Department of Public Works
Bureau of Environmental Services
Stormwater Management Division

Biological Assessment of the Middle Patuxent River Watershed, Howard County, Maryland

Spring 2002 Index Period

Middle Patuxent River

Final Report
April, 2003

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ACKNOWLEDGMENT

The principal authors of this report are Kristen L. Pavlik and James B. Stribling, both of Tetra Tech. They were assisted by Erik W. Leppo, S. Abby Markowitz, David W. Bressler, and Michael J. Paul, also of Tetra Tech. This report presents results from the first and second years of sampling by the Howard County Biological Monitoring and Assessment Program.

The program's Technical Advisory Committee (TAC), assembled by Howard County, to provide support and guidance, included: Howard Saltzman and Angela Morales, Stormwater Management Division (SWMD), Susan Overstreet, Department of Planning and Zoning (DPZ) and Brenda Belensky, Department of Recreation and Parks (DRP), Ron Klauda, (MBSS/DNR), Wayne Davis (USEPA), and Keith Van Ness (Montgomery County Department of Environmental Protection).

Fieldwork was conducted by Tetra Tech staff including Kristen Pavlik and Colin Hill. Other Tetra Tech staff (Carmela Biddle, Carolina Gallardo, Matthew Geiman, Christopher LaMotte, Andria Langham, and Angela Seis) performed laboratory processing (sorting and subsampling) of the Middle Patuxent River watershed samples. Amanda Richardson, also of Tetra Tech, completed quality assurance/quality control assessments on data entered into and retrieved from the Ecological Data Application System (EDAS). Benthic macroinvertebrates from this watershed were identified by Dr. R. Deedee Kathman, of Aquatic Resources Center (ARC; College Station, Tennessee). Martin Hurd, of the Maryland Biological Stream Survey (MBSS), provided additional program data. Hunter Loftin, Linda Shook, and Brenda Decker, all of Tetra Tech, assisted with budget tracking and clerical support. The appropriate citation for this report is:

Pavlik, K.L. and J.B. Stribling. 2003. *Biological Assessment of the Middle Patuxent River Watershed, Howard County, Maryland.* Prepared by Tetra Tech, Inc., Owings Mills, MD for Howard County, Department of Public Works. Stormwater Management Division. Columbia, MD.

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ABSTRACT

Stream biota rely on the quality of physical habitat, hydrology, and water chemistry for their survival and reproduction. Human activities, such as land cover alterations, can affect abiotic stream conditions which, in turn, can influence biotic assemblages. Thus, many biological monitoring and assessment programs use composite biological indicators both as a measure of stream ecological response to land cover conversions, and as an overall descriptor of water resource integrity.

Several indicators (benthic macroinvertebrates, physical habitat quality, sediment particle size distribution, and channel size) were sampled or measured at 30 stream locations in the Middle Patuxent River watershed in Howard County, Maryland during March 2002. Sampling site locations were selected at random and were pre-stratified by subwatershed (Upper, Middle, and Lower) and stream order, so that 10 sites were selected in each subwatershed. Benthic macroinvertebrates were collected using Maryland Biological Stream Survey (MBSS) methods (multihabitat, 20-jab).

This report presents the sampling and assessment results for all three subwatersheds of the Middle Patuxent. Composite assessments are presented for watershed-scale biological and habitat assessments. The report also presents individual site by site assessments. Watershed comparisons were also made between the 2001 and 2002 results.

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ACRONYMS

ARC	Aquatic Resources Center
B-IBI	Benthic Index of Biotic Integrity
BMP	Best Management Practice
BRF	Biological Research Facility
DQO	Data Quality Objectives
DNR	Department of Natural Resources
DPW	Department of Public Works
DPZ	Department of Planning and Zoning
DRP	Department of Recreation and Parks
EDAS	Ecological Data Application System
EPT	Ephemeroptera, Plecoptera, Trichoptera
FLD	Field
MBSS	Maryland Biological Stream Survey
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RBP	Rapid Biological Protocols
RPD	Relative Percent Difference
SD	Standard Deviation
SOP	Standard Operating Procedure
SWMD	Stormwater Management Division
TAC	Technical Advisory Committee
TCR	Taxonomic Certainty Rating
USEPA	United States Environmental Protection Agency
UT	Unnamed Tributary
WRD	Watershed Restoration Division

EXECUTIVE SUMMARY

In 2001, the Howard County Department of Public Works (DPW) Stormwater Management Division (SWMD) initiated biological monitoring for its streams and wadeable rivers on an annual, rotating basin cycle. The primary goal of this program is to assess the current status of the County's streams and watersheds and to establish a baseline for comparing future assessments. The program is designed to provide assessments at three geographic scales: stream-specific, watershed wide; and, after the three-year sampling rotation is complete, county-wide. The Howard County biomonitoring program was designed to be comparable with the statewide Maryland Biological Stream Survey (MBSS). Comparability allows a greater density of sampling locations with consistent interpretation. The Little Patuxent River, Cattail Creek, and Brighton Dam watersheds were sampled in 2001. This report presents results of 2002 assessment in the Middle Patuxent River watershed was sampled during the 2002 Spring Index Period. Sampling methods were identical to those used by the MBSS: benthic macroinvertebrates sampled using a D-frame net in multiple habitats (20-jab method), visual-based assessment of physical habitat quality, and selected field chemistry measurements. In addition to the MBSS protocols, substrate particle size distribution and stream channel cross sectional area were also evaluated. Biological condition scores were derived using the MBSS's Benthic Index of Biotic Integrity (B-IBI). The B-IBI was used to rate the biological condition of each site as good, fair, poor, or very poor. Assessment of physical habitat quality combined MBSS methods and USEPA's Rapid Bioassessment Protocols (RBP). A rating scale based on the latter was assigned to each stream, and used categories of: comparable, supporting, partially supporting, or non-supporting. MBSS measures were taken for additional information. Results of the study will be used for developing protection/restoration priorities. The public will be able to access the yearly report via the County website, as well as through brochures highlighting specific watersheds.

All three subwatersheds received a "fair" biological quality rating and a "non supporting" physical habitat assessment. Predominant sources of stressors seemed to be agriculture, transportation corridors, and the creation of housing developments. Two of the streams from the sampling plan of the Upper Middle Patuxent subwatershed were dry, most likely due to the recent regional drought.

I. PROGRAM OVERVIEW

INTRODUCTION

Background

The Howard County Stormwater Management Division (SWMD) began a multi-year, rotating basin sampling effort to assess the ecological condition of streams and watersheds across the county in 2001. That year, the Little Patuxent River, Cattail Creek, and Upper and Lower Brighton Dam subwatersheds were assessed, followed by the Middle Patuxent River basin in 2002. This report presents the sampling and assessment results from Upper, Middle, and Lower subwatersheds of the Middle Patuxent River basin.

Streams in Howard County are tributaries of the Patuxent and Patapsco Rivers (Figure 3). Since streams of all sizes function as components of larger watershed systems (Vannote et al. 1980, Frissell et al. 1986, Pringle et al. 1988, Power et al. 1988), monitoring conditions in the county will also contribute to an understanding of ecological conditions across the state. Moreover, as the Patuxent and Patapsco drain into the Chesapeake Bay, if we uncover the conditions of smaller streams leading into both rivers, we also gain some understanding of conditions contributing to the Chesapeake Bay.

The principal indicator of stream health is based on the structure and function of the aquatic biota, since they are dependent on instream physical, chemical, and hydrologic characteristics. Thus, ecological condition can be measured through direct sampling and analysis of resident instream biota (Karr et al. 1986, Stribling et al. 1998, Barbour et al 1999). As instream conditions change due to human activities (land cover conversions, erosive and contaminated stormwater discharges, destruction of riparian vegetation, landscape and in-channel erosion, and others), in response, so will the biota.

The primary goals of the County biomonitoring program are to assess the ecological status of Howard County streams and watersheds, and to establish a baseline for comparing future assessments. Results will also be related to potential programmatic activities, such as BMP siting, installation, and evaluation (Stribling et al. 2001); stormwater discharge permits; contributing to restorations initiatives (such as DNR's watershed restoration action strategy [WRAS]; and guidelines for low impact development [LID] (PG County 2000).

Purpose of Biological and Physical Habitat Assessment

Physical habitat quality was also assessed at each sampling location (Barbour et al. 1999), and reflects the potential of the stream to support a vigorous biota and to maintain normal hydrogeomorphic function . As land use/land cover conversions occur in a watershed, there are changes in stream and watershed hydrology that cause acceleration of stream channel erosion. Impacts on physical habitat through increased farming operations, housing density, and other urban-suburban developments cause sedimentation, degradation of riparian vegetation, and bank instability, leading to reduced overall habitat quality (Richards et al. 1996).

Although habitat alteration can lead to a diminished capacity of a stream to support certain aquatic organisms, many other factors also affect the biological quality of any stream or watershed (Figure 1). Degraded habitat quality, interruption of natural hydrologic regimes, alterations in food/energy sources and water quality, and unnatural biological interactions cause the biological condition of a stream to worsen (Karr et al. 1986). Potential stressors that cause this type of degradation include nutrient enrichment, toxic spills, flood control engineering, temperature extremes due to depletion of riparian zones or effluent discharge, elevated levels of suspended sediment due to animals access, clearing of riparian areas, construction runoff, etc. Sources of these stressors exist throughout Howard County. However, although biological monitoring is a critical tool for detecting impairment, it can not identify specific causal relationships between stressors and stressor sources (Cormier et al. 2000). This report reflects the current biological and physical habitat condition of the Middle Patuxent River watershed, and provides potential reasons for those conditions.

Participating Agencies

Membership on the County's Technical Advisory Committee (TAC) included Howard County Government (Stormwater Management Division (SWMD), Department of Recreation and Parks (DRP), and Department of Planning and Zoning (DPZ)), the State of Maryland Department of Natural Resources Biological Stream Survey (MBSS), Montgomery County Department of

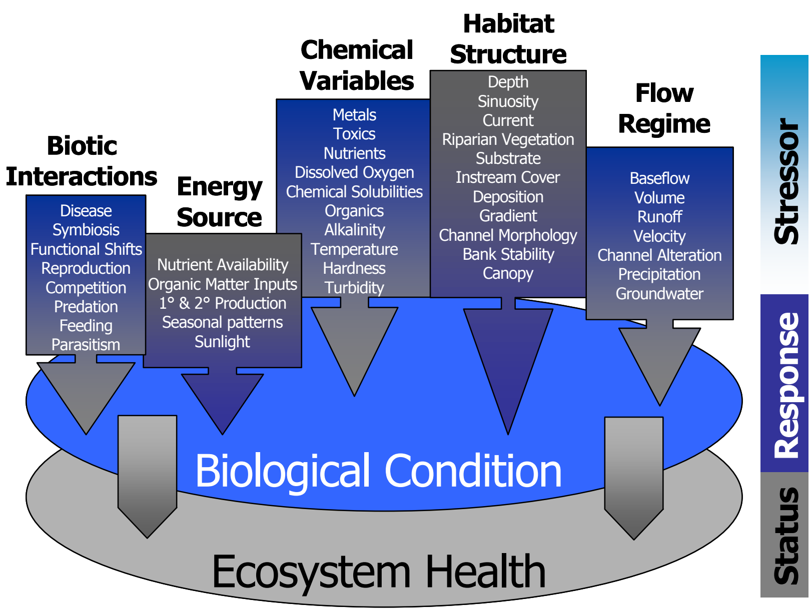

Figure 1. Five classes of environmental variables that affect water resource integrity and overall biological condition (modified from Karr et al. 1999).

Environmental Protection (DEP), and representatives from USEPA. Selected TAC members (Howard County SWMD, DPZ, DRP; MBSS) reviewed the first draft of this report, and provided comments that were integrated into the final report.

METHODS

Network Design

Summary of Sampling Design

The measurement and data quality objectives (MQOs and DQOs) on which the Howard County biological monitoring program is based can be found in the *Quality Assurance Project Plan (QAPP) for Howard County Biological Monitoring and Assessment Program* (DPW 2001). The overall sampling design was developed to be directly comparable to the MBSS, and to allow the eventual sharing of data assessment among agencies. The program is designed so that 10 sites in three subwatersheds per year are sampled (n = 30/year). A total of 15 subwatersheds will be sampled during a span of three years. Specific details of the sampling design can be found in *Design of the Biological Monitoring and Assessment Program for Howard County Maryland* (Pavlik et al. 2001). Spatial allocation of the sampling segments was based on random selection within Strahler (1957) stream orders. The number of sampling segments within each of the first through fourth order channel distances (m) was proportional to total stream length. Thus, final selection and placement of sampling segments was random, and stratified by subwatershed and stream order.

To address issues of measurement error (= systematic error), duplicate (repeated) biological samples were taken at 10% of the overall number of sites. Sites where this repeat sampling occurred were chosen at random, before the sampling event took place.

Site Selection

In 2001, six subwatersheds were sampled: Upper and Lower Brighton Dam and Cattail Creek (Howard County) as well as the Upper, Middle, and Lower Little Patuxent (DNR/Watershed Restoration Division (WRD)). The sites sampled by WRD were completed as part of the statewide Watershed Restoration Action Strategy (WRAS) cooperative. The remaining nine subwatersheds were randomly selected, three more during the second year (Figure 2), six in the third year (Table 1). In year 2002, 10 additional primary and 10 secondary (alternate) sites were chosen in the three subwatersheds of the Middle Patuxent River watershed (Upper, Middle, and Lower). Ten percent of the sites in each watershed were randomly selected as quality control (QC) sites, and one additional sample (biology, chemistry, and habitat) was at each QC site. Figure 3 shows the location of all of the sites sampled in year two.

Field Sampling and Laboratory Processing

One two-person field team completed all sampling during the Spring 2002 Index Period. Benthic macroinvertebrate sampling and physical habitat assessments were conducted in accordance with the Standard Operating Procedures (SOP FLD003/09.07.00; FLD005/02.27.01) contained within the Quality Assurance Project Plan (QAPP) (DPW 2001), as well as methods explained in the

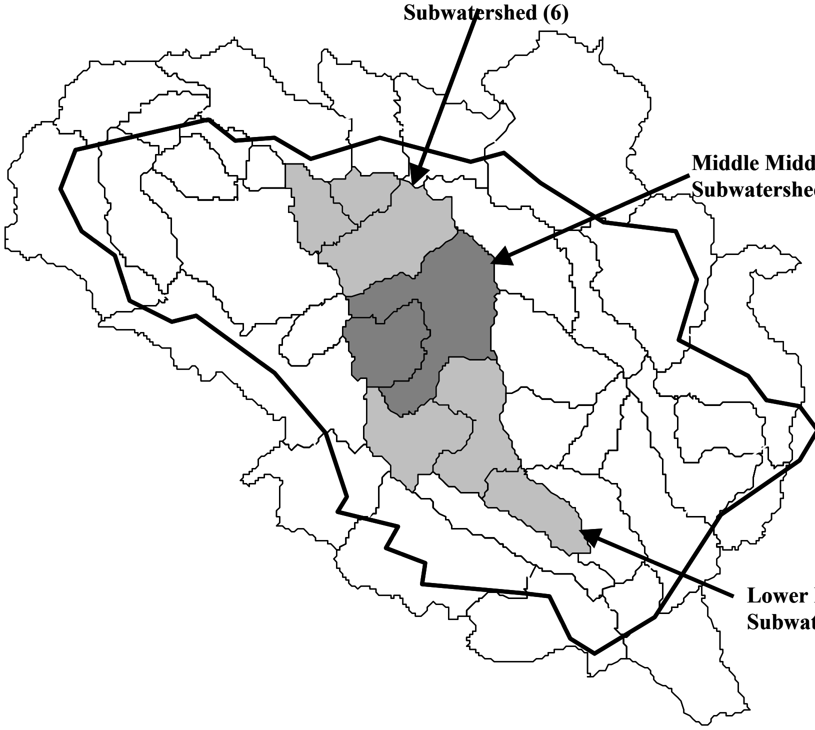

Figure 2. Howard County, Maryland. Watersheds sampled as part of the 2002 Spring Index Period. Numbers in parentheses correlate to the subwatershed numbers in Table 2.

MBSS Sampling Manual (Kazyak 2000). Field chemistry sampling, modified Wolman pebble count, and channel cross sections in the Middle Patuxent River watershed were conducted according to SOPs BRF050/07.07.97, FLD032/01.25.99, and FLD043/07.19.99, respectively.

Benthic Sampling and Processing

At each site, benthic macroinvertebrates were collected from a 75 m reach by sampling approximately 20 ft^2 of surface area with a D-frame net (595 µ mesh), in proportion to the frequency of habitat types (riffles, snags, vegetated banks, sandy bottom) found within the reach. All sampled material (including leaf litter, small woody debris, and sediment) was composited in a 595 µ sieve bucket, placed in one or more one L sample containers and preserved in 70 - 80% ethanol. Internal and external labels were completed for each container. Samples were tracked

Table 1. Howard County sampling schedule by watershed. WRD indicates that field sampling and laboratory processing of benthic samples was performed by DNR Watershed Restoration Division.

Year	Watershed Name or Surrogate	Subwatershed #	Primary Sampling Unit (PSU)
1 (2001)	Little Patuxent River	11	Upper Little Patuxent (10 sites, WRD)
		12	Mid Little Patuxent (10 sites, WRD)
		13	Lower Little Patuxent (10 sites, WRD)
	Brighton Dam	2	Upper Brighton Dam (10 sites)
		5	Lower Brighton Dam (10 sites)
	Cattail Creek	3	Cattail Creek (10 sites)
2 (2002)	Middle Patuxent River	6	Upper Middle Patuxent (10 sites)
		7	Mid Middle Patuxent (10 sites)
		8	Lower Middle Patuxent (10 sites)
3 (2003)	Boundary Tributaries	10	S Branch Patapsco R Tribs (10 sites)
		1	Patapsco River L Br A (10 sites)
		4	Patapsco River L Br B (10 sites)
	Little Patuxent River	14	Hammond Branch (10 sites)
		15	Dorsey Run (10 sites)
		9	Rocky Gorge Dam (10 sites)

on chain-of-custody forms for each subwatershed. In the lab, the composited samples were randomly subsampled to approximately 100 organisms and identified to genus level (Howard County DPW/SWMD 2001, Boward and Friedman 2000).

Benthic Taxonomy

Benthic macroinvertebrates were usually identified to the genus level. In some cases, e.g., when individuals were of early instars or had damaged or missing diagnostic morphological features, identification was restricted to a higher taxonomic level, such as family. All identifications were performed by ARC, College Grove, Tennessee (R. D. Kathmann, principal). Taxonomic data were received in Excel spreadsheets and were loaded into the Ecological Data Application System, Version 3.0 (EDAS; Tetra Tech 1999). Functional feeding group, habit, and tolerance value designations were assigned to each taxon according to Meritt and Cummins (1996), Barbour et al. (1999), and Stribling et al. (1998). Tolerance of a taxon is based on its ability to survive short and long term exposure to physicochemical stressors that result from chemical pollution, hydrologic alteration, or habitat degradation (Stribling et al. 1998). Following Hilsenhoff's basic framework (1982), tolerance values were assigned to individual taxa on a scale of 0-10, with zero identifying those taxa with greatest sensitivity (least tolerance) to stressors, and 10, those taxa with the least sensitivity (greatest tolerance) to stressors.

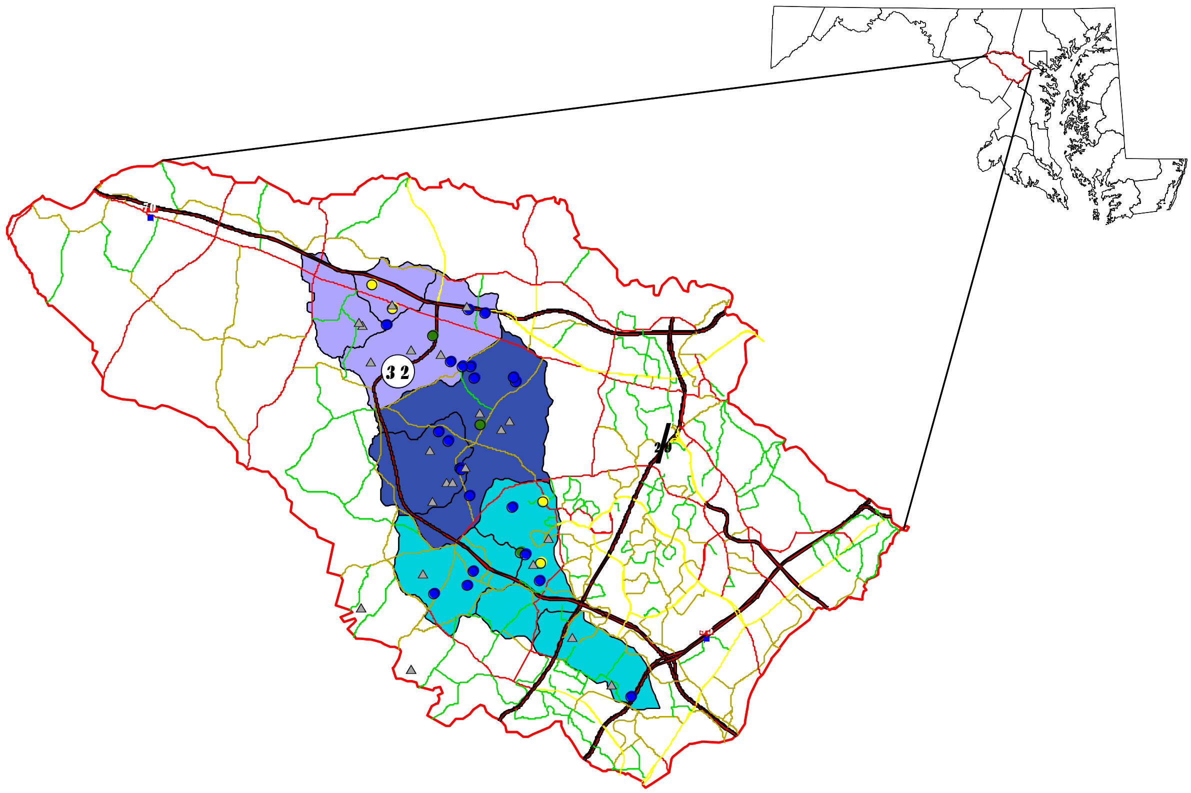

Figure 3. Sites sampled in 2002. Circles indicate Howard County sites, triangles indicated MBSS sites.

Physical Habitat Rating (Methods for Calculation and Scoring)

As outlined in the QAPP (DPW 2001), 10 parameters describing physical habitat quality and stability were visually assessed at each site. These parameters were ranked as optimal, suboptimal, marginal, or poor based on a 20-point scale, with 20 being the best possible (optimal) conditions and zero representing the worst (poor) conditions. A reference database, and thus, a degraded/non-degraded threshold has not been developed by the MBSS to allow direct comparison to physical habitat characteristics. Moreover, MBSS records any qualitative physical habitat measurements during the Summer Index Period, while sampling fish. Currently, Howard County does not support summer time fish and habitat sampling. For these reasons, the non-Coastal plain categories found in the Rapid Bioassessment Protocols (RBPs; Barbour et al. 1999) were used. However, since the RBPs were not used to rate reference sites, the values were summed and compared to the maximum possible score (200) for overall percent comparability for each site. The following 10 parameters were evaluated:

1. *Epifaunal substrate/available cover.* Includes the relative quantity and variety of natural structures in the stream, such as cobble (riffles), large rocks, fallen trees, logs and branches, and undercut banks, available as refuge, feeding, or sites for spawning and nursery functions of aquatic macrofauna.
2. *Embeddedness.* Refers to the extent to which rocks (gravel, cobble, and boulders) and snags are covered or sunken into the silt, or mud of the stream bottom.
3. *Velocity/depth regime.* The occurrence of flow patterns relates to the stream's ability to provide and maintain a stable aquatic environment.
4. *Sediment deposition.* Measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition.
5. *Channel flow status.* The degree to which a stream is filled with water.
6. *Channel alteration.* Measures large-scale (usually anthropogenic) changes in the shape of the stream channel.
7. *Frequency of riffles/bends.* Measures the heterogeneity occurring in a stream. Riffles are a source of high-quality habitat and diverse fauna. Therefore, increased frequency of occurrence greatly enhances the diversity of the stream community.
8. *Bank stability.* Measures whether the stream banks are eroded (or have potential for erosion).
9. *Vegetative protection.* Measures the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone.
10. *Riparian vegetative zone width.* Measures the width of natural vegetation from the edge of the stream bank out through the riparian zone.

Parameters 8-10 evaluate each bank separately. The range of scores for each bank is 0 (poor) to 10 (optimal). Left and right banks were determined looking downstream. Example habitat forms can be found in the QAPP (SOP FLD005/02.27.01). Table 2 provides narrative ratings that correspond to physical habitat quality scores. These scores express the potential of a stream or watershed to support a healthy biological community. Percentages and their narrative ratings were adapted from Plafkin et al. (1989).

Table 2. Total habitat scores as a percentage of maximum possible and corresponding ratings.

% of Maximum	Narrative Habitat Rating	Definition
> 90.0	Comparable	Capable of maintaining biological conditions similar to reference streams
75.1 - 89.9	Supporting	Habitat of somewhat reduced condition, but often can support reference quality biology
60.1 - 75.0	Partially Supporting	Capable of supporting biological conditions of lower quality than reference conditions
< 60.0	Non-Supporting	Not able to maintain healthy biological conditions

Habitat forms developed by MBSS were also filled out at each site in all three subwatersheds. These sheets evaluated land use/land cover designations, occurrence/severity of refuse, buffer breaks (storm drains, roads, pastures, etc.), and channelization. Information from these forms is described in the narrative watershed and site-by-site assessment sections of this report.

Water Quality

Conductivity, dissolved oxygen, pH, and temperature were measured at each site using a Hydrolab Surveyor 4a (SOP BRF050/07.07.97). This instrument was calibrated for each parameter at the start of each sampling day, and the readings were recorded on a calibration log sheet.

Modified Wolman Pebble Count

In addition to the qualitative habitat assessment, this physical habitat feature was measured for all stream sites in the Middle Patuxent watershed. While not a part of the MBSS protocols, the County performed pebble counts to obtain more specific data on stream substrates. Ten transects were proportionally distributed (approximately one every 7.5 m) through the assessment segment beginning on each bank at approximate bankfull level and spanning the width of the active channel. A total of 10 particles per transect were selected by hand (each particle is defined as a size of geologic substrate material within various classes: silt/clay, sand, gravel, cobble, boulder, and bedrock). Each particle was chosen, measured, and recorded at evenly spaced intervals across the channel. To reduce sampler bias, each particle was chosen without the sampler looking in the stream at what was being collected (DPW 2001, SOP FLD 032/01.25.99; Harrelson et al. 1994). Calipers and a sand card were used for particle measurement.

Channel Cross-Section

Although not measured by MBSS, the County includes this measurement to provide a coarse characterization of channel cross-sectional area and changes to channel volume over time. After a thorough visual assessment of the channel characteristics, a representative section was selected for analysis as the cross-section area. A tape measure is drawn between monuments that are set on each bank. The monuments are bank pins, that are temporarily inserted into the ground, in order to keep the tape measure taut during measurement, to ensure accurate height/width values. Height measurements are taken using a laser-level and survey rod. The measurements are taken across the entire width of the channel, at transitional areas along the bank and streambed (e.g., bankfull and thalweg). This procedure is outlined in detail in SOP FLD043/07.19.99 (DPW 2001).

Inability to Sample Stream Sites

Ten primary sampling sites were randomly chosen for each subwatershed. In addition to the primary sites, ten secondary, or replacement, sites were randomly chosen for each subwatershed to provide backup locations in the event that the primary sampling site was deemed unsampleable (i.e., landowner denied access, no channel remaining [filled in] or, channel too deep). Two primary sites in the Middle Patuxent River watershed were replaced with secondary sites because the channel no longer existed (i.e., filled with dirt, grass, etc.). Two sites in the Upper Patuxent subwatershed were could not be sampled for invertebrates because they were dry. However, habitat assessments were still performed at these sites and the drought conditions were taken into account in describing the site.

Data Analysis

Data Structure

Benthic macroinvertebrate, physical habitat, and water quality data were entered into EDAS, Version 3.0 (Tetra Tech 1999). This relational database allows for the management of location and other metadata, taxonomic and count data, raw physical habitat scores, the calculation of metric values, physical habitat and water quality rankings, and B-IBI values.

Biological Index Rating (Methods for Calculation and Scoring)

The biological indicator used in this project is based on the Index of Biological Integrity (IBI; Karr et al. 1986) and uses characteristics of the benthic macroinvertebrate and fish assemblage structure and function to assess the overall water resource condition. Benthic and fish IBIs were developed by the Maryland Biological Stream Survey (MBSS) and calibrated for different geographic areas of Maryland (Stribling et al. 1998, Roth et al. 2000).

The benthic metrics used were those selected and calibrated by the MBSS (Stribling et al. 1998) for Maryland non-Coastal plain streams. The nine metrics calculated for each of the benthic macroinvertebrate samples were:

1. *Total number of taxa.* The taxa richness of a community is commonly used as a qualitative measure of stream water and habitat quality. Stream degradation generally causes a decrease in the total number of taxa (Resh and Grodhaus 1983).
2. *Number of EPT taxa.* Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are generally sensitive to degraded stream conditions. A low number of taxa representing these orders is indicative of stream degradation (Lenat 1988).
3. *Number of Ephemeroptera taxa.* Mayflies are generally sensitive to pollution and the number of mayfly genera represented by individuals in a sample can be an indicator of stream conditions, generally decreasing with increasing stress.

4. *Number of Diptera taxa.* As an order, Dipterans are relatively diverse, as well as variable in their tolerance to stress. Many taxa, especially Chironomidae, have wide distributions and may occur even in highly polluted streams. However, a high diversity of Diptera taxa generally suggests good water and habitat quality.
5. *Percent Ephemeroptera.* The degree to which mayflies dominate the community can indicate the relative success of these generally pollution intolerant individuals in sustaining reproduction. The presence of stresses will reduce the abundance of mayflies relative to other, more tolerant individuals; although, some mayfly groups, such as several genera of the family Baetidae, are known to increase in numbers in cases of nutrient enrichment.
6. *Percent Tanytarsini.* The tribe Tanytarsini is a relatively intolerant group of midges. A high percentage of Tanytarsini, proportional to the overall sample is taken to indicate lower levels of stress. This metric increases with high numbers of Tanytarsini and decreases with high numbers of non-Tanytarsini.
7. *Number of Intolerant Taxa.* Intolerant taxa are the first to be eliminated by perturbations. Often, intolerant taxa are specialists and perturbations can alter or eliminate specialized habitat or water quality requirements. Taxa with tolerance ratings from 0 - 3 were considered intolerant (Hilsenhoff 1987).
8. *Percent Tolerant.* As stressor intensity increases, tolerant individuals (tolerance values 7 - 10) tend to dominate samples. Values for this metric increase in cases of elevated stress. Intolerant individuals become less abundant as stress increases, leading to more opportunity for tolerant taxa to colonize a stream (Hilsenhoff 1987).
9. *Percent Collectors.* Abundance of detritivores, which feed on fine particulate organic matter in deposits, typically decreases with increased disturbance. This ecological response may be highly represented by intolerant taxa.

Each metric was scored on a 5, 3, 1 basis (5 being the best, 1 being the worst) according to stream health. Metric scoring criteria are listed in Table 3. Overall biological index scores are obtained by summing of the nine metric scores for each site, and dividing by the number of metrics (9). Using the format established by MBSS, the resulting value is then compared to the index scoring criteria for translation into narrative categories (Table 4; Stribling et al. 1998). Again, using the MBSS protocol, if the total number of organisms in a sample was less than 60, metrics were not calculated (D. Boward, personal communication). Sites with < 60 organisms were rated as “very poor” unless there was evidence that this represented a natural condition (Stribling et al. 1999).

Table 3. Metric scoring criteria for the Benthic IBI (Stribling et al. 1998).

Benthic Macroinvertebrate Metrics	**Criteria**		
	5	**3**	**1**
Total number of taxa	>22	16 - 22	<16
Number of EPT taxa	>12	5 - 12	<5
Number of Ephemeroptera taxa	>4	2 - 4	<2
Number of Diptera taxa	>9	6 - 9	<6
% Ephemeroptera	>20.3	5.7 - 20.3	<5.7
% Tanytarsini	>4.8	0.0 - 4.8	0.0
Number of intolerant taxa	>8	3 - 8	<3
% tolerant	<11.8	11.8 - 48.0	>48.0
% collectors	>31.0	13.5 - 31.0	<13.5

Table 4. Benthic IBI score ranges and corresponding narrative ratings.

Benthic IBI Score Range	**Narrative Biological Rating**
4.0 - 5.0	Good
3.0 - 3.9	Fair
2.0 - 2.9	Poor
1.0 - 1.9	Very Poor

Watershed Assessments

In this report, a narrative explanation of the biological condition and physical habitat quality scores are given for each site. Important features recorded during sampling or found during subsampling are used to further illustrate potential reasons for site rating. Tolerance values (t.v.) are used in site descriptions to further explain information about the organisms sampled, and how their tolerance to pollution affects the overall metric score. The mean and standard deviation for benthic macroinvertebrate metrics and physical habitat scores were calculated in MS Excel for each watershed. The "Percent of maximum" values presented in the appendix were calculated by dividing the total habitat score by the total possible score represented on the habitat data sheets (method maximum), rather than a mean of field measurements or median from a set of reference sites. RBP habitat data sheets have a total possible score of 200.

QUALITY ASSURANCE/QUALITY CONTROL

Quality Assurance/Quality Control (QA/QC) activities are designed to ensure data quality and document data characteristics. To this end, Howard County has:

- documented standard operating procedures (SOPs) for field sampling, laboratory processing, and completing chain-of-custody forms

The SOPs and procedures for these QC activities are documented in the Howard County Biological Monitoring and Assessment Program plan (DPW 2001). All SOPs are cited in the methods section of this report. Chain-of-custody and sample log sheets were maintained to track the inventory and processing status of all samples. Sample documentation forms are kept in three-ring binders in Tetra Tech's Biological Research Facility (BRF).

- held annual orientation sessions for field sampling

The County field orientation is held as a "refresher" for experienced samplers and as an introduction for new samplers. All two-person field teams are divided into Team Leader and Crew Member. Team Leaders are required to have completed at least one field season as a Crew Member. Crew Members have completed either the introductory or "refresher" field orientation. The orientation for this index period was held on February 19-20, 2002. Part of the first day was devoted to field notes and procedural guidelines. The second day was a hands-on training session at Red Run (in Baltimore County). At least one person from each field crew also attended the MBSS training session conducted by DNR staff, which was held on February 26, 2002, at Morgan Run Natural Environmental Area (Carroll County).

- conducted field audits

The County field crew was visited on-site by an experienced field ecologist who was not involved in the fieldwork for the project. MBSS staff also conducted independent audits of the Howard County field team. Field team procedures were observed for adherence to SOPs and consistency in completion of all data collection requirements including, field data sheets, sample preservation, and photo documentation. Results of field audits can be found in Appendix H. County officials also visited a site to observe the field team's sampling technique.

- repeated continual training and QC checks for sample sorting and subsampling

All sorting and subsampling of samples was performed by a single individual in the Tetra Tech BRF. Early sorting was checked by the laboratory manager and principal project taxonomist to ensure that there were no missed specimens in removed grid debris. Once a 90% sorting efficiency was attained, random checks were performed on approximately one out of 10 samples.

- made consistent use of up-to-date technical taxonomic literature

The target level of taxonomic identification for benthic macroinvertebrates for this project was genus. State-of-the-science technical literature was used throughout and includes the references listed in Table 5.

- verified taxonomy for questionable invertebrate specimens by senior taxonomists or independent specialists

There are two principal sources of error that can cause uncertainty in some taxonomic identifications. One is that the specimens in question are of very early instars (juvenile) and lack morphological structures necessary for positive identification. Another is that any specimen can have damaged or missing morphological features (gills, antennae, legs, caudal filaments) rendering final, positive identification problematic. In addition, for midges, inadequate mounting medium can make genus level identification nearly impossible.

- created, maintained, and used reference collection and voucher samples

During the first sampling year, Howard County created a taxonomic reference collection for benthic macroinvertebrates collected in the county. One or more specimens removed from samples are kept as representative of the taxonomist's concept of that taxon. These organisms of reference quality collected during the spring 2002 index period were added to the reference collection. As sampling continues, the reference collection will be updated with any new example specimens. Specimens in the reference collection were identified by Aquatic Resources Center (ARC), College Grove, TN (R. Deedee Kathman, Ph.D.). Voucher samples (stored in ~ 75% ethanol) are kept from all sampling in Howard County for at least three years in the Tetra Tech BRF.

- standardized data entry and management system

All biological, physical habitat, chemical, and ancillary data were entered directly from field data sheets or Excel spreadsheets into EDAS. The data and analytical results from future index periods will be managed in this system.

- conducted independent QC checks of all data entry

One hundred percent of the data set, once entered, was checked by hand against the original, hand-written field sheets. If discrepancies were encountered, they were corrected in EDAS.

Table 5. The following table lists the taxonomic references used for organism identification.

Burch, J. B. 1989. *North American Freshwater Snails*. Malacological Publ., Hamburg, Michigan. 365p.
Burch, J. B. 1982. *Freshwater Snails (Mollusca: Gastropoda) of North America*. EPA-600/3-82-026, USEPA, Cincinnati, Ohio. 294 p.
Edmunds, G. F., Jr., Jensen, S. K. and Berner, L. 1976. *The Mayflies of North and Central America*. Univ. Minn. Press, Minneapolis. 330 p.
Epler, J. H. 1995. *Identification Manual for the Larval Chironomidae (Diptera) of Florida*. rev. ed. Dept. Environ. Prot., Tallahassee, FL. 9 sections.
Epler, J. H. 1996. *Identification Manual for the Water beetles of Florida (Coleoptera: Dryopidae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Hydraenidae, Hydrophilidae, Noteridae, Psephenidae, Ptilodactylidae, Scirtidae).* Dept. Environ. Prot., Tallahassee. 15 sections.
Kathman, R. D. and Brinkhurst, R. O. 1998. *Guide to the Freshwater Oligochaetes of North America.* Aquatic Resources Center, College Grove, TN. 264 p.
McAlpine, J. F., Peterson, B. V., Shewell, G. E., Teskey, H. J., Vockeroth, J. R. and Wood, D. M. (Coords.) 1981. *Manual of Nearctic Diptera*. Vol. 1, Monogr. 27. Can. Govt. Publ. Centre, Hull, Quebec. 674p.
Merritt, R. W. and Cummins, K. W. 1996. *An Introduction to the Aquatic Insects of North America. 3rd, Edition.* Kendall/Hunt Publ. Co., Dubuque, Iowa. 862p.
Needham, J. G. and Westfall, M. J., Jr. 1954. *A Manual of the Dragonflies of North America (Anisoptera)*. Univ. Calif. Press, Berkeley. 615 p.
Oliver, D. R. and Dillon M. E. 1990. *A Catalog of Nearctic Chironomidae*. Research Branch, Agriculture Canada. Publ. 1857/B:1-89.
Westfall, M. T., Jr. and May, M. L. 1996. *Damselflies of North America*. Scientific Publishers, Gainesville, Florida. 649 p.
Wiederholm, T. (ed.) 1983. Chironomidae of the Holarctic region. Keys and diagnoses. Part l. Larvae. *Entomol. Scand. Suppl*. 19. 457 p.
Wiederholm, T. (ed.) 1986. Chironomidae of the Holarctic region. Keys and diagnoses. Part 2. Pupae. *Entomol. Scand. Suppl*. 28. 482 p.
Wiggins, G.B. 1996. *Larvae of North American Caddisfly Genera (Trichoptera), 2nd Ed.* University of Toronto Press, Toronto. 457 p.

- collected duplicate samples for estimating precision using Relative Percent Difference (RPD)

Duplicate biological and physical habitat samples were taken at three sites (10% of the total sampled) in the Middle Patuxent River watershed. Comparisons of the differences between the results from these sites provide estimates of the precision of the biological assessments and the consistency of sampling activity. Relative percent difference (RPD) provides an estimate of the difference between sample pairs. Table 6 illustrates RPD for biological metrics and Table 7 presents RPD for physical habitat scores.

Table 6. Relative Percent Difference (RPD) calculations of biological scores for sites in the Middle Patuxent Watershed.

Station #	125	125QC	146	146QC	168	168QC
Location	UT to Middle Patuxent	UT to Middle Patuxent	UT to Middle Patuxent	UT to Middle Patuxent	Terrapin Branch	Terrapin Branch
Metric Score	2.78	3.00	3.67	3.67	4.33	4.11
Narrative Rating	Poor	Fair	Fair	Fair	Good	Good
Total Organisms	117	103	104	108	99	112
RPD	8%		0		5%	

The measurement performance criteria outlined in the QAPP (DPW 2001) calls for RPD agreement of the overall bioassessment scores to be ≤ 5%. Since the metric scores are based on a 1, 3, 5 scale, and not a continuous scale, a change in only one metric category (i.e., one "point") is enough to alter the overall score above the acceptable limit. The QC sites in the Middle and Upper Middle Patuxent River watersheds meet this criterion. However, the Lower Middle Patuxent River RPD score is 3% over the acceptable limit. Further review of the individual biological metrics revealed that between site 125 and 125QC, only one metric category (% Tanytarsini) varied enough to change the metric score from a 3 to a 5. This could be due to the random selection of the original site, combined with the preselection of the QC site. Since the QC sites are chosen at random, but are still located in the adjacent 75-m upstream reach, obstructions such as a fence or a bridge can alter the scores between probability vs. QC site. Performing the QC bioassessment at an adjoining reach has some potential for differences in habitat availability and organisms sampled.

Table 7. Relative Percent Difference (RPD) calculations of physical habitat scores for sites in the Middle Patuxent Watershed.

Station #	125	125QC	146	146QC	168	168QC
Location	UT to Middle Patuxent	UT to Middle Patuxent	UT to Middle Patuxent	UT to Middle Patuxent	Terrapin Branch	Terrapin Branch
Total Score	139	116	105	93	113	114
% Compared to Maximum (200)	69.5	58	52.5	46.5	56.5	57
Narrative Rating	Partially Supporting	Non Supporting	Non Supporting	Non Supporting	Non Supporting	Non Supporting
RPD	18%		12%		1%	

The measurement performance criteria outlined in the QAPP (DPW 2001) calls for RPD agreement of the overall physical habitat assessment scores to be ≤ 20%. The QC sites in each subwatershed meet this criterion.

- compared sample variation with design assumptions

The standard deviations from the three subwatersheds (following the year 2 biomonitoring schedule) were compared to the standard deviations (SD) associated with MBSS samples (reference and test) collected in general non-Coastal plain proximity and in Howard County. In the program sampling design (Pavlik et al. 2001), the MBSS values were used to assign a target number (number of sites to sample) per subwatershed to meet specified data quality objectives (DQOs).

- Reference = 0.69
- MBSS Test = 0.83
- Spring 2002 Sampling = 0.47

Since the calculated SD from this dataset is 0.47, and is below the design criteria of 0.69 and 0.83, the DQO is met.

II. SUBWATERSHED SITE ASSESSMENTS

Middle Patuxent River

The Middle Patuxent River watershed is located in the center of Howard County. Its headwaters are in the northern portion of the county, originating primarily in agricultural areas. The river flows through various farms and subdivisions, and the more southern portions (below MD-Rte. 108) are near the Columbia business center, in the Planned Service Area. The main transportation corridors in the watershed are I-70 across the northern section, I-95, and MD-Rtes. 29 in the southern portion, and MD-Rte 32, which runs the length of the watershed. Land use/land cover in the watershed is a mixture of developed areas (e.g., subdivisions, farmland, parking lots, and shopping centers). Although the watershed is on the outskirts of the high density urban areas around Columbia and Ellicott City, it is still affected by the more broadly-spread areas of development. A list of all sites, water body names and sampling locations can be found in Appendix E.

Watershed Assessment

Table 8 provides an overview of mean scores and narrative characterization for each subwatershed. A graphic display of the subwatershed ratings in the Middle Patuxent can be found in Figure 4. Correlations run between total physical habitat score and B-IBI scores (Pearson product moment) produced an r-value of 0.24 (n=28).

Table 8. Means of the biological and physical habitat scores for each subwatershed, with their corresponding narrative ratings. Confidence limits are represented by a single

	Narrative Rating	**Index Mean Score**
Upper Middle Patuxent		
Physical Habitat Quality	"Non Supporting"	$\bar{x} = 102 \pm 23.47$ (n = 10)
Biological Condition (B-IBI)	"Fair"	$\bar{x} = 3.39 \pm 0.57$ (n = 8)
Middle Middle Patuxent		
Physical Habitat Quality	"Non Supporting"	$\bar{x} = 105.6 \pm 13.22$ (n = 10)
Biological Condition (B-IBI)	"Fair"	$\bar{x} = 3.59 \pm 0.29$ (n = 10)
Lower Middle Patuxent		
Physical Habitat Quality	"Non Supporting"	$\bar{x} = 117.4 \pm 15.31$ (n = 10)
Biological Condition (B-IBI)	"Fair"	$\bar{x} = 3.22 \pm 0.56$ (n = 10)

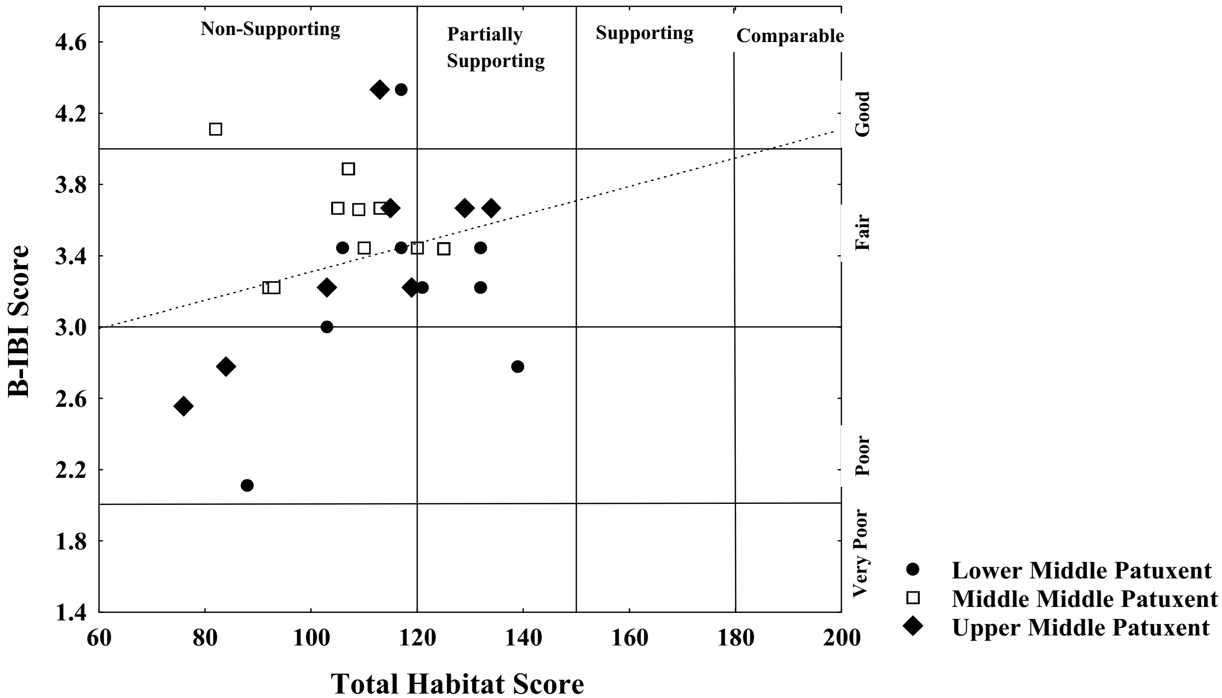

Figure 4. Benthic IBI scores and physical habitat ratings for each site in the Middle Patuxent River.

SUBWATERSHED RESULTS

Lower Middle Patuxent

Data Overview

In this subwatershed, four 1st-order, one 2nd-order, two 3rd-order, and three 4th-order streams were sampled (Figure 5). The mean biological condition for this subwatershed is "fair" ($\overline{X}$ = 3.22 ± 0.56, n = 10). One site received a "good" rating, seven were rated "fair", and two were found to be in "poor" biological condition (Table 9). The mean physical habitat rating in this subwatershed is "non-supporting" (58% of maximum) (Table 9). Of the ten sites sampled, four received "partially-supporting" ratings, while the other six were rated as "non-supporting". Correlating between physical habitat quality and biological condition had a low r-value of 0.34 (Pearson product moment), suggesting that stressors other than habitat are having a substantial effect on overall biological condition.

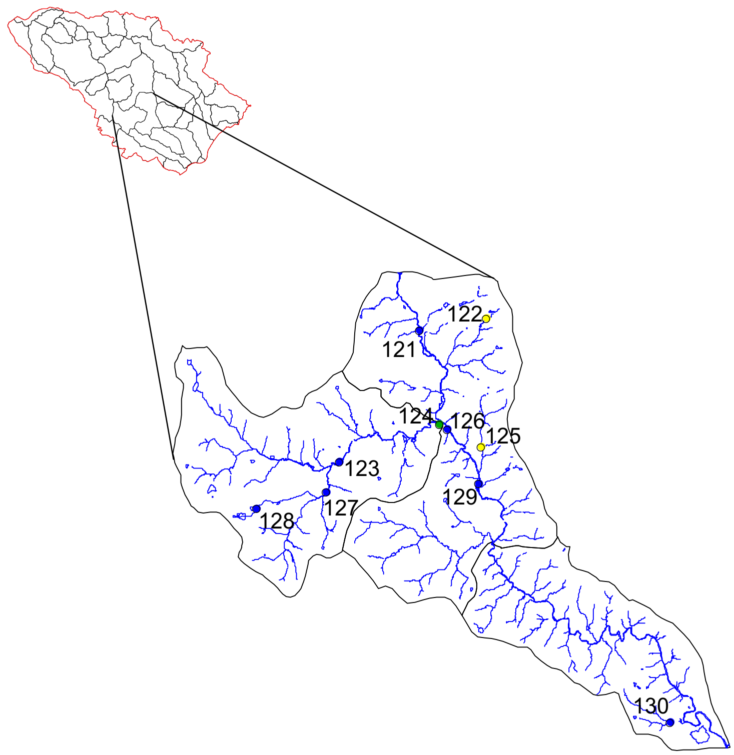

Figure 5. Color-coded biological condition ratings for the Lower Middle Patuxent River subwatershed. Green = good, blue = fair, yellow = poor, red = very poor. 121-129 indicate site numbers.

Table 9. Summary of biological and habitat scores for each sampled site in the Lower Middle Patuxent subwatershed.

Site	Benthic IBI Score	Biological Rating	Habitat Score	Habitat Rating	Stream Order
121	3.44	Fair	117	Non Supporting	4
122	2.11	Poor	88	Non Supporting	1
123	3.44	Fair	132	Partially Supporting	3
124	4.33	Good	117	Non Supporting	3
125	2.78	Poor	139	Partially Supporting	1
126	3.22	Fair	119	Non Supporting	4
127	3.44	Fair	106	Non Supporting	2
128	3.22	Fair	132	Partially Supporting	1
129	3.22	Fair	121	Partially Supporting	4
130	3.00	Fair	103	Non Supporting	1

Site Specific Results

Site 121 - Located off a dirt-path between the 14th and 15th holes of Hobbits Glen Golf Course, this fourth-order stream received a "fair" biological rating (3.44). The subsample contained 115 individual organisms from 36 total taxa. Most metric scores were in the moderate range (3), except for % Tanytarsini (metric value = 6.96%), which received the highest metric score possible (5). The organisms found most often were *Cricotopus* (tolerance value [t.v.] = 7) and *Thienemannimyia* (t.v. = 6); (Diptera: Chironomidae).

Physical habitat was rated "non-supporting" (58.5%). Water from this stream is pumped into a holding pond used for irrigating the golf course. Vegetative protection of the stream bank and bank stability were marginal. Fine sand-silts in the stream limited the preferred habitat of many organisms and caused high embeddedness (50-75%). This stream had the highest percentage of sands (very fine - very coarse) found at any site in the subwatershed (55%).

Site 122 - This 1st-order stream is located off Wilson Bottom Service Road. It received the lowest biological rating ("poor," 2.11) of any site in this subwatershed. There were no representatives of EPT taxa in the sample. Only 22 taxa were in the subsample, the lowest total for the Lower Middle Patuxent subwatershed. The most common organisms were *Chaetocladius* and *Orthocladius* (Diptera: Chironomidae), both with t.v. = 6.

Physical habitat at this site was rated "non -supporting" (44%). Marginal scores were given in the bank stability, channel flow status, embeddedness, riparian zone, sediment deposition, and vegetative protection categories. This stream may be impacted by construction of a strip-mall upstream, and/or a nearby housing development.

Site 123 - Located off Welcome Night Path, this 3rd-order stream received a "fair" biological rating (3.44). There were 42 total taxa in the sample. This stream exhibited the highest diversity of organisms in the subwatershed. Ten percent of the sample was composed of Ephemeroptera (mayflies), an organism that is sensitive to pollution. However, the most common organisms found were *Cheumatopsyche* (Trichoptera: Hydopsychidae, t.v. = 5) and *Parakiefferiella* (Diptera: Chironomidae, t.v. = 4).

This site received a "partially-supporting" (66%) physical habitat rating. Bank stability, vegetative protection, and embeddedness scored in the high marginal category. The sampling team observed a braiding of the stream channel due to recent sediment deposits. This may be in response to recent construction of a housing development.

Site 124 - This third-order stream received the highest biological rating (good, 4.33) in the Lower Middle Patuxent subwatershed. It is located in the woods off Towering Oak Path. This site had the highest percent Ephemeroptera and EPT taxa metric values in the subwatershed, 22.77% and

15, respectively. This site also had the lowest percentage of pollution tolerant organisms (6.93%).

Physical habitat was rated "non-supporting" (58.5%). The site was located on a bend, near the stream's confluence with a 4th-order stream. High flows have apparently caused bank erosion, as evidenced in low scores in the sediment deposition and channel flow status categories. The right bank was heavily eroded and received poor bank stability and vegetative protection scores.

Site 125 - This site is located at the bottom of the circle on Harmel Drive. Biological condition at this site was rated "poor" (2.78). It had the highest number of individuals subsampled in this subwatershed (117). However, it also had the highest percentage of pollution tolerant organisms (26.50%) in the subwatershed. *Stegopterna* (Diptera: Simuliidae, t.v. = 7) and *Neophylax* (Trichoptera: Uenoidae, t.v. = 3) were the most common organisms in the subsample. Large boulders in the downstream portion of the site may have contributed to the "poor" biological condition. Fast-flowing water over boulders prevents organisms from inhabiting such areas.

The physical habitat at this site was rated "partially-supporting" (69.5%). A paved walking path on the right bank, and an upstream playground, could have some impact on the habitat condition surrounding the stream.

Site 126 - Located off Towering Oak Path, this 4th-order stream was rated "fair" (3.22) for biological condition. There were 94 total organisms found, the lowest total of the subwatershed, representing 31 total taxa. The most common organisms found were moderately pollution tolerant – *Cheumatopsyche* (t.v. = 5) and *Hydropsyche* (Trichoptera: Hydropsychidae, t.v. = 6), both net-spinning caddisflies. Twelve cobble samples were taken from a single 20m long riffle area, the only riffle available to sample. The remaining eight jabs were divided between snag and vegetated bank habitat.

Physical habitat condition was rated in the "non-supporting" category (59.5%). This score is close to the "partially-supporting" cutoff (60.1). Marginal scores were given in the bank stability, embeddedness, epifaunal substrate/available cover, and vegetative protection categories.

Site 127 - This 2nd-order stream is located off Guilford Road, and was rated in "fair" biological condition (3.44). The subsample contained 101 individuals. Mayflies of the pollution intolerant family Ephemerellidae (Ephemeroptera, t.v. = 2) were the most common taxa. Dipertans (true flies) were also abundant in the sample.

The physical habitat at site was rated "non-supporting" of aquatic life (53%). Pebble count data revealed over half of the site (51%) was dominated by sand, reducing available habitat for benthic macroinvertebrates. The right bank received a poor riparian zone width score, due to the site being bordered by a mowed lawn.

Site 128 - This site is on a 1st-order stream, located at the 13050 block of Rt. 108 (Clarksville Pike). It received a "fair" (3.22) biological rating. Of the 108 total individuals subsampled, 17.6% were organisms in the tribe Tanytarsini, a relatively sensitive Chironomid (midge). Dipterans were represented by 25 different taxa.

Physical habitat was rated "partially-supporting" (66%). This small stream runs near mowed lawns, which could be impacting the riparian vegetative zone width and the vegetative protection (both of which received the lowest scores at this site).

Site 129 - The mainstem of the Middle Patuxent River is considered a 4th-order stream at this site. The biological condition was rated "fair" (3.22). Of the 108 individuals subsampled, only 14% were considered to be pollution tolerant. The most common organisms found were the moderately tolerant *Cheumatopsyche* (t.v. = 5).

This site was rated "partially-supporting" (60.5%) for physical habitat condition. Sediment deposition and channel flow status scored in the marginal range. Pebble count data revealed that 43% of the site contained sand of various sizes (very fine - very coarse) which increase the amount of deposition in the channel, therefore reducing flow.

Site 130 - This site is located on a 1st-order stream just upstream of I-95, near the exit ramp of the Maryland Welcome Center. It received a "fair" (3.00) biological condition rating. Twenty-five percent of the 106 total organisms subsampled were pollution tolerant, such as *Prosimulium* (Diptera: Simuliidae, t.v. = 7). However, 18 of the 30 total taxa represented were relatively pollution sensitive (t.v. = 0-3). The downstream portion of this site is located at the mouth of the culvert under I-95. Two concrete drains allow runoff from the highway to directly enter the stream. This location probably contributes to the "non-supporting" (51.6%) physical habitat rating for this site.

Middle Middle Patuxent

Data Overview

Three 3rd-order, two 2nd-order, and five 1st-order streams were sampled in this subwatershed (Figure 6, Table 10). The mean biological rating for this subwatershed is "fair" ($\overline{X}$ = 3.59 ± 0.29, n = 10). Nine of the ten sites sampled received "fair" ratings and one site received a "good" rating.

The mean physical habitat rating for this subwatershed is "non-supporting" (53% of maximum). Two sites were rated "partially-supporting" and the other eight sites received "non-supporting" ratings. There was a negative correlation between habitat and the B-IBI for this subwatershed (r=0.39). This is an indication that potential nutrient enrichment is causing an elevation in overall biological condition. This portion of the subwatershed has a higher level of agriculture and pasture lands than the Upper or Lower Middle Patuxent.

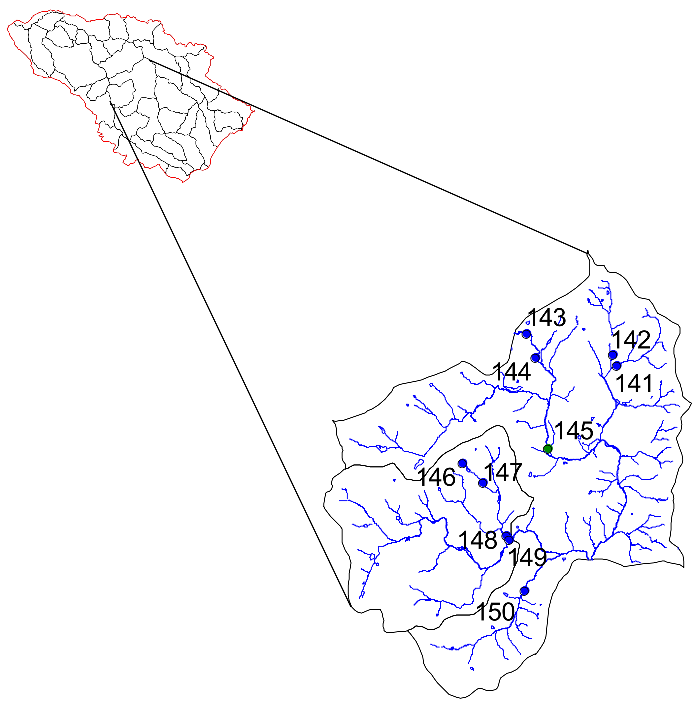

Figure 6. Color-coded biological condition ratings for the Middle Middle Patuxent River subwatershed. Green = good, blue = fair, yellow = poor, red = very poor. 141-150 indicate site numbers.

Table10. Summary of biological and habitat scores in the Middle Middle Patuxent subwatershed.

Site	Benthic IBI Score	Biological Rating	Habitat Score	Habitat Rating	Stream Order
141	3.67	Fair	113	Non Supporting	1
142	3.89	Fair	107	Non Supporting	1
143	3.66	Fair	109	Non Supporting	3
144	3	Fair	125	Partially Supporting	3
145	4.11	Good	82	Non Supporting	3
146	3.67	Fair	105	Non Supporting	1
147	3.22	Fair	92	Non Supporting	1
148	3.44	Fair	110	Non Supporting	2
149	3.44	Fair	120	Partially Supporting	2
150	3.22	Fair	93	Non Supporting	1

Site Specific Results

Site 141 - This site is on a 1st-order stream on the Holly House Farm property, off Folly Quarter Road. It is the first stream crossing at the farm headed away from the main road. Biological condition was rated "fair" (3.67). Of the 26 total taxa subsampled, almost 52% were pollution sensitive Ephemeropterans (mayflies), the highest percentage in this subwatershed. Forty-nine of the 104 individuals were Ephemerellidae (t.v. = 2). The location of this site in a horse pasture, just downstream of the farm drive culvert, probably influenced the "non-supporting" (56.5%) physical habitat rating. The riparian zone was narrow (especially along the left bank) due to surrounding farm fields. Pebble count data estimated 51% of the streambed was covered in sand.

Site 142 - This site is also located on the Holly House Farm property, off Folly Quarter Road. It received a "fair" (3.89) rating for biological condition. There were 123 total individuals in the subsample, representing 45 total taxa. Eleven percent of the subsample consisted of Tanytarsini, a relatively sensitive midge. The most common taxa was Ephemerellidae (t.v. = 2) composing 15% of the subsample.

Physical habitat was rated "non-supporting" (53.5%). Other than a narrow riparian zone, this stream is surrounded by horse pasture. A large amount of sediment was observed in the stream. High sediment volumes fill in the optimal spaces where benthic macroinvertebrates live. Sediment also increases the turbidity in a stream, allowing less sunlight to enter the system.

Site 143 - Located on a 3rd-order stream in the 12200 block of Triadelphia Road, this site was rated in "fair" (3.66) biological condition. Of the 103 total individuals subsampled, 20% were in the pollution sensitive order Ephemeroptera (mayflies). Less than 1% of the sample contained organisms considered to be pollution tolerant (t.v. - 7-10).

This site received a “non-supporting” (54.5%) physical habitat rating. Both vegetative protection and bank stability scored in the marginal to poor range. Pebble count data indicated that sand and gravel are found in equal amounts in the stream (33%). There was also an abundance of silt/clay sampled (24%).

Site 144 - This 3rd-order stream is located off Etchison Drive. The biological condition was rated “fair” (3.44). Only 23 total taxa were found, the lowest total in the subwatershed. However, this site is the only one in the entire Middle Patuxent River Watershed that did not have any organisms that were tolerant of pollution. The dominant taxon was Ephemerellidae (t.v. = 2).

High riparian zone scores ensured this site a “partially-supporting” (62.5%) physical habitat rating. However, the bank stability and vegetative protection categories scored in the marginal range. Twenty-nine percent of the streambottom was sand (very fine - very coarse).

Site 145 - The University of Maryland Central Farm surrounds this site on the mainstem of the Middle Patuxent River. Biological condition was rated “good” (4.11). This site had 13 EPT taxa, the highest total in the subwatershed.

However, the location of this site on experimental farm property appeared to have substantially influenced the physical habitat score. In fact, this site received the lowest total habitat score in the subwatershed, placing it in the “non-supporting” (41%) category. Mowed or grazed land surrounded the site, with only a couple trees present. Extreme bank sloughing and many raw areas influenced the bank stability and vegetative protection scores. The location of this site on experimental farmland, suggests that a mixture of stream stressors (manure: nutrients, crops: pesticides) could be raising the biological scores above the natural potential in a physically degraded stream. This is evidenced in the combination of a high rating for biological condition and a low physical habitat score.

Site 146 - This 1st-order stream is located off Heritage Hill Lane. The biological condition was rated “fair” (3.67). The subsampled contained 104 total individuals, representing 29 total taxa. The most common taxa were *Diplectrona* (Trichoptera: Hydropsychidae, t.v. = 2), *Rhyacophila* (Trichoptera: Rhyacophilidae, t.v. = 21), and *Larsia* (Diptera: Chironomidae, t.v. = 6).

Physical habitat condition at this site received a “non-supporting” (52.5%) rating. Pebble count data at this site indicated that 79% of the channel is composed of sand, the highest percentage in the subwatershed. Private property, with a mowed lawn, bordered the left bank, decreasing the riparian zone width enough to rank it in the poor category.

Site 147 - This 1st-order stream, located off Heritage Hill Lane was rated in “fair” (3.22) biological condition. Pollution tolerant taxa such as *Stegopterna* (t.v. = 7) and *Corynoneura*

(Diptera: Chironomidae, t.v. = 7) comprised 45% of the sample, the highest percentage of tolerant individuals found in this subwatershed. The physical habitat received a "non-supporting" (46%) rating. Most of the parameters scored in the marginal range. The narrow riparian zone on the right bank (bordered by a cornfield) was placed in the poor category.

Site 148 - Biological condition was rated "fair" (3.44) at this 2nd-order stream located on the Brick House Farm property, around the 4800 block of Sheppard Lane. Seventeen percent of the 105 individuals subsampled were Ephemeropterans (mayflies). Fifteen of the 28 total taxa were in the Dipteran order. The most common sensitive organisms were *Ephemerella* (Ephemeroptera: Ephemerellidae, t.v. = 2), *Oulimnius* (Coleoptera: Elmidae, t.v. = 2), and *Amphinemura* (Plecoptera: Nemouridae, t.v. = 3).

In addition to containing a horse pasture, Brick House Farm runs a factory that bottles water from nearby underground springs. It is likely, however, that the groundwater aquifer feeds the stream, thus the operation *could* affect total flow. This site was rated "non-supporting" (55%) of aquatic life. Impacts on the physical habitat surrounding the stream tend to be typical of streams that run through farmland – marginal bank stability and vegetative protection. Also, the high biological condition score combined with a low physical habitat score tends to suggest the possibility of nutrient enrichment in the stream, likely increased by runoff from the adjacent pasture.

Site 149 - This site is also located on the Brick House Farm property, off Sheppard Lane. This site received a "fair" (3.44) biological condition rating. Forty-three total taxa were found in the subsample, one of the highest totals in this subwatershed. Midges such as *Orthocladius* (Diptera: Chironomidae, t.v. = 6), composed 63% of the sample, the highest percentage in the whole subwatershed. This site is on the same 2nd-order stream that runs through the Brick House Farm property. It received a "non-supporting" (60%) physical habitat rating. Half of the bottom substrates were fines (sands and silt/clay).

Site 150 - This site is located on a 1st-order stream, downstream of the culvert under Sheppard Lane. It received a "fair" rating (3.22) for biological condition. Of the 113 total individuals subsampled, 15% were in the tanytarsine midges, relatively sensitive organisms.

An upstream culvert and nearby maintained lawns may have contributed to the "non-supporting" (46.5%) physical habitat rating. Banks were eroded and vegetation was sparse, resulting in bank stability and vegetative protection parameters being scored in the poor category.

Upper Middle Patuxent

Data Overview

Of the 10 sites in this subwatershed, only eight sites were sampled for benthic macroinvertebrates due to dry channels (Figure 7, Table 11). Habitat assessments were conducted at all sites. Sites located on channels that are dry during the sampling season are not replaced with alternates due to the probability-based design of the project. In this case, it allows for extrapolation that 20% of the first-order streams in the Upper Patuxent subwatershed were dry during the Spring of 2002. Both of the dry streams were most likely affected by the statewide drought and unusually dry winter. As a result, five 1st-order, one 2nd-order, and two 3rd-order streams were sampled for benthic macroinvertebrates. The mean biological condition in this subwatershed was “fair” ($\overline{X}$ = 3.39 ± 0.57, n = 8). Two streams were rated “poor”, five were “fair”, and one was in “good” biological condition.

The mean physical condition in this subwatershed was “non-supporting” (51% of maximum). Of the ten sites sampled for physical condition, eight were “non-supporting” and two were “partially-supporting” of aquatic life.

Site Specific Results

Site 161 - This 1st-order stream is off McKendree Road. The biological condition received a “poor” (2.56) rating. This site had the highest occurrence of pollution tolerant organisms in the subwatershed (47%), such as *Simulium* (t.v. = 7).

This stream was immediately adjacent to pastureland. The physical habitat rating was “non-supporting” (38%). Pebble count data revealed that 49% of the channel was composed of silt/clay. An abundance of this type of sediment takes up spaces that benthic macroinvertebrates prefer to inhabit. It also creates higher levels of turbidity, which block the sun’s rays from shining into the stream to promote algal growth. Habitat categories that received poor ratings included bank stability, riparian zone width, and vegetative protection.

Site 162 - On the date biology and physical habitat were sampled (March 6, 2002), the channel was dry. As stated in the data overview for this subwatershed, this condition was most likely caused by the recent regional drought. Since the stream was dry during the index period, the stream could not be sampled with a D-net for benthic macroinvertebrates.

The drought had a substantial effect on the “non-supporting” (37%) physical habitat rating. Channel flow status and velocity/depth regime received zeros. Because this is a small headwater stream it likely responds quickly to drought conditions.

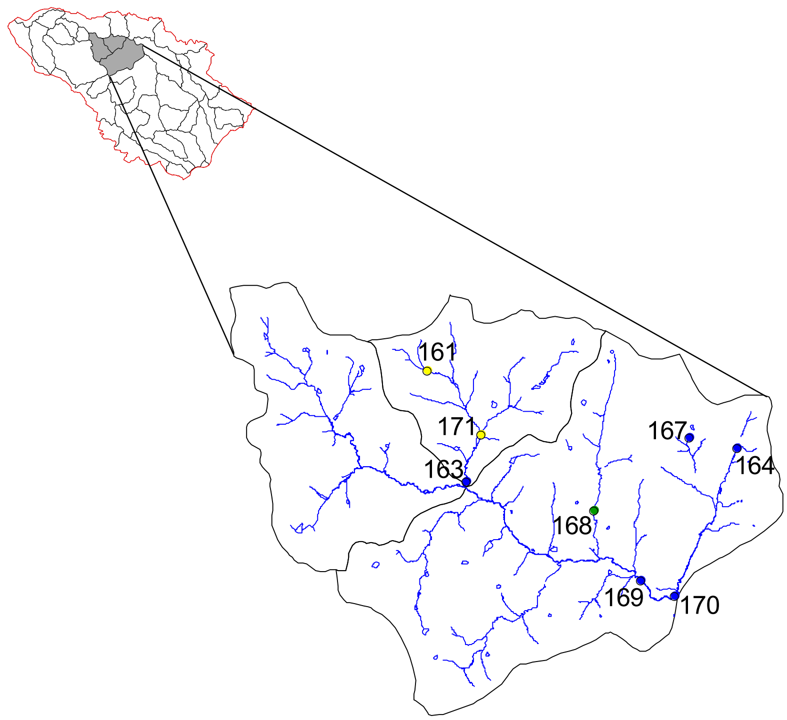

Figure 7. Color-coded biological condition ratings for the Upper Middle Patuxent River subwatershed. Green = good, blue = fair, yellow = poor, red = very poor. 161-170 indicate site numbers.

Table 11. Summary of biological and habitat scores in the Upper Middle Patuxent subwatershed.

Site	Benthic IBI Score	Biological Rating	Habitat Score	Habitat Rating	Stream Order
161	2.56	Poor	76	Non Supporting	1
162	NA	Dry	74	Non Supporting	1
163	3.67	Fair	134	Partially Supporting	2
164	3.22	Fair	119	Non Supporting	1
166	NA	Dry	73	Non Supporting	1
167	3.22	Fair	103	Non Supporting	1
168	4.33	Good	113	Non Supporting	1
169	3.67	Fair	129	Partially Supporting	3
170	3.67	Fair	115	Non Supporting	3
171	2.78	Poor	84	Non Supporting	1

*NA = Biology was not sampled at these sites due to dry conditions.

Site 163 - This 2nd-order stream off Pfeffercorn Road was rated in “fair” (3.67) biological condition. Of the 99 organisms subsampled, only 5% were pollution tolerant. In addition, 7% of the subsample contained organisms in the sensitive Tanytarsini tribe.

This site received one of the two “partially-supporting” physical habitat ratings. It received 67% of the 200 points possible on the habitat assessment form. The stream had a wide riparian zone, which was surrounded by what seemed to be fields that were no longer cultivated. It is unknown if any of this land will be developed further.

Site 164 - Forty-one total taxa, from the 114 organisms subsampled contributed substantially in this 1st-order stream’s biological condition rating of “fair” (3.22). There were also 25 different Dipteran taxa in the subsample, the highest diversity in this subwatershed. A mixture of Dipterans is generally associated with good water quality.

Physical habitat at this site was rated “non-supporting” (59.5). As this site is located downstream of I-70, there is a high potential for non-point source (NPS) pollution or runoff. Bank stability, vegetative protection, channel flow status, and embeddedness all scored in the high end of the marginal category.

Site 166 - This 1st-order stream channel is located on Crestlawn Memorial Gardens property, just north of I-70. On the day biological sampling was to occur (March 13, 2002), the stream was dry. Changes in landuse from farmland to mowed, chemically-treated cemetery property, could have made this stream particularly susceptible to the recent regional drought. However, a physical habitat assessment was performed at this site. The drought and poor surrounding landuse appeared to influence this stream, and a rating of “non-supporting” (36.5%) was assigned.

Site 167 - The biological condition of this 1st-order stream was rated “fair” (3.22). The subsampled contained 115 organisms, representing 37 total taxa.

Located just south of I-70, this stream was rated “non-supporting” (51.5%) for aquatic life use. Pebble count data revealed that the majority of the channel bed was composed of silt/clay (34%) and sands (33%). These fine sediments increased the embeddedness of riffles and covered over or filled in other epifaunal substrates. Runoff from the highway as well as upstream erosion are potential sources of these fines.

Site 168 - This site is on Terrapin Branch, a 1st-order stream on the Nixon Farm property, just north of Rt. 32. It is the only site in this subwatershed to receive a “good” (4.33) biological rating. While the site did not have any particular biological metric categories that scored substantially higher than any of the other sites, it had the most metrics that received a “good” score (5). The most abundant organisms were Ephemerellidae and *Oulimnius* (both with t.v. =

2). The downstream end of this site was about 1m upstream of a bridge/culvert for Nixon's Farm lane. This site was rated "non-supporting" for physical habitat condition (56.5%). A vineyard and apparent pastureland were both nearby. Some of this land was in close proximity to the stream, resulting in the left bank riparian zone being rated in the poor category.

Site 169 - This site is located on a 3rd-order portion on the mainstem of the Middle Patuxent, off of Elbicore Court. Biological condition was rated "fair" (3.67). Of the 111 organisms in the subsample, 40% were pollution sensitive Ephemeropterans (mayflies). This was the highest percentage in the subwatershed.

Physical habitat at this site received a "partially-supporting" (64.5%) rating. Categories given marginal scores included bank stability and vegetative protection.

Site 170 - This 3rd-order portion of the Middle Patuxent is approximately 100m downstream from the crossing of Triadelphia Mill Road. Biological condition was rated "fair" (3.67). Of the 116 organisms, less than 1% were considered to be pollution tolerant (t.v. = 7-10). The most common taxa were Ephemerellidae (t.v. = 2), *Hydropsyche* (t.v. = 6) and *Cheumatopsyche* (t.v. = 5). This site was rated in "non-supporting" (57.5%) physical habitat condition. The right bank was bordered by a partially cleared forest, allowing for little vegetative protection and poor bank stability.

Site 171 - This 1st-order stream located on the Dawn Acres Angus Farm on Rte. 144, was the only alternate site chosen in the Middle Patuxent Watershed. It replaced Site 165, which was located on the Crestlawn Memorial Gardens property, but had been filled in by the property owner to the point that there was no longer any channel. The biological condition received a "poor" (2.78) rating. The subsample contained 99 individuals, representing 27 total taxa. There were no sensitive Ephemeropterans (mayflies) found in the sample. The most common organism was *Parametriocnemus* (Diptera: Chironomidae, t.v. = 5, 35%).

Physical habitat condition was rated "non-supporting" (42%) at this site. This stream was shallow, narrow, and had marginal bank stability and vegetative protection. The embeddedness, sediment deposition, and channel flow status categories were all ranked in "poor" condition. Pebble count data revealed that the entire channel was composed of fines (73% silt/clay, 27% sands).

WATERSHED COMPARISONS

The monitoring and assessment program thus far has sampled three major watershed groups: the Little Patuxent River, Middle Patuxent River, and Cattail Creek/Brighton Dam. For these three, the Middle Patuxent River has the highest mean B-IBI score (3.65 ± 0.18), as compared to 3.40 ± 0.49 and 2.26 ± 0.39 for the Cattail Creek/Brighton Dam and Little Patuxent River watersheds, respectively. These correspond somewhat to expectations, based on the intensity of land use conversions. For example, the biological condition of the Middle Patuxent River watershed tended to decrease with an increase of agriculture and other managed land uses (Figure 8). Generally, the biological condition varies with the predominant land use type: forested vs. developed vs. agriculture.

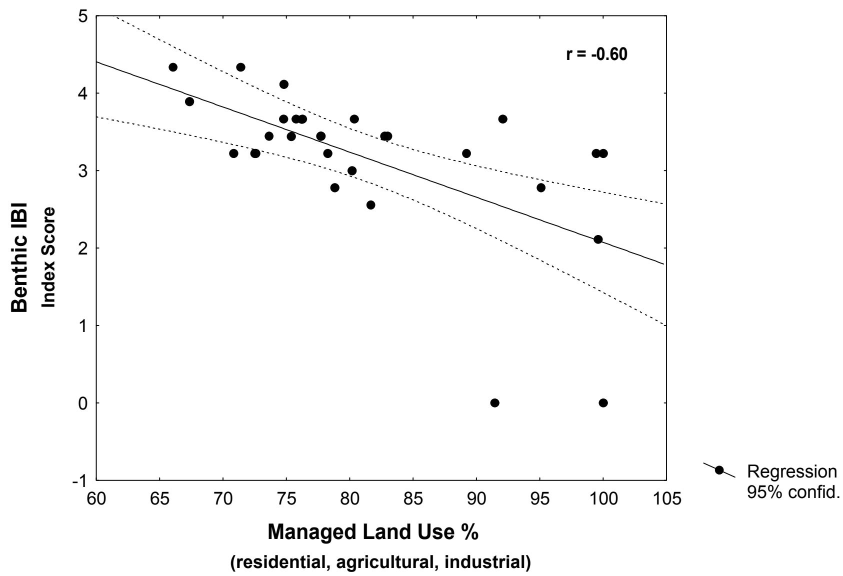

Figure 8. Relationship between managed land use percent and resulting biological conditions.

The majority of the sites within the Cattail Creek/Brighton Dam subwatershed, received "fair" or "good" biological ratings, paired with "partially" or "non-supporting" physical habitat ratings (Figure 9). This is believed to be due to nutrient enrichment that can occur as a result of increasing agricultural or urban land uses (Wang et al. 2001). The unnatural addition of nutrients to the stream artificially raises the biological quality beyond the potential that the existing habitat would naturally support.

The biological conditions in the Little Patuxent River subwatersheds show a more conventional response to habitat alteration (Paul & Meyer 2001). The biological conditions were mostly rated as "poor" and "very poor" with "partially or non-supporting" physical habitat assessments (Figure 10). This is the tendency that would be expected with habitat depletion. Poor riparian zone and in-stream habitat allow for only those organisms that are most tolerant of severe stressors to remain in that system.

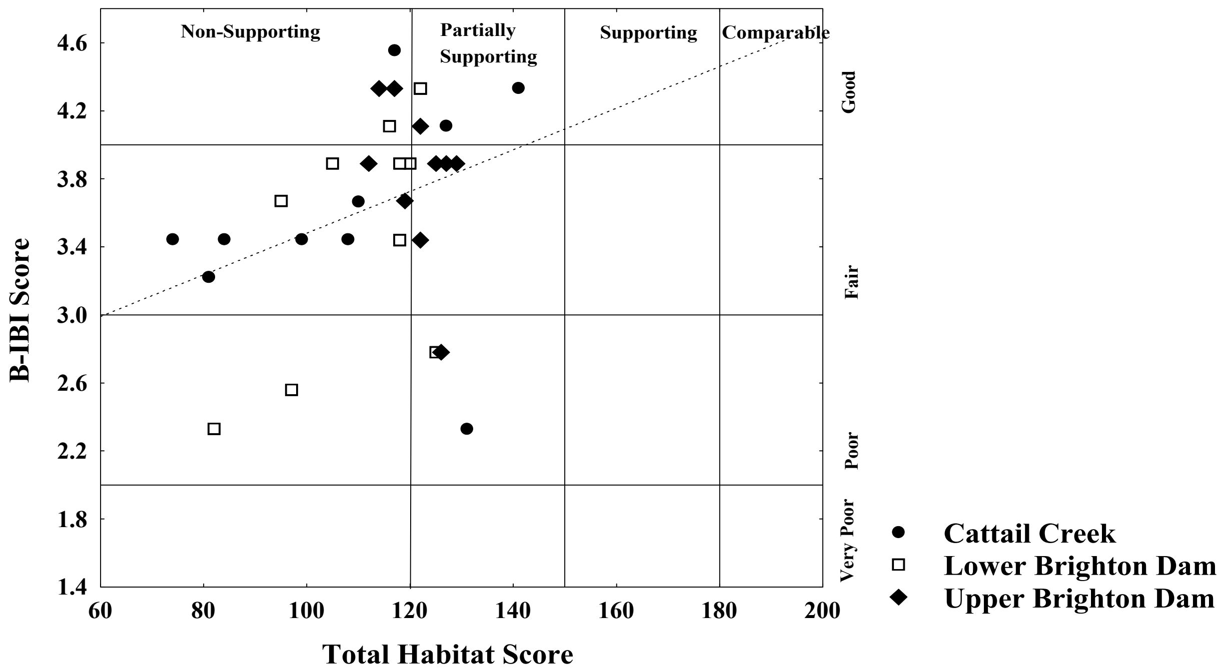

Figure 9. Benthic IBI scores and physical habitat ratings for each site in the Cattail Creek and Brighton Dam subwatersheds.

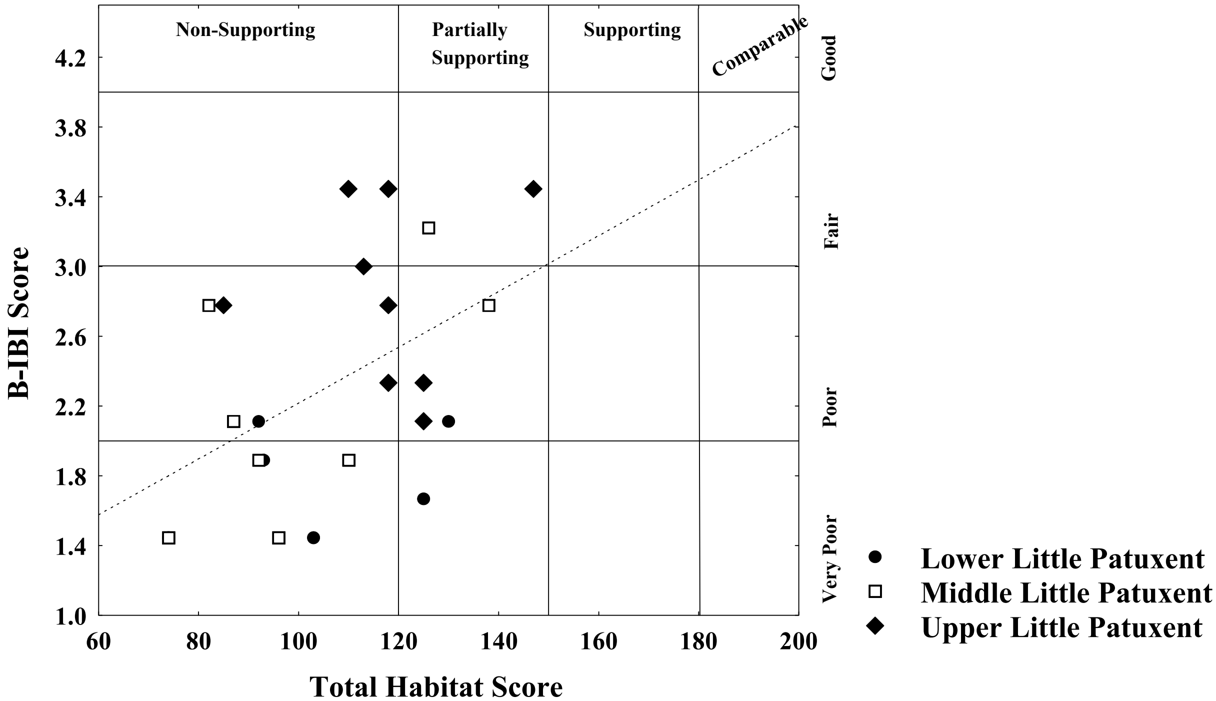

Figure 10. Benthic IBI scores and physical habitat ratings for each site in the Little Patuxent watershed.

III. CONCLUSIONS AND RECOMMENDATIONS

The results of these biological assessments lead to six general recommendations:

- develop watershed protection and rehabilitation actions
- conduct further diagnostic analyses
- ensure baseline condition for comparison with long-term monitoring activities
- implement public outreach strategies
- maintain comparability with State methods
- maintain quality assurance/quality control standards.

In this section, summary recommendations are provided to facilitate use of the results both in natural resource management decision-making and in communicating the ecological status of watersheds to the public.

Further Monitoring and Diagnostic Analysis

- Perform detailed geomorphic stability assessments for streams with suspected but unidentified hydrologic alteration.

- Perform additional analyses of Spring 2002 Index Period data: a) investigate individual metrics for correspondence with known stressor/stressor sources, b) evaluate coverage of stream sampling . Namely, report on frequency of intermittent or dry streams, streams destroyed (filled in) or enclosed by pipes due to development, streams heavily influenced by beaver activity, and those streams inaccessible due to landowner issues. This information will provide more general knowledge about the health of County streams, and offer additional possible explanations for current stream condition.

- Ensure continuation of a multi-year, rotating basin program.

- Select several individual, probability-based, sites for annual monitoring for long term trend analysis. Selected probability sites in each watershed become targeted. Select sites monitored in years one and two that could benefit from future restoration. Also, select sites to be revisited to see if high biological condition is being maintained naturally.

- Collect and maintain historic cross-sectional measurement data to identify major changes in stream channel size and shape.

- Supplement MBSS sampling throughout the county with additional biomonitoring sites.

- Select biological monitoring sites to perform targeted sampling to assess long-term County projects, such as effectiveness of BMPs, or identify sites where BMPs (e.g., retention ponds, riparian revegetation, bank stabilization, grade control structures, or limiting access of cattle to streams) could be installed to improve physical habitat and biological conditions.

- Produce an overall 3-year Countywide report of stream condition by compiling the results of the complete 3-year rotation cycle.

Protection and Rehabilitation

- Use aggregated biological index scores to prioritize watersheds for protection or rehabilitation activities. The protection and rehabilitation of natural resources must be integrated to maintain a healthy environment. It is as important to exclude stressors from moderate to high quality streams (protection), as it is to remove stressors and restructure areas with depleted physical habitat and biological condition (rehabilitation/ restoration) from fair to very poor quality streams. Where streams exhibit "good" biological condition, effective protection and preservation will require preventing the introduction of new stressors.

- Perform diagnostic sampling and analysis on streams with "fair", "poor", or "very poor" biological condition to determine the predominant stressors. If the stream is physically unstable, determination and correction of upstream hydrologic or geomorphic alteration is recommended. If nutrient enrichment or toxic contamination is suspected, sediment and water column chemical analyses and toxicity testing should be conducted to determine, correct, and eliminate sources.

- Create incentives for BMP installation and maintenance. Develop stakeholder groups to help farmers and developers work together to have the least impact possible on their surrounding environment.

Public Outreach

- Provide the public and water quality professionals access to biomonitoring information through a variety of mechanisms including: internet PDF files, advertisement to citizens, presentation at community meetings, and press releases announcing availability of the report. Expedite printing and public release of the report.

- Create reader-friendly public brochures that present data and findings to the general public. Update these brochures as biomonitoring continues to keep the public current on the health of their local watersheds.

Comparability with State methods

- Expand communication and collaboration with other state organizations (WRD, University of Maryland) that could potentially assist with future sampling.

- Continue inter-agency (multiple Howard County offices and MBSS) review of yearly biomonitoring reports.

Quality Assurance/Quality Control (QA/QC)

- Maintain QA/QC training and documentation for program.

- Continue attendance at MBSS training in order to ensure comparability with State program.

- Perform blind re-identification of 10% total benthic samples using an independent taxonomist.

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V. APPENDICES