region"; USEPA Region III, Wheeling Field Office, Wheeling, WV.

Mid-Atlantic Coastal Streams (MACS) Workgroup; 1993b; "Development of a habitat assessment methodology for low gradient nontidal streams"; USEPA Region III, Wheeling Field Office, Wheeling WV.

Miller, A.C., D.C. Beckett, C.M. Way, and E.J. Bacon; 1989; "The habitat value of aquatic macrophytes for macroinvertebrates"; Department of the Army, U.S. Corps of Engineers, Waterways Experiment Station, Technical Report A-89-3.

Mitsch, W.J. and J.G. Gosselink; 1993; Wetlands; 2nd edition, Van Nostrand Reingold, New York; 537 pages.

Moring, J.R.; 1975; "Fisheries research report no. 9"; Oregon Department of Fish and Wildlife, Corvallis, OR.

National Council on the Paper Industry for Air and Stream Improvement (NCASI); 1987; "Managing oregon's riparian zone for timber, fish and wildlife"; technical bulletin no. 514; New York, NY.

Nixon, S.W. and V. Lee; 1986; "Wetlands and water quality: a regional review of recent research in the United States on the role of freshwater and saltwater wetlands as sources, sinks, and transformers of nitrogen, phosphorus, and various heavy metals"; U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS; technical report Y-86-2, 229 pp.

Omernik, J.M.; 1987; "Ecoregions of the conterminous United States"; Annals of the Association of American Geographers 77(1), pp. 118-125.

Peterjohn, W.T. and D.L. Correll; 1989; "Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest"; Ecology 65(5), pp. 1466-1475.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes; 1989; “Rapid bioassessment protocols for use in streams and rivers: macroinvertebrates and fish”; USEPA, Office of Water; EPA/444/4-89-001.

Platts, W.S., W.F. Megahan, and G.W. Minshall; 1983; "Methods for evaluating streams, riparian, and biotic conditions"; general technical report INT-138; U.S. DOE, Forest Service, Ogden UT.
Roeding, C.E. and L.A. Smock; 1989; "Ecology of macroinvertebrate shredders in a low-gradient sandy-bottomed stream"; Journal of the North American Benthological Society 8(2); pp. 149-161.
Rosenberg, P. and V. Resh; 1993; Freshwater biomonitoring and benthic macroinvertebrates; Chapman and Hall; 512 pages.
Shirey, C.A.; 1993; personal communication; Delaware DNREC, Division of Fish and Wildlife.
Shirey, C.A.; 1989; "Stream and inland bays fish survey: an inventory of fishes and macroinvertebrates in Delaware streams"; Delaware DNREC, Division of Fish and Wildlife, Dover, DE; No. F-37-R.
Smith, L.C. and L.A. Smock; 1992; "Ecology of invertebrate predators in a coastal plain stream"; Freshwater Biology 28, pp. 319-329.
Smock, L.A. and E. Gilinsky; 1992; "Coastal plain blackwater streams", contained in Biodiversity of southeastern United States aquatic communities ; Hackney, Adams, and Martin (eds), John Wiley and Sons, Inc.
Smock, L.A., G.M. Metzler, and J.E. Gladden; 1989; "Role of debris dams in the structure and function of low-gradient headwater streams"; Ecology 70(3); pp. 764-775.
Smock, L.A., E. Gilinsky, and D.L. Stoneburner; 1985; "Macroinvertebrate production in a southeastern United States blackwater stream"; Ecology 66(5); pp. 1491-1503.
Strecker, E.W., J.M. Kersnar, E.D. Driscoll, and R.R. Horner; 1992; “The use of wetlands for controlling stormwater pollution”; USEPA, Region 4, distributed by the Terrene Institute, Washington, D.C.
Tarplee, W.H. Jr., D. E. Louder, and A.J. Weber; 1971; "Evaluation of the effects of channelization on fish populations in North Carolina's coastal plain streams"; North Carolina Wildlife Resources Commission, Raleigh, NC.
U.S. Environmental Protection Agency (USEPA);1996; “Biological criteria - technical guidance for streams and small rivers”; Office of Water, Washington, D.C.; EPA 822-B-96-001.
USEPA; 1995a; “Volunteer stream monitoring - a methods manual”; field test draft; Office of Water, Washington, D.C.; EPA-841-D-95-001.
USEPA; 1995b; “”Water quality functions of riparian forest buffer systems in the Chesapeake Bay watershed; nutrient subcommittee of the Chesapeake Bay program; Annapolis, MD; EPA 903-R-95-004; 67 pages.
USEPA; 1994; “Watershed protection: TMDL Note #2 - bioassessment and TMDL”; Office of Water, Washington, D.C.; EPA 841-K-94-005a.
USEPA; 1991; “Technical support document for water quality-based toxics control”; Office of Water; EPA/505/2-90-001, PB91-127415; 145 pages.
USEPA; 1990; “Freshwater macroinvertebrate species list including tolerance values and functional feeding group designations for use in rapid bioassessment protocols”; prepared for the Assessment and Watershed Protection Division, Washington, D.C. by EA Engineering, Science and Technology, Inc., Mid-Atlantic Regional Operations; report no. 11075.05 (with disk).
USEPA; 1983; “Technical support manual: waterbody surveys and assessments for conducting use attainability analyses”; Office of Water Regulations and Standards; Washington, D.C.
Winger, P.V.; 1986; "Forested wetlands of the southeast: review of major characteristics and role in maintaining water quality"; resource publication no. 163; U.S. Fish and Wildlife Service, Washington, D.C., 16 pages.
Zimmer, D.W. and R.W. Bachman; 1976; "A study of the effects of stream channelization and bank stabilization on warmwater sport fish in Iowa, subproject no. 4, the effects of long reach channelization on habitat and invertebrate drift in some Iowa streams"; U.S. Fish and Wildlife Service, Washington, D.C.; FWS/OBS-76/14.

Taxonomic Keys Used by the MACS Workgroup:

Brigham, A.H., W.U. Brigham, and A. Gnilka; 1982; “Aquatic insects and oligochaetes of north and south Carolina”; Midwest Aquatic Enterprises, Mahomet, IL; 800 pages.
Brinkhurst, R.O.; 1986; “Guide to the freshwater aquatic microdrile oligochaetes of North America”; Canadian Special Publication of Fisheries and Aquatic Sciences, No. 84; 259 pages.

Epler, J.H.; 1992; “Identification manual for the larval Chironomidae of Florida; State of Florida, Department of Environmental Regulation, Orlando, FL; Contract No. SP251.
Hilsenhoff, W.L.; 1975 (undated revision); “Aquatic insects of Wisconsin - keys to Wisconsin genera and notes on biology, distribution, and species”; Geological and Natural History Survey, Madison, WS; publication No. 2.
Merritt, R.W. and K.W. Cummins; 1996; An introduction to the aquatic insects of North America; 3rd edition; Kendall/Hunt Publishing Company, Dubuque, IA.
Mozley, S.C.; 1980 (revised 1981); “Biological indicators of water quality in North Carolina - I. Guide to the generic identity of Orthocladiine Chironomidae”; report to the North Carolina Department of Natural Resources, Raleigh, NC.
Needham, J.G. and M.J. Westfall; 1954; “A manual of the dragonflies of North America”; University of California Press, Berkeley; 615 pages.
Peckarsky, B.L., P.R. Fraissinet, M.A. Denton, and D.J. Conklin, Jr.; 1990; “Freshwater macroinvertebrates of northeast North America”; Cornell University Press, Ithaca, NY; 442 pages.
Pennak, R.W.; 1989; Fresh-water invertebrates of the United States - Protozoa to Mollusca; 3rd edition; John Wiley and Sons, Inc., New York, NY.
Schuster, G.A. and D.A. Etnier; 1978; “A manual for the identification of the larvae of the caddisfly genera Hydropsychidae Pictet and Symphitopsyche Ulmer in eastern and central North America”; EPA-600/4-78-060.
Simpson, K.W., and R.W. Bode; 1980; “Common larvae of Chironomidae from New York State streams and rivers”; New York State Museum, University of the State of New York, Education Department, Albany, New York; Bulletin No. 439.
Stewart, K.W. and B.P. Stark; 1988; “Nymphs of North American stonefly genera”; The Thomas Say Foundation; Vol. 12, 460 pages.
USEPA; 1982; “Freshwater snails (Mollusca: Gastropoda) of North America”; prepared by J.B. Burch; Environmental Monitoring and Support Laboratory, Cincinnatti, OH; EPA-600/3-82-026.
USEPA; 1976; “Aquatic dryopoid beetles (Coleoptera) of the United States”; prepared by H.P. Brown; Analytical Quality Control Laboratory, National Environmental Research Center, Cincinnatti, OH; Water Pollution Control Research Series 18050 ELD 04/72.
USEPA; 1976; “Crayfish (Astacidae) of north and middle America”; prepared by H.H. Hobbs, Jr.; Analytical Quality Control Laboratory, National Environmental Research Center, Cincinnatti, OH; Water Pollution Control Research Series 18050 ELD 05/72.
USEPA; 1976; “Freshwater isopods (Asellidae) of North America”; prepared by W.D. Williams; Analytical Quality Control Laboratory, National Environmental Research Center, Cincinnatti, OH; Water Pollution Control Research Series 18050 ELD 05/72; 45 pages.
USEPA; 1973; “Freshwater unionacean clams (Mollusca: Pelecypoda) of North America”; prepared by J.B. Burch, Analytical Quality Control Laboratory, National Environmental Research Center, Cincinnatti, OH.; Water Pollution Control Research Series 18050 ELD, Id. Manual No.11.
USEPA; 1973; “An introduction to the identification of Chironomidae (Diptera) larvae”; prepared by W.T. Mason, Jr.; Analytical Quality Control Laboratory, National Environmental Research Center, Cincinnatti, OH.
Ward, H. and G Whipple; 1966; Freshwater biology; 2nd edition; John Wiley and Sons, Inc., New York, NY.
Wiederholm, T.; 1983; “Chironomidae of the holarctic region - keys and diagnoses - Part 1 - larvae”; Entomologica Scandinavica, supplement no. 19:1-457.
Wiggins, G.B.; 1977; “Larvae of North American caddisfly (Trichoptera) genera”; University of Toronto Press, Toronto, Canada; 457 pages.

Appendix A

Habitat Assessment Field Data Sheets - Coastal Plain

Field and Laboratory Methods
for Macroinvertebrate and Habitat Assessment
of Low Gradient, Nontidal Streams

Mid-Atlantic Coastal Streams (MACS) Workgroup

July 1997

Habitat Assessment Field Data Sheet

(MACS Workgroup Method - USEPA 1997)

Survey No: ____________ Date: ____________ Rater(s): ______________ Basin: ________________

Station ID/location: ____

	Excellent	Good	Fair	Poor
1. Channel Modification	natural channel, bends frequent, good diversity of runs and bends 20-16	natural channel, long runs, bends infrequent 15-11	modified channel with bends, OR stream meanders within straight channel 10-6	modified channel with no bends 5-0
2. Instream Habitat snags vegetated banks undercut banks macrophytes riffles	3-4 types present > 50 % coverage 20-16	3-4 types present < 50 % coverage 15-11	1-2 types present > 50 % coverage 10-6	1-2 types present < 50 % coverage 5-0
3. Pools abundant: >5 /100m shallow: >1 ft deep: 2-3 ft (> prevailing depth)	deep and shallow pools present and pools are abundant 20-16	deep and shallow pools present and pools are rare, OR stream is uniformly deep 15-11	all pools shallow and pools are abundant 10-6	all pools are shallow and rare, or pools are absent 5-0
4. Bank Stability (⇒ while facing downstream)	very stable, no evidence of erosion or bank failure left 10-9 right 10-9	moderately stable, areas of erosion healed over 8-6 8-6	moderately unstable, 5-10% of the bank shows signs of active erosion 5-3 5-3	very unstable, many eroded areas along both runs and bends; > 10% of the bank shows signs of erosion 2-0 2-0
5. Bank Vegetative Type (⇒ while facing downstream)	dominant vegetation is shrubs left 10-9 right 10-9	dominant vegetation is trees 8-6 8-6	dominant vegetation is grass and herbaceous plants (briars) 5-3 5-3	stream bank dominated by non-vegetation (rock, soil, bulkhead, etc.) 2-0 2-0
6. Shading sun overhead full leaf-out	25-90% of the water surface shaded; a mixture of conditions; areas fully shaded, fully open, and degrees of filtered light 20-16	> 90% of water surface shaded, full canopy; entire water surface receives filtered or no light 15-11	no scoring in this category 10-6	< 25% of water surface shaded; lack of a canopy; full sunlight reaches water surface 5-0
7. Riparian Zone Width (⇒ while facing downstream)	no evidence of human activity within 18 meters (60 feet) left 10-9 right 10-9	no evidence of human activity within 12 meters (40 feet) 8-6 8-6	no evidence of human activity within 6 meters (20 feet) 5-3 5-3	evidence of human activity within 6 meters (20 feet) 2-0 2-0

column totals _______ _______ _______ _______

Habitat Assessment Field Data Sheet - Supplement

(MACS Workgroup Method - USEPA 1997)

Date: ______________ Time on: _____________ Time off: _____________ Crew: _______________________

Station ID/location: ____

General:

photos taken: _______ high water mark (ft): ___________ recent weather: _____________________

flow (cfs): __________ mean velocity (ft/sec): ______________ maximum velocity (ft/sec): ______________

water surface width (ft): __________ mean depth (ft): ___________

channel type: (circle one): natural channelized no channel (braided/wetland) other (specify):

bottom type (circle one): hard (sand,gravel) soft (easy to walk) very soft (hard to walk) not wadable (too deep)

upstream habitat (as compared to the assessment area): ____

macroinvertebrate sample collected: yes no if yes, describe how collected (circle one)

throughout along edge top of bank

Proportion of Habitats Sampled for Macroinvertebrates:

	sampled # jabs	sampled %	condition
snags	____	____	______________________________
banks	____	____	______________________________
macrophytes	____	____	______________________________

Description (land use, type of vegetation) of the Riparian Zone:

	width (meters)	description (left bank)	description (right bank)
near (e.g., 1-2 meters)	___________	______________________	______________________
mediate (e.g., 2-10 meters)	___________	______________________	______________________
far (e.g., 10-20 meters)	___________	______________________	______________________

Comments:

Appendix B

Technical Basis

Field and Laboratory Methods
for Macroinvertebrate and Habitat Assessment
of Low Gradient, Nontidal Streams

Mid-Atlantic Coastal Streams (MACS) Workgroup

July 1997

Macroinvertebrate Assessment

1. *Habitats to Sample*

Literature Review

Stable habitats provide the greatest density and diversity of macroinvertebrates in nontidal streams. While the riffle habitat is used extensively for macroinvertebrate collections, riffles are often not present throughout much of the middle and southern Atlantic coastal plain. In the low gradient streams that dominate this region, submerged woody material within the stream channel (e.g., snags), roots and vegetation along the stream banks, and submerged macrophytes provide the most stable and productive habitats for macroinvertebrates. The selected sampling equipment and techniques are designed to efficiently sample these target habitats.

Much of the literature on coastal plain streams has been done in North Carolina, South Carolina, Georgia, and Virginia. The importance of snag habitats to the macroinvertebrate community in coastal plain streams is well documented in the literature (Benke et al. 1984; Benke et al. 1985; Benke and Meyers 1988; Benke and Parsons 1990; Jacobi and Benke 1991; Roeding and Smock 1989; Smith and Smock 1992; Smock et al. 1985; Smock et al. 1989). Snags provide a stable substrate to support the macroinvertebrate community. Benke and Parsons (1990) found that snags in the Ogeechee River, Georgia increased the available surface area of the stream channel 2-4 times. This additional surface area provides additional living space for aquatic life beyond what would be found in streams without snags. Snags divert flow, create pools, and generally diversify habitat for aquatic life.

Snags also benefit water quality by trapping sediments and suspended organic matter and the nutrients and contaminants associated with suspended material. This physical mechanism of removing suspended material from the water column is, in turn, further aided by biological mechanisms provided by aquatic organisms. Thus, snags are an important habitat with regard to biological integrity and water quality.

Benke, Henry, Gillespie, and Hunter (1985) found that snags of the Satilla River had 10 and 64 times the invertebrate biomass of mud and sand habitats, respectively (Table B1). Similarly, the snags had 4 times the invertebrate productivity of both mud and sand habitats (Table B1). The Satilla River is a blackwater river in Southeastern Georgia and is typical of the wooded coastal plain streams of the Mid-Atlantic region.

Table B1. Mean annual biomass (g dry wt/m^2) and productivity (g dry wt/m^2/yr) of macroinvertebrates found in three habitats of the Satilla River, GA (Benke et al. 1985).

Habitat	Biomass	Production
Mud	0.59	13.9
Sand	0.09	13.7
Snag	5.80	57.4

Benke, Van Arsdall, Gillespie, and Parrish (1984) evaluated the community composition within these three habitats of the Satilla River. The greatest taxonomic richness and number of sensitive EPT genera were in the snag habitat as compared to the sand and mud habitats (Table B2). Approximately half (52%) of the total taxonomic richness (at genus level) was found in the snag habitat, and the snags contained 84% of the pollution sensitive EPT genera (16 of 19) (Table B2). Only the Oligochaeta group had a higher taxonomic richness in the mud and sand habitats. The Diptera group had the highest taxonomic richness for all habitats.

Table B2: Number of genera, by order, found in snag, sand, and mud habitats of the Satilla River, Georgia (Benke et al. 1984).

Group (order)	Snags	Sand	Mud
Diptera	17	15	11
Ephemeroptera	5	0	0
Plecoptera	2	0	0
Trichoptera	9	0	3
Coleoptera	3	1	1
Megaloptera	1	0	0
Odonata	3	1	0
Oligochaeta	0	3	2
Totals	40 (52%)	20 (26%)	17 (22%)

Smock, Metzler, and Gladden (1989) found 10 times the density and 5 times the biomass on snags as compared to the bottom sediments in two low gradient headwater streams in the coastal plain of Virginia; Buzzards Branch and Collier Creek. Roeding and Smock (1989) further studied Buzzards Branch and found 4 times the total shredder density, 5 times the shredder biomass, and 8 times the productivity on snags compared to bottom sediments, even though the snag habitat comprised only 3 percent of the stream surface area. Smith and Smock (1992) also studied Buzzards Branch and found 5 times the density, 12 times the biomass, and 6 times the productivity of predators in snags as compared to sediments.

Smock, Gilinsky, and Stoneburner (1985) studied three sites on Cedar Creek located in the coastal plain of South Carolina. Macroinvertebrates were sampled monthly from October 1981 to September 1982 in each of five major habitats. Mean annual density, biomass, and production (per meter^{2}) were highest in the snag habitats at all sites except the upstream site where the density was highest in the macrophytes. Production was the lowest in the leaf pack habitat. The density, biomass, and productivity of macroinvertebrates in Cedar Creek, South Carolina may be summarized in the following order: snags > macrophytes > banks > stream bottom > leaf packs.

Many coastal plain streams are maintained as open channels with little woody riparian vegetation and woody snag habitat. Submerged macrophytes are a particularly important habitat for macroinvertebrates in open channels that receive direct sunlight. The available literature on the value of aquatic plants to the macroinvertebrate community has recently been summarized by Miller, Beckett, Way, and Bacon (1989). They collected macroinvertebrates in vegetated and unvegetated sites of Eau Galle Reservoir, Wisconsin. The density of macroinvertebrates in vegetated sites was 6 to 13 times greater than in unvegetated sites (Table B3).

Table B3. Density (#/m^2) of macroinvertebrates in three habitat types of Eau Galle Reservoir, Wisconsin (Miller et al. 1989).

Ceratophyllum	35,260
Potamogeton	18,387
no macrophytes	2,730

Both macrophyte genera had higher densities of macroinvertebrates compared to unvegetated sites suggesting that the physical structure of the plants was more important in determining density than the type (genera) of plant (Table B3). There are no studies to indicate that the taxonomic richness of macroinvertebrates varies with plant type. The sampling of all macrophyte types ensures that all microhabitats within macrophytes are sampled for macroinvertebrates.

Workgroup Studies

The Delaware Department of Natural Resources and Environmental Control (DNREC) collected macroinvertebrates in a coastal plain stream that contained all of the major habitat types found in low gradient streams of the Mid-Atlantic region (Maxted and Dickey 1990). Dukes Ditch, located in Sussex County Delaware, is a channelized stream that is cleared of woody vegetation along one side to provide sufficient light for aquatic plant growth, and contains natural vegetation (trees and shrubs) with associated bank and snag habitats on the other side. Macroinvertebrate collections were made on June 19, 1990 by hand and using a D-frame net. Each major habitat type was sampled and processed separately.

Table B4. Mean abundance and taxonomic richness (family level) of macroinvertebrates found in the major aquatic habitats of Dukes Ditch, Delaware; (Maxted and Dickey 1990).

Habitat	Method	N	Abundance	(%)	Richness	**
snag/woody banks	dip net	2	241	(21)	11	-
macrophytes	dip net	4	268	(23)	10	-
macrophytes	hand	2	315	(27)	10	-
sticks/leaf packs	hand	2	60	(5)	9	0
gravel/sand	dip net	3	125	(11)	9	3
silt/mud	dip net	1	152	(13)	7	0
totals			1161	(100)	27	3

** number of families not found in banks or macrophytes

Consistent with the literature, the greatest abundance and diversity of macroinvertebrates were in the snags, in the vegetation along the stream banks, and in the submerged macrophytes. The majority (71%) of the organisms identified were from the snags and macrophyte habitats (Table B4). A total of 27 Families were identified. The majority (85%) of the taxonomic richness (family level) was found in the snag and macrophyte habitats. Only 3 Families (11%) were unique to other habitats. There was no difference in the abundance or taxonomic richness in macrophytes sampled by hand and with a dip net (Table B4).

The North Carolina Department of Environment, Health, and Natural Resources conducted a study of major aquatic habitats in 12 nontidal coastal plain streams (Medlin 1992). Two replicate collections were made in six major habitats using a variety of collection methods. The results were compiled using a ranking system based upon the number of taxa found in each habitat. The habitat with the greatest taxonomic richness was scored with 6 points, the second highest 5 points, down to the habitat with the lowest richness receiving 1 point. Mean values were calculated for each habitat type. The Mean Richness Rank is a relative measure of the number of taxa found in the habitat sampled. The Mean Rare Taxa Rank is a relative measure of the number of taxa from the specified habitat that were not found in any other habitat sampled. Banks and macrophytes were ranked the highest for both taxonomic richness and the incidence of rare taxa (Table B5). The D-framed dip net collected more taxa than either hand washing or hand picking.

Table B5. Relative ranking (out of a possible 6 points) of taxonomic richness and the incidence of rare taxa (species level) by habitat type and collection method (Medlin 1992).

Habitat	Method	N	Mean Richness Rank	Mean Rare Taxa Rank
bank/root mat	dip net	2	5.00	4.42
macrophyte	dip net	2	4.67	4.00
detritus	dip net	2	4.00	3.92
visual (all habitats)	hand pick	2	3.25	3.75
logs	hand wash	2	2.75	3.25
leaf packs	hand wash	2	1.67	1.67

2. Collection Gear and Sampling Technique

Literature Review

No literature was found that evaluated the macroinvertebrate community in the coastal plain using a variety of sampling gear and collection techniques.

Workgroup Studies

A variety of collection devices were available to the MACS Workgroup for consideration; nets, coring devices, artificial substrates (multiplates), and hand collections. The Surber sampler and coring devices such as the Ponar grab are designed for quantitative analyses and cover a relatively small area of a single habitat type. Contrary to steeper gradient streams with riffle habitats, there is no single productive habitat in low gradient streams. These types of devices were not considered further because they do not efficiently sample the variety of productive habitats. Hand collection was also eliminated from consideration due to difficulties in standardization. The selection was narrowed down to artificial substrates and dip nets.

The MACS Workgroup conducted a comparison of these two collection methods at six locations during the Summer of 1991 (MACS Workgroup 1993a). Replicate collections at three sites allowed for statistical analyses. Summary RBP scores (% of reference) were computed by comparison with an independent reference condition using six biological metrics. The two methods yielded statistically different mean RBP scores ($p < 0.015$) at each of the sites replicated. Generally, the artificial substrate sampler produced lower RBP scores than the dip net sampler, particularly at sites with low velocities (less than 0.5 fps). This suggests that artificial substrates underestimate biological quality possibly due to the deposition of silt on the plates.

In a separate study, the Maryland Department of the Environment reported a 13 percent loss of data using multiplate samplers due to vandalism and burying of the samplers by sediment (Boward 1992). These results suggested that multiplate samplers not be used in coastal plain streams with velocities less than 0.5 fps. Artificial substrate samplers were not selected because they are prone to vandalism and may underestimate biological quality due to fouling with sediment.

3. Sample Area

Literature Review

No literature was found that evaluated the optimal level of effort in coastal plain streams using dip nets.

Workgroup Studies

Two studies were conducted by MACS Workgroup members to determine the optimal area to sample (i.e., number of jabs). The Delaware DNREC collected replicate samples in a stream near Bridgeville, Delaware (Maxted et al. 1992). Six metrics were used to evaluate five levels of effort ; taxonomic richness (TR), EPT richness (EPT), percent EPT abundance (% EPT), percent Chironomidae abundance (% C), percent dominant taxon (% DT), and Hilsenhoff Biotic Index (HBI). The largest change in metric values occurred within the first two levels of effort (18 jabs); relatively little change in metrics values occurred beyond 18 jabs (Table B6). There was insufficient data to conduct statistical analyses. The results provided a subjective measure of the sensitivity of the collection method to sample area.

Table B6. Effect of sample area on biological metrics (family level) using the MACS Workgroup method (Maxted et al. 1992).

Level of Effort (# of jabs)	TR	EPT	% EPT	% C	% DT	HBI
9	20	3	23.5	12.9	22.4	6.64
18	26	3	11.7	9.1	18.9	6.97
27	29	3	11.7	9.1	17.3	6.95
36	32	4	13.4	9.0	14.4	6.67
45	34	4	16.5	14.2	14.2	6.61

A second analysis was performed by the Workgroup as part of the evaluation of collection devices (MACS Workgroup 1993a). Replicate collections made at two sites provided the basis for comparing three levels of effort (20, 40, and 60 jabs). There was no apparent difference in metric values between the three levels of effort (Table B7). These two sites cover the full range of velocity condition for the coastal plain streams from no detectable velocity for Blackbird Creek to a relatively fast velocity of 0.6-1.0 fps for Toms River. There was insufficient data to conduct statistical analyses. The results provided a subjective measure of the sensitivity of the collection method to sample area.

Table B7. Effect of sample area on biological metrics (family level) using the MACS Workgroup method (MACS Workgroup 1993a).

Level of Effort (# of jabs)	TR	EPT	% EPT	% C	% DT	HBI
Toms River, NJ						
20 jabs	10	6	10	85	84	5.6
40 jabs	15	7	17	77	77	6.1
60 jabs	19	9	20	72	72	5.9
Blackbird Creek, DE						
20 jabs	13	3	30	20	30	5.0
40 jabs	14	3	22	29	30	5.2
60 jabs	17	3	18	36	36	5.5

4. Subsampling and Taxonomy

The single 100-organism subsample was selected as the standard sample size for data analysis. Individual States have compared metric data derived from 100, 200, and 300-organism subsamples as well as whole picked (i.e., all macroinvertebrates removed) samples. No attempt is made here to summarize these results. The recommended level of subsampling was determined from a consensus of the Workgroup.

Workgroup data collected in 1995 show no difference between 100-organism and 200-organism subsamples for the % EPT, %C, %DT, and HBI metrics at the genus level (MACS Workgroup 1995). The richness metrics (TR and EPT) were 25% lower for the 100-organism subsample compared to the 200-organism subsample. The recommended level of subsampling will be evaluated further as additional replicate subsampling data are collected.

The genus level was selected as the minimum level of taxonomy. This was determined from a consensus of the Workgroup. While some environmental stressors may be evaluated at the family or even order levels, the additional information gained at the genus level provides the basis for more in-depth analyses. The genus level also assigns a scientific name to each organism. Genus level taxonomy was determined to be cost-effective when combined with subsampling. The species level was determined to be highly variable due to differences in the knowledge, keys, and nomenclature of each taxonomists. The recommended methods often yields early instars that are difficult to identify beyond the genus level.

Two experienced taxonomist separately identified a reference collection of 201 species collected in the coastal plain of Delaware. 28% of the identifications were different at the species level, 14% were different at the genus level, and 1% were different at the family level (Maxted, personal communication). Both taxonomists had over 20 years of experience in freshwater invertebrate taxonomy. Most of the differences were due to difficulties in the identification of early instars. Identification should be based upon the evidence provided by each specimen (no educated guessing), and sorting should avoid very early instars that are difficult to identify at the genus level.

5. Analysis of Variance

There is insufficient replicate data to estimate the variability in RBP scores using the recommended method. In addition, the scoring criteria (thresholds) for calculating RBP scores are likely to be different in the coastal plain than those used by the States in the higher gradient streams (e.g., piedmont riffles). The Workgroup is currently evaluating metrics and RBP scoring criteria from data collected using the recommended method, and the results will be provided in future updates of these methods. Future efforts of the Workgroup will include the collection of replicate samples for the purpose of estimating the variability in RBP scores.

Replicate collections (n=6) were made by the Workgroup at two sites during the Spring of 1995 (MACS Workgroup 1996). Site 1 (Maidstone Branch) represented "good" biological and physical habitat conditions (natural wooded floodplain) while Site 2 (Tappahanna Ditch) represented "poor" conditions (channelized, unshaded) (Figure B2). Metrics were derived from 100-organism subsamples identified to the genus level. These data were used to evaluate the variability in biological metrics between the six States. CV values ranged from 2.2 to 53.1 percent (Table B8). The EPT, %EPT, and %C metrics were more variable than TR and HBI metrics (Table B8).

Table B8. Mean, standard deviation (SD), and coefficient of variation (CV) for six biological metrics derived from replicate collections (n=6) using the MACS Workgroup method; natural (S1) and channelized (S2) stream; genus level (MACS Workgroup 1995).

	TR		EPT		% EPT		% C		% DT		HBI	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
mean	33.0	18.0	5.0	2.7	6.9	17.0	68.1	28.3	20.9	44.0	5.8	5.9
SD	4.6	2.4	2.0	0.8	3.7	7.7	11.4	14.1	6.6	10.0	0.1	0.2
CV	**13.8**	**13.1**	**40.0**	**30.6**	**53.1**	**45.1**	**16.7**	**49.9**	**31.7**	**22.7**	**2.2**	**3.4**

Habitat Assessment

This habitat assessment method is a visual-based technique for assessing habitat quality. It was designed to provide quantitative measures of habitat quality based upon qualitative estimates of selected habitat attributes. This approach was selected over detailed quantitative measures of specific habitat attributes in order to provide a rapid measure of habitat quality. More detailed measures of habitat quality may be needed to meet specific project objectives. Habitat parameters were selected to reflect the overall characteristics of habitat quality necessary to protect aquatic organisms, particularly macroinvertebrates and fish.

The assessment procedures and parameters were adapted from EPA guidance (Plafkin et al. 1989). The parameters used to evaluate riffle habitats were modified by the MACS Workgroup to reflect the conditions commonly found in low gradient streams. Modifications were made by first eliminating parameters not sensitive to habitat conditions of the coastal plain streams and then modifying the remaining parameters using literature, field testing, and best professional judgment. A technical report on the development and field testing of the habitat assessment method by the MACS Workgroup is available (MACS Workgroup 1993b).

The overall process of numerically scoring habitat quality is taken from EPA guidance (Plafkin et al. 1989), in particular Ball (1982) and Platts, Megahan, and Minshall (1983). The technical basis for the seven habitat parameters used in the MACS Workgroup method is also taken largely from EPA guidance (USEPA 1983; Plafkin et al. 1989). An update of EPA's habitat assessment method has been developed for low gradient streams (Barbour and Stribling 1993) along with a compilation of the literature that supports the various habitat parameters (Barbour and Stribling 1991). The technical basis that supports each of the seven habitat parameters selected by the MACS Workgroup is discussed below.

1. Channel Modification (CM)

Scoring of this parameter is based upon the degree of channel reconstruction and the frequency of bends. EPA has prepared a summary of the literature on the affects of channelization on the physical, chemical, and biological characteristics of nontidal streams (EPA 1983). Channelization eliminates stable habitats from the stream channel, eliminates pools, reduces the depth through the widening of the channel, and degrades shoreline habitat. Gorman and Karr (1978) demonstrated a relationship between overall habitat structure and fish species diversity. Recently, Smock and Gilinsky (1992) prepared a summary of the literature on the affects of channelization on stream ecology and water quality.

Tarplee, Louder, and Weber (1971) studied the affects of channelization on the fish and macrobenthos of 46 channelized stream in North Carolina. They found that natural streams had 3 times the total fish biomass (pounds per unit area), 4 times the game fish biomass, 4 times the number of harvestable game fish (per unit area), and 3 times the average fish size (by weight) compared to channelized streams. They concluded that the greatest single factor affecting the aquatic community was the loss of stream cover and its affect on temperature and dissolved oxygen.

The removal of bends reduces the stream channel length and thereby increases the slope and current velocity. Channelization of two streams in Iowa (Bulkley 1975) and Oklahoma (Barclay 1980) reduced average channel length by 45 percent and 31 percent, respectively. This reduction in channel length reduces the living space for aquatic organisms. Zimmer and Bachman (1976) found that habitat diversity was directly related to the degree of meandering in natural and channelized streams in Iowa. The straightening of the channel directly degrades bank habitat which is a productive habitat for macroinvertebrates and fish.

Channelization also lowers the surrounding water table and alters the hydrology of adjacent wetlands; i.e., draining wetlands. Placement of spoil material adjacent to the stream channel creates a berm which isolates the stream from the adjacent floodplain. Channelization reduces the streams capacity to assimilate contaminants by more efficiently delivering water and contaminants downstream. The alteration of stream channels to promote drainage directly and indirectly affect streams with regard to aquatic life, wildlife, water quality, and flood attenuation.

2. Instream Habitat (IH)

Scoring of his parameter is based upon the abundance and diversity of submerged stable habitats. The importance of stable habitats is presented in the previous section on Macroinvertebrate Assessment . In addition, macroinvertebrates are the primary food source for the fish community in coastal plain streams. Of the 55 fish species collected in nontidal coastal plain streams in Delaware (Shirey 1989), 80 percent rely predominantly on macroinvertebrates as their primary food source (Shirey 1993). Tarplee, Louder, and Weber (1971) found that natural streams had 5 times the macroinvertebrate biomass of channelized streams.

Stable habitats also benefit water quality by trapping sediments and suspended organic matter, nutrients, and other contaminants. Smock, Metzler, and Gladden (1989) studied two coastal plain streams in Southeastern Virginia. They found that snags stored 21 percent and 85 percent of the course particulate organic matter in Colliers Creek and Buzzards Branch, respectively. Snags also serve to divert flow to surrounding wetland floodplain areas to further remove suspended and dissolved contaminants.

3. Pools (P)

Scoring of this parameter is based upon the abundance and diversity of pools. Pools provide living space for aquatic life under drought conditions, and are particularly important to the fish community of small streams (EPA 1983). The selection of 5 pools per 100 meters to define abundant pools was based upon best professional judgment and the frequency of pools found in least impacted streams in the region. The depths selected to define shallow and deep pools was taken from the pool rating system developed by Platts, Megahan, and Minshall (1983).

4. Bank Stability (BS)

Scoring of this parameter is based upon the percentage of the stream bank that shows evidence of erosion. The soil along the banks is held in place by the plant root system. Therefore, the percentage of the banks that are covered in these stable materials is an indicator of the stability of the bank and the potential to cause erosion and sedimentation. Erosion delivers sediment to the stream which fills in pools and smothers productive habitats. Increased sediment production downstream of eroded stream banks degrades habitat, the quality of the aquatic community, and water quality.

The percentages for this parameter recommended by EPA (Plafkin et al. 1989) were taken largely from studies of Western streams where annual rainfall is lower and the growing season shorter than in the Mid-Atlantic and Southeastern regions. Thus, stream channels are generally more vegetated in the East than in the West. These percentages were modified by the MACS Workgroup to reflect the range of conditions that occur in the Mid-Atlantic Coastal Plain region.

5. Bank Vegetative Type (BV)

Scoring of this parameter is based upon the types of vegetation along the stream bank. Trees and woody shrubs have deeper and more permanent root systems than grasses and herbaceous plants (Kohnke and Bertrand 1959) and are, therefore, more effective in reducing erosion. Woody plants provide this benefit throughout the year while grasses and herbaceous plants provide this benefit only during growing season. In addition, trees and shrubs provide a source for woody debris in the stream channel that is the principle stable aquatic habitat in coastal plain streams.

6. Shading (S)

Scoring of this parameter is based upon the percentage of the water surface that is shaded by vegetation. The lack of shade affects the aquatic community by raising the water temperature and promoting the excessive growth of submerged macrophytes and algae. Algae indirectly affects the community through diel variation in dissolved oxygen (DO), pH, and temperature.

Hewlett and Fortson (1982) found that clearcutting in Oregon increased the maximum and minimum stream temperature in June by 8°C (14°F) and 4°C (7°F), respectively. Similarly, Karr and Schlosser (1976) showed that the removal of shade in agricultural watersheds in Illinois increase stream temperatures by 5-8°C (10-15°F). Other studies have documented the importance of shade in moderating stream temperatures (Karr and Schlosser 1978, Moring 1975, Campbell 1970). A summary of the literature on the affects of shade on stream temperature is available from the US Fish and Wildlife Service (Bartholow 1989) and the National Council of the Paper Industry for Air and Stream Improvement (NCASI 1987). Shade is a major factor in riparian evaluations in EPA guidance (USEPA 1983). Shade is also identified as an important factor in many papers that address the relationship between riparian forests and stream quality (see discussion of Riparian Zone Width).

In Delaware, continuous measurements of temperature and DO were taken over a 40 day period in shaded and unshaded sites during the Summer of 1993 (Maxted et al. 1995). Unshaded sites exceeded the daily minimum DO criterion of 4.0 ppm on 73 percent of the days surveyed while the maximum temperature criteria of 86°F was exceeded on 38 percent of the days surveyed. There were no exceedence of either criteria at shaded sites. These results show a direct relationship between shade and the exceedence of temperature and DO criteria.

Undisturbed streams in the Mid-Atlantic Coastal Plain region are in wooded floodplains that are well shaded by vegetation. They are open to direct sunlight only in isolated spots near fallen trees or near beaver activity. Open unshaded stream channels in the coastal plain are almost exclusively the result of human activities. Therefore, shade provides a measure of anthropogenic disturbance.

The percentages used to score this parameter were based upon best professional judgment. Greater than 25 percent of the water surface shaded was considered sufficient to minimize temperature and DO problems. Since some direct sunlight promotes the growth of submerged macrophytes and thus diversifies overall habitat quality, a mixture of light conditions was considered more beneficial than fully shaded conditions. Less than 25 percent shaded was used to define a predominantly open channel that would exhibit temperature and DO problems related to the lack of shade.

7. Riparian Zone Width (RZ)

Scoring of this parameter is based upon the width of the riparian zone where there is no evidence of human activity. Two factors were considered for this parameter; (1) the relationship between buffer width and water quality and (2) the relationship between buffer width and shading of the water surface.

There is extensive literature on the water quality benefits of riparian forested buffers, and in particular forested buffers in agricultural areas (USEPA 1995b, Lowrance 1995, Lowrance et al. 1986, Lowrance et al. 1985; Lowrance et al. 1984a; Lowrance et al. 1984b; Peterjohn and Correll 1989; Brinson et al. 1981; and Cooper et al. 1987). Since streams in the coastal plain are often associated with wetlands, the literature on the water quality benefits of wetlands is also pertinent. No attempt has been made here to summarize the literature in these areas. Winger (1986) and Kuenzler (1989) have prepared summaries of the water quality benefits of riparian forested wetlands of the Southeastern United States. Detailed summaries of the literature on the water quality functions of wetlands have been prepared by the US Department of the Army, Corps of Engineers (Nixon and Lee 1986), the US Environmental Protection Agency (Johnston et al. 1990), and the US Department of Agriculture, Soil Conservation Service (Dickerman 1985). The role of freshwater wetlands in sediment and nutrient retention has recently been summarized (Strecker et al. 1992 and Johnston et al. 1991).

The shading of the stream channel is dependent upon the width of the riparian zone. Brazier and Brown (1973) found that canopy density along the path of solar radiation (e.g., south side) in Oregon was the primary factor affecting shading capacity. The width of the stream and the height and density of vegetation also affect the width needed to shade the channel. Barton and Taylor (1985) found a relationship between stream temperature and buffer strip length and width, and recommended a minimum 10 meter (33 feet) buffer width. Bartholow (1989) developed a relationship between buffer width and percent shade and defined a maximum buffer width of 18 meter (60 feet).

The relationship developed by Bartholow (1989) was used by Barbour and Stribling (1991) as the basis for scoring the "Riparian Vegetative Zone Width" parameter. The criteria selected by Barbour and Stribling (1993) were adopted by the MACS Workgroup for scoring this parameter.

8. Analysis of Variance

The habitat assessment method was developed through revision and field testing by the MACS Workgroup. Testing in the field involved the independent scoring by 7-13 Workgroup members at 7 sites on 3 occasions; two sites in Virginia on May 8, 1990 (MACS Workgroup 1993a), three sites in Maryland on June 11, 1992 (MACS Workgroup 1993a), and two sites in Delaware on April 27, 1995 (MACS Workgroup 1995). The testing in Delaware used the habitat parameters and criteria presented in this document. Generally, the variability in total habitat scores decreased with each field test. Scoring and testing was done primarily in streams with “good” and “poor” habitat scores (Figure B1). No sites were scored middle or “fair” scoring range (e.g., 60-80 points). It is likely that scores in this range will have greater variability between investigators than scores in the low and high ranges.

The data collected in Delaware provides an estimate of the variability in scoring using the recommended method (MACS Workgroup 1995). Variance was measured using the standard deviation (SD), the coefficient of variation (SD/mean - CV), and the percent deviation (SD/maximum possible points - PD). The PD statistic was used to compare the variability between sites with different habitat scores. Extremely high CV values (e.g., > 100%) occurred where mean scores are low (e.g., < 1 point). Thus, the PD provides a measure of data variability independent of habitat score.

The PD on individual habitat parameters ranged from a low of 1.9 percent for the Shading parameter at Site 1 to a high of 14.5 percent for the Pool parameter at Site 2 (Table B9). Therefore, the scores for any one habitat parameter varied no more than 3 points out of 20 points between Workgroup members (i.e., +/- 1 standard deviation). The PD on the total scores were 4.9 percent for Site 1 and 3.8 percent for Site 2 (Table B9). Therefore, the total habitat scores varied no more than 7 points out of 140 (+/- 5%) between Workgroup members (i.e., +/- 1 standard deviation). Variability is likely to be greater for scores in the middle ranges (“fair” quality).

These results show sensitivity in the scoring between sites with different levels of anthropogenic disturbance. Site 1 (Maidstone Branch) was a wooded floodplain with minimal human disturbance while Site 2 (Tappahanna Ditch) was a channelized stream with a heavily managed riparian zone (Figure B2).

There was an 82 point difference in mean habitat score between the two sites using the recommended method (Figure B1) (Table B9).

Based upon these data, the variability in habitat scores reported as a percent of reference using the Workgroup method is estimated to be +/- 5 percent at "good" and "poor" sites (i.e., within +/- 1 standard deviation). Further testing by the Workgroup is needed to estimate the variance at sites with intermediate habitat conditions (i.e., "fair" quality).

Figure B1. Distribution in total habitat scores between investigators at seven sites; in Virginia and Maryland (MACS Workgroup 1993), and in Delaware (MACS Workgroup 1995).

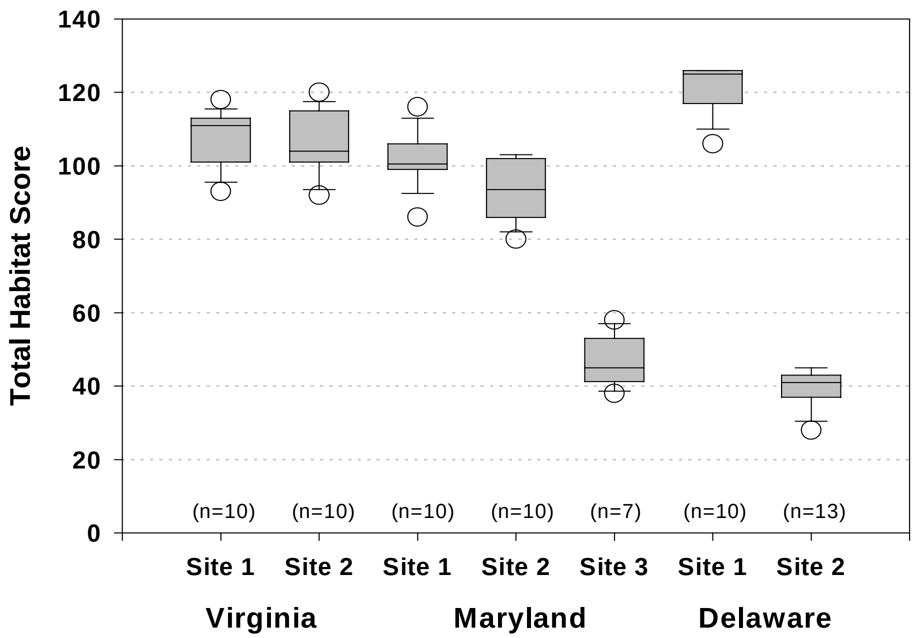

Table B9. Mean, standard deviation (SD), coefficient of variation (CV as %), and percent deviation (PD as %) for seven habitat metrics and total habitat scores derived from replicate collections (MACS Workgroup 1995); see text for abbreviations.

		CM	IH	P	BS	BV	S	RZ	Total
Site 1	(n=10)								
mean		17.7	15.8	16.6	17.1	17.0	17.8	19.5	121.5
SD		1.9	2.4	2.4	2.1	2.6	1.3	0.8	6.9
CV		11.0	15.2	14.5	12.5	15.3	7.4	4.4	5.7
PD		**9.7**	**12.0**	**12.1**	**10.7**	**12.9**	**6.6**	**4.2**	**4.9**
Site 2	(n=13)								
mean		6.5	6.6	7.5	9.5	8.4	0.1	0.8	39.5
SD		2.0	1.9	2.9	2.1	1.7	0.4	1.0	5.3
CV		31.3	29.3	38.9	22.5	19.7	244.1	131.7	13.5
PD		**10.1**	**9.7**	**14.5**	**10.7**	**8.3**	**1.9**	**5.1**	**3.8**

Figure B2. Photographs of sites where the recommended methods were tested by the MACS Workgroup (MACS Workgroup 1995); habitat scores out of a possible 140 points (see Table B9).

Site 1 - Maidstone Branch, Kent County, Delaware Mean Habitat Score = 121.5

Site 2 - Tappahanna Ditch, Kent County, Delaware Mean Habitat Score = 39.5