Watershed Report for Biological Impairment of the Upper Pocomoke River Watershed, Wicomico and Worcester Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation

FINAL

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Submitted to:

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1650 Arch Street
Philadelphia, PA 19103-2029

January 2012

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List of Abbreviations

AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BMP	Best Management Practices
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DO	Dissolved Oxygen
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
MH	Mantel-Haenzel
mg/L	Milligrams per liter
NMP	Nutrient Management Plans
NPDES	National Pollution Discharge Elimination System
OP	Orthophosphates
SSA	Science Services Administration
SO_4	Sulfates
TMDL	Total Maximum Daily Load
TP	Total Phosphates
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

Executive Summary

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met.

The Maryland Department of the Environment (MDE) has identified the waters of the Upper Pocomoke River in Maryland's Integrated Report as impaired by sediments (1996), nutrients (1996), and impacts to biological communities (2002) (MDE 2008). All impairments are listed for non-tidal streams. The Adkins Pond impoundment was listed as impaired for nutrients and sediment in 1998. The 1996 nutrients listing was refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance. Similarly, the 1996 suspended sediment listing was refined in the 2008 Integrated Report to a listing for total suspended solids. A TMDL for sediments and phosphorus for the Adkins Pond impoundment was approved by the USEPA in 2001.

In 2002, the State began listing biological impairments on the Integrated Report. The current MDE biological assessment methodology assesses and lists only at the Maryland 8-digit watershed scale, which maintains consistency with how other listings on the Integrated Report are made, how TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds with multiple impacted sites by measuring the percentage of stream miles that have an Index of Biotic Integrity (IBI) score less than 3, and calculating whether this is significant from a reference condition watershed (i.e., healthy stream, <10% stream miles degraded).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the non-tidal Upper Pocomoke River and its tributaries is Use I – water contact recreation, and protection of non-tidal warmwater aquatic life. The Upper Pocomoke River watershed is not attaining its designated use of protection of aquatic life because of biological impairments. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause of reduced biological conditions, which will enable the

Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors, sources of stressors and the biological community, and the likely impact these stressors would have on the degraded sites in the watershed.

The BSID analysis uses data available from the statewide MDDNR MBSS. Once the BSID analysis is completed, a number of stressors (pollutants) may be identified as probable or unlikely causes of poor biological conditions within the Maryland 8-digit watershed study. BSID analysis results can be used as guidance to refine biological impairment listings in the Integrated Report by specifying the probable stressors and sources linked to biological degradation.

This Upper Pocomoke River watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and may be reviewed in more detail in the report entitled "Maryland Biological Stressor Identification Process" (MDE 2009). Data suggest that the degradation of biological communities in the Upper Pocomoke River watershed is strongly influenced by agricultural land use and its concomitant effects: altered stream morphology (channelization) and elevated levels of sediments and nutrients. The development of landscapes creates broad and interrelated forms of degradation (i.e., hydrological, morphological, and water chemistry) that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between agricultural landscapes and degradation in the aquatic health of non-tidal stream ecosystems.

The results of the BSID process, and the probable causes and sources of the biological impairments of the Upper Pocomoke River watershed can be summarized as follows:

- The BSID process has determined that biological communities in the Upper Pocomoke River watershed are likely degraded due to sediment and in-stream habitat related stressors. Specifically, channelization of streams has led to increased settling of sediment in the stream substrate throughout the watershed, which is the probable cause of impacts to biological communities. The BSID results thus confirm the 2008 Category 5 listing for total suspended solids as an impairing substance in the Upper Pocomoke River non-tidal 8-digit watershed, and links this pollutant to biological conditions in these waters.

- The BSID process has also determined that the biological communities in the Upper Pocomoke River watershed are likely degraded due to water chemistry related stressors. Specifically, agricultural land use practices have resulted in the potential elevation of nutrient inputs throughout the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus confirm the 2008 Category 5 listing for phosphorus as an impairing substance in the Upper Pocomoke River non-tidal 8-digit watershed, and links this pollutant to biological conditions in these waters.

- The BSID process has also determined that biological communities in the Upper Pocomoke River watershed are likely degraded due to anthropogenic channelization of stream segments. MDE considers channelization as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution. Category 4c listings include segments impaired due to stream channelization or the lack of adequate flow. MDE recommends a Category 4c listing for the Upper Pocomoke River watershed based on channelization being present in approximately 46% of degraded stream miles.

- The BSID process has also determined that biological communities in the Upper Pocomoke River watershed are likely degraded due to anthropogenic alterations of riparian buffer zones. MDE considers inadequate riparian buffer zones as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards as a result of pollution. MDE recommends a Category 4c listing for the Upper Pocomoke River watershed based on inadequate riparian buffer zones in approximately 49% of degraded stream miles.

1.0 Introduction

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met. In 2002, the State began listing biological impairments on the Integrated Report. Maryland Department of the Environment (MDE) has developed a biological assessment methodology to support the determination of proper category placement for 8-digit watershed listings.

The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that guides the assignment of biological condition to Integrated Report categories. In the data quality review step, available relevant data are reviewed to ensure they meet the biological listing methodology criteria of the Integrated Report (MDE 2008). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or blackwater streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy stream, <10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report. If a watershed is not determined to differ significantly from the reference condition, the assessment must have an acceptable precision (i.e., margin of error) before the watershed is listed as meeting water quality standards (Category 1 or 2). If the level of precision is not acceptable, the status of the watershed is listed as inconclusive and subsequent monitoring options are considered (Category 3). If a watershed is classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary.

The MDE biological stressor identification (BSID) analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of the biological impairment. Identification of stressors responsible for biological impairments was limited to the round two Maryland Biological Stream Survey (MBSS) dataset (2000–2004) because it provides a broad spectrum of paired data variables (i.e., biological monitoring and stressor information) to best enable a complete stressor analysis. The BSID analysis then links potential causes/stressors with general causal scenarios and concludes with a review for ecological plausibility by State scientists. Once the BSID analysis is completed, one or several stressors (pollutants) may be identified as probable or unlikely causes of the poor biological conditions within the

Maryland 8-digit watershed. BSID analysis results can be used together with a variety of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

The remainder of this report provides a characterization of the Upper Pocomoke River watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Upper Pocomoke River Watershed Characterization

2.1 Location

The Pocomoke River originates in the Great Cypress Swamp on the Delaware-Maryland border and flows for approximately sixty miles through Maryland into Pocomoke Sound at the Chesapeake Bay (LESHC 1994). The outlet of the 8-digit Upper Pocomoke River watershed is located north of the town of Snow Hill and extends to the Delaware border. Streams are mostly non-tidal, with some tidal influence in the lowest reach of the Pocomoke mainstem. The watershed is situated in Wicomico and Worcester Counties and drains approximately 122 stream miles (see Figure 1). The largest towns within the Upper Pocomoke River watershed are Willards and Pittsville. The watershed is located in the Coastal Plains region of three distinct eco-regions identified in the MBSS indices of biological integrity (IBI) metrics (Southerland et al. 2005) (see Figure 2).

2.2 Land Use

The Upper Pocomoke River watershed covers approximately 95,500 acres of land in Wicomico and Worcester Counties, Maryland. There is a significant amount of agricultural activity within the watershed that consists mostly of row crops (primarily corn and soy) and poultry operations, but also includes some pasture (cattle and horses). Ditching on agricultural lands in the Pocomoke River watershed is an extensive practice that has been used to drain wetlands for agriculture. Ditching goes back to the 1840s and much of the land clearing in the Pocomoke River watershed was completed prior to the 1940s (Gellis et al. 2009, Bell and Favero 2000).

The Upper Pocomoke River watershed contains urban, agricultural, and forested land uses (see Figure 3). The land use distribution consists of agricultural (39%), forested/wetland (53%), and urban pervious (7%) and impervious (1%) land uses (see Figure 4) (USEPA 2010, MDP 2002).

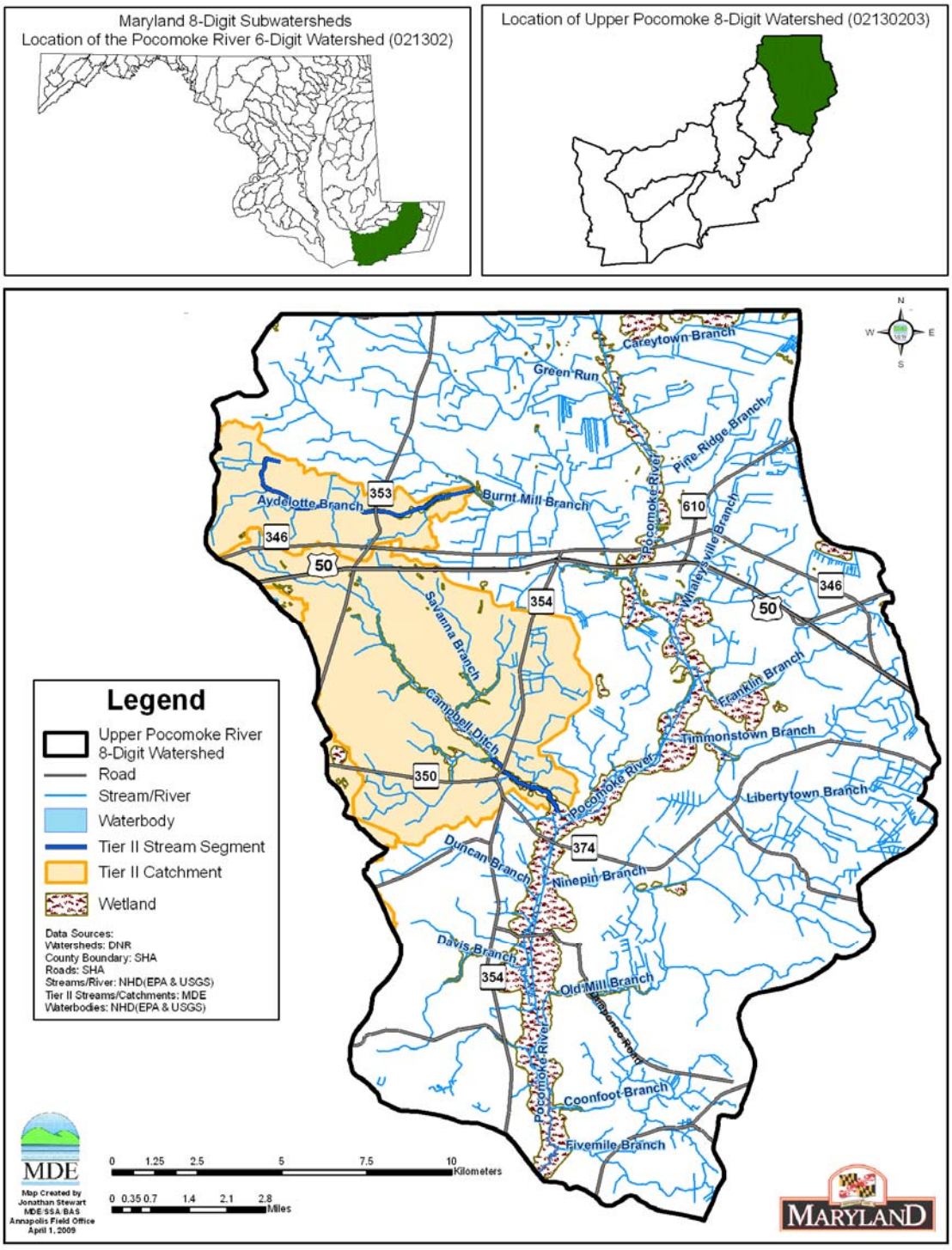


Figure 1. Location Map of the Upper Pocomoke River Watershed

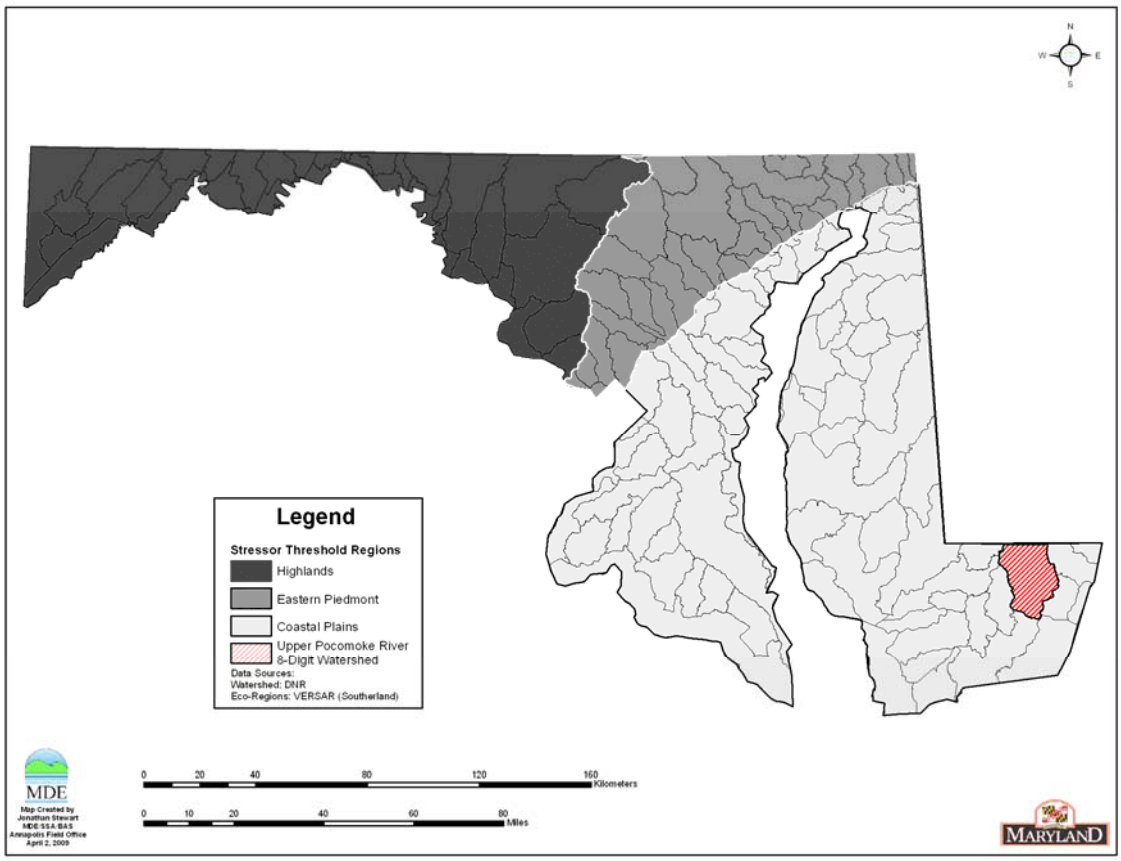


Figure 2. Eco-Region Map of the Upper Pocomoke River Watershed

2.3 Soils/hydrology

The Upper Pocomoke River watershed lies in the Coastal Plain physiographic province. The Coastal Plain province is characterized by flat or gently rolling topography and elevations rising from sea level to about 100 feet (DNR 2009). The Coastal Plain Province is underlain by a wedge of unconsolidated sediments including gravel, sand, silt, and clay (MGS 2009). The predominant soils in the Upper Pocomoke River watershed are level to nearly level, poorly drained soils in the Pocomoke-Fallsington and Othello-Fallsington-Portsmouth Associations (SCS 1970, SCS 1973).

The Upper Pocomoke River is located in the Delmarva Peninsula region of the Coastal Plain. The Peninsula contains a series of confined aquifers that are overlain by an extensive surficial (unconfined) aquifer. The typically sandy unconfined surficial aquifer on the Delmarva Peninsula is vulnerable to anthropogenic contamination from a variety of sources, including septic system discharges and applications of fertilizer, pesticides, lime, and manure (Ator et al. 2005). Groundwater flow paths generally are shorter than a few miles in length, and in areas with a high density of streams or drainage ditches, groundwater flow paths commonly are shorter than a few hundred feet (Hamilton et al.

1993). Hydrologic studies conducted within the non-tidal Pocomoke watershed indicate that groundwater is a significant hydrologic transport pathway in the Upper Pocomoke River watershed, and that periods of significant overland flow occur mainly during large storm events (Ator et al. 2005).

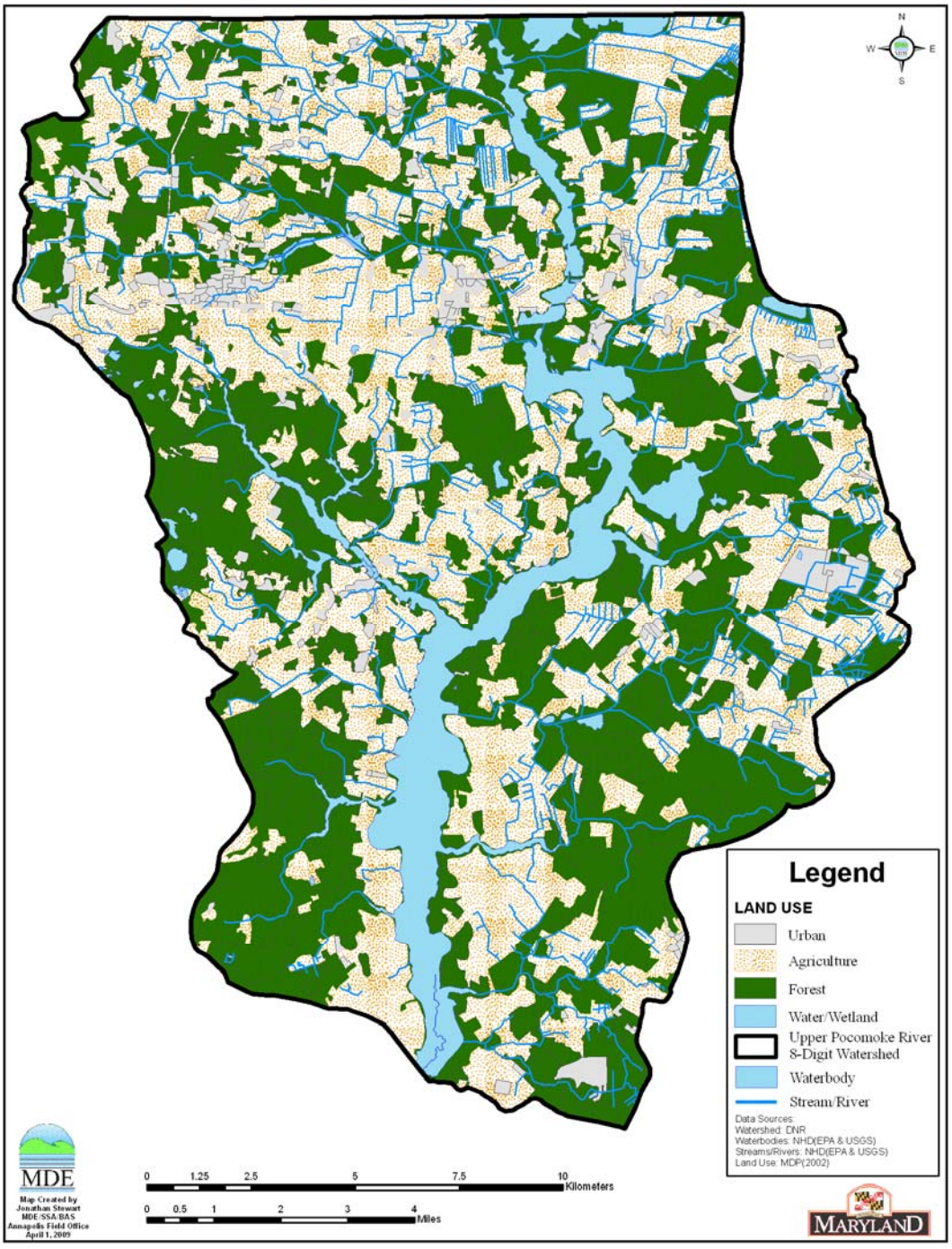


Figure 3. Land Use Map of the Upper Pocomoke River Watershed

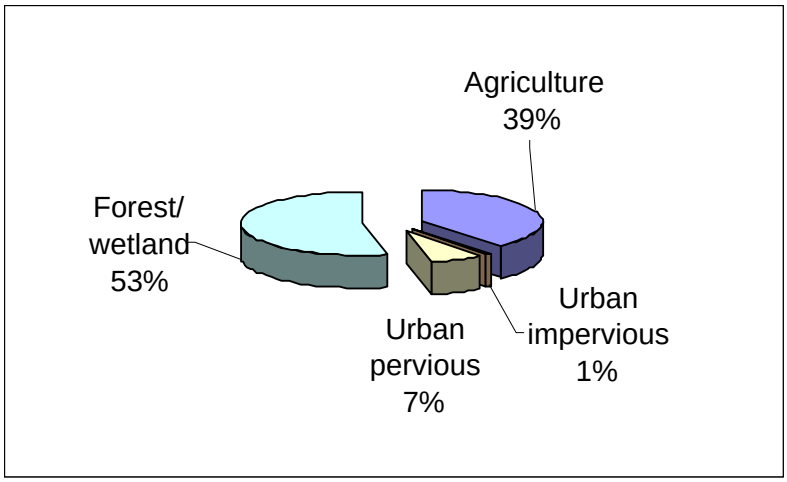


Figure 4. Proportions of Land Use in the Upper Pocomoke River Watershed

3.0 Upper Pocomoke River Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Maryland Department of the Environment (MDE) has identified the waters of the Upper Pocomoke River in the Maryland's Integrated Report as impaired by sediments (1996), nutrients (1996), and impacts to biological communities (2002) (MDE 2008). All impairments are listed for non-tidal streams. The Adkins Pond impoundment was listed as impaired for nutrients and sediment in 1998. The 1996 nutrients listing were refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance. Similarly, the 1996 suspended sediment listing was refined in the 2008 Integrated Report to a listing for total suspended solids. A TMDL for sediments and phosphorus for the Adkins Pond impoundment was approved by the USEPA in 2001.

3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the non-tidal Upper Pocomoke River and its tributaries is Use I – water contact recreation, and protection of non-tidal warmwater aquatic life. The Upper Pocomoke River watershed is not attaining its designated use of protection of aquatic life because of biological impairments. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

The Upper Pocomoke River watershed is listed under Category 5 of the 2008 Integrated Report as impaired for impacts to biological communities. Approximately 35% of stream miles in the Upper Pocomoke River watershed are estimated as having fish and and/or benthic indices of biological impairment in the poor to very poor category. The

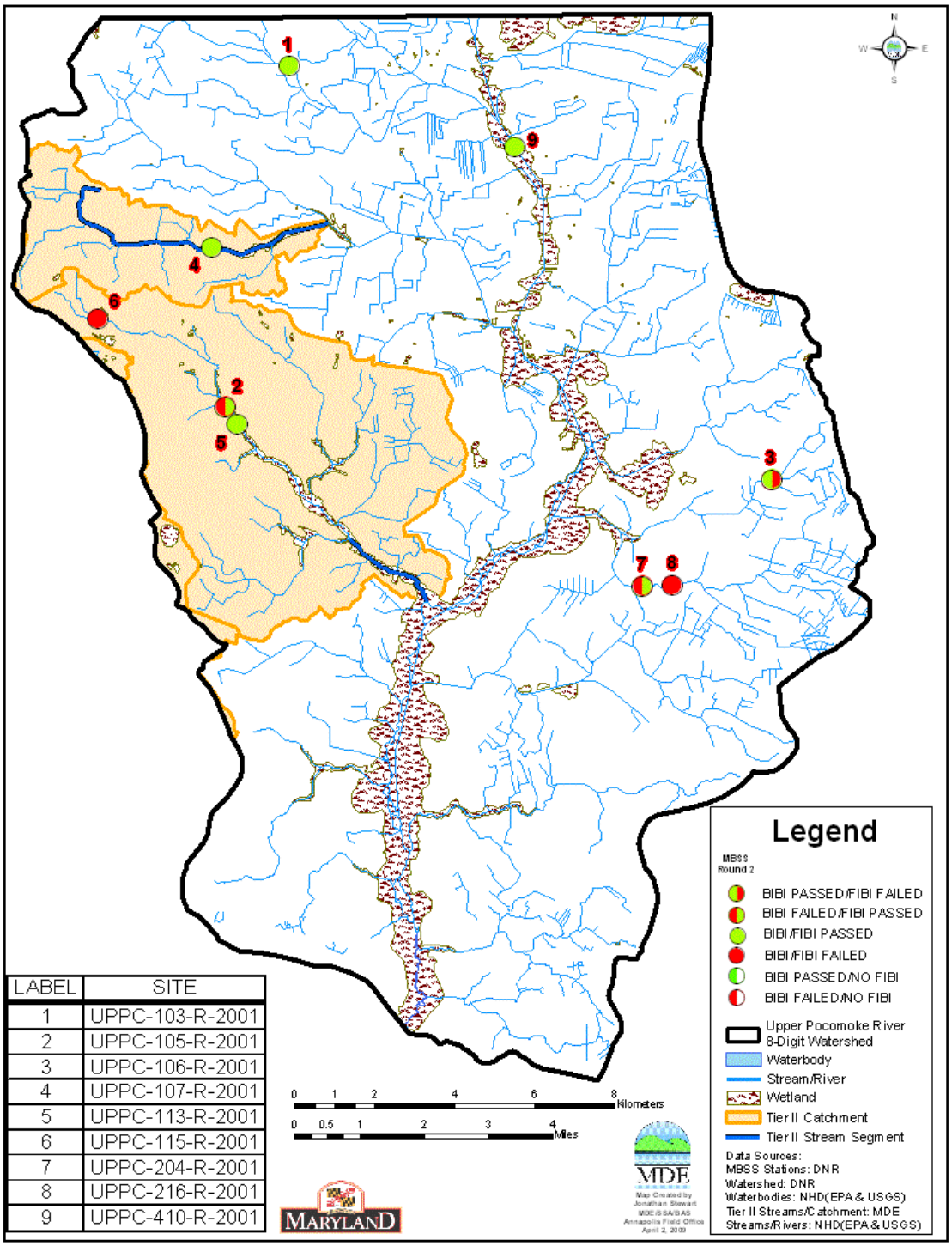
biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data, which include twenty-three sites. Ten of the twenty three have benthic and/or fish index of biotic integrity (BIBI, FIBI) scores significantly lower than 3.0 (i.e., poor to very poor). The principal dataset, i.e. MBSS Round 2 contains nine MBSS sites with five having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Upper Pocomoke River watershed.

4.0 Stressor Identification Results

The BSID process uses results from the BSID data analysis to evaluate each biologically impaired watershed and determine potential stressors and sources. Interpretation of the BSID data analysis results is based upon components of Hill's Postulates (Hill 1965), which propose a set of standards that could be used to judge when an association might be causal. The components applied are: 1) the strength of association which is assessed using the odds ratio; 2) the specificity of the association for a specific stressor (risk among controls); 3) the presence of a biological gradient; 4) ecological plausibility which is illustrated through final causal models; and 5) experimental evidence gathered through literature reviews to help support the causal linkage.

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores lower than 3.0 (i.e., poor to very poor). The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups – 1st and 2nd-4th order), that have fair to good biological conditions.

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the Mantel-Haenzel (MH) (1959) approach and is based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are very poor to poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and very poor to poor biological conditions, and is used to identify potential stressors.



LABEL	SITE
1	UPPC-103-R-2001
2	UPPC-105-R-2001
3	UPPC-106-R-2001
4	UPPC-107-R-2001
5	UPPC-113-R-2001
6	UPPC-115-R-2001
7	UPPC-204-R-2001
8	UPPC-216-R-2001
9	UPPC-410-R-2001

Figure 5. Principal Dataset Sites for the Upper Pocomoke River Watershed

Once potential stressors are identified (i.e., odds ratio significantly greater than one), the risk attributable to each stressor is quantified for all sites with very poor to poor biological conditions within the watershed (i.e., cases). The attributable risk (AR) defined herein is the portion of the cases with very poor to poor biological conditions that are associated with the stressor. The AR is calculated as the difference between the proportion of case sites with the stressor present and the proportion of control sites with the stressor present.

Once the AR is calculated for each possible stressor, the AR for groups of stressors is calculated. Similar to the AR calculation for each stressor, the AR calculation for a group of stressors is also summed over the case sites using the individual site characteristics (i.e., stressors present at that site). The only difference is that the absolute risk for the controls at each site is estimated based on the stressor present at the site that has the lowest absolute risk among the controls.

After determining the AR for each stressor and the AR for groups of stressors, the AR for all potential stressors is calculated. This value represents the proportion of cases, sites in the watershed with poor to very poor biological conditions, which would be improved if the potential stressors were eliminated (Van Sickle and Paulsen 2008). The purpose of this metric is to determine if stressors have been identified for an acceptable proportion of cases (MDE 2009).

Through the BSID analysis, MDE identified sediment, in-stream and riparian habitat parameters, water chemistry parameters, and potential sources significantly associated with poor to very poor benthic and/or fish biological conditions. As shown in Table 1 through Table 3, parameters from the sediment, habitat, and water chemistry groups are identified as possible biological stressors in the Upper Pocomoke River watershed. Parameters identified as representing possible sources are listed in Table 4 and include various agricultural land uses in the stream buffer zones. A summary of combined AR values for each stressor group is shown in Table 5. A summary of combined AR values for each source group is shown in Table 6.

Table 1. Sediment Biological Stressor Identification Analysis Results for the Upper Pocomoke River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher that odds or stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Sediment	extensive bar formation present	9	5	108	40%	21%	No	----
	moderate bar formation present	9	5	108	60%	54%	No	----
	bar formation present	9	5	108	80%	79%	No	----
	channel alteration marginal to poor	9	5	105	60%	60%	No	----
	channel alteration poor	9	5	105	60%	23%	Yes	39%
	high embeddedness	9	5	108	0%	0%	No	----
	epifaunal substrate marginal to poor	9	5	108	80%	39%	Yes	43%
	epifaunal substrate poor	9	5	108	60%	8%	Yes	53%
	moderate to severe erosion present	9	5	108	40%	45%	No	----
	severe erosion present	9	5	108	20%	12%	No	----
	poor bank stability index	9	5	108	0%	23%	No	----
	silt clay present	9	5	108	100%	99%	No	----

Table 2. Habitat Biological Stressor Identification Analysis Results for the Upper Pocomoke River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher that odds or stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
In-Stream Habitat	channelization present	9	5	110	60%	14%	Yes	46%
	instream habitat structure marginal to poor	9	5	108	80%	34%	Yes	49%
	instream habitat structure poor	9	5	108	0%	4%	No	----
	pool/glide/eddy quality marginal to poor	9	5	108	80%	36%	Yes	48%
	pool/glide/eddy quality poor	9	5	108	0%	3%	No	----
	riffle/run quality marginal to poor	9	5	108	100%	42%	Yes	60%
	riffle/run quality poor	9	5	108	80%	19%	Yes	60%
	velocity/depth diversity marginal to poor	9	5	108	100%	52%	Yes	51%
	velocity/depth diversity poor	9	5	108	60%	11%	Yes	51%
	concrete/gabion present	9	5	113	0%	2%	No	----
	beaver pond present	9	5	106	0%	7%	No	----
Riparian Habitat	no riparian buffer	9	5	110	60%	12%	Yes	49%
	low shading	9	5	108	20%	9%	No	----

Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Upper Pocomoke River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher that odds or stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Water Chemistry	high total nitrogen	9	5	208	20%	25%	No	----
	ammonia acute with salmonid present	9	5	208	40%	39%	No	----
	ammonia acute with salmonid absent	9	5	208	20%	26%	No	----
	ammonia chronic with salmonid present	9	5	208	80%	67%	No	----
	ammonia chronic with salmonid absent	9	5	208	80%	57%	No	----
	low lab pH	9	5	208	20%	38%	No	----
	high lab pH	9	5	208	0%	0%	No	----
	low field pH	9	5	207	0%	39%	No	----
	high field pH	9	5	207	0%	0%	No	----
	high total phosphorus	9	5	208	40%	3%	Yes	37%
	high orthophosphate	9	5	208	80%	13%	Yes	68%
	dissolved oxygen < 5mg/l	9	5	206	100%	14%	Yes	86%
	dissolved oxygen < 6mg/l	9	5	206	100%	22%	Yes	78%
	low dissolved oxygen saturation	9	5	184	80%	18%	Yes	62%
	high dissolved oxygen saturation	9	5	184	0%	0%	No	----
	acid neutralizing capacity below chronic level	9	5	208	0%	9%	No	----
	acid neutralizing capacity below episodic level	9	5	208	0%	48%	No	----
	high chlorides	9	5	208	0%	6%	No	----
	high conductivity	9	5	208	0%	5%	No	----
	high sulfates	9	5	208	40%	4%	Yes	36%

Table 4. Stressor Source Identification Analysis Results for the Upper Pocomoke River Watershed

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher that odds or sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources - Urban	high impervious surface in watershed	9	5	214	0%	5%	No	----
	high % of high intensity urban in watershed	9	5	214	0%	9%	No	----
	high % of low intensity urban in watershed	9	5	214	0%	4%	No	----
	high % of transportation in watershed	9	5	214	0%	7%	No	----
	high % of high intensity urban in 60m buffer	9	5	212	0%	7%	No	----
	high % of low intensity urban in 60m buffer	9	5	212	0%	5%	No	----
	high % of transportation in 60m buffer	9	5	212	40%	9%	Yes	31%
Sources - Agr	high % of agriculture in watershed	9	5	214	20%	18%	No	----
	high % of cropland in watershed	9	5	214	20%	27%	No	----
	high % of pasture/hay in watershed	9	5	214	20%	6%	No	----
	high % of agriculture in 60m buffer	9	5	212	80%	8%	Yes	72%
	high % of cropland in 60m buffer	9	5	212	20%	18%	No	----
	high % of pasture/hay in 60m buffer	9	5	212	80%	8%	Yes	72%
Sources - Barren	high % of barren land in watershed	9	5	214	0%	23%	No	----
	high % of barren land in 60m buffer	9	5	212	0%	6%	No	----
Sources - Anthropogenic	low % of forest in watershed	9	5	214	0%	5%	No	----
	low % of forest in 60m buffer	9	5	212	40%	5%	Yes	35%
Sources - Acidity	atmospheric deposition present	9	5	208	0%	40%	No	----
	AMD acid source present	9	5	208	0%	0%	No	----
	organic acid source present	9	5	208	0%	6%	No	----
	agricultural acid source present	9	5	208	0%	7%	No	----

Table 5. Summary AR Values for Stressor Groups for the Upper Pocomoke River Watershed

Stressor Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Sediment	84%	95%
In-Stream Habitat	86%	
Riparian Habitat	49%	
Water Chemistry	94%	

Table 6. Summary AR Values for Source Groups for the Upper Pocomoke River Watershed

Source Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Urban	31%	93%
Agriculture	92%	
Barren Land	----	
Anthropogenic	35%	
Acidity	----	

Sediment Conditions

BSID analysis results for the Upper Pocomoke River watershed identified three sediment parameters that have a statistically significant association with poor to very poor stream biological condition: *channel alteration (poor)* and *epifaunal substrate (marginal to poor* and *poor).*

Channel alteration was identified as significantly associated with degraded biological conditions in the Upper Pocomoke River watershed, and found to impact 39% (*poor* rating) of the stream miles with poor to very poor biological conditions. Channel alteration measures large-scale modifications in the shape of the stream channel due to the presence of artificial structures (*channelization present* and/or bar formations).

Epifaunal substrate was identified as significantly associated with degraded biological conditions in the Upper Pocomoke River watershed, and found to impact approximately 43% (*marginal to poor* rating) and 53% (*poor* rating) of the stream miles with poor to very poor biological conditions. Epifaunal substrate is a visual observation of the abundance, variety, and stability of substrates that offer the potential for full colonization by benthic macroinvertebrates. Epifaunal substrate quality is confounded by natural variability (i.e., streams will naturally have more or less available productive substrate). Greater availability of productive substrate increases the potential for full colonization; conversely, less availability of productive substrate decreases or inhibits colonization by benthic macroinvertebrates. Epifaunal substrate conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, where stable substrate is lacking, or particles are over 75% surrounded by fine sediment and/or flocculent material; and 2) marginal to poor, where large boulders and/or bedrock are prevalent and cobble, woody debris, or other preferred surfaces are uncommon.

The BSID analysis applied a threshold of 100% for embeddedness in the Coastal Plains since the eco-region is naturally embedded. Consequently, embeddedness was not identified as significantly associated with degraded biological conditions in the Upper Pocomoke River watershed in this analysis. The data review did, however, identify eight of the nine DNR MBSS round two sites used in this analysis as 100% embedded. Embeddedness describes the percentage of fine sediment surrounding gravel, cobble, and boulder particles in the streambed. High embeddedness is a result of excessive sediment deposition that may interfere with feeding or reproductive processes.

The Upper Pocomoke River watershed consists of approximately 39% agricultural land uses (USEPA 2010). Ditching on agricultural lands in the Pocomoke River is an extensive practice that has been used to drain wetlands for agriculture (Bell and Favero 2000; Gellis et al. 2009). The majority of agricultural uses in the watershed are comprised of cropland (primarily corn and soy), pasture and poultry operations. Agricultural practices, such as row crop cultivation and cattle grazing typically extend directly to the stream and ditch banks, lacking adequate forested or vegetated buffer zones. Ditching and

straightening (channelization) of the mainstem Pocomoke River, and continual dredging have created conditions favorable for channel-corridor erosion (channel and ditch banks and ditch beds) in the Pocomoke River (Gellis et al. 2009).

The BSID analysis has confirmed that channel alteration due to extensive ditching practices in the watershed has occurred. Channel and bank erosion have increased sediment deposition throughout the streambed primarily through settling of sediment in the stream substrate, as demonstrated by the lack of adequate epifaunal substrate. This effect is compounded by the low topographic relief throughout the watershed that does not allow for sediment transport to downstream reaches. Sediment deposited on the streambed can suffocate benthic organisms, especially in the embryonic and larval stages (NRCS 1997). The sediment deposition in the watershed has led to a loss of suitable habitat to support the full colonization of a healthy fish and benthic macroinvertebrate community.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the sediment stressor group is approximately 84% suggesting these stressors impact a substantial proportion of the degraded stream miles in the Upper Pocomoke River watershed (See Table 5).

In-stream Habitat Conditions

BSID analysis results for the Upper Pocomoke River watershed identified seven in-stream habitat parameters that have a statistically significant association with poor to very poor stream biological condition: *channelization present*, *instream habitat structure (marginal to poor*, *pool/glide/eddy quality (marginal to poor), riffle/run quality (marginal to poor* and *poor),* and *velocity depth diversity (marginal to poor* and *poor).*

Channelization present was identified as significantly associated with degraded biological conditions in the Upper Pocomoke River watershed, and found in 46% of the stream miles with poor to very poor biological conditions. This stressor measures the presence/absence of channelization in stream banks. It describes both the straightening of channels and their fortification with concrete or other hard materials. Natural channels have diverse habitats with varying water velocities as the morphology changes between riffles and pools. The diverse nature of natural channels provides slow water refugia during high flow and many resting areas. With less structural diversity, channelized systems have minimal resting areas and organisms are easily swept away during high flows. In low flow periods, natural channels have sufficient water depth to support fish and aquatic species during the dry season; where as, channelized streams often have insufficient depth to sustain diverse aquatic life (Bolton and Shellberg 2001).

Instream habitat structure (marginal to poor) was identified as significantly associated with degraded biological conditions in the Upper Pocomoke River watershed, and found to impact approximately 49% of the stream miles with poor to very poor biological conditions. In-stream habitat is a visual rating based on the perceived value of habitat within the stream channel to the fish community. Multiple habitat types, varied particle sizes, and uneven stream bottoms provide valuable habitat for fish. High in-stream habitat scores are evidence of the lack of sediment deposition. In-stream habitat conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, which is defined as less than 10% stable habit where lack of habitat is obvious; and 2) marginal to poor, where there is a 10-30% mix of stable habitat but habitat availability is less than desirable.

Pool/glide/eddy quality (marginal to poor) was identified as significantly associated with degraded biological conditions in the Upper Pocomoke River watershed, and found to impact approximately 48% of the stream miles with poor to very poor biological conditions. Pool/glide/eddy quality is a visual observation and quantitative measurement of the variety and spatial complexity of slow or still water habitat and cover within a stream segment referred to as pool/glide/eddy. Stream morphology complexity directly increases the diversity and abundance of fish species found within the stream segment. The increase in heterogeneous habitat such as a variety in depths of pools, slow moving water, and complex covers likely provide valuable habitat for fish species; conversely, a lack of heterogeneity within the pool/glide/eddy habitat decreases valuable habitat for fish species. Poor pool/glide/eddy quality conditions are defined as minimal heterogeneous habitat with a max depth of <0.2 meters or being absent completely.

Riffle/run quality (marginal to poor and *poor)* was identified as significantly associated with degraded biological conditions in the Upper Pocomoke River watershed, and both categories were found to impact approximately 60% of the stream miles with poor to very poor biological conditions. Riffle/run quality is a visual observation and quantitative measurement based on the depth, complexity, and functional importance of riffle/run habitat within the stream segment. An increase in the heterogeneity of riffle/run habitat within the stream segment likely increases the abundance and diversity of fish species, while a decrease in heterogeneity likely decreases abundance and diversity. Riffle/run quality conditions indicating biological degradation are set at two levels: 1) poor, defined as riffle/run depths < 1 cm or riffle/run substrates concreted; and 2) marginal to poor, defined as riffle/run depths generally 1 – 5 cm with a primarily single current velocity. The presence of a well-developed riffle/run system is indicative of different types of habitat within a stream reach, and thereby an assumed higher biodiversity of organisms (Richards et al. 1993). Because stream organisms are highly specialized in many cases, a diverse array of habitat typically leads to a diverse array of macroinvertebrates (Karr 1997).

Velocity/depth diversity (marginal to poor and *poor)* was identified as significantly associated with degraded biological conditions in Upper Pocomoke River watershed, and both categories were found to impact approximately 51% of the stream miles with poor to very poor biological conditions. Velocity/depth diversity is a visual observation and quantitative measurement based on the variety of velocity/depth regimes present at a site (i.e., slow-shallow, slow-deep, fast-shallow, and fast-deep). Like pool quality and riffle quality, the increase in the number of different velocity/depth regimes likely increases the abundance and diversity of fish species within the stream segment. The decrease in the number of different velocity/depth regimes likely decreases the abundance and diversity of fish species within the stream segment. The marginal or poor diversity categories could identify the absence of available habitat to sustain a diverse aquatic community. This measure may reflect natural conditions (e.g., bedrock), anthropogenic conditions (e.g., widened channels, dams, channel dredging, etc.), or excessive erosional conditions (e.g., bar formation, entrenchment, etc.). Poor velocity/depth diversity conditions are defined as the stream segment being dominated by one velocity/depth regime.

The Upper Pocomoke River watershed is heavily ditched and channelized throughout its reaches. Ditching on agricultural lands in the Pocomoke River watershed is an extensive practice that has been used to drain wetlands for agriculture since the 1840s (Gellis et al. 2009; Bell and Favero 2000). Ditching occurred at several scales, from ditches on farm fields to straightening and deepening of main-stem rivers and tributaries (Gellis et al. 2009). Practices to maintain ditches include targeting woody growth removal by mowing and spraying with herbicides, and mechanically removing sediments and debris by "dipping". These practices occur on approximately 2 to 5 year, and 15 to 20 year intervals, respectively (Bell and Favero 2000).

The BSID analysis has confirmed that *channelization present* is a significant stressor in the Upper Pocomoke River watershed. The remaining in-stream habitat stressors identified in the analysis are indicative of channelization and ditching practices in the watershed. Channelization, ditching and subsequent maintenance eliminates the natural riffle-pool complexes, velocity/depth diversity and stable, diverse substrates that provide fish and macroinvertebrates with adequate stream morphology complexity to support healthy populations. The decrease in a variety and abundance of substrates can lead to a homogeneous habitat that is unsuitable for the full colonization of fish and macroinvertebrate communities.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the in-stream habitat stressor group is approximately 86% suggesting this stressor impacts a substantial proportion of the degraded stream miles in the Upper Pocomoke River watershed (See Table 5).

Riparian Habitat Conditions

BSID analysis results for the Upper Pocomoke River identified one riparian habitat parameter that has a statistically significant association with poor to very poor stream biological condition: *no riparian buffer.*

No riparian buffer was identified as significantly associated with degraded biological conditions in the Upper Pocomoke River, and found to impact approximately 49% of the stream miles with poor to very poor biological conditions. Riparian buffer width represents the minimum width of vegetated buffer in meters, looking at both sides of the stream. Riparian buffer width is measured from 0 m to 50 m, with 0 m having no buffer and 50 m having a full buffer. Riparian buffers serve a number of critical ecological functions. They control erosion and sedimentation, modulate stream temperature, provide organic matter, and maintain benthic macroinvertebrate communities and fish assemblages (Lee et al 2004). Decreased riparian buffer leads to reduced amounts of large wood in the stream. Stable wood substrate in streams performs multiple functions, influencing channel features, flow, habitat, and providing cover for fish.

The Upper Pocomoke River watershed is comprised largely of agricultural row crops (corn and soy) and pasture. These row crops typically extend to the edge of the nearby streams and ditches. Even in some forested areas, a grass buffer strip is often located next to the stream for ditch maintenance.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the riparian habitat stressor group is approximately 49% suggesting this stressor impacts a moderate proportion of the degraded stream miles in the Upper Pocomoke River (See Table 5).

Water Chemistry

BSID analysis results for the Upper Pocomoke River watershed identified six water chemistry parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters are *high total phosphorus, high orthophosphate,* l*ow (<6mg/L* and *< 5mg/L) dissolved oxygen* (DO), l*ow* (< 60%) *DO saturation* and *high sulfate.*

High total phosphorus levels were identified as significantly associated with degraded biological conditions and found in approximately 37% of the degraded stream miles within the Upper Pocomoke River watershed. Total Phosphorous (TP) is a measure of the amount of TP in the water column. Phosphorus occurs naturally in rocks and other mineral deposits, and is usually found in the form of phosphates in natural waters. The majority of phosphate mined in the United States is used for fertilizers, with a minor component used for animal feed supplements and other products. Anthropogenic sources of phosphorus are fertilizers, chemicals, animal waste and municipal sewage. TP input to

surface waters typically increases in watersheds where urban and agricultural land uses are predominant.

High orthophosphate concentrations were identified as significantly associated with degraded biological conditions in the Upper Pocomoke River watershed, and found to impact approximately 68% of the stream miles with poor to very poor biological conditions. The orthophosphate (OP) parameter is the measure of the amount of OP in the water column. OP is the most readily available form of phosphorus for uptake by aquatic organisms. Phosphorus forms the basis of a very large number of compounds, the most important class of which is the phosphates. For every form of life, phosphates play an essential role in all energy-transfer processes such as metabolism and photosynthesis. Excessive phosphorus concentrations in surface water can accelerate eutrophication, resulting in increased growth of undesirable algae and aquatic weeds. Eutrophication can potentially results in low dissolved oxygen and high pH levels, which can exceed tolerance levels of many biological organisms. OP loads to surface waters typically increases in watersheds where urban and agricultural developments are predominant.

Low (< 5mg/L and *< 6mg/L) dissolved oxygen* (DO) concentrations were identified as significantly associated with degraded biological conditions and found in 86% and 78%, respectively, of the stream miles with poor to very poor biological conditions in the Upper Pocomoke River watershed. Low DO concentrations may indicate organic pollution due to excessive oxygen demand and may stress aquatic organisms. The DO threshold value, at which concentrations below 5.0 mg/L may indicate biological degradation, is established by COMAR 2007.

Low (< 60%) DO saturation were identified as significantly associated with degraded biological conditions and found in 62% of the stream miles with poor to very poor biological conditions in the Upper Pocomoke River watershed. Natural diurnal fluctuations can become exaggerated in streams with excessive primary production. High and low DO saturation accounts for physical solubility limitations of oxygen in water and provides a more targeted assessment of oxygen dynamics than concentration alone. High DO saturation is considered to demonstrate oxygen production associated with high levels of photosynthesis. Low DO saturation is considered to demonstrate high respiration associated with excessive decomposition of organic material.

High sulfates were identified as significantly associated with degraded biological conditions and found in 36% of the stream miles with poor to very poor biological conditions in the Upper Pocomoke River watershed. Sulfate is the amount of dissolved sulfate (SO_4^{2-}) in the water column. MDDNR MBSS measures sulfate once in the spring and reports it as mg/L. Sulfur is an essential plant nutrient. Sulfate loads to surface waters can be naturally occurring or originate from urban runoff, agricultural runoff, acid mine drainage, atmospheric deposition, and wastewater dischargers. When naturally occurring, they are often the result of the breakdown of leaves that fall into a stream, of water passing through rock or soil containing gypsum and other common minerals.

Poultry operations are located extensively throughout the Upper Pocomoke River watershed. The poultry manure generated by these operations is commonly spread on fields as fertilizers (often near streams or ditches that drain to nearby streams). The Water Quality Improvement Act of 1998 mandated that farmers use nutrient management plans (NMPs) to reduce nitrogen and phosphorus inputs. The NMPs do not require use of storage sheds for poultry litter, and it is sometimes stored outdoors. If manure is stored uncovered too close to a nearby body of water for more than a few days, or on top of the ground with no barrier, there are serious risks of groundwater and surface water contamination (MAG 2008).

Poultry litter applications to pastures have been shown to result in relatively high phosphorus runoff, even when litter is applied at recommended rates (Moore et al. 1998; Edwards et al. 1992). Aluminum sulfate is an amendment of poultry litter that is used as a best management practice (BMP) to help reduce the phosphorus loads to streams from surface runoff and leaching. Studies have shown that treating poultry litter with alum is a cost-effective management practice that significantly reduces nonpoint source phosphorus runoff (Moore et al. 1998). The elevated sulfate identified by the BSID indicates that this BMP practice may be occurring in the watershed.

The water chemistry stressors identified by the BSID are indicative of agricultural activities that degrade water quality by causing an increase in contaminant loads from fertilizer/manure application. Although NMPs and BMPs are in place to control nutrient runoff in the watershed, the BSID analyses revealed that agricultural practices continue to create conditions in the watershed that are negatively impacting biological resources. The excess phosphorus from fertilizer applications is leading to eutrophication in the watershed, as evidenced by the *high total phosphorus* and *orthophosphate*, and the *low dissolved oxygen* and *low dissolved oxygen saturation* stressors identified as significantly associated with degraded biological conditions in the watershed. The impact is compounded by the low topography and slow moving waters in the region.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the water chemistry stressor group is approximately 94% suggesting that these stressors impact a substantial proportion of degraded stream miles in the Upper Pocomoke River watershed (Table 5).

Sources

All sixteen stressor parameters, identified in Tables 1-3, that are significantly associated with biological degradation in the Upper Pocomoke River watershed BSID analysis, are representative of impacts from agricultural land use and its practices.

The BSID results identified several land uses within the 60 meter (M) buffer zone that indicate agricultural practices are negatively impacting the biological resources in this watershed. The high percentage of agricultural land use in the watershed is indicative of the agricultural crops that are cultivated to the stream banks. The high percentage of

pasture/hay land use in the 60 M buffer is indicative of agricultural practices that allow cattle to have direct access to ditches and streams. Sediments in runoff from cultivated land and livestock trampling are considered to be particularly influential in stream impairment (Waters 1995).

Agricultural land uses comprise thirty-nine percent of the Upper Pocomoke River watershed. Agricultural land use within the watershed, as well as within the sixty meter riparian zone, were found to be significantly associated with poor to very poor biological conditions in the watershed. Although NMPs and BMPs are in place to control nutrient runoff in the watershed, the BSID analyses revealed that agricultural practices continue to create conditions in the watershed that are impacting biological resources. The excess phosphorus from fertilizer applications is leading to eutrophication in the watershed, as evidenced by the *low dissolved oxygen* and *low dissolved oxygen saturation* stressors identified as significantly associated with degraded biological conditions in the watershed.

The BSID source analysis (Table 4) identifies various types of agricultural land uses as potential sources of stressors that may cause negative biological impacts. The AR for the agricultural source group is approximately 92% suggesting that agricultural development potentially impacts a substantial proportion of the degraded stream miles in Upper Pocomoke River watershed (Table 6).

Summary

The Upper Pocomoke River watershed is a highly agricultural landscape consisting of row crops, pasture and poultry operations. Agricultural practices include row crops that are commonly cultivated to the stream banks, disturbed buffer zones maintained for ditch maintenance, and poultry manure application to fields. Cattle in the watershed have direct access to ditches and streams. Despite the NMPs and BMPs applied in the watershed, agricultural practices continue to impact the water quality.

The BSID sediment and in-stream habitat analysis results suggest that degraded biological communities in the Upper Pocomoke River watershed are a result of agricultural land use practices that have altered the stream morphology (primarily through channelization and ditching). These practices have led to increased sediment settling in the stream substrate and a homogeneous habitat unsuitable for full colonization of a healthy fish and macroinvertebrate community structure.

The BSID water chemistry analysis results also suggest that degraded biological communities in the Upper Pocomoke River watershed are a result of agricultural land use practices that have led to increased nutrients from fertilizer applications. The increased nutrients have created conditions favorable for eutrophication in the watershed and led to low dissolved oxygen levels that exceed species tolerances, thereby decreasing the diversity needed to support the full colonization of a healthy fish and macroinvertebrate community structure.

The combined AR for all the stressors is approximately 95%, suggesting that the sediment, in-stream and riparian habitat, and water chemistry stressors adequately account for the biological impairment in the Upper Pocomoke River watershed.

The BSID analysis evaluates numerous key stressors using the most comprehensive data sets available that meet the requirements outlined in the methodology report. It is important to recognize that stressors could act independently or act as part of a complex causal scenario (e.g., eutrophication, urbanization, habitat modification). Also, uncertainties in the analysis could arise from the absence of unknown key stressors and other limitations of the principal data set. The results are based on the best available data at the time of evaluation.

Final Causal Model for the Upper Pocomoke River Watershed

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr 1991and USEPA 2007). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 6 illustrates the final causal model for the Upper Pocomoke River watershed, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

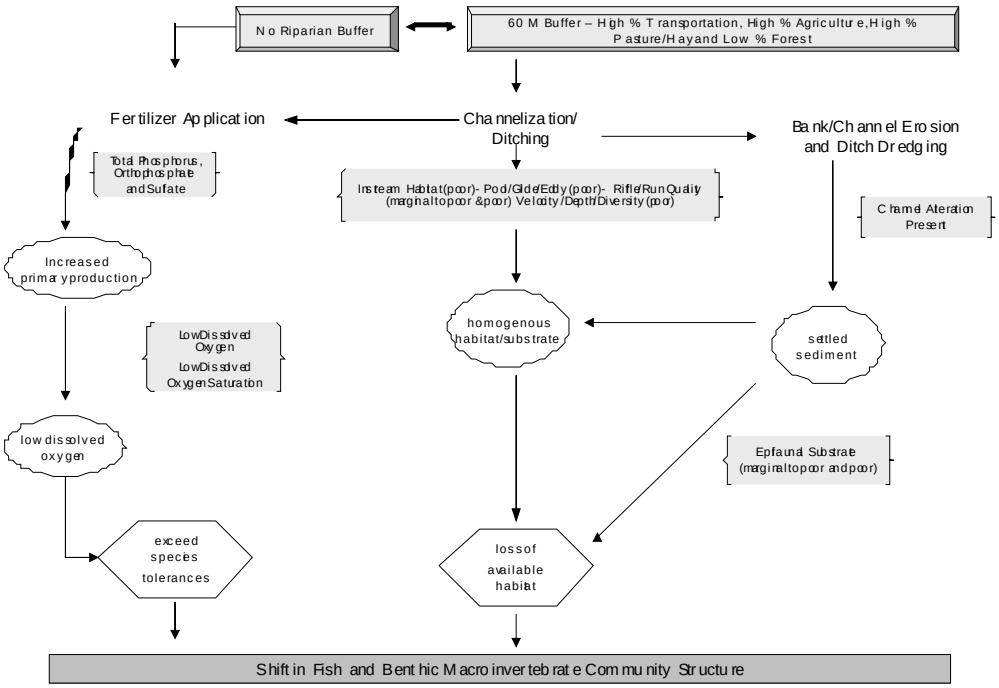


Figure 6. Final Causal Model for the Upper Pocomoke River Watershed

5.0 Conclusion

Data suggest that the Upper Pocomoke River watershed's biological communities are strongly influenced by agricultural land use, which alters the stream morphology resulting in increased erosion, sediment, and nutrient pollutant loading. There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to agricultural landscapes, which often cause increased contaminant loads from runoff. Based upon the results of the BSID process, the probable causes and sources of the biological impairments of the Upper Pocomoke River watershed are summarized as follows:

- The BSID process has determined that biological communities in the Upper Pocomoke River watershed are likely degraded due to sediment and in-stream habitat related stressors. Specifically, channelization of streams has led to increased settling of sediment in the stream substrate throughout the watershed, which is the probable cause of impacts to biological communities. The BSID results thus confirm the 2008 Category 5 listing for total suspended solids as an impairing substance in the Upper Pocomoke River non-tidal 8-digit watershed, and links this pollutant to biological conditions in these waters.

- The BSID process has also determined that the biological communities in the Upper Pocomoke River watershed are likely degraded due to water chemistry related stressors. Specifically, agricultural land use practices have resulted in the potential elevation of nutrient inputs throughout the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus confirm the 2008 Category 5 listing for phosphorus as an impairing substance in the Upper Pocomoke River non-tidal 8-digit watershed, and links this pollutant to biological conditions in these waters.

- The BSID process has also determined that biological communities in the Upper Pocomoke River watershed are likely degraded due to anthropogenic channelization of stream segments. MDE considers channelization as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution. Category 4c listings include segments impaired due to stream channelization or the lack of adequate flow. MDE recommends a Category 4c listing for the Upper Pocomoke River watershed based on channelization being present in approximately 46% of degraded stream miles.

- The BSID process has also determined that biological communities in the Upper Pocomoke River watershed are likely degraded due to anthropogenic alterations of riparian buffer zones. MDE considers inadequate riparian buffer zones as pollution not a pollutant; therefore, a Category 5 listing for this stressor is

inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards as a result of pollution. MDE recommends a Category 4c listing for the Upper Pocomoke River watershed based on inadequate riparian buffer zones in approximately 49% of degraded stream miles.

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