Poultry's Phosphorus Problem

Phosphorus and Algae in Eastern Shore Waterways:

High Concentrations, No Improvement in Past Decade

July 14, 2014

ENVIRONMENTAL INTEGRITY PROJECT

About the Environmental Integrity Project
The Environmental Integrity Project (EIP) is a nonpartisan, nonprofit organization dedicated to the enforcement of the nation's anti-pollution laws and to the prevention of political interference with those laws. EIP provides objective analysis of how the failure to enforce or implement environmental laws increases pollution and harms public health, and helps local communities obtain the protection of environmental laws.

Cover photograph credits
Poultry houses on the Chester River, west of Crumpton, July 2, 2009. Author: Jane Thomas, Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/).

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"We believe that the current nutrient management plan more than adequately addresses agriculture nutrient issues." - Maryland Farm Bureau, December, 2013

Introduction

The Chesapeake Bay is overloaded with phosphorus and nitrogen, nutrients that trigger algae blooms that block sunlight and rob Bay waters of the oxygen needed to sustain a healthy ecosystem. EPA and states that share the Bay watershed have agreed to restrict discharges from agricultural, industrial and urban sources to help meet Bay water quality goals by 2025. The U.S. Environmental Protection Agency's Chesapeake Bay Program estimates that agricultural sources accounted for 57% of the phosphorus and 42% of the nitrogen discharged to Bay waters in 2013, more than any other sector.[1] Not surprisingly, farm runoff contributes the largest share of nutrients to the tidal rivers that meander through Maryland's Eastern Shore, which are located near the heart of the state's poultry industry. Agriculture is the source of 60 to 73% of the nitrogen and 68 to 84% of the phosphorus in Eastern Shore watersheds, which include the Chester, Choptank, Transquaking, Nanticoke, Sassafras, Manokin, Pocomoke and Wicomico rivers.

These watersheds help replenish the Bay, provide critical habitat for fish and other wildlife, and are an invaluable recreational resource for those who visit or live on the Eastern Shore. They are also surrounded by 1,339 chicken farms that sent over 500 million broilers to market in 2012, according to the U.S. Department of Agriculture, while generating over 1 billion pounds of manure containing an estimated 30.2 million pounds of phosphate. A thousand broiler chickens create about a ton of phosphorus-rich manure per year, which is then typically spread on cropland or pasture as fertilizer. Because the lower Eastern shore is already saturated with phosphorus, the amount that cannot be absorbed by soil or plants finds its way to the Bay through surface runoff or the discharge from groundwater underneath fields to nearby creeks.

Phosphorus is the nutrient of greatest concern on the Eastern Shore, while high chlorophyll-a levels indicate unwelcome algae growth. The University of Maryland's Center for Environmental Sciences (UMCES) has identified benchmark levels that indicate when concentrations of phosphorus and chlorophyll-a are low enough to indicate good water quality. The Environmental Integrity Project analyzed water quality data that reflect actual conditions in Eastern Shore tidal waterways from 2003 to 2013 (please see the discussion of methodology on page 6).[2] The analysis reveals that:

- Average spring and summer concentrations of total phosphorus were higher (sometimes much higher) than the UMCES benchmarks at all but two of the eighteen monitoring stations in the eight lower Eastern Shore's tidal rivers between 2011 and 2013. Longer-term trends indicate that concentrations of total phosphorus are not improving at 14 stations and have worsened at four stations since 2003.

- Average summer chlorophyll-a levels exceed the UMCES criteria at all but one monitoring station over the same three year period, while spring concentrations were higher at twelve of eighteen locations. Trends indicate no improvement at most stations since 2003, while spring and/or summer chlorophyll-a concentrations are on the rise in several waterways.

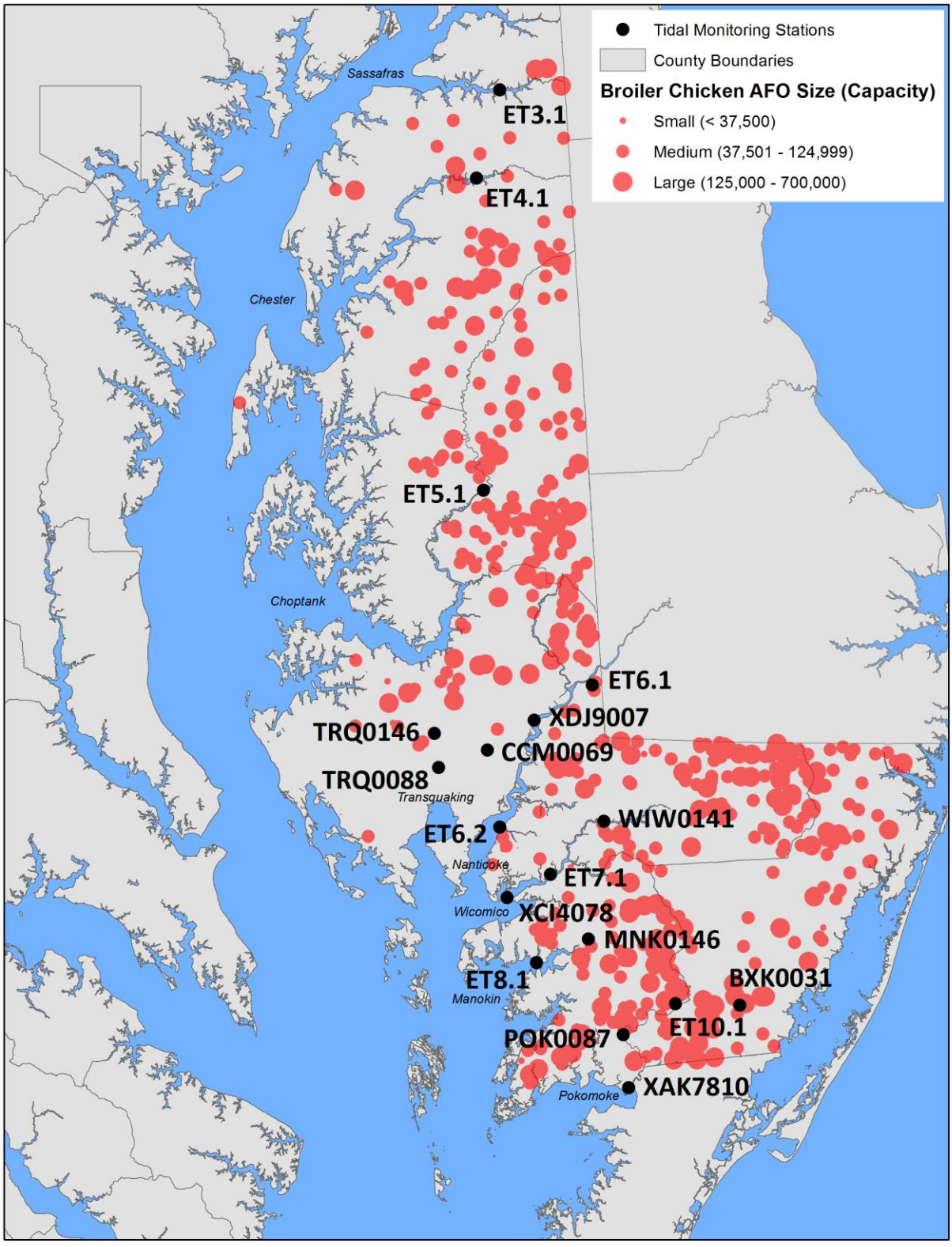
On November 15, 2013, in response to pressure from state farming interests, the Department of Agriculture withdrew a proposed "Phosphorus Management Tool" to identify fields with the greatest potential for phosphorus runoff for more effective control of these hotspots. While calling for additional reductions from sewage treatment plants, the Maryland Farm Bureau has insisted that current practices are good enough to meet Bay water quality goals.

Given the high and persistent concentrations of phosphorus and chlorophyll in Eastern Shore watersheds, it is far too early for the farm lobby to declare victory or to block efforts to target and clean up nutrient hotspots. As Professor Donald Boesch, the long-time director of the University of Maryland Center for Environmental Sciences has warned:

> It took many years of phosphorus application in excess of crop removal to build soil phosphorus concentrations to levels of environmental concern. Accordingly, it will take many years for soil phosphorus concentrations to decline after phosphorus applications are reduced or cease and, consequently, for water quality benefits to be seen…without action, high phosphorus "hot spots" will continue to contribute phosphorus to surface waters, counteracting our best practices elsewhere to attain the required 2025 load reductions.[3]

If it will take many years to improve the quality of waters that are already overloaded with phosphorus, Maryland must find the political will today to target the hotspots that threaten to ruin the Eastern Shore's rivers for generations to come.

Figure 1. Map of tidal monitoring stations assessed and broiler chicken feeding operations on Maryland's Eastern Shore[4]



Scope and Methods

The Environmental Integrity Project examined water and habitat quality at 18 tidal monitoring locations in eight Eastern Shore waterways in order to:

- Quantify the extent to which seasonal average concentrations of phosphorus and chlorophyll-a exceeded water quality benchmarks from 2011-2013;
- Determine whether seasonal average concentrations of phosphorus and chlorophyll-a have increased, decreased, or stagnated since 2003;
- Determine whether indices of biotic integrity indicate if waterways are or have been healthy enough to support healthy communities of fish and other aquatic life over the same time periods.

Table 1. Data Sources

Data	Source
Tidal waterway water quality monitoring data for total phosphorus and chlorophyll-a, and benthic index of biotic integrity scores for 3 tidal waterways (2003-2013)	Chesapeake Bay Program, samples collected by the Maryland Department of Resources (MDNR) [5]
Freshwater stream impairments and % attributable to agriculture (2000-2004)	Maryland Biological Stream Survey Round 2 data, Watershed Report(s) for Biological Impairment – Biological Stressor Identification Analysis Results and Interpretation, Maryland Department of the Environment (2012-2014)[6]
Number of broiler chicken operations and broiler chicken, manure, and phosphate production by county[7]	U.S. Department of Agriculture's 2012 Census of Agriculture[8]; University of Maryland Extension[9]
Broiler chicken animal feeding operation (AFO) locations	Chesapeake Commons and Center for Progressive Reform, original data obtained through public information requests to the Maryland Department of the Environment[10]
Land Use/Land Cover by watershed; HUC 8 and 10 watershed boundaries	U.S. Geological Survey (USGS) 2011 National Land Cover Dataset[11]; USGS Watershed Boundary Dataset[12]

We evaluated waterway conditions from 2011-2013 by assessing three-year seasonal average concentrations of total phosphorus and chlorophyll-a at each monitoring station alongside relevant UMCES benchmark values.[13] The UMCES benchmarks represent concentrations of total phosphorus and chlorophyll-a that are characteristic of "healthy" waterways, and they vary by salinity and/or season.[14] Seasonal averages for total phosphorus include samples collected from March through September, spring chlorophyll-a concentrations include samples taken from March through May, and summer chlorophyll-a concentrations include samples taken from July through September.[15] The use of seasonal averages helps to "smooth out" changes in water flow, salinity, weather, and other sampling conditions that may vary from week to week or from one year to the next.

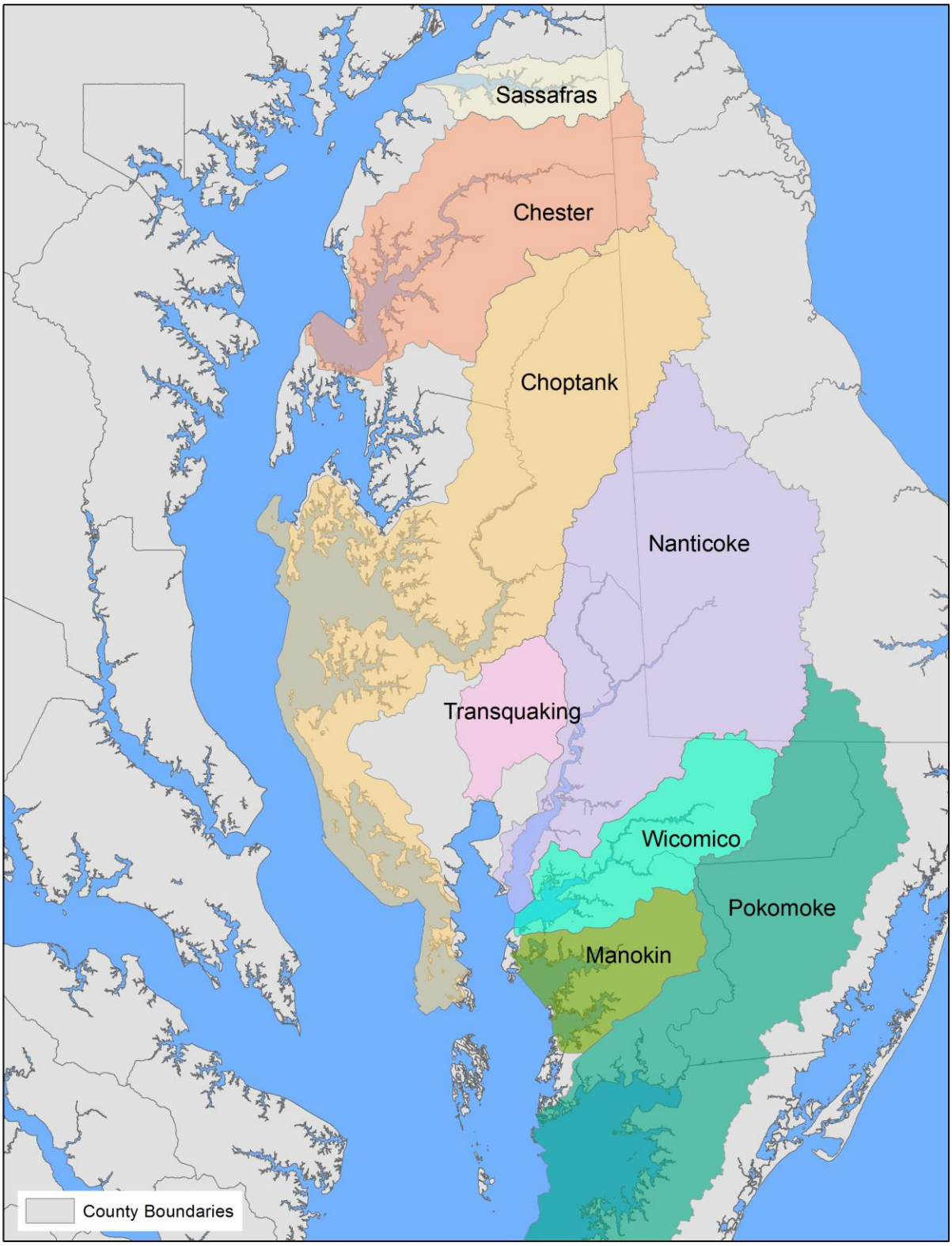
We evaluated trends in total phosphorus and chlorophyll-a concentrations with scatter plots of seasonal average concentrations and a widely-used statistical trend test.[16] Examining trends allows us to determine whether conditions have improved, worsened, or remained stagnant over an extended period of time, as year-to-year comparisons may not reflect true trends due to

changes in flow, sources, and other factors. The trend analysis begins in 2003 because it marks when monitoring began in upstream portions of several Eastern Shore watersheds.[17] Trends are not flow-adjusted or flow-normalized, and they represent actual concentrations at the time of sampling.[18] Our results appear to follow similar patterns reported in a recent USGS 10-year analysis of flow-adjusted trends in non-tidal waterways leading to the Chesapeake Bay.[19]

Index of biotic integrity (IBI) scores are based on field surveys conducted by the Maryland Department of Natural Resources and its contractors, and they are used to indicate whether aquatic habitat has been harmed by water pollution or other habitat-degrading alterations. These scores can apply to fish or benthic organisms like clams, snails, and worms. Most of this information dates from 2001 to 2004, so it could not be used to assess recent conditions or trends over the past ten years, though it provides some context and background on the extent of the water and habitat quality problems in the region.

The amount of manure and total phosphorus produced was calculated by the Environmental Integrity Project based on the U.S. Department of Agriculture's 2012 Census of Agriculture's estimate of annual broiler chicken production by county. While manure generation varies from operation to operation, we assumed manure generation to be around 1 ton of manure per 1000 chickens.[20] We assumed that the average phosphate content in that manure, without any chicken litter, was around 2.81%.[21] These assumptions are based on manure production rate estimates and average phosphate content used by the University of Maryland Extension and presented to the Chesapeake Bay Program.[22]

Figure 2. Map of Eastern Shore Watersheds



Results

Phosphorus and Chlorophyll a: Pollution Far Above Benchmarks

Average spring and summer total phosphorus concentrations from 2011-2013 exceeded UMCES benchmarks at all but 2 out of 18 monitoring stations in the Eastern Shore tidal rivers. They exceeded these benchmarks by at least 160% in the Transquaking, 21% in the lower Pokomoke, 47% in the upper Choptank, 338% in the Manokin, 15% in the Nanticoke, 50% in the Wicomico, 69% in the Chester, and 64% in the Sassafras. One station in the Transquaking river recorded the highest levels, with average concentrations more than five times the UMCES benchmark from 2011-2013.

Concentrations of spring and summer chlorophyll-a were much higher in the Eastern Shore than the yardstick UMCES uses to identify unhealthy conditions. In 2011-2013, average spring concentrations exceeded benchmark levels by 51% to 1152% in the Transquaking, Upper Choptank, Manokin, and Sassafras. Results were mixed in the Nanticoke and Wicomico and were below benchmark values in the Lower Pocomoke and upper Chester.

Summer chlorophyll-a concentrations exceeded benchmarks at all monitoring stations by 24% to 1005%, except at one monitoring station in the Lower Pokomoke that fell below the benchmark. From 2011-2013, the highest average spring concentration were more than 12 times the benchmark at one monitoring station in the Transquaking, and more than 11 times the benchmark at another location in the Sassafras.

Table 2. Percent Above or Below Benchmark Values, 2011-2013 Seasonal Average Concentrations

River	Station	Total Phosphorus	Spring Chlorophyll-a	Summer Chlorophyll-a
Transquaking	TRQ0088	160%	318%	262%
	TRQ0146	415%	1152%	900%
	CCM0069	275%	86%	497%
Lower Pokomoke	BXK0031	111%	-26%	47%
	POK0087	100%	-68%	24%
	XAK7810	21%	-25%	63%
	ET10.1	133%	-67%	-45%
Upper Choptank	ET5.1	147%	51%	119%
Manokin	ET8.1	0%	80%	31%
	MNK0146	338%	368%	381%
Nanticoke	ET6.2	58%	155%	132%
	XDJ9007	16%	-21%	167%
	ET6.1	15%	77%	172%
Wicomico	ET7.1	50%	47%	125%
	WIW0141	158%	466%	703%
	XCI4078	-3%	-5%	29%
Upper Chester	ET4.1	69%	-62%	90%

River	Station	Total Phosphorus	Spring Chlorophyll-a	Summer Chlorophyll-a
Sassafras	ET3.1	64%	107%	1005%

Phosphorus and Chlorophyll-a Concentrations Since 2003: Little to No Improvement

Trends from 2003-2013 indicate that concentrations of total phosphorus and chlorophyll-a at most Eastern Shore monitoring stations have remained the same. Only chlorophyll-a concentrations in the Manokin appear to have improved. Both total phosphorus and spring chlorophyll-a concentrations have increased in the Sassafras. Trends in two waterways with multiple stations showed mixed results. Total phosphorus increased at one out of three stations in the Nanticoke, while summer concentrations of chlorophyll-a increased at two stations. Total phosphorus increased at two of the three stations in the Transquaking, and summer chlorophyll-a concentrations also increased at one of those stations.

Table 3. Trends in Seasonal Average Concentrations, 2003-2013

Waterway	Station	Total Phosphorus	Spring Chlorophyll-a	Summer Chlorophyll-a
Lower Pokomoke	BXK0031	No Change	No Change	No Change
	ET10.1	No Change	No Change	No Change
	POK0087	No Change	No Change	No Change
	XAK7810	No Change	No Change	No Change
Manokin	ET8.1	No Change	Better	Better
	MNK0146	No Change	No Change	No Change
Upper Choptank	ET5.1	No Change	No Change	No Change
Nanticoke	ET6.1	Worse	No Change	Worse
	ET6.2	No Change	No Change	No Change
	XDJ9007	No Change	No Change	Worse
Sassafras	ET3.1	Worse	Worse	No Change
Transquaking	CCM0069	Worse	No Change	Worse
	TRQ0088	No Change	No Change	No Change
	TRQ0146	Worse	No Change	No Change
Upper Chester	ET4.1	No Change	No Change	No Change
Wicomico	ET7.1	No Change	No Change	No Change
	WIW0141	No Change	No Change	No Change
	XCI4078	No Change	No Change	No Change

Biotic Integrity: Habitat Quality

Conditions for aquatic life in many of the tidal rivers and non-tidal streams on the Eastern Shore are mixed, but it is clear that many of these waterways are impaired due to low fish and benthic IBI scores. The Chesapeake Bay Benthic Monitoring Program monitors benthic conditions at a four fixed locations in the tidal portions of the Chester, Choptank, and Nanticoke Rivers. Benthic

IBI scores are available for each station from 2003-2012. Scores below 3 indicate marginally degraded, degraded, or severely degraded conditions, while scores of 3 or above indicate relatively good conditions for sediment-dwelling organisms. Since 2003, Benthic IBI scores in the middle Chester River showed good conditions. In the upper Choptank, conditions were marginally degraded or degraded in 6 out of the 10 years since 2003. Conditions in the lower Choptank were slightly better, with marginally degraded or degraded conditions in 3 out of the 10 years. The Nanticoke River was in the worst condition by a long margin, with 8 out of the 10 years since 2003 falling into the marginally degraded, degraded, and severely degraded categories.

Maryland Department of Natural Resources, in determining its list of impaired waterways under the Clean Water Act, assessed how many miles of non-tidal streams in specific watersheds were impaired, and what percentage of those impairments could be traced back to agriculture.[23] The upper and lower Choptank, Transquaking, middle and lower Chester, lower Wicomico, and upper Pokomoke were recently assessed based on data collected between 2000 and 2004 (Table 3). Twenty percent to 67% of the miles of non-tidal streams in these watersheds were found impaired due to low fish and/or benthic IBI scores. Of those impaired miles of streams, and when sources of the impairments were discernable, 42% to 92% of those impairments were attributed to agriculture. The Transquaking had the highest percentage of impaired stream miles (67%), and 92% of those miles of impaired waterways were traced back to agriculture. However, while 60% of streams in the lower Wicomico watershed were impaired with nutrients, the connection to agricultural sources was unclear. While MDNR's conclusions are based on data collected from 2000-2004, subsequent rounds of sampling have occurred or are currently underway. These results from the beginning of the decade help explain the lasting impact that intensive agriculture has on aquatic habitats.

Table 4. Stream miles impaired due to low IBI scores, attributed to agriculture, 2000-2004

Watershed	% Stream Miles Impaired*	% Due to Agriculture
Upper Choptank	38	42
Lower Choptank	45	60**
Transquaking	67	92
Middle Chester	36	37
Lower Chester	20	79
Lower Wicomico	60	--
Upper Pocomoke	35	92

* Impairments due to low IBI scores

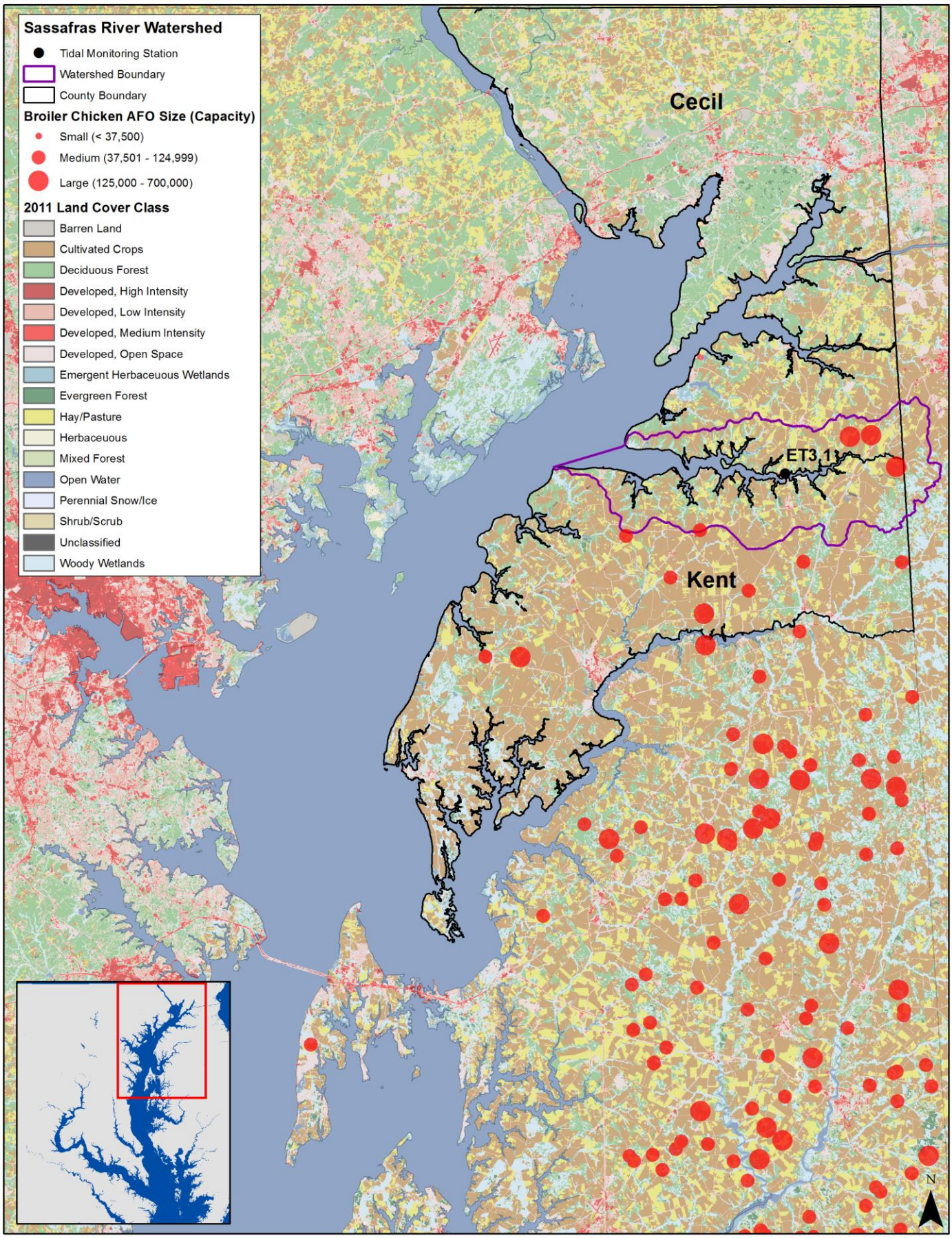
** Agricultural sources of acidity

Sassafras River

The Sassafras River rises in New Castle County in Delaware and courses between Kent and Cecil Counties in Maryland. Average seasonal concentrations of total phosphorus and chlorophyll-a observed in the Sassafras have exceeded benchmark values since at least 2003. Spring and summer concentrations of total phosphorus and spring concentrations of chlorophyll-a have increased since 2003.

Water Quality					
Parameter	Station	Benchmark	2011-2013 Seasonal Average	2011-2013 % +/- Benchmark	2003-2013 Trend
Total Phosphorus (mg/L)	ET3.1	0.07	0.115	64%	Worse
Spring Chlorophyll-a (ug/L)	ET3.1	20.9	43.25	107%	Worse
Summer Chlorophyll-a (ug/L)	ET3.1	9.5	104.95	1005%	No Trend

2012 Broiler, Manure, and Phosphate Production by County					**2011 Land Use**	
County	No. Poultry Operations	No. Broiler Chickens Produced	Pounds of Manure Produced	Pounds of Phosphate Produced	Agriculture	66%
					Forest	17%
Kent	9	4,665,000	9,330,000	262,173	Wetland	11%
Cecil	10	(withheld)	NA	NA	Urban	6%


Sassafras River Watershed
Tidal Monitoring Station
Watershed Boundary
County Boundary
Broiler Chicken AFO Size (Capacity)
Small (< 37,500)
Medium (37,501 - 124,999)
Large (125,000 - 700,000)
2011 Land Cover Class
Barren Land
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Emergent Herbaceuous Wetlands
Evergreen Forest
Hay/Pasture
Herbaceuous
Mixed Forest
Open Water
Perennial Snow/Ice
Shrub/Scrub
Unclassified
Woody Wetlands
Cecil
ET3.1
Kent
N

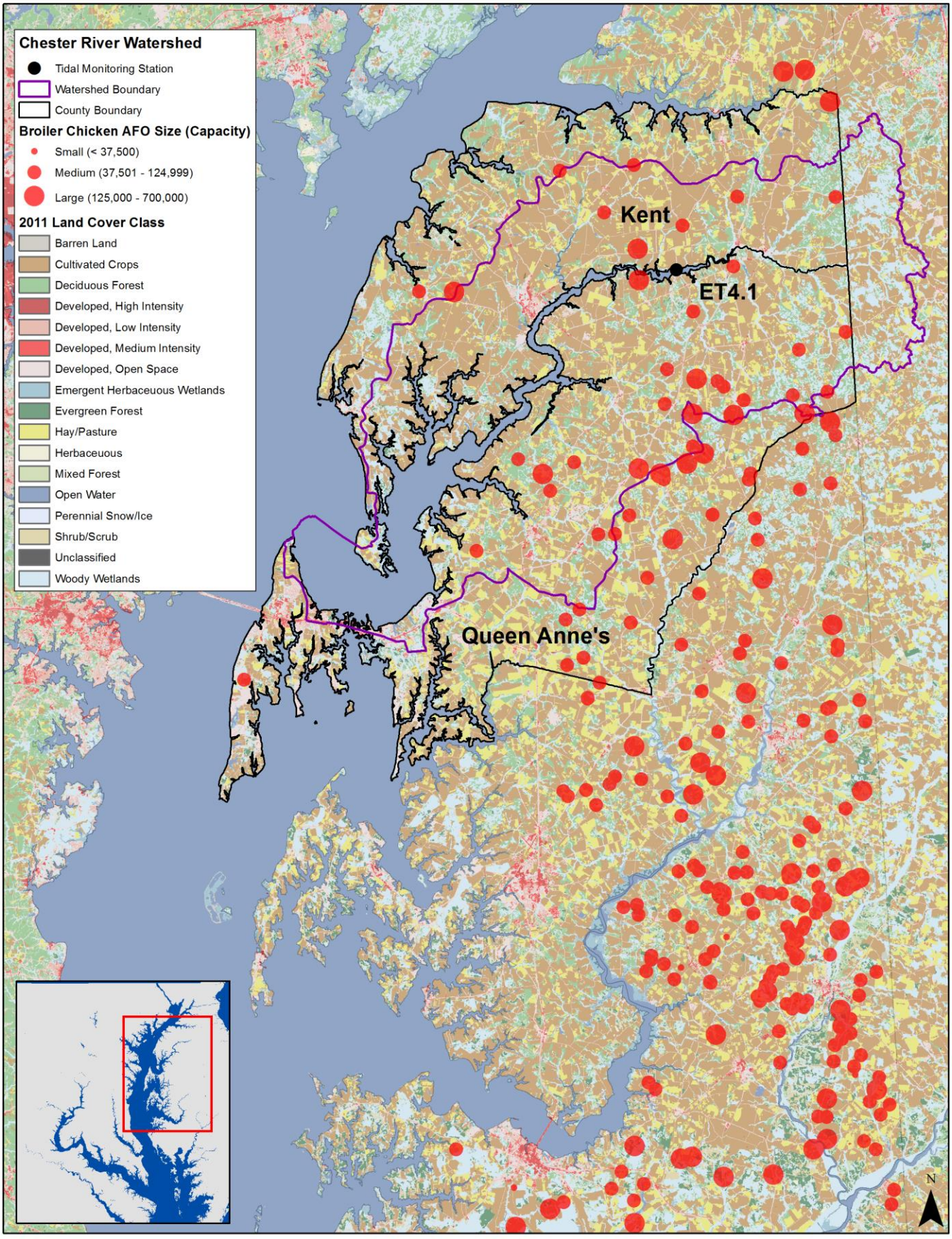
Upper Chester River

The Chester River runs between Kent and Queen Anne's Counties in Maryland, and its headwaters originate in New Castle County, Delaware. Average seasonal concentrations of total phosphorus exceeded benchmark levels by 69% from 2011-2013. Average spring chlorophyll-a concentrations were below benchmark values by 62%, and summer chlorophyll-a concentrations exceeded benchmark levels by 90% during the same time period. There was no significant trend in concentrations from 2003 to 2013.

Water Quality					
Parameter	Station	Benchmark	2011-2013 Seasonal Average	2011-2013 % +/- Benchmark	2003-2013 Trend
Total Phosphorus (mg/L)	ET4.1	0.07	0.118	69%	No Trend
Spring Chlorophyll-a (ug/L)	ET4.1	20.9	7.99	-62%	No Trend
Summer Chlorophyll-a (ug/L)	ET4.1	9.5	18.09	90%	No Trend

Benthic Conditions & Impairments					
Tidal River (Middle Chester)		Freshwater Streams (Lower Chester, 2000-2004)			
2012 Benthic Condition (IBI score)	Met Restoration Goals (3.53)	% Stream miles impaired due to low IBI scores	20%	% Impaired stream miles attributed to agriculture	79%

2012 Broiler, Manure, and Phosphate Production by County					**2011 Land Use**	
County	No. Poultry Operations	No. Broiler Chickens Produced	Pounds of Manure Produced	Pounds of Phosphate Produced	Agriculture	62%
					Forest	17%
Kent	9	4,665,000	9,330,000	262,173	Wetland	12%
Queen Anne's	50	21,789,292	43,578,584	1,224,558	Urban	8%


Chester River Watershed
Tidal Monitoring Station
Watershed Boundary
County Boundary
Broiler Chicken AFO Size (Capacity)
Small (< 37,500)
Medium (37,501 - 124,999)
Large (125,000 - 700,000)
2011 Land Cover Class
Barren Land
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Emergent Herbaceuous Wetlands
Evergreen Forest
Hay/Pasture
Herbaceuous
Mixed Forest
Open Water
Perennial Snow/Ice
Shrub/Scrub
Unclassified
Woody Wetlands
Kent
ET4.1
Queen Anne's
N

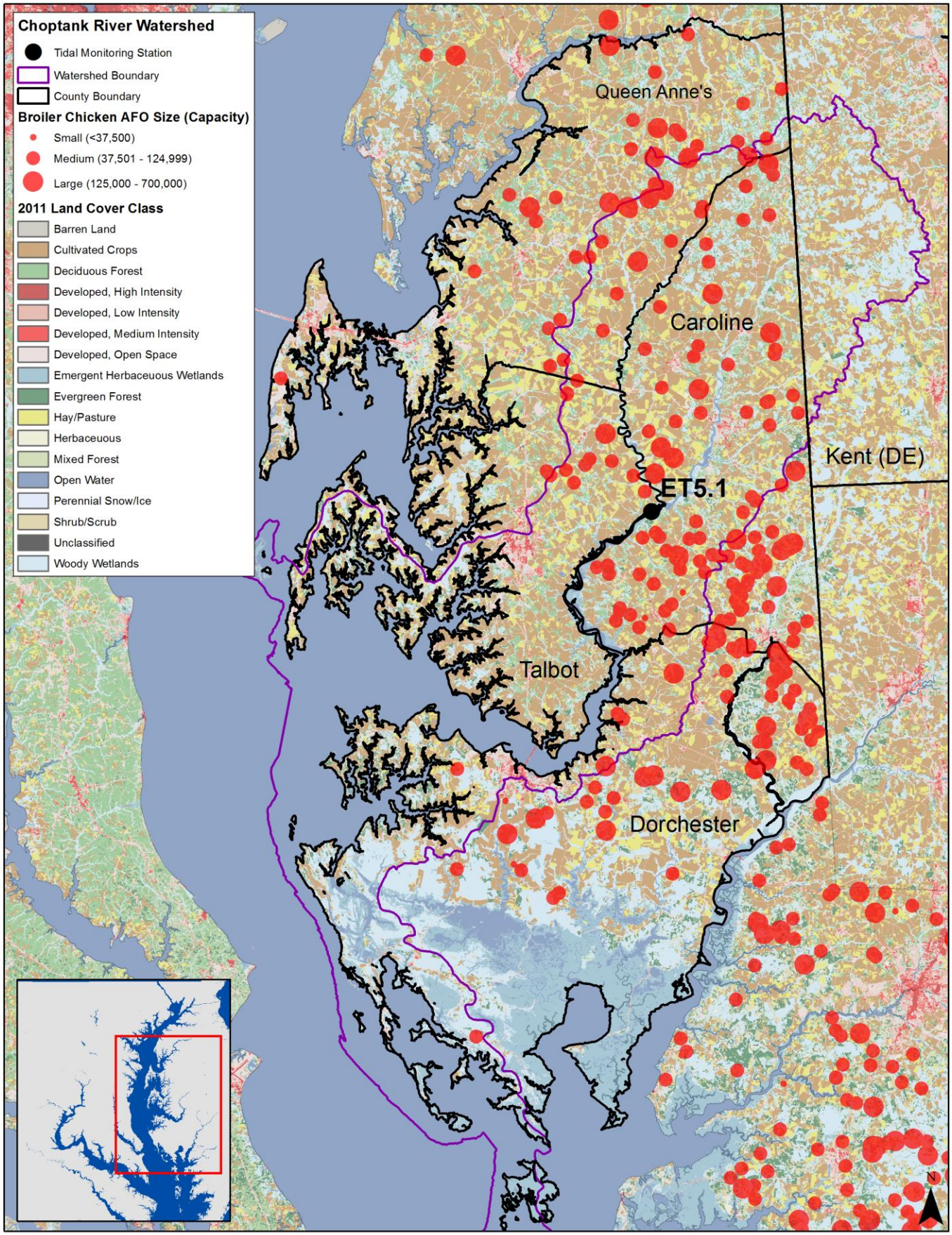
Upper Choptank River

The Choptank River rises in Kent County, Delaware, courses through Caroline County and serves as the border between Talbot and Dorchester Counties in Maryland as it flows toward the Chesapeake Bay. Average seasonal concentrations of total phosphorus and chlorophyll-a exceeded benchmark values by 51-147% from 2011-2013. There has been no trend in concentrations from 2003-2013. Benthic conditions in the tidal Upper Choptank were degraded in 2012 (B-IBI score of 2.47) and have been variable since 2003.

Water Quality					
Parameter	Station	Benchmark	2011-2013 Seasonal Average	2011-2013 % +/- Benchmark	2003-2013 Trend
Total Phosphorus (mg/L)	ET5.1	0.07	0.148	147%	No Trend
Spring Chlorophyll-a (ug/L)	ET5.1	20.9	31.48	51%	No Trend
Summer Chlorophyll-a (ug/L)	ET5.1	9.5	20.8	119%	No Trend

Benthic Conditions & Impairments					
Tidal River				Freshwater Streams (2000-2004)	
2012 Benthic Condition (IBI score)	Degraded (2.47)	% Stream miles impaired due to low IBI scores	38%	% Impaired stream miles attributed to agriculture	42%

2012 Broiler, Manure, and Phosphate Production by County					**2011 Land Use**	
County	No. Broiler Chicken Operations	No. Broiler Chickens Produced	Pounds of Manure Produced	Pounds of Phosphate Produced	Agriculture	55%
					Forest	14%
Caroline	164	62,703,500	125,407,000	3,523,937	Wetland	24%
Dorchester	70	29,388,301	58,737,802	1,650,532	Urban	7%
Talbot	30	9,333,120	18,666,240	524,521		
Queen Anne's	50	21,789,292	43,578,584	1,224,558		
Kent, DE	122	37,533,471	75,066,942	2,109,381		


Choptank River Watershed
Tidal Monitoring Station
Watershed Boundary
County Boundary
Broiler Chicken AFO Size (Capacity)
Small (<37,500)
Medium (37,501 - 124,999)
Large (125,000 - 700,000)
2011 Land Cover Class
Barren Land
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Emergent Herbaceuous Wetlands
Evergreen Forest
Hay/Pasture
Herbaceuous
Mixed Forest
Open Water
Perennial Snow/Ice
Shrub/Scrub
Unclassified
Woody Wetlands
Queen Anne's
Caroline
Kent (DE)
ET5.1
Talbot
Dorchester
N

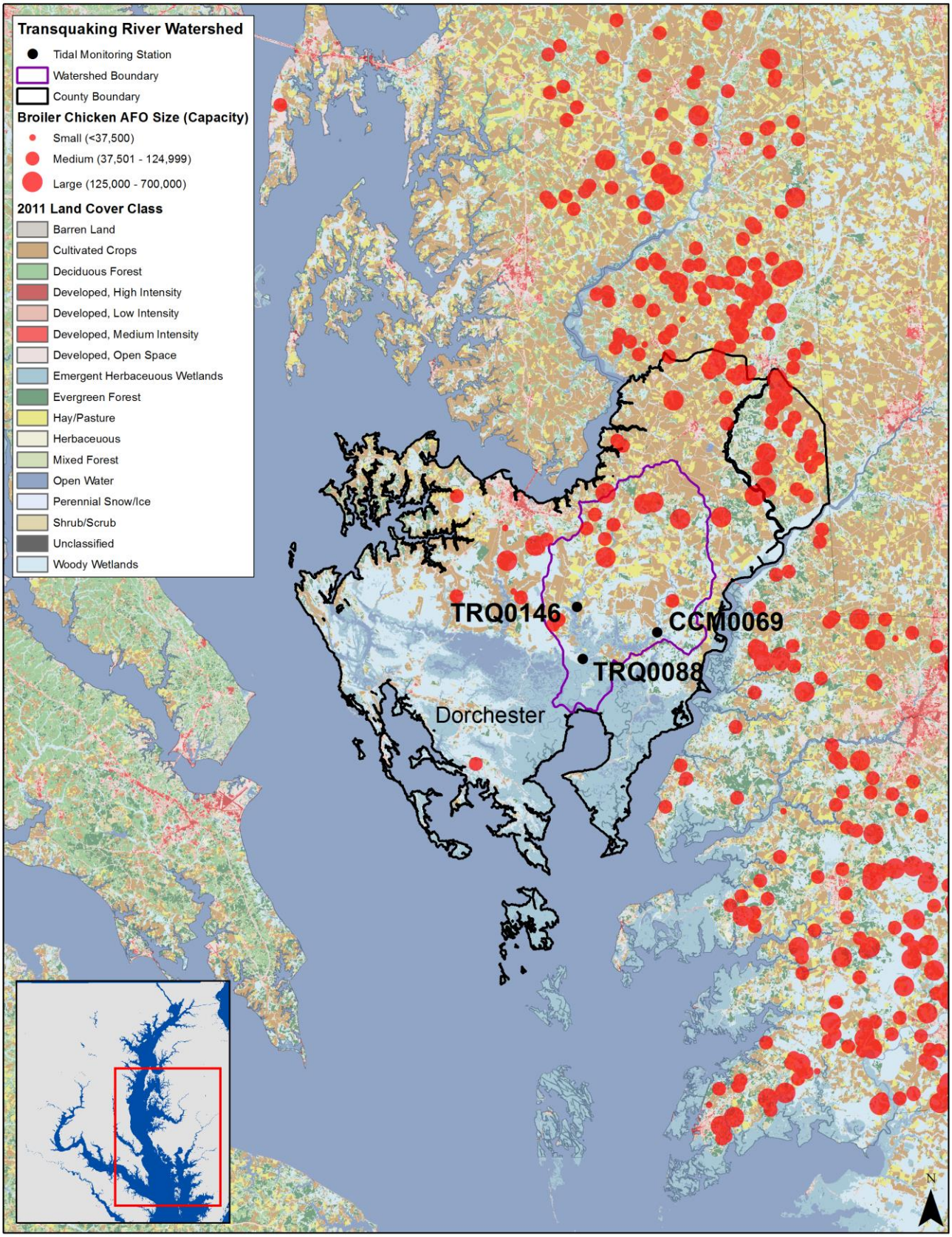
Transquaking River

The Transquaking River meanders through Dorchester County, Maryland and empties into Fishing Bay. Three tidal monitoring stations are located in the river, CCM0069, TRQ0088, and TRQ0146. Seasonal average concentrations of both total phosphorus and chlorophyll-a drastically exceeded benchmark values from 2011-2013 at all three stations. Station CCM0069 recorded increasing levels of both total phosphorus and chlorophyll-a from 2003-2013. Station TRQ0146 also recorded increases in total phosphorus concentrations over the same time period. According to the Maryland Department of Natural Resources, 67% of stream miles leading to the Transquaking are impaired due to low biotic integrity scores, and 92% of those impaired miles can be attributed to agriculture.

Water Quality					
Parameter	Station	Benchmark	2011-2013 Seasonal Average	2011-2013 % +/- Benchmark	2003-2013 Trend
Total Phosphorus (mg/L)	CCM0069	0.04	0.15	275%	Worse
	TRQ0088	0.04	0.104	160%	No Trend
	TRQ0146	0.04	0.206	415%	Worse
Spring Chlorophyll-a (ug/L)	CCM0069	20.9	38.81	86%	Worse
	TRQ0088	6.2	25.91	318%	No Trend
	TRQ0146	6.2	77.64	1152%	No Trend
Summer Chlorophyll-a (ug/L)	CCM0069	9.5	56.69	497%	No Trend
	TRQ0088	7.7	27.9	262%	No Trend
	TRQ0146	7.7	76.97	900%	No Trend

Benthic Conditions & Impairments					
Tidal River		Freshwater Streams (2000-2004)			
2012 Benthic Condition (IBI score)	N/A	% Stream miles impaired due to low IBI scores	67%	% Impaired stream miles attributed to agriculture	92%

2012 Broiler, Manure, and Phosphate Production by County					**2011 Land Use**	
County	No. Poultry Operations	No. Broiler Chickens Produced	Pounds of Manure Produced	Pounds of Phosphate Produced	Agriculture	42%
					Forest	12%
Dorchester	70	29,388,301	58,737,802	1,650,532	Wetland	42%
					Urban	3%


Transquaking River Watershed
Tidal Monitoring Station
Watershed Boundary
County Boundary
Broiler Chicken AFO Size (Capacity)
Small (<37,500)
Medium (37,501 - 124,999)
Large (125,000 - 700,000)
2011 Land Cover Class
Barren Land
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Emergent Herbaceuous Wetlands
Evergreen Forest
Hay/Pasture
Herbaceuous
Mixed Forest
Open Water
Perennial Snow/Ice
Shrub/Scrub
Unclassified
Woody Wetlands
TRQ0146
CCM0069
TRQ0088
Dorchester
N

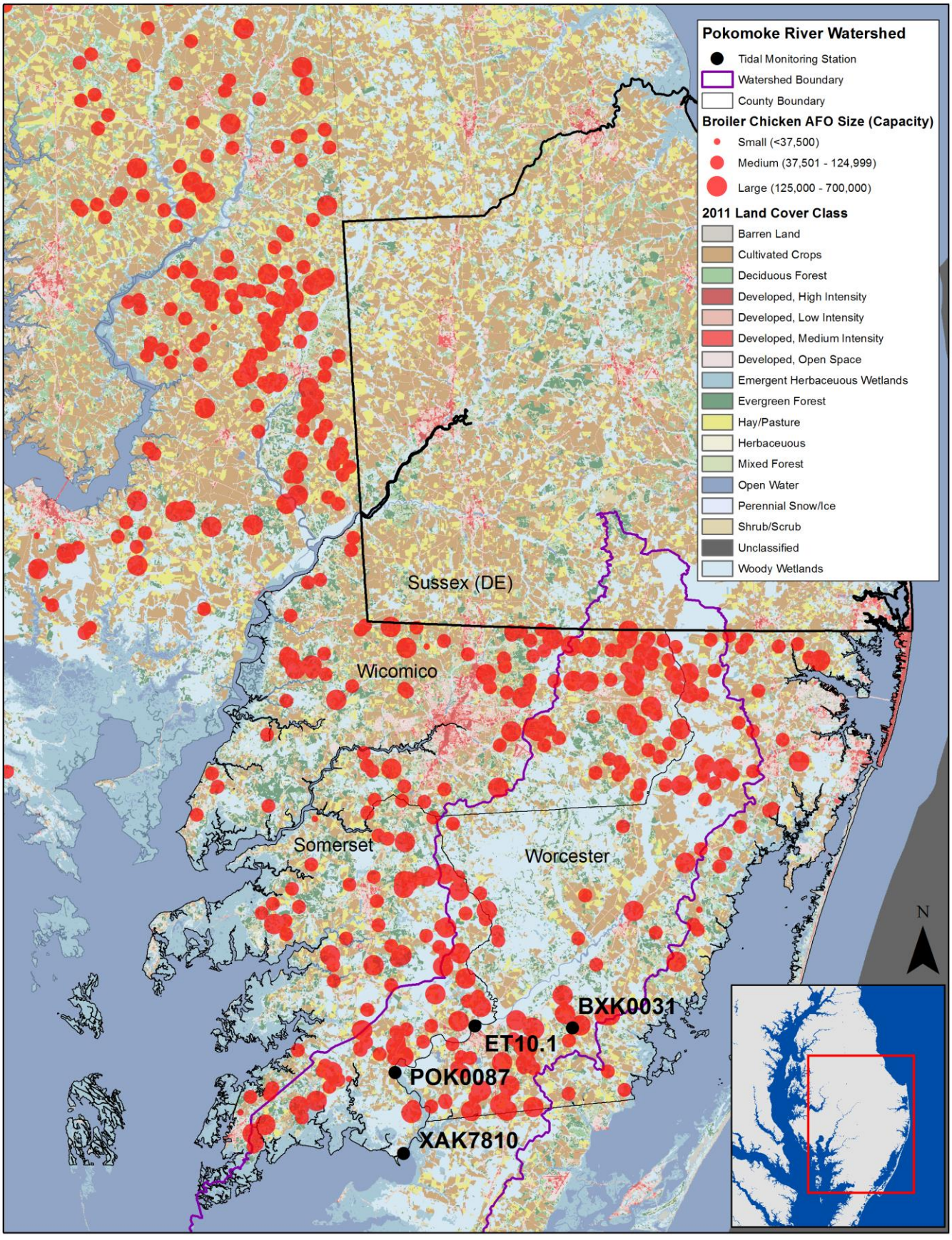
Lower Pokomoke River

The Pokomoke River runs through Wicomico, Somerset, and Worchester counties in Maryland, after rising in Sussex County, Delaware. Four tidal sampling stations are located in this sub watershed; three in oligohaline segments (BXK0031, POK0087, and XAK7810) and one in a tidal fresh segment (ET10.1). Seasonal average concentrations of total phosphorus exceeded benchmark levels at all four stations, and summer concentrations of chlorophyll-a exceeded benchmark levels at three of the four stations from 2011-2013. There was no significant trend in concentrations total phosphorus or chlorophyll-a from 2003 to 2013. According to the Maryland Department of Natural Resources, 35% of stream miles leading to the upper Pokomoke are impaired due to low biotic integrity scores, and 92% of those impaired miles can be attributed to agriculture.

Water Quality					
Parameter	Station	Benchmark	2011-2013 Seasonal Average	2011-2013 % +/- Benchmark	2003-2013 Trend
Total Phosphorus (mg/L)	BXK0031	0.07	0.148	111%	No Trend
	POK0087	0.07	0.14	100%	No Trend
	XAK7810	0.07	0.085	21%	No Trend
	ET10.1	0.06	0.14	133%	No Trend
Spring Chlorophyll-a (ug/L)	BXK0031	20.9	15.43	-26%	No Trend
	POK0087	20.9	6.59	-68%	No Trend
	XAK7810	20.9	15.76	-25%	No Trend
	ET10.1	14	4.66	-67%	No Trend
Summer Chlorophyll-a (ug/L)	BXK0031	9.5	13.98	47%	No Trend
	POK0087	9.5	11.81	24%	No Trend
	XAK7810	9.5	15.52	63%	No Trend
	ET10.1	12	6.57	-45%	No Trend

Benthic Conditions & Impairments					
Tidal River		Freshwater Streams (Upper Pokomoke, 2000-2004)			
2012 Benthic Condition (IBI score)	N/A	% Stream miles impaired due to low IBI scores	35%	% Impaired stream miles attributed to agriculture	92%

2012 Broiler, Manure, and Phosphate Production by County					**2011 Land Use**	
County	No. Poultry Operations	No. Broiler Chickens Produced	Lbs. of Manure Produced	Lbs. of Phosphate Produced	Agriculture	27%
					Forest	15%
Wicomico	110	57,122,282	114,244,564	3,210,272	Wetland	52%
Worcester	99	55,509,628	111,019,256	3,119,641	Urban	6%
Somerset	98	63,651,156	127,302,312	3,577,195		
Sussex, DE	537	174,042,650	348,085,300	9,781,197		


Pokomoke River Watershed
Tidal Monitoring Station
Watershed Boundary
County Boundary
Broiler Chicken AFO Size (Capacity)
Small (<37,500)
Medium (37,501 - 124,999)
Large (125,000 - 700,000)
2011 Land Cover Class
Barren Land
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Emergent Herbaceuous Wetlands
Evergreen Forest
Hay/Pasture
Herbaceuous
Mixed Forest
Open Water
Perennial Snow/Ice
Shrub/Scrub
Unclassified
Woody Wetlands
Sussex (DE)
Wicomico
Somerset
Worcester
BXK0031
ET10.1
POK0087
XAK7810
N

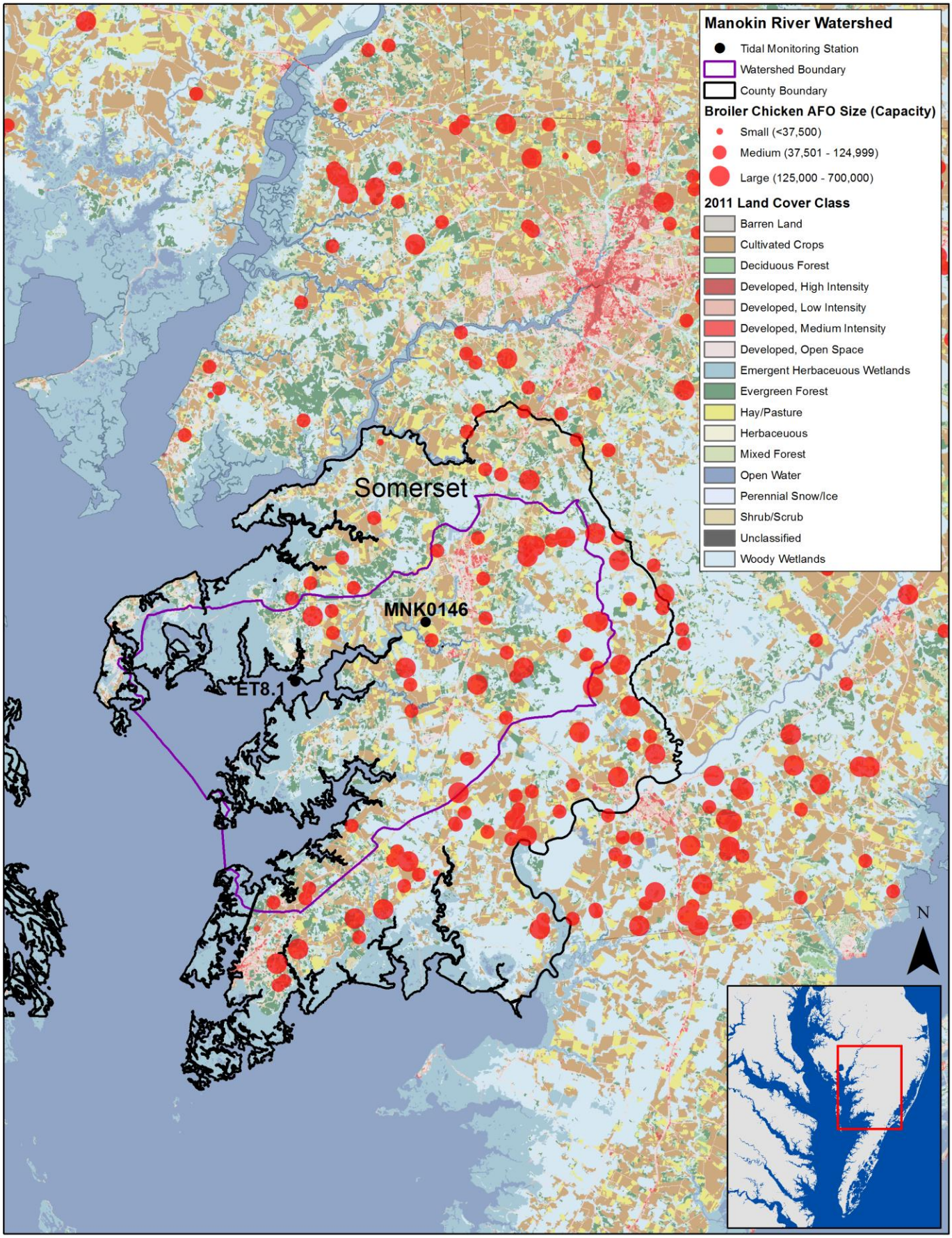
Manokin River

The Manokin River runs through Somerset County in Maryland. Two tidal monitoring stations are located on the river, ET8.1 and MNK0146. Average seasonal concentrations of total phosphorus and chlorophyll-a exceeded benchmark values from 2011-2013, except at station ET10.1, where total phosphorus concentrations met benchmark levels. Spring and summer average chlorophyll-a concentrations have improved at station ET8.1 from 2003 to 2013. There were no significant trends in total phosphorus at both monitoring stations. There were also no significant trends in chlorophyll-a concentrations at station MNK0146.

Water Quality					
Parameter	Station	Benchmark	2011-2013 Seasonal Average	2011-2013 % +/- Benchmark	2003-2013 Trend
Total Phosphorus (mg/L)	ET8.1	0.04	0.04	0%	No Trend
	MNK0146	0.04	0.175	338%	No Trend
Spring Chlorophyll-a (ug/L)	ET8.1	6.2	11.17	80%	Better
	MNK0146	6.2	29.01	368%	No Trend
Summer Chlorophyll-a (ug/L)	ET 8.1	7.7	10.12	31%	Better
	MNK0146	7.7	37.05	381%	No Trend

Benthic Conditions & Impairments					
Tidal River		Freshwater Streams (Upper Pokomoke, 2000-2004)			
2012 Benthic Condition (IBI score)	N/A	% Stream miles impaired due to low IBI scores	N/A	% Impaired stream miles attributed to agriculture	N/A

2012 Broiler, Manure, and Phosphate Production by County					**2011 Land Use**	
County	No. Poultry Operations	No. Broiler Chickens Produced	Tons of Manure Produced	Tons of Phosphate Produced	Agriculture	24%
					Forest	17%
Somerset	98	63,651,156	127,302,312	3,577,195	Wetland	52%
					Urban	7%


Manokin River Watershed
Tidal Monitoring Station
Watershed Boundary
County Boundary
Broiler Chicken AFO Size (Capacity)
Small (<37,500)
Medium (37,501 - 124,999)
Large (125,000 - 700,000)
2011 Land Cover Class
Barren Land
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Emergent Herbaceuous Wetlands
Evergreen Forest
Hay/Pasture
Herbaceuous
Mixed Forest
Open Water
Perennial Snow/Ice
Shrub/Scrub
Unclassified
Woody Wetlands
Somerset
MNK0146
ET8.1
N

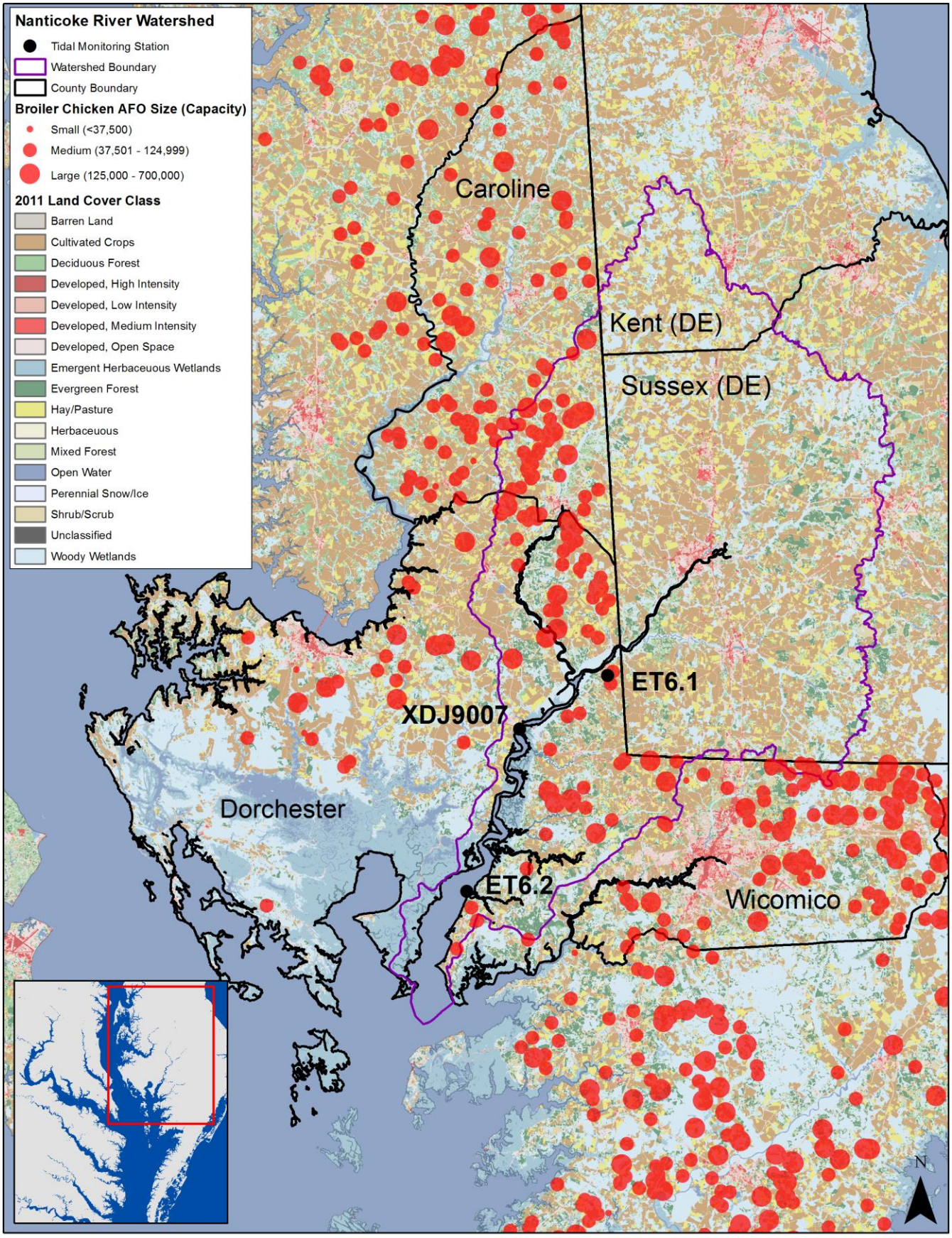
Nanticoke River

The Nanticoke River watershed spans over portions of Kent and Sussex counties in Delaware, and Caroline, Dorchester, and Wicomico Counties in Maryland. Three tidal monitoring stations are located in the river, ET6.1, ET6.2, and XDJ9007. Seasonal average concentrations of total phosphorus and chlorophyll-a exceeded benchmark values from 2011-2013 at all monitoring stations, except for station XDJ9007 where spring chlorophyll-a concentrations were below the benchmark. Station ET6.1 recorded increasing concentrations of both total phosphorus and summer chlorophyll-a, and station XDJ9007 recorded increasing concentrations of summer chlorophyll-a concentrations from 2003 to 2013. Benthic conditions in the tidal portion of the river were degraded in 2012 and have been degraded to some degree since 2006.

Water Quality					
Parameter	Station	Benchmark	2011-2013 Seasonal Average	2011-2013 % +/- Benchmark	2003-2013 Trend
Total Phosphorus (mg/L)	ET6.2	0.04	0.063	58%	No Trend
	XDJ9007	0.07	0.081	16%	No Trend
	ET6.1	0.06	0.069	15%	Worse
Spring Chlorophyll-a (ug/L)	ET6.2	6.2	15.82	155%	No Trend
	XDJ9007	20.9	16.41	-21%	No Trend
	ET6.1	14	24.8	77%	No Trend
Summer Chlorophyll-a (ug/L)	ET6.2	7.7	17.9	132%	No Trend
	XDJ9007	9.5	25.39	167%	Worse
	ET6.1	12	32.6	172%	Worse

Benthic Conditions & Impairments					
Tidal River		Freshwater Streams (2000-2004)			
2012 Benthic Condition (B-IBI score)	Degraded (2.6)	% Stream miles impaired due to low IBI scores	N/A	% Impaired stream miles attributed to agriculture	N/A

2012 Broiler, Manure, and Phosphate Production by County					**2011 Land Use**	
County	No. Poultry Operations	No. Broiler Chickens Produced	Tons of Manure Produced	Tons of Phosphate Produced	Agriculture	48%
					Forest	13%
Kent, DE	122	37,533,471	75,066,942	2,109,381	Wetland	26%
Sussex, DE	537	174,042,650	348,085,300	9,781,197	Urban	6%
Dorchester, MD	70	29,388,301	58,737,802	1,650,532		
Wicomico, MD	110	57,122,282	114,244,564	3,210,272		


Nanticoke River Watershed
Tidal Monitoring Station
Watershed Boundary
County Boundary
Broiler Chicken AFO Size (Capacity)
Small (<37,500)
Medium (37,501 - 124,999)
Large (125,000 - 700,000)
2011 Land Cover Class
Barren Land
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Emergent Herbaceuous Wetlands
Evergreen Forest
Hay/Pasture
Herbaceuous
Mixed Forest
Open Water
Perennial Snow/Ice
Shrub/Scrub
Unclassified
Woody Wetlands
Caroline
Kent (DE)
Sussex (DE)
ET6.1
XDJ9007
Dorchester
ET6.2
Wicomico
N

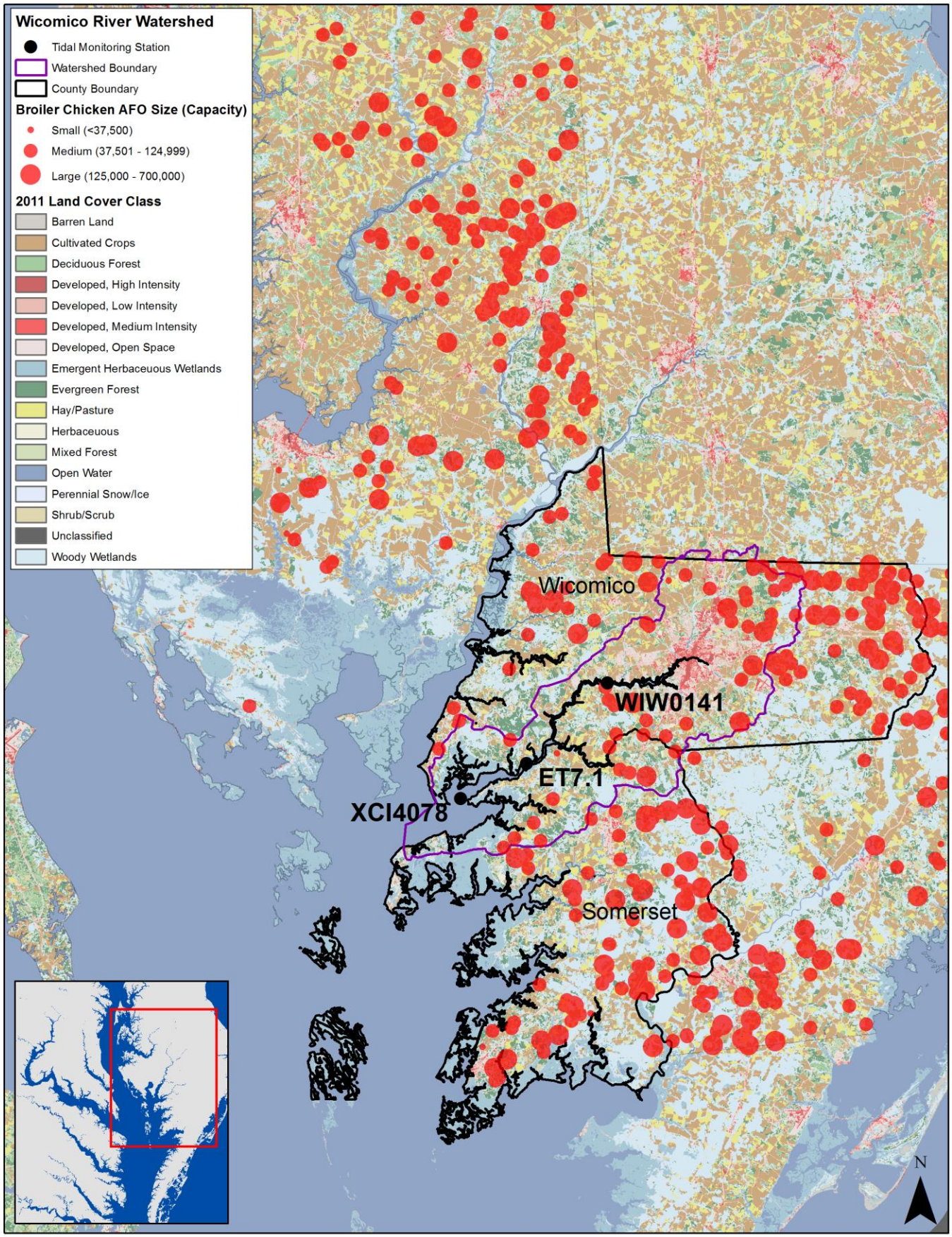
Wicomico River

The Wicomico River courses through Wicomico and Somerset counties in Maryland. There are three tidal monitoring stations in this watershed, WIW-141, ET7.1, and XCI4078. Stations ET7.1 and WIW0141 had seasonal average concentrations of total phosphorus and chlorophyll-a above benchmark values from 2011-2013. Total phosphorus and spring chlorophyll-a concentrations hovered below benchmark values at station XCI4078 from 2011-2013, while average summer chlorophyll-a concentrations exceeded benchmark values during the same time period. There were no significant trends in concentrations observed from 2003 to 2013. According to the Maryland Department of Natural Resources, 60% of stream miles leading to the Wicomico River are impaired due to low biotic integrity scores. MDNR was unable to confidently associate the impairments with a possible source, though nutrients are a major cause of the low biotic integrity scores. The Wicomico watershed also has the most urban land use of the Eastern Shore watersheds, and the river receives wastewater from the City of Salisbury.

Water Quality					
Parameter	Station	Benchmark	2011-2013 Seasonal Average	2011-2013 % +/- Benchmark	2003-2013 Trend
Total Phosphorus (mg/L)	ET7.1	0.04	0.06	50%	No Trend
	WIW0141	0.04	0.103	158%	No Trend
	XCI4078	0.04	0.039	-3%	No Trend
Spring Chlorophyll-a (ug/L)	ET7.1	6.2	9.1	47%	No Trend
	WIW0141	6.2	35.11	466%	No Trend
	XCI4078	6.2	5.91	-5%	No Trend
Summer Chlorophyll-a (ug/L)	ET7.1	7.7	17.36	125%	No Trend
	WIW0141	7.7	61.82	703%	No Trend
	XCI4078	7.7	9.97	29%	No Trend

Benthic Conditions & Impairments					
Tidal River		Freshwater Streams (2000-2004)			
2012 Benthic Condition (B-IBI score)	N/A	% Stream miles impaired due to low IBI scores	60%	% Impaired stream miles attributed to agriculture	N/A

2012 Broiler, Manure, and Phosphate Production by County					**2011 Land Use**	
County	No. Poultry Operations	No. Broiler Chickens Produced	Pounds of Manure Produced	Pounds of Phosphate Produced	Agriculture	29%
					Forest	24%
Wicomico	110	57,122,282	114,244,564	3,210,272	Wetland	29%
Somerset	98	63,651,156	127,302,312	3,577,195	Urban	18%


Wicomico River Watershed
Tidal Monitoring Station
Watershed Boundary
County Boundary
Broiler Chicken AFO Size (Capacity)
Small (<37,500)
Medium (37,501 - 124,999)
Large (125,000 - 700,000)
2011 Land Cover Class
Barren Land
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Emergent Herbaceuous Wetlands
Evergreen Forest
Hay/Pasture
Herbaceuous
Mixed Forest
Open Water
Perennial Snow/Ice
Shrub/Scrub
Unclassified
Woody Wetlands
Wicomico
WIW0141
ET7.1
XCI4078
Somerset
N

[1] Chesapeake Bay Program http://www.chesapeakebay.net/issues/issue/agriculture#inline
[2] Water quality data was not adjusted or normalized by river flow in order to maintain its comparability to healthy concentrations identified by the University of Maryland Center for Environmental Sciences.
[3] University of Maryland Center for Environmental Sciences, "Why We Need the Phosphorus Management Tool (PMT)", January 7, 2014, available from: http://www.umces.edu/sites/default/files/Why%20We%20Need%20the%20Phosphorus%20Management%20Tool%20Updated.pdf
[4] Chesapeake Bay monitoring station locations were downloaded from the Chesapeake Bay Program. AFO locations were downloaded from http://chesapeake-commons.org/afo/. All maps are presented in WGS 1984 Web Mercator Auxiliary Sphere. Some stations in the eastern shore watersheds were omitted because they were located too close to open Bay waters.
[5] CBP Water Quality Database (1984-present). Available from: http://www.chesapeakebay.net/data/downloads/cbp_water_quality_database_1984_present. Sampling results used in this analysis were collected by the Maryland Department of Natural Resources.
[6] Maryland Department of the Environment, Biological Stressor Identification Studies (2012-2014), available from: http://www.mde.state.md.us/programs/Water/TMDL/Pages/Programs/WaterPrograms/tmdl/bsid_studies.aspx
[7] While poultry operations can be located in specific watersheds and counties, chicken manure can be spread on fields that lie beyond those boundaries. We did not feel it was necessary to present poultry operation statistics on a watershed level because it would not reduce any uncertainty about where manure from a specific poultry operation could enter a waterway. At the time of this analysis, the USDA Census of Agriculture had not provided 2012 statistics by watershed.
[8] U.S. Department of Agriculture 2012 Census of Agriculture, Maryland and Delaware Counties, Table 19; available from: http://www.agcensus.usda.gov/
[9] University of Maryland Extension, 2003 Manure Summary Report, available from: https://extension.umd.edu/sites/default/files/_images/programs/anmp/Manure_Summary_Report_for_2003_8-8-11.pdf
[10] Chesapeake Commons.org, Maryland AFO locations, project for the Center for Progressive Reform (2013), data available from: http://chesapeake-commons.org/afo/
[11] Jin, S., Yang, L., Danielson, P., Homer, C., Fry, J., and Xian, G. 2013. A comprehensive change detection method for updating the National Land Cover Database to circa 2011. *Remote Sensing of Environment*, 132: 159 – 175. GIS dataset available from: http://www.mrlc.gov/nlcd2011.php
[12] USGS Watershed Boundary Dataset available from: http://nhd.usgs.gov/wbd.html
[13] Integration and Application Network, University of Maryland Center for Environmental Science, Chesapeake Bay Report Card, http://ian.umces.edu/ecocheck/report-cards/chesapeake-bay/2013/
[14] *Id.*
[15] June is considered a highly variable month for chlorophyll-a, and the benchmark values do not apply during June. *See*: Buchannan, et al. (2005) "Phytoplankton Reference Communities for Chesapeake Bay and its Tidal Tributaries," *Estuaries*. (28:1) pp. 138-159.
[16] We employed the Mann-Kendall trend test. For more information about this method, see D.R. Helsel and R.M. Hirsch, *US Geological Survey, Techniques of Water-Resources Investigations, Book 4, Statistical Methods in Water Resources, Chapter 12, Trend Analysis*. Available online at: http://pubs.usgs.gov/twri/twri4a3/ . Trend calculations were carried out in R, a free, open-source statistical computing program.
[17] According to the USGS, this is likely a "short term" analysis. However, due to the limited amount of data available prior to 2003 in many for these locations, a longer-term trend analysis was not possible. See: USGS (2013) Summary of Trends and Yields Measures at the Chesapeake Bay Nontidal Network Sites: Water Year 2012 Update, available from: http://cbrim.er.usgs.gov/trendandyieldhighlights.html
[18] See: USGS National Water-Quality Assessment Program (2008) Nutrient Trends in Streams and Rivers of the United States, 1993-2003. Pp. 4-5. See also: note 15.
[19] USGS (2013) Summary of Trends and Yields Measures at the Chesapeake Bay Nontidal Network Sites: Water Year 2012 Update, available from: http://cbrim.er.usgs.gov/trendandyieldhighlights.html
[20] Glancey, et al. (2011) Comparison of Methods for Estimating Poultry Manure Nutrient Generation in the Chesapeake Bay Watershed, PowerPoint presentation available from: http://archive.chesapeakebay.net/pubs/calendar/47984_05-09-11_Presentation_1_11291.pdf

[21]University of Maryland Extension, 2003 Manure Summary Report, available at: https://extension.umd.edu/sites/default/files/_images/programs/anmp/Manure_Summary_Report_for_2003_8-8-11.pdf

[22] *Supra, n. 20 and 21*

[23] Maryland Department of the Environment, Biological Stressor Identification Studies , available from: http://www.mde.state.md.us/programs/Water/TMDL/Pages/Programs/WaterPrograms/tmdl/bsid_studies.aspx