Results from Round 3 of the Maryland Biological Stream Survey (2007-2009)

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1. Introduction

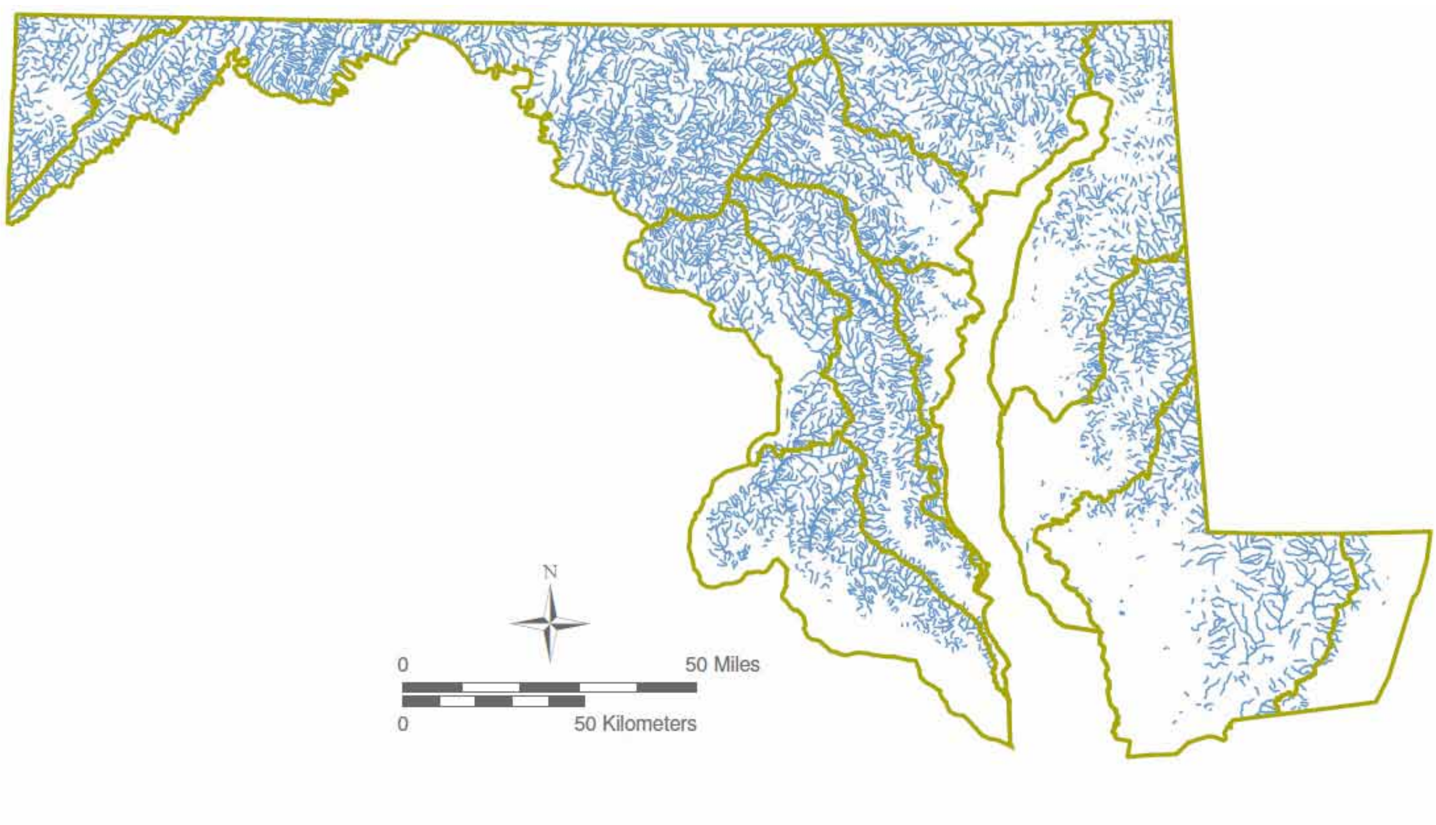
The Maryland Biological Stream Survey (MBSS) is a statewide survey led by the Maryland Department of Natural Resources (DNR). It is a comprehensive program to assess the status of biological resources in Maryland's non-tidal streams; quantify the extent to which acidic deposition affects critical biological resources in the state; examine which other water chemistry, physical habitat, and land use factors are important in explaining stream conditions; provide a statewide inventory of stream biota; establish a benchmark for long-term monitoring; and target future local-scale assessments and mitigation measures needed to restore degraded biological resources.

Following pilot and demonstration projects in 1993 and 1994, the MBSS began its first "round" of sampling to characterize stream conditions and inventory resources statewide. While the MBSS monitors Maryland streams every year in support of multiple objectives, each statewide round of sampling focuses on random sites that provide probability-based estimates of conditions and resources with known confidence. These estimates are computed for the entire state as well as small geographic regions and watersheds. Round 1 of the MBSS was conducted in 1995-1997 and Round 2 was conducted in 2000-2004.

The following pages report the results of Round 3 of the MBSS which was conducted in 2007-2009. Unlike the previous rounds, which were reported as a single volume (Round 1) or multiple volumes (Round 2), Round 3 results are reported as answers to the important questions, one each to a web page. It is hoped that this format will make the results accessible to a wider audience and increase the understanding of Maryland's streams. A complete copy of this MBSS Round 3 information can be downloaded and printed as a pdf.

Click on each link to view the desired question and answer:

- How Many Streams Are in Maryland?
- How is Stream Condition Measured?
- What is the Condition of Streams in Maryland?
- What is the Trend in the Condition of Streams in Maryland?
- What is Degrading Maryland Streams?
- Where are the Best and Worst Streams in Maryland?
- How are Maryland's Fish Doing?
- How are the Other Freshwater Animals Doing in Maryland?
- What Can Marylanders Do to Help Their Streams?
- Will there be a Round Four Maryland Biological Stream Survey?



Map depicting the streams (1st-4th order) of Maryland

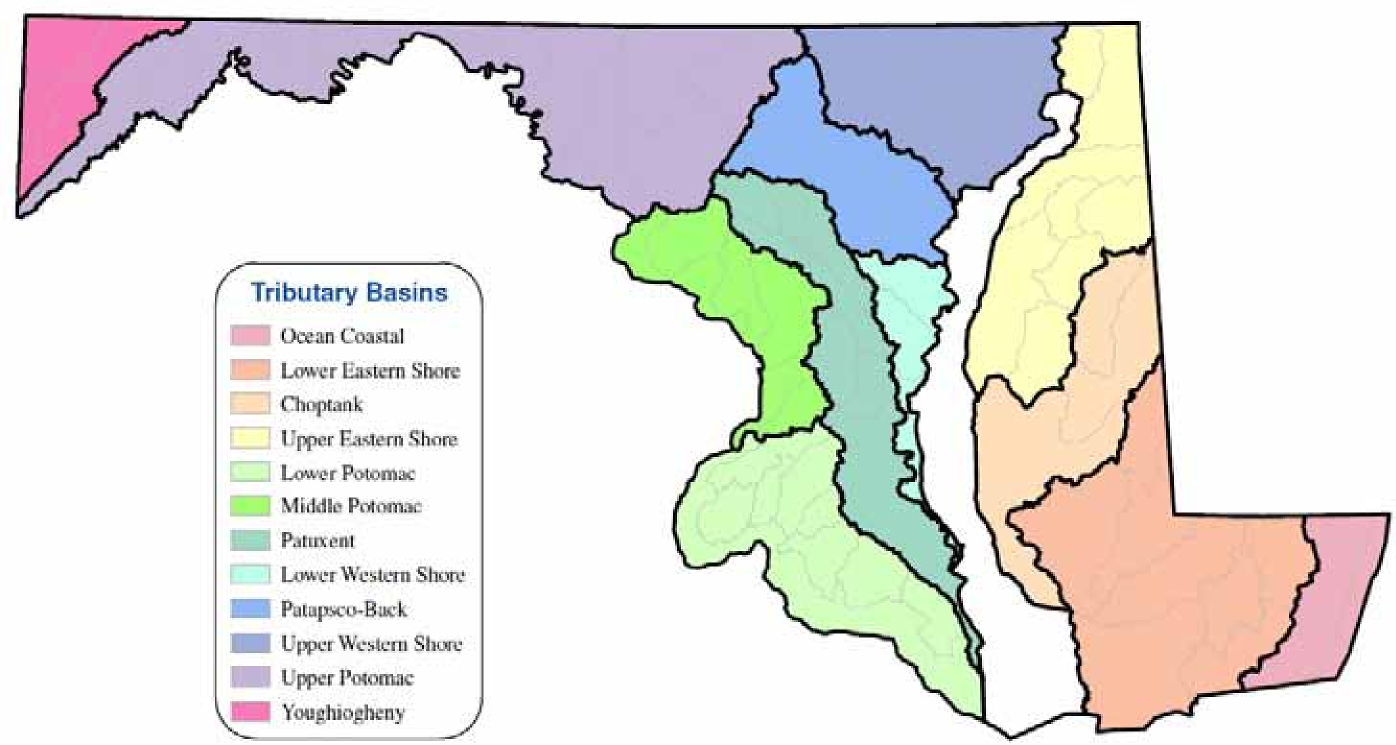
2. How Many Streams are in Maryland?

Maryland is a state vitally connected to its waterbodies. Water makes up 21% of the total area of Maryland (sixth among the 50 states). Almost every person in Maryland lives a short distance from the Bay, a river, a lake, or a stream. A total of 1,542,000 acres of the Chesapeake Bay and its associated estuaries are Maryland waters, as are 69,650 acres of Coastal Bays along the Atlantic Coast. There are approximately 25,000 acres of large rivers in Maryland, including portions of the Potomac River, the Susquehanna River, the Patuxent River, and the Youghiogheny River. The Youghiogheny River Basin drains to the Gulf of Mexico. All other river basins in Maryland drain to the Atlantic Ocean. Although Maryland has no natural lakes, there are 9 manmade lakes greater than 1 square mile (640 acres), comprising 24,794 acres of water, as well as numerous smaller lakes, ponds, and seasonal (vernal) pools.

Tributary Basin	Number of Stream Miles
Choptank	492
Lower Eastern Shore	696
Lower Potomac	788
Lower Western Shore	210
Middle Potomac	715
Ocean Coastal	74
Patapsco / Back	658
Patuxent	1,032
Upper Eastern Shore	624
Upper Potomac	2,518
Upper Western Shore	999
Youghiogheny	397

There are 9,203 miles of wadeable, mostly pernnial streams in Maryland comprising 16,300 acres, as well as an equal or greater number of smaller and intermittent streams.

The number and location of these stream miles by major



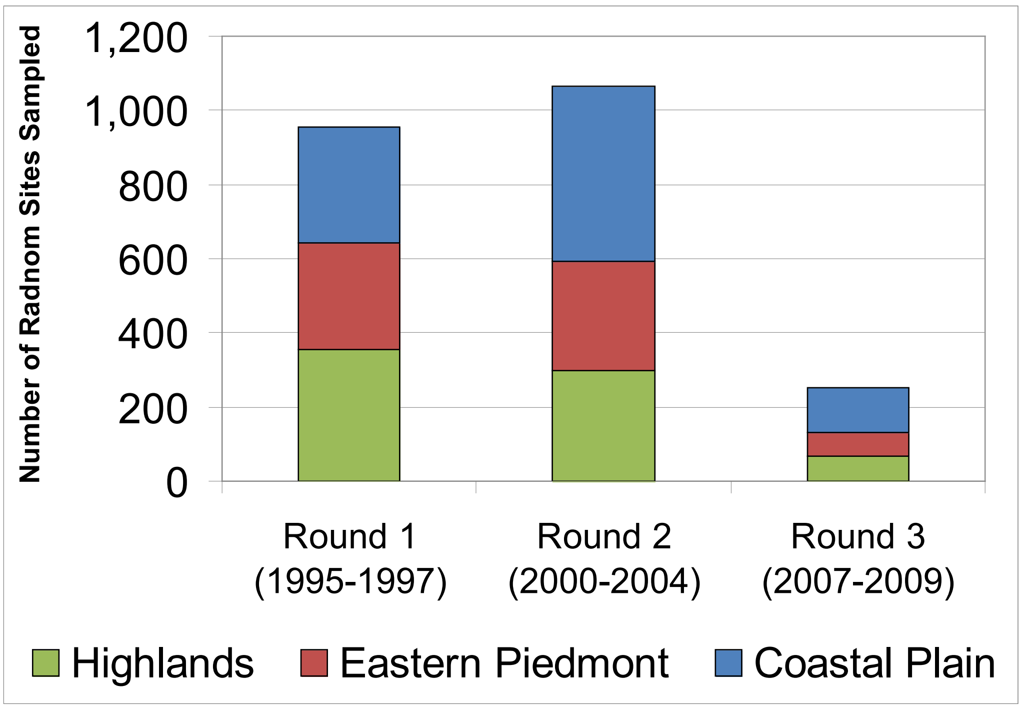
tributary basin in Maryland are shown in the table and map below.

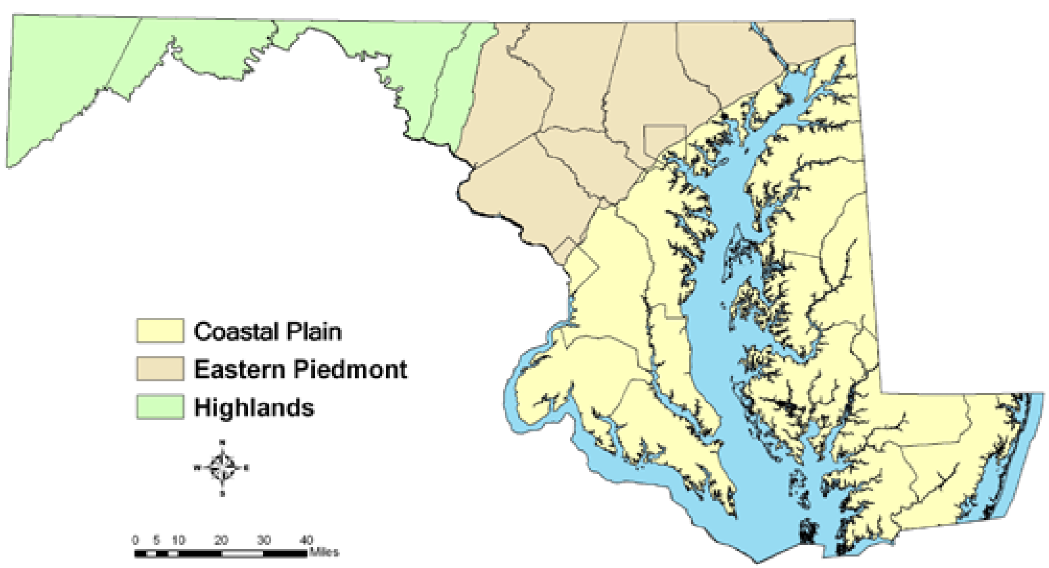
The MBSS samples wadeable first- through fourth-order streams in Maryland as described in the Maryland Biological Stream Survey, Round Three Field Sampling Manual. Each MBSS crew samples a 75-meter stream segment. Since 1995, 2,271 randomly selected sites have been sampled, meaning that crews have directly sampled 106 miles (or 1.2%) of all wadeable streams in Maryland. It is critical to understand that the random nature of the MBSS survey design allows the entire wadeable stream system (100%) to be assessed by extrapolating site results to provide statistically valid estimates of conditions (with known confidence) statewide, as well as by basin, county, or watershed.

The number of randomly selected stream sites sampled in each Round of the MBSS is as follows:

- Round 1 – 955 sites
- Round 2 – 1,066 sites
- Round 3 – 252 sites

The number of random sites allocated to each region are shown in the below histogram. Fewer random sites were sampled during Round 3, however, the number of targeted sites increased to address other program needs, such as identification at high quality waters, rare species and stream types, invasive species, and other specific stream issues. The average annual stream efforts has remained approximately the same over the duration of MBSS sampling.





Maryland's Physiographic Regions

3. How is Stream Condition Measured?

A primary goal of the Maryland Biological Stream Survey (MBSS) is to assess the condition of Maryland's freshwater, non-tidal streams. This assessment is critical to meeting the requirements of the Clean Water Act and for managing the stream resources of the state.

The Clean Water Act requires that all streams in Maryland have water quality standards that consist of both designated uses (e.g., protection of aquatic life) and water quality criteria (e.g., a benthic macroinvertebrate community index score of at least 3 or fair condition). These water quality criteria must use a robust and scientifically sound method for assigning stream condition and should include three elements: physical, chemical, and biological integrity. Biological integrity is the best indicator of the overall condition of streams, while physical and chemical integrity provide evidence of specific stressors (e.g., low dissolved oxygen). Biological integrity is commonly defined as :

> "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region"

The key aspect of assigning stream condition based on biological integrity is comparing the target stream to a reference or minimally disturbed stream. The fish and benthic macroinvertebrate indices of biotic integrity (IBIs) developed by the MBSS for Maryland streams use this reference-based approach and divide the state into different stream types based on geographic regions. Each IBI provides a numerical score of 1 to 5 and rates the stream as Good, Fair, Poor, or Very Poor, compared to reference conditions.

It is important, however, to recognize that IBIs do not capture all the information about the biota of a stream, as they are designed as a consistent indicator across fairly large regions. The MBSS also collects substantial species-specific information for fish, benthic macroinvertebrates, and other organisms (amphibians, reptiles, crayfish, mussels) to better characterize the biological diversity of the stream. This information is critical to managing individual species such as game fish and rare or imperiled species.

The methods for measuring the MBSS indicator of stream condition and collecting biodiversity information are described below.

Narrative descriptions of stream biological integrity with each of the IBI categories		
Good	IBI score 4.0-5.0	Comparable to reference streams considered to be minimally disturbed. On average, biological metrics fall within the upper 50% of reference site conditions.
Fair	IBI score 3.0-3.9	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of these minimally disturbed streams. On average, biological metrics fall within the lower portion of the range of reference sites (10th to 50th percentile).
Poor	IBI score 2.0-2.9	Significant deviation from reference conditions, with many aspects of biological integrity not resembling the qualities of these minimally disturbed streams, indicating degradation. On average, biological metrics fall below the 10th percentile of reference site conditions.
Very Poor	IBI score 1.0-1.9	Strong deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of these minimally disturbed streams, indicating severe degradation. On average, biological metrics fall below the 10th percentile of reference site values; most or all metrics are below this level.

3.1 BIOLOGICAL INDICATORS

Because an IBI score of 3 represents the threshold of reference condition, values less than 3 (Poor or Very Poor) represent sites that are degraded. In contrast, values greater than or equal to 3 (Fair or Good) indicate that most attributes of the community are within the range of those at reference sites and therefore not degraded.

Fish Index of Biotic Integrity (FIBI) is a stream assessment tool that evaluates the biological integrity at a site based on the characteristics of the fish that are found there. The MBSS computes the FIBI as the average of individual metric scores. Individual metric scores are based on comparisons to reference sites within each geographic region. More information about scoring metrics and calculating IBIs can be found in the report titled "New Biological Indicators To Better Assess The Condition Of Maryland Streams".

Benthic Macroinvertebrate Index of Biotic Integrity (BIBI), like the fish IBI, is a stream assessment tool that evaluates the biological integrity at a site based on the characteristics of the benthic macroinvertebrates assemblages that are found there. The methods for scoring the BIBI and rate stream condition are the same as for the FIBI, although each was developed independently. Refer to the table above for these stream condition classifications.

Combined Index of Biotic Integrity (CBI) is the average of the fish and benthic IBI scores. While the fish and benthic IBIs provide valuable complementary information on biotic integrity (i.e., each responds differently to anthropogenic stress), the CBI is a useful indicator for community stream condition as a single number. Refer to the table above for these stream condition classifications.

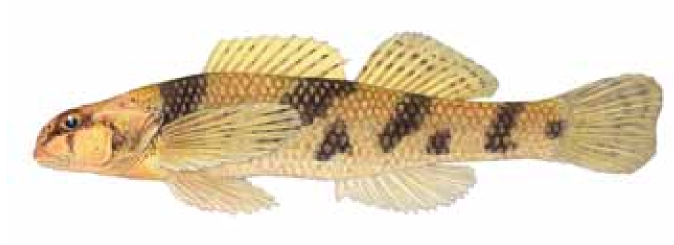
3.2 BIODIVERSITY AND SPECIES-SPECIFIC INFORMATION

While multi-metric Indices of Biotic Integrity (IBIs) used by the MBSS have been very successful in improving the understanding and management of water resources around the region, they are by design too general to capture all aspects of biotic change resulting from degradation of streams. The analysis of individual aquatic species can help diagnose more subtle changes in natural stream conditions, such as:

- Identifying the loss of and threats to rare species,
- Assessing impacts of stream blockages through documentation of migratory fish declines, and
- Emphasizing important species that are not typically included with benthic macroinvertebrate or fish IBIs.

In addition, documenting aquatic biodiversity beyond IBIs or metrics, as discussed in the examples below, provides the more complete picture needed for the preservation and restoration of Maryland's streams. The MBSS provides these additional data on a wide range of aquatic taxa, including freshwater mussels, crayfishes, amphibians, and reptiles that are not captured by IBIs, as well as the taxa-specific information on fishes and benthic macroinvertebrates.

Rare Species. Many rare, threatened, and endangered (RTE) species in Maryland are absent from streams where they were historically known to reside, despite the streams having high IBI scores. For example, the Maryland darter is a federally-endangered fish that has not been observed since 1988. One of the species' only known localities is Deer Creek, a tributary to the lower Susquehanna River, which has IBI scores ranging from Fair to Good. Even though conditions in the stream appear to be good, some modifications to the stream ecosystem not captured by the IBI scores have apparently led to the decline and extirpation of Maryland darter from Deer Creek.



Maryland Darter (*Etheostoma sellare*)
Courtesy Maryland DNR

Conversely, RTE species may be found in streams with low IBI scores. In the Breton Bay watershed of the lower Potomac River basin, several imperiled dragonfly and damselfly species were collected in streams that scored in the Poor and Fair condition range for the benthic macroinvertebrate IBI. While benthic macroinvertebrate taxa important for high-quality IBI scores are absent from these areas, these unique and rare species are still present because the local environments are suitable to their survival. Additionally, the Maryland benthic macroinvertebrate IBI is based on genus-level identifications. As a result, they cannot make true estimates of stream biodiversity or document the loss of individual macroinvertebrate species.

Migratory Fish. Approximately 10 migratory Maryland fish species currently or historically used Maryland's streams to complete their life cycles. However, dams, road culverts, and other stream blockages severely limit the access of these migratory species to their freshwater habitats, and therefore have eliminated their role in trophic webs and freshwater mussel reproduction. Streams in Maryland with high fish IBI scores may lack these species, and therefore not account for the impacts of their absences owing to man-made stream blockages.

Freshwater Mussels and Crayfishes. The filter feeding behavior of freshwater mussels helps maintain water quality of streams, while crayfishes are a key component of aquatic food webs. Freshwater mussels and crayfishes are also two of the most imperiled animal groups in flowing aquatic systems. Beginning in 2006, the MBSS added searches for freshwater mussels and crayfishes to gather data on the distribution of and address the ecological needs of these imperiled organisms. Freshwater mussels are sometimes absent from streams with high fish or macroinvertebrate IBI scores. This may be a result of stressors not reflected by IBIs or the loss of host fish species necessary for freshwater mussels to complete their life cycles.

Dwarf Wedgemussel
(Alasmidonta heterodon)
Courtesy of USFWS

3.3 PHYSICAL INDICATORS

Physical Habitat Index (PHI) is derived from MBSS data that measures the extent and type of physical habitat degradation (e.g., bank erosion) occurring in Maryland streams. A PHI was developed during Round 1 of the MBSS and revised using Round 2 data. Data from the 2007-2009 MBSS were analyzed to examine key physical habitat parameters

that may affect biological communities.

The PHI is scored as follows:

Description of PHI Scoring Categories	
Minimally Degraded	81 - 100
Partially Degraded	66 - 80
Degraded	51 - 65
Severely Degraded	0 -50

Streams are "Not Rated" when they are not sampleable due to lack of baseflow.

Trash Rating (sometimes referred to as an aesthetic quality rating) of a stream is assessed (on a 0-20 point scale) by observing the area surrounding each sampled stream segment. While the amount of trash may not directly affect stream animals, it is often associated with other human stressors. It also characterizes the visual appeal of a site and may reflect the value humans attach to the stream.

3.4 CHEMICAL INDICATORS

Acidification. Stream acidification is known to have detrimental effects on aquatic animals. Acidification can have direct effects on animals' physiological functions, as well as indirect effects, by influencing the availability and toxicity of metals to aquatic animals. One measure of acidification is pH, while another is Acid Neutralizing Capacity (ANC).

Nitrogen. In the absence of human influence, all streams contain a background level of nitrogen that is essential to the survival of the plants and animals in that stream. However, during the last several hundred years, the amount of nitrogen in many streams has increased as a result of human influences, such as agricultural runoff, wastewater discharge, and urban/suburban nonpoint sources.

Elevated nitrogen concentration is one contributor to nutrient enrichment in aquatic systems. Excessive nitrogen may lead to decreased amounts of dissolved oxygen available to aquatic animals. Prolonged exposure to low dissolved oxygen situations can suffocate adult fish or lead to reduced spawning success. Increased nutrient loads are also thought to cause toxic algal blooms.

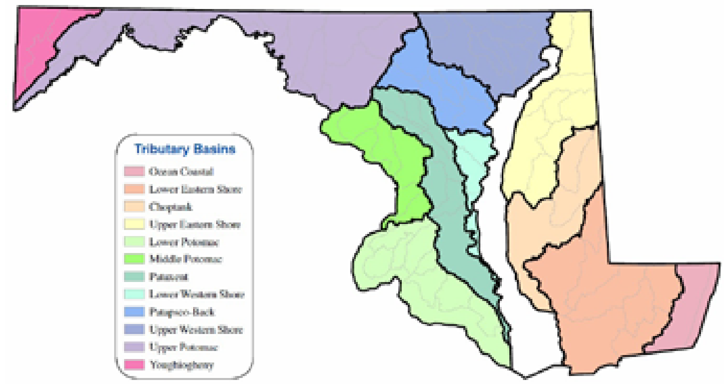
Nitrate-nitrogen (NO_3) is one of the most common and stable forms of nitrogen found in aquatic systems and its toxicity to stream animals is of particular concern. Other forms of nitrogen assessed in Round 3 of the MBSS include Nitrite-Nitrogen (NO_2), Ammonia (NH_3), and Total Nitrogen (TN).

Phosphorus. Elevated levels of phosphorus in Maryland waters are usually associated with agricultural impacts, especially those from poultry farming on the Eastern Shore. The MBSS measues both total phosphorus (TP) and orthophosphate concentrations. In Round 3 of the MBSS, total phosphorus concentrations less than 0.025 mg/l were rated Low, between 0.025 mg/l and 0.07 mg/l were rated Moderate, and those concentrations greater than 0.07 mg/l were rated High.

Dissolved Oxygen. Like terrestrial animals, fish and other aquatic organisms need oxygen to live. As water moves past their gills (or other breathing apparatus), microscopic bubbles of oxygen gas in the water called dissolved oxygen (DO) are transferred from the water to their tissues. Nutrient enrichment can cause a decrease in stream oxygen concentrations. The Code of Maryland Regulations (COMAR) state that DO concentrations greater than 5 mg/l are the standard and a level generally considered healthy for aquatic life. In Round 3 of the MBSS, DO concentrations greater than 5.0 mg/l were rated High, between 3.0 mg/l and 5.0 mg/l were rated Moderate, and those concentrations less than 3.0 mg/l were rated Low.

4. What is the Condition of Streams in Maryland?

The probability-based survey design of the Maryland Biological Stream Survey (MBSS) provides robust estimates of stream conditions at varying geographic scales. Stream condition results from Round 3 (2007-2009) of the MBSS are presented both statewide and by 12 major tributary basins that drain to the Chesapeake Bay (Tributary Strategy Basins) or the Ohio River (Youghiogheny River Basin) or the Atlantic Ocean (Ocean Coastal Basin) (see map to the right).



Major tributary basins in Maryland, including the Chesapeake Bay Tributary Strategy Basins, Youghiogheny River Basin, and the Ocean Coastal Basin

The ecological condition of streams is determined by their physical, chemical, and biological integrity. Biological integrity scores integrate perturbations (natural and anthropogenic) over time and are useful indicators of the overall condition of streams, while physical and chemical integrity provide evidence of specific stressors. Water quality criteria under the federal Clean Water Act require attainment of all three elements of integrity. Estimates of stream conditions described by each of these elements are provided via the links below.

BIOLOGICAL RESULTS

- Fish Index of Biotic Integrity
- Benthic Macroinvertabrate Index of Biotic Integrity
- Combined Index of Biotic Integrity

PHYSICAL RESULTS

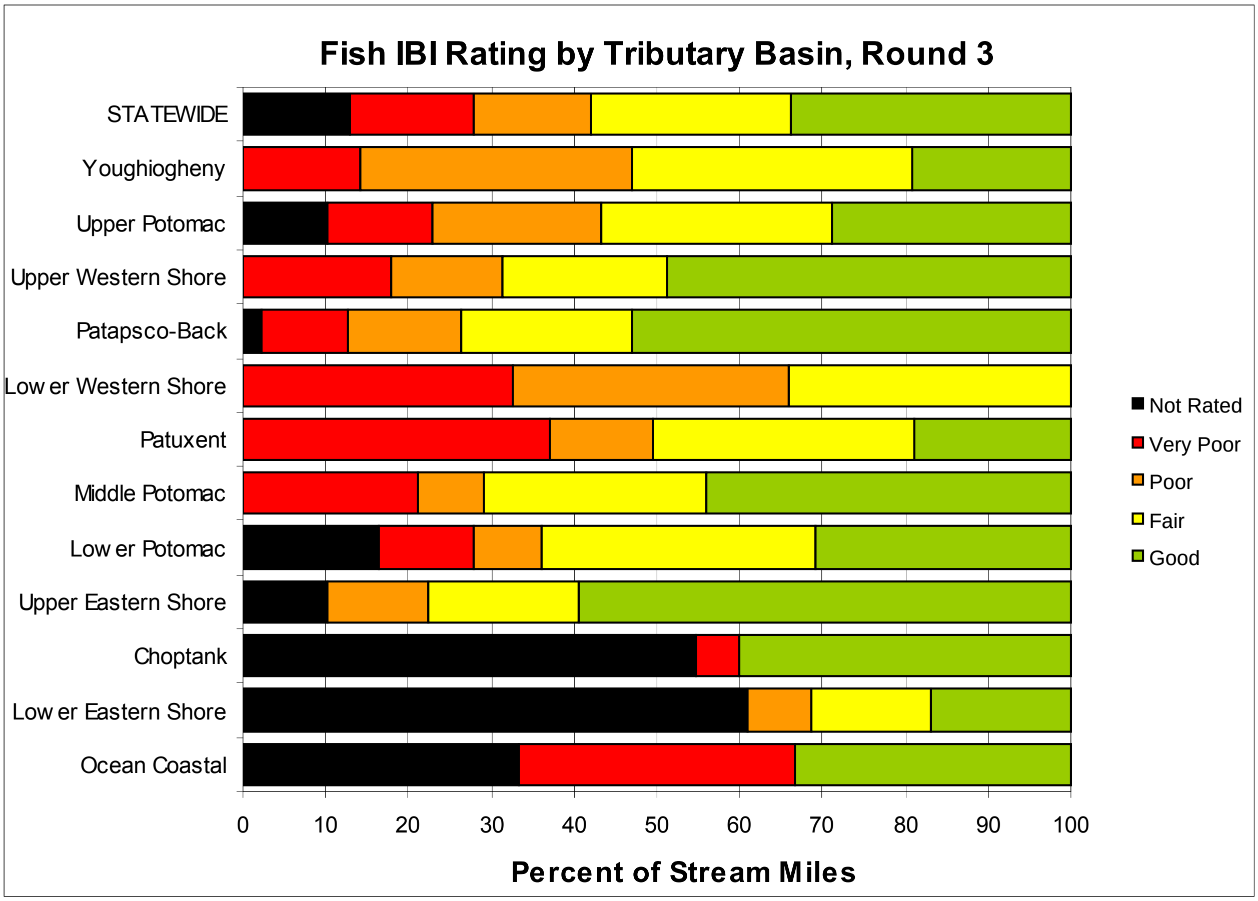
- Physical Habitat Index Rating
- Trash Rating

CHEMISTRY RESULTS

- Acidification
  - pH
  - Acid Neutralizing Capacity (ANC)
- Nitrogen
  - Nitrate-Nitrogen (NO_3)
  - Nitrite-Nitrogen (NO_2)
  - Ammonia (NH_3)
  - Total Nitrogen (TN)
- Phosphorus
  - Total Phosphorus (TP)
  - Orthophosphate
- Dissolved Oxygen

4.1 FISH INDEX OF BIOTIC INTEGRITY

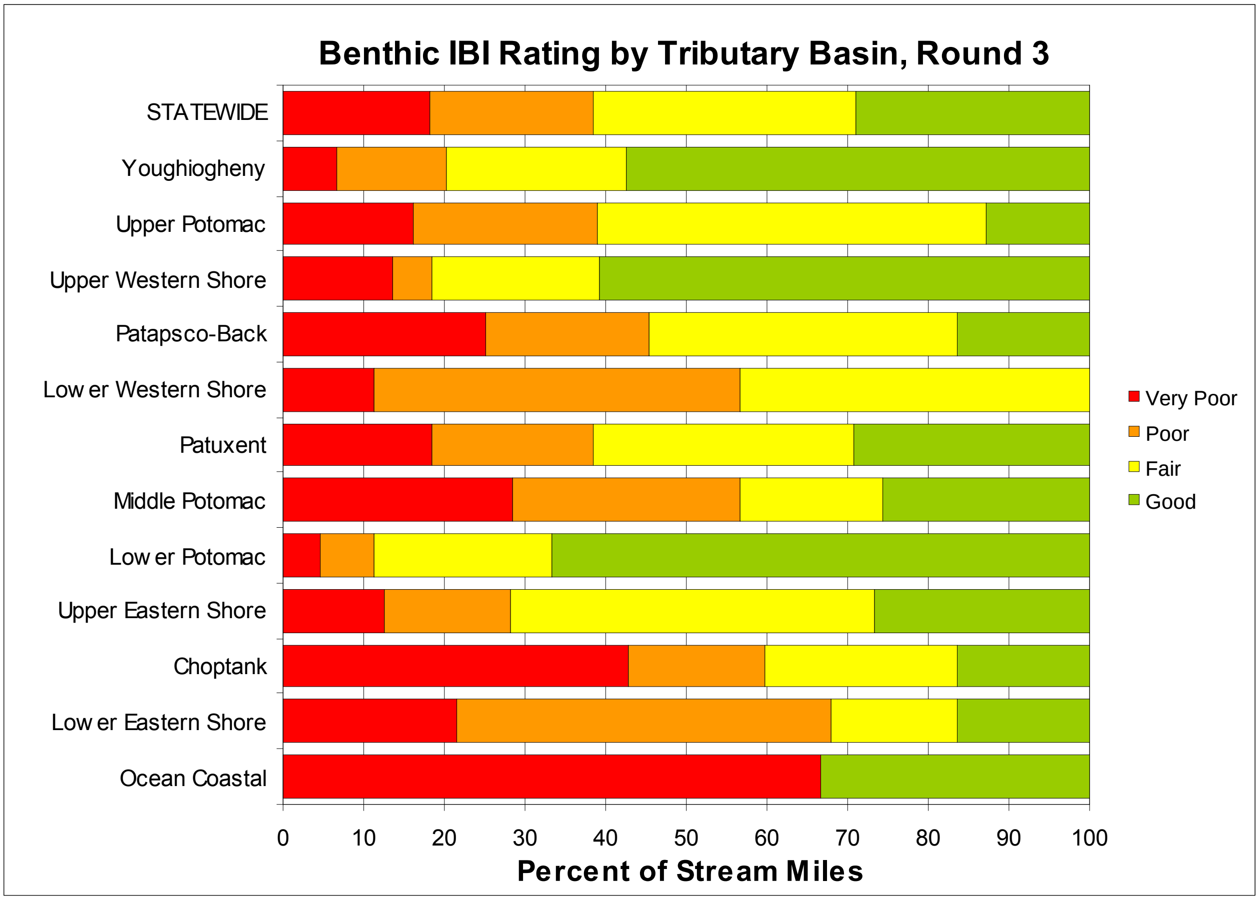
The Fish Index of Biotic Integrity (FIBI) is a stream assessment tool that evaluates the biological integrity at a site based on the characteristics of the fish community found there. The FIBI scores streams on a 1 to 5 scale and rates stream condition as Good, Fair, Poor, or Very Poor. Because an IBI score of 3 represents the threshold of reference conditions, values less than 3 (Poor or Very Poor) represent sites that are degraded. In contrast, values greater than or equal to 3 (Fair or Good) indicate that most attributes of the fish community are within the range of those at reference sites and therefore not degraded. Streams are "Not Rated" when they cannot be sampled owing to lack of baseflow, or when blackwater conditions are present that result in an inaccurate FIBI assessment.



Results from the MBSS Round 3 indicate that statewide, 34% of all stream miles are rated Good using the Fish IBI (see chart above). The Upper Eastern Shore Tributary Basin had the greatest percentage of stream miles rated Good (60%). Alternately, the Patuxent Tributary Basin had the greatest percentage of stream miles rated Very Poor (37%).

4.2 BENTHIC MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY

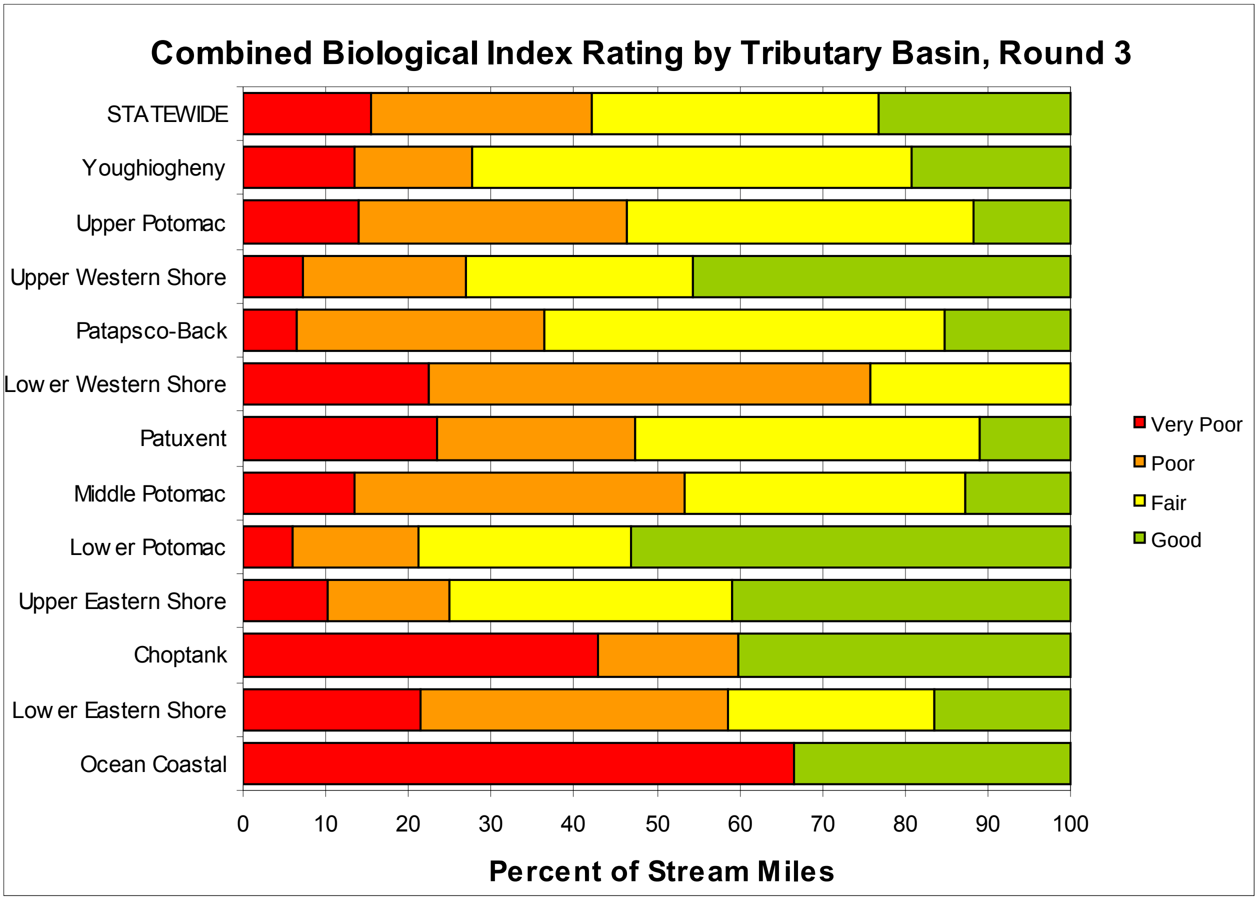
The Benthic Macroinvertebrate Index of Biotic Integrity (BIBI) is a stream assessment tool that evaluates the biological integrity at a site based on the characteristics of the benthic macroinvertebrate community found there. The BIBI scores streams on a 1 to 5 scale and rates stream condition as Good, Fair, Poor, or Very Poor. Because a BIBI score of 3 represents the threshold of minimally-distributed reference conditions, values less than 3 (Poor or Very Poor) represent sites that are degraded. In contrast, values greater than or equal to 3 (Fair or Good) indicate that most attributes of the community are within the range of those at reference sites and therefore not degraded.



Results from the MBSS Round 3 indicate that statewide, 29% of stream miles are rated Good using the Benthic macroinvertebrate IBI. The Lower Potomac Tributary Basin had the greatest percentage of stream miles rated Good (67%). Alternately, the Ocean Coastal Basin had the greatest percentage of stream miles rated Very Poor (67%) (see chart above).

4.3 COMBINED INDEX OF BIOTIC INTEGRITY

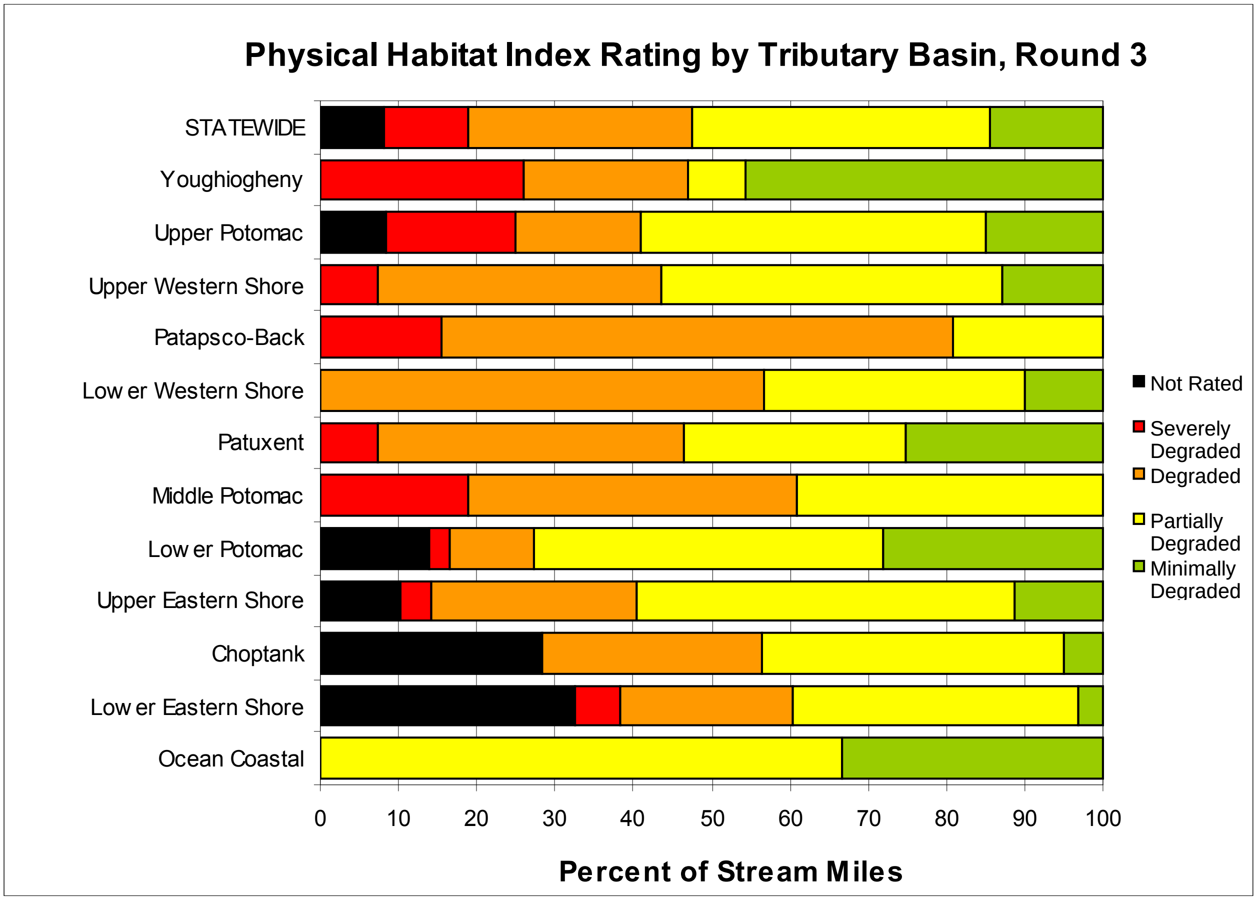
The Combined Biotic Index (CBI) is the average of fish and benthic IBI scores. While the fish and benthic macroinvertebrate IBIs provide valuable complementary information on biotic integrity (i.e., each responds differently to anthropogenic stress), the CBI is a useful single numeric score useful for rating biological stream condition.



Results from the MBSS Round 3 indicate that statewide, 23% of stream miles are rated Good using the CBI (see chart above). The Lower Potomac Tributary Basin had the greatest percentage of stream miles rated Good (53%). Alternately, the Ocean Coastal Basin had the greatest percentage of stream miles rated Very Poor (67%).

4.4 PHYSICAL HABITAT INDEX RATING

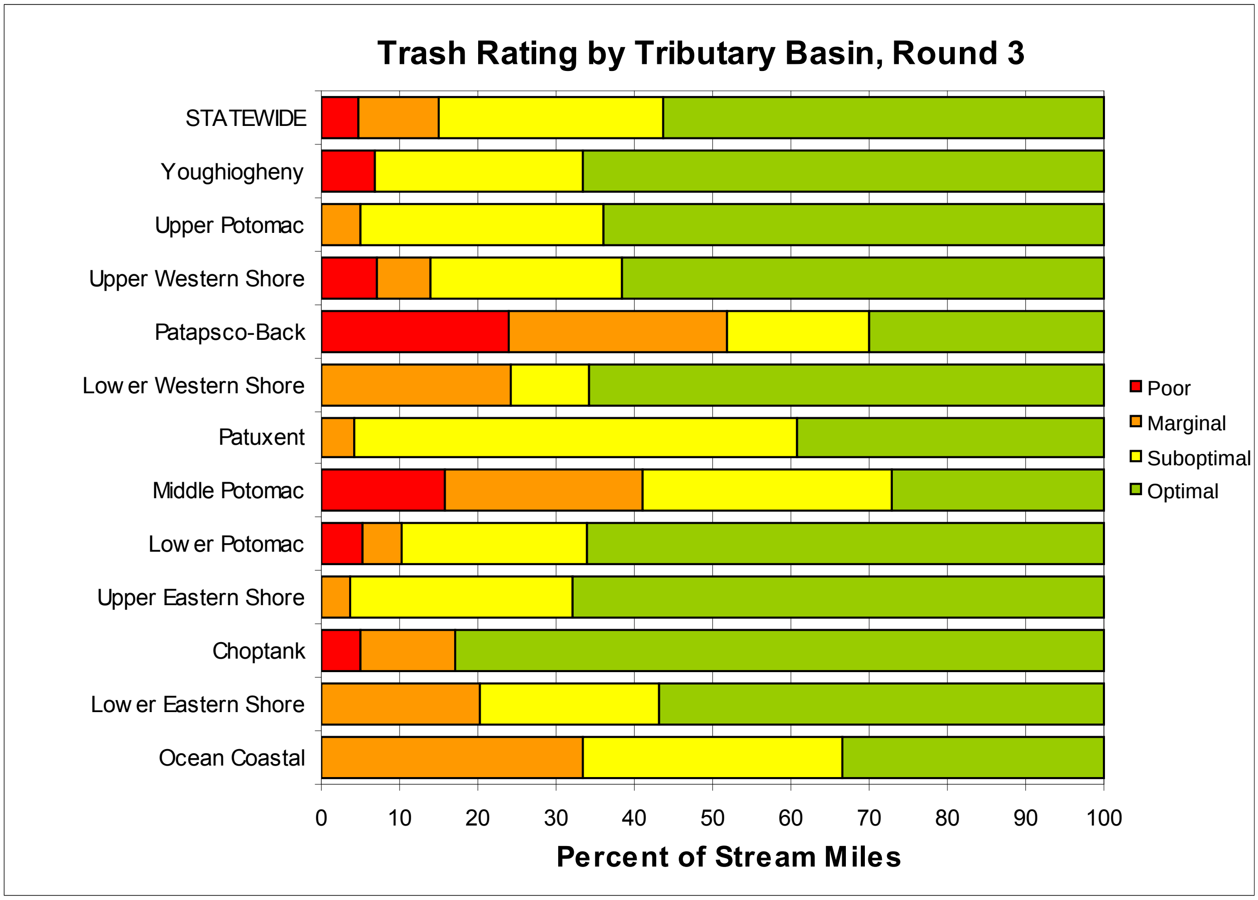
The MBSS collects data to assess the extent and type of physical habitat degradation occurring in Maryland streams and calculates a multi-metric Physical Habitat Index (PHI) for each site. Streams are "Not Rated" when they cannot be sampled owing to lack of flow.



Results from the MBSS Round 3 indicate that statewide, 14% of stream miles are rated Minimally Degraded using the PHI, while the largest percentage (38%) are rated Partially Degraded (See chart above). The Youghiogheny Tributary Basin had the greatest percentage of stream miles rated Minimally Degraded (46%). Alternately, the Patapsco-Back River and Middle Potomac River Tributary Basins had no stream miles that scored Minimally Degraded for the PHI.

4.5 TRASH RATING

The trash rating (sometimes referred to as an aesthetic quality rating) of a stream is assessed (on a 0-20 point scale) by observing the area surrounding each sampled stream segment. While the amount of trash may not directly affect stream animals, it is often associated with other human stressors. The trash rating also characterizes the visual appeal of a site and may reflect the value humans attach to the stream.

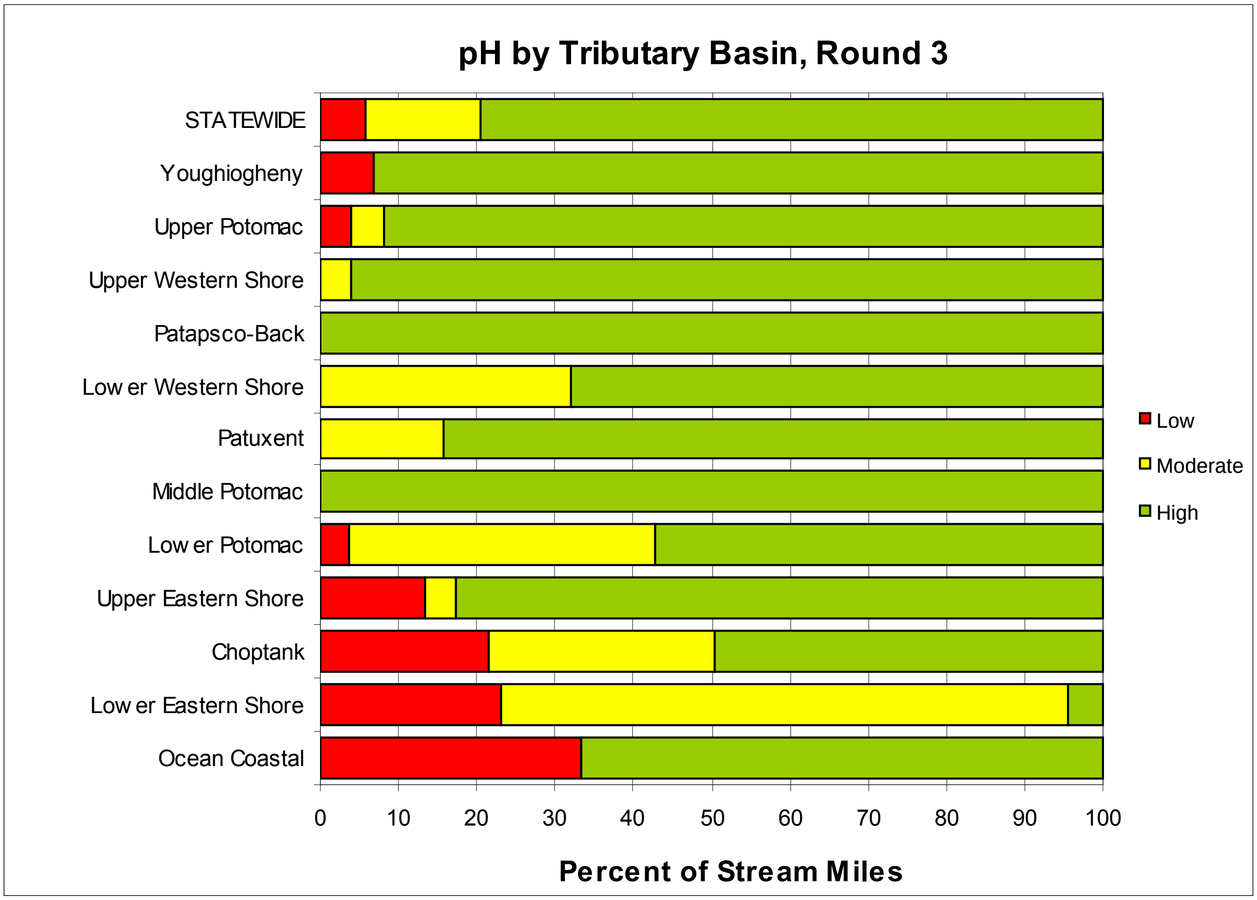


Results from the MBSS Round 3 indicate that statewide, 56% of stream miles are rated Optimal for their trash rating (scoring 16 or more points out of 20) (see chart above). The Choptank River Basin had the greatest percentage of stream miles rated Optimal (83%). The two basins with the highest number of stream miles rated Poor for trash were the Patapsco-Back River Basin and the Middle Potomac Basin (24% and 16%, respectively). These two basins encompass most of the urbanized areas of the Baltimore-Washington corridor and are severely impacted by human disturbance.

4.6 ACIDIFICATION

Stream acidification is known to have detrimental effects on aquatic animals. Acidification can have direct effects on animals' bodily functions, as well as indirect effects, by influencing the availability and toxicity of metals to aquatic animals. One measure of acidification is pH, while another is Acid Neutralizing Capacity (ANC).

Acidification - as Measured by pH

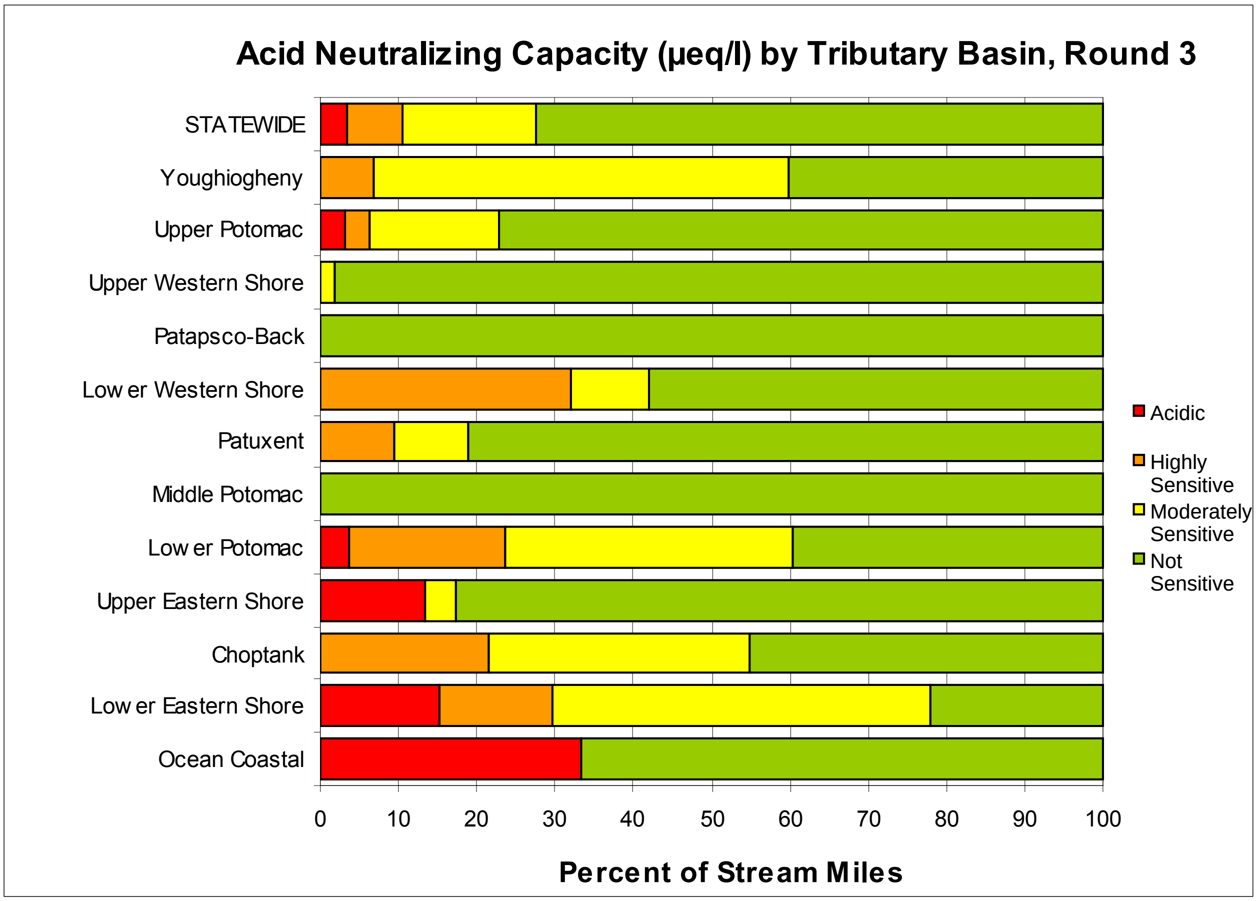


pH was measured during spring MBSS sampling in Round 3. High pH values are greater than 6.5 (neutral to more basic), Moderate pH values are between 5.5 and 6.5, and low pH values are less than 5.5 (more acidic). Results from the MBSS Round 3 indicate that statewide, 80% of stream miles had pH values greater than 6.5 (see chart above). All stream miles in the Middle Potomac and Patapsco-Back River Tributary Basins had pH values greater than 6.5. The Ocean Coastal Basin had the greatest percentage of stream miles with pH less than 5.5 and quite acidic (33%).

Acidification - as Measured by Acid Neutralizing Capacity (ANC)

ANC is a measure of the capacity of dissolved constituents in the water to react with and neutralize acids. It is used as an index of the sensitivity of surface waters to acidification. The higher the ANC, the more acid a system can assimilate before experiencing a decrease in pH. ANC also indicates which systems are more likely to become acidified under episodic acid input conditions. An ANC of 200 μeq/l is usually considered the threshold for defining acid-sensitive streams and lakes. The following categories were used to characterize Maryland streams according to acid sensitivity:

- ANC less than 0μeq/l = Acidic
- ANC greater than or equal to 0 but less than 50μeq/l = Highly Sensitive to Acidification
- ANC greater than or equal to 50μeq/l but less than 200μeq/l = Moderately Sensitive to Acidification
- ANC greater than or equal to 200μeq/l = Not Sensitive to Acidification



Results from the MBSS Round 3 indicate that statewide, 72% of the stream miles were Not Sensitive to Acidification, while 3% were rated Acidic (see chart above). All stream miles in the Middle Potomac and Patapsco-Back River Tributary Basins were rated Not Sensitive to Acidification. The Ocean Coastal Basin had the greatest percentage of stream miles rated Acidic (33%).

4.7 NITROGEN

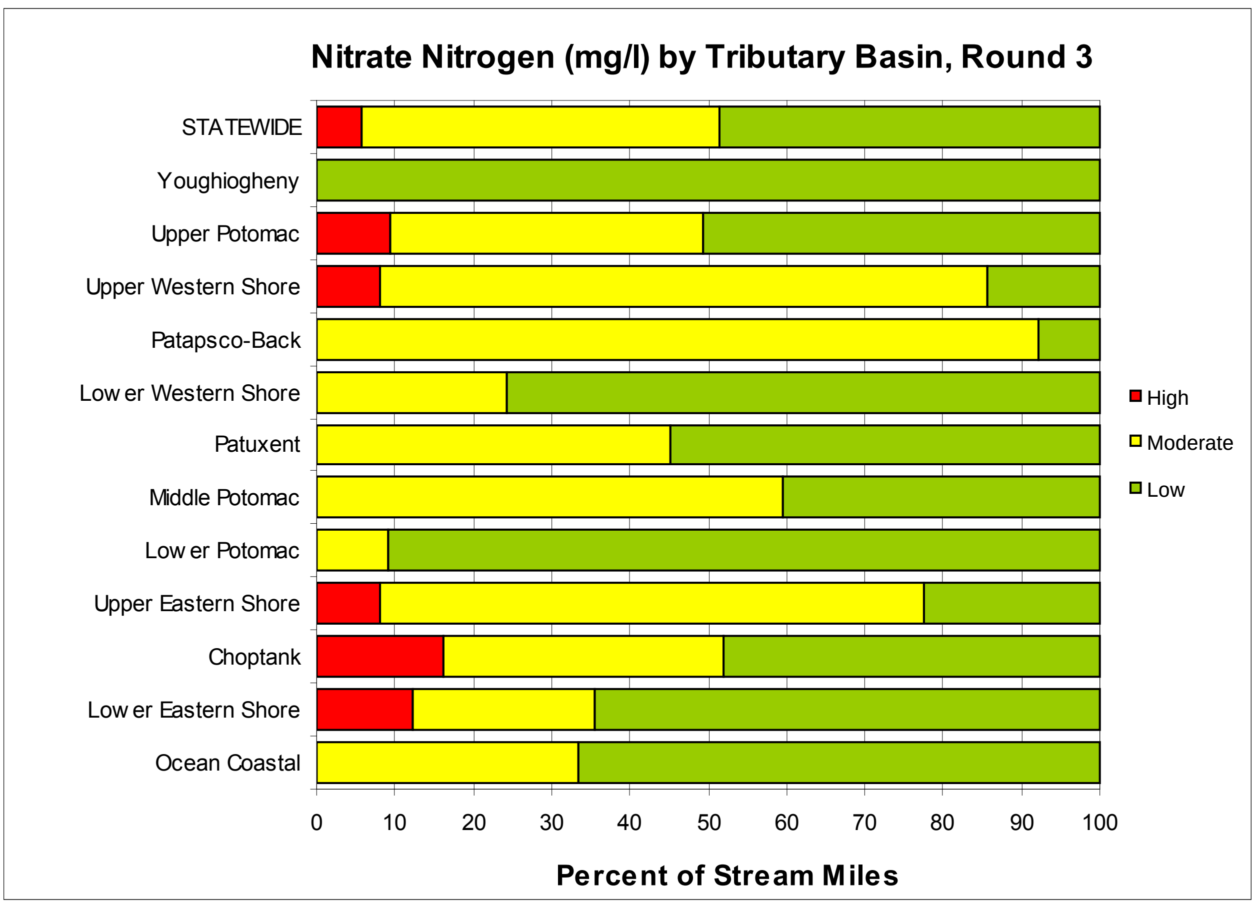
In the absence of human influence, all streams contain a background level of nitrogen that is essential to the survival of plants and animals living in that stream. However, during the last several hundred years, the amount of nitrogen in many streams has increased as a result of many human influences, such as agricultural runoff, wastewater discharge, and urban/suburban nonpoint source pollution.

Elevated nitrogen concentration is one contributor to nutrient enrichment in aquatic systems. Excessive nitrogen may lead to decreased amounts of dissolved oxygen available to aquatic animals. Prolonged exposure to low dissolved oxygen situations can suffocate adult fish or lead to reduced spawning success. Increased nutrient loads are also thought to cause toxic algal blooms.

Forms of nitrogen assessed in Round 3 of MBSS include Nitrate-Nitrogen (NO_3), Nitrite-Nitrogen (NO_2), Ammonia (NH_3), and Total Nitrogen (TN).

Nitrogen in the Form of Nitrate-Nitrogen (NO_3)

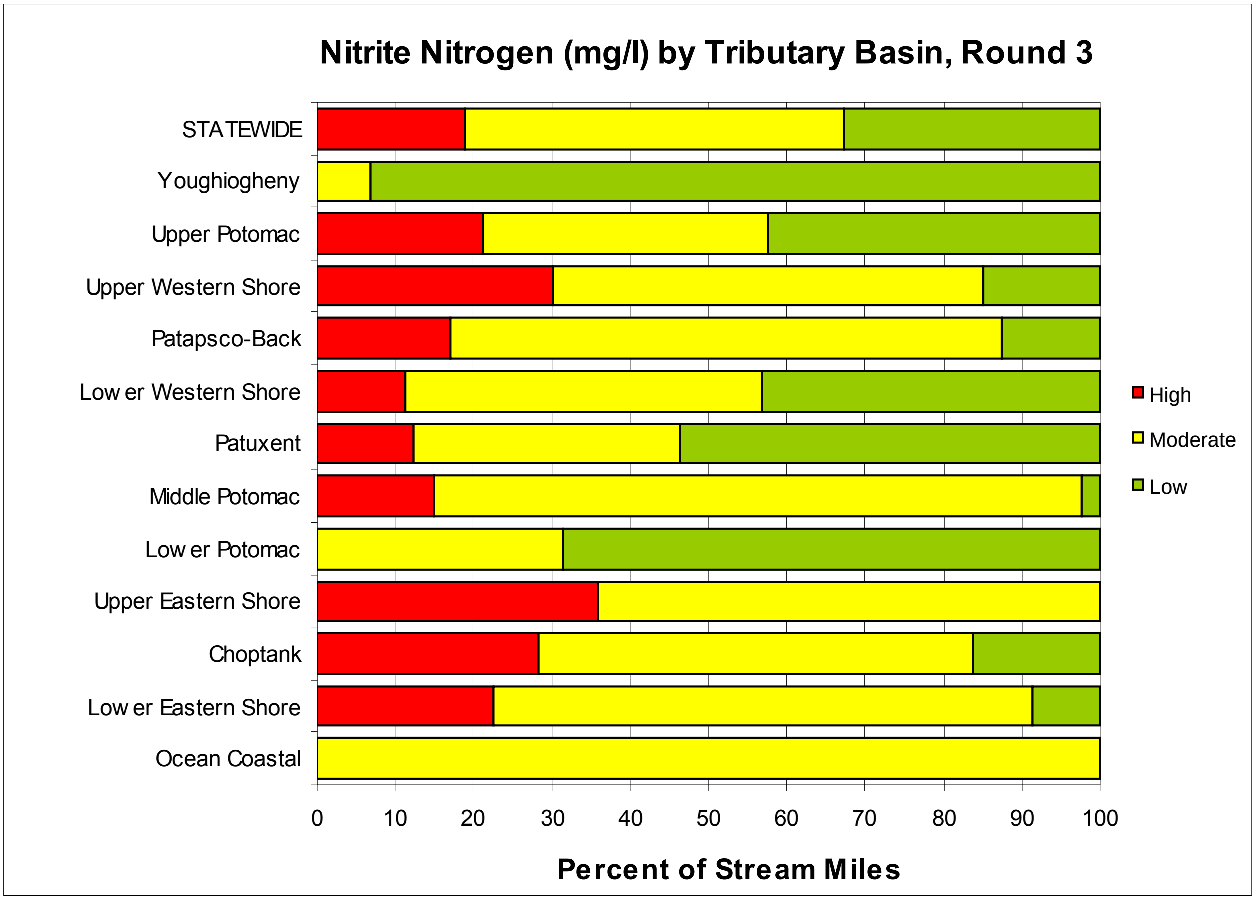
Nitrate-nitrogen (NO_3) is one of the most common and stable forms of nitrogen found in aquatic systems and its toxicity to stream animals is of particular concern.



Statewide, the majority of stream miles had NO_3 concentrations less than 5.0 mg/l, as only 6% of stream miles statewide exceeded 5.0 mg/l. Two Tributary Strategy Basins had greater than 10% of stream miles with greater than 5.0 mg/l of NO_3: the Choptank River Basin (16%) and the Lower Eastern Shore (12%). These are areas on the Eastern Shore, with large amounts of agricultural land use contributing to NO_3 input to streams.

Nitrogen in the Form of Nitrite-Nitrogen (NO_2)

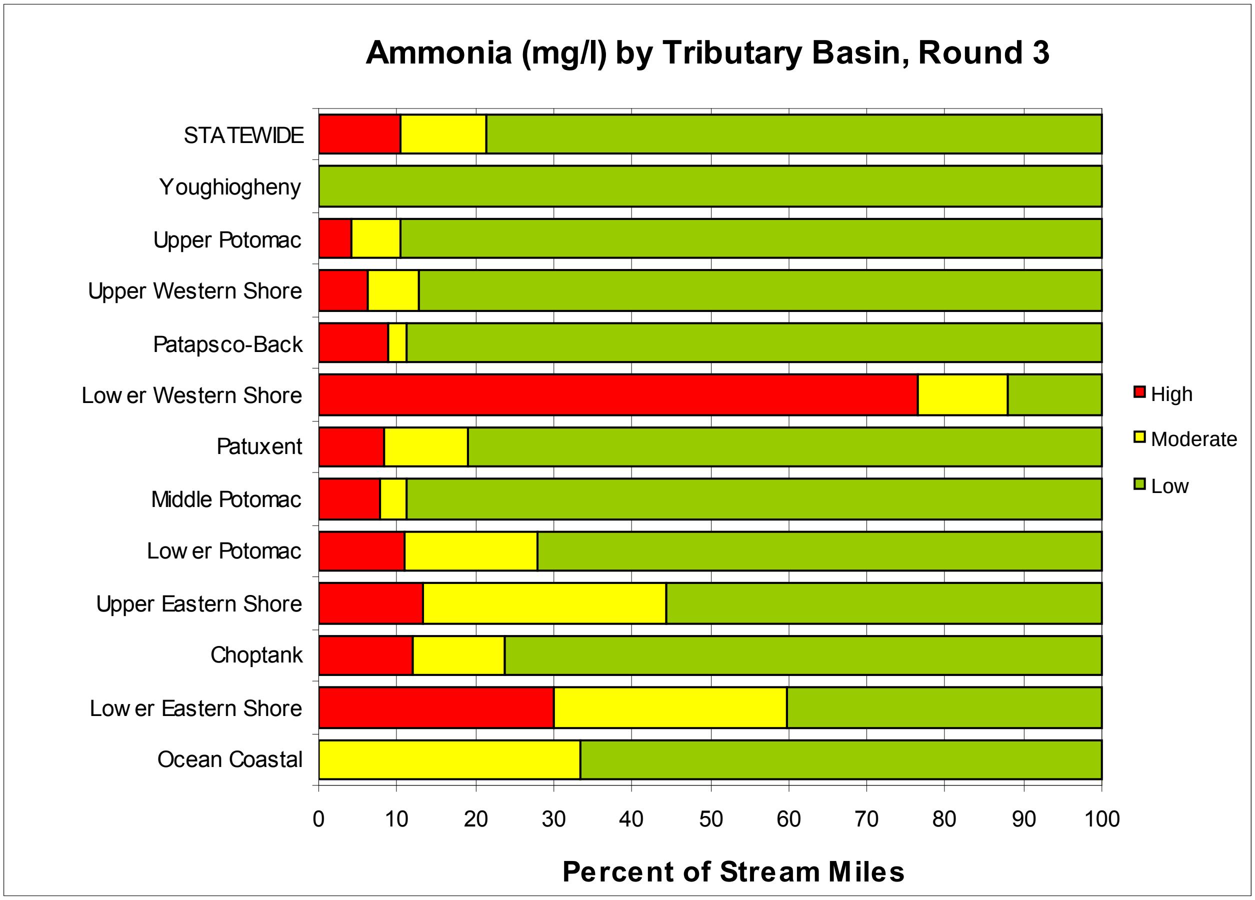
Nitrite-nitrogen (NO_2) concentrations above 0.01 mg/l were rated High, between 0.0025 mg/l and 0.01 mg/l were rated Moderate, and concentrations less than 0.0025 mg/l were rated Low.



Statewide, results from the MBSS Round 3 indicate that only 19% of stream miles had nitrite-nitrogen concentrations above 0.01 mg/l (see above chart). The Upper Eastern Shore and Upper Western Shore Tributary Basins had the highest percentage of stream miles with nitrite-nitrogen greater than 0.01 mg/l (36% and 30%, respectively). Alternatively, the Youghiogheny River Tributary Basin had the greatest percentage of stream miles with low nitrite-nitrogen concentrations (93% were less than 0.0025 mg/l).

Nitrogen in the Form of Ammonia (NH_3)

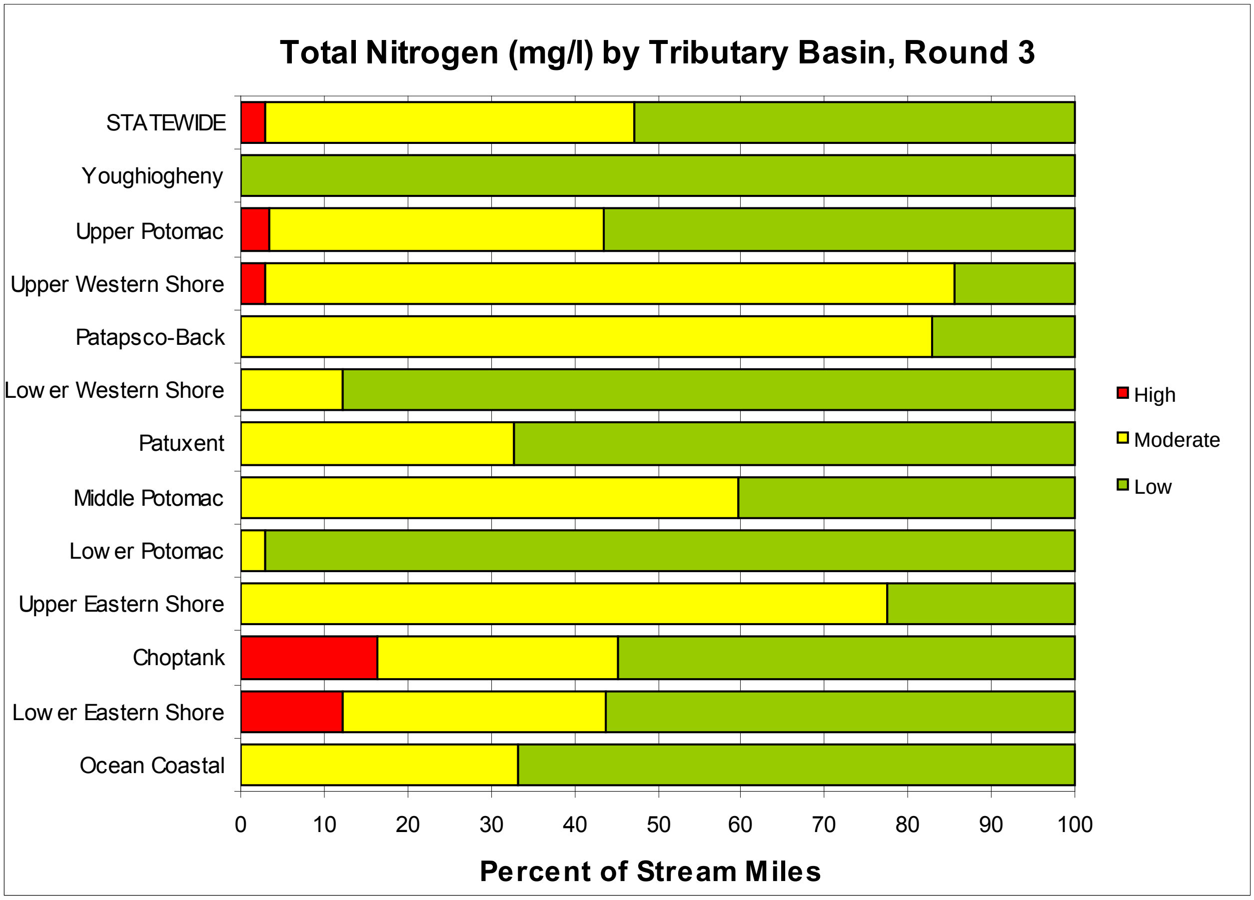
Ammonia (NH_3) concentrations less than 0.03 mg/l were rated Low, between 0.03 mg/l and 0.07 mg/l were rated Moderate, and concentrations greater than 0.07 mg/l were rated High.



Results from Round 3 of the MBSS indicate that 78% of stream miles in Maryland have Low concentrations of ammonia and only 11% of stream miles had High ammonia concentrations (see above chart). The Lower Western Shore Tributary Basin had, by far, the greatest percentage of stream miles with high (greater than 0.07 mg/l) ammonia concentrations (77% of stream miles). The western-most Tributary Basins, the Youghiogheny River and Upper Potomac River Basins, had the greatest percentage of stream miles with low ammonia concentrations (100% and 90%, respectively).

Nitrogen in the Form of Total Nitrogen

Total nitrogen (TN) concentrations less than 1.5 mg/l were rated Low, between 1.5 mg/l and 7.0 mg/l were rated Moderate, and those concentrations greater than 7.0 mg/l were rated High.



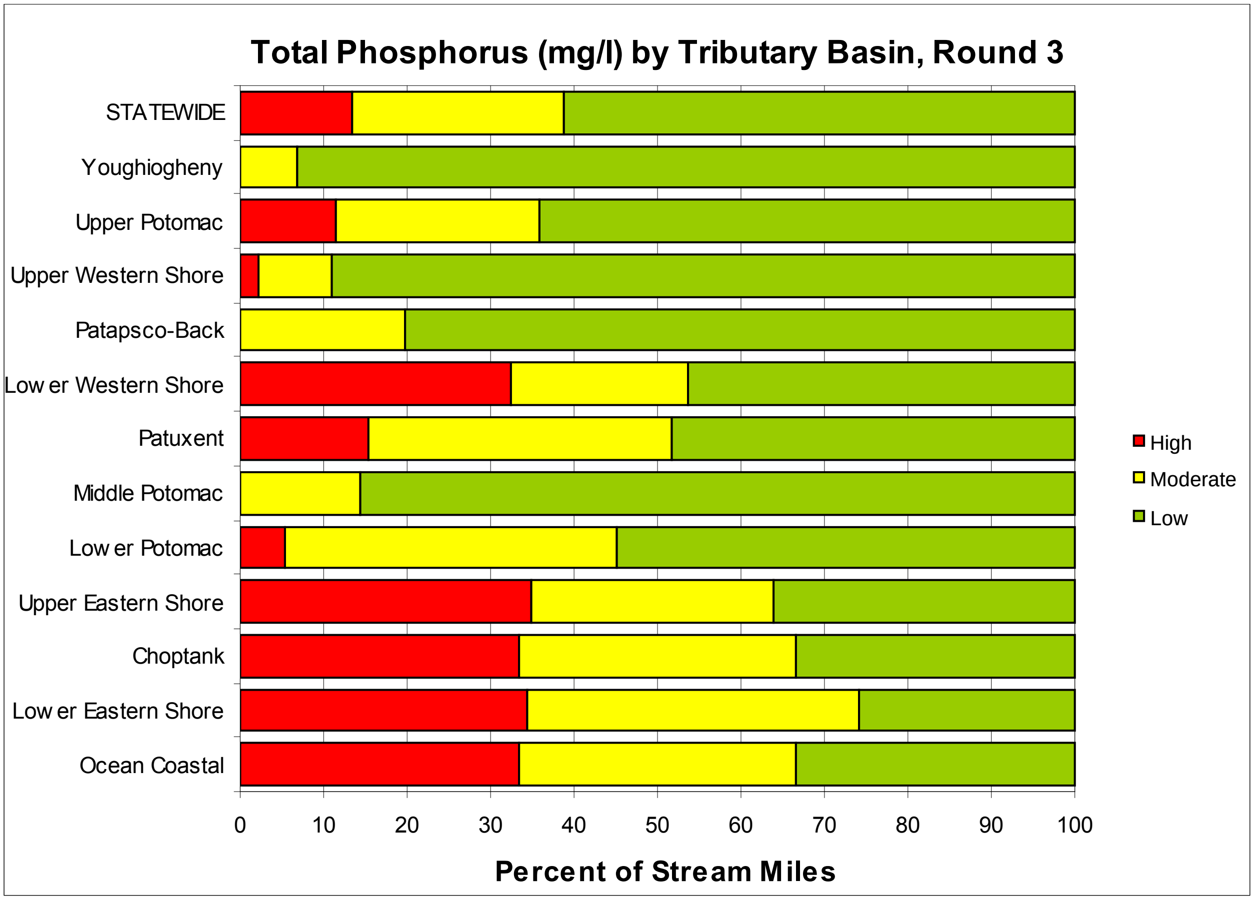
Results from Round 3 of the MBSS indicate that 53% of stream miles in Maryland have low concentrations of total nitrogen, and only 3% of stream miles had High total nitrogen concentrations (see above chart). The Choptank River and Lower Eastern Shore Tributary Basins had the greatest percentage of stream miles with high (greater than 7.0 mg/l) total nitrogen concentrations (16% and 12% of stream miles, respectively). All stream miles in the Youghiogheny River Basin had low total nitrogen concentrations.

4.8 PHOSPHORUS

Elevated levels of phosphorus in Maryland streams are mostly associated with agricultural impacts, especially those from poultry farming on the Eastern Shore. In Round 3 of the MBSS, total phosphorus (TP) and orthophosphate were measured.

Phosphorus in the Form of Total Phosphorus

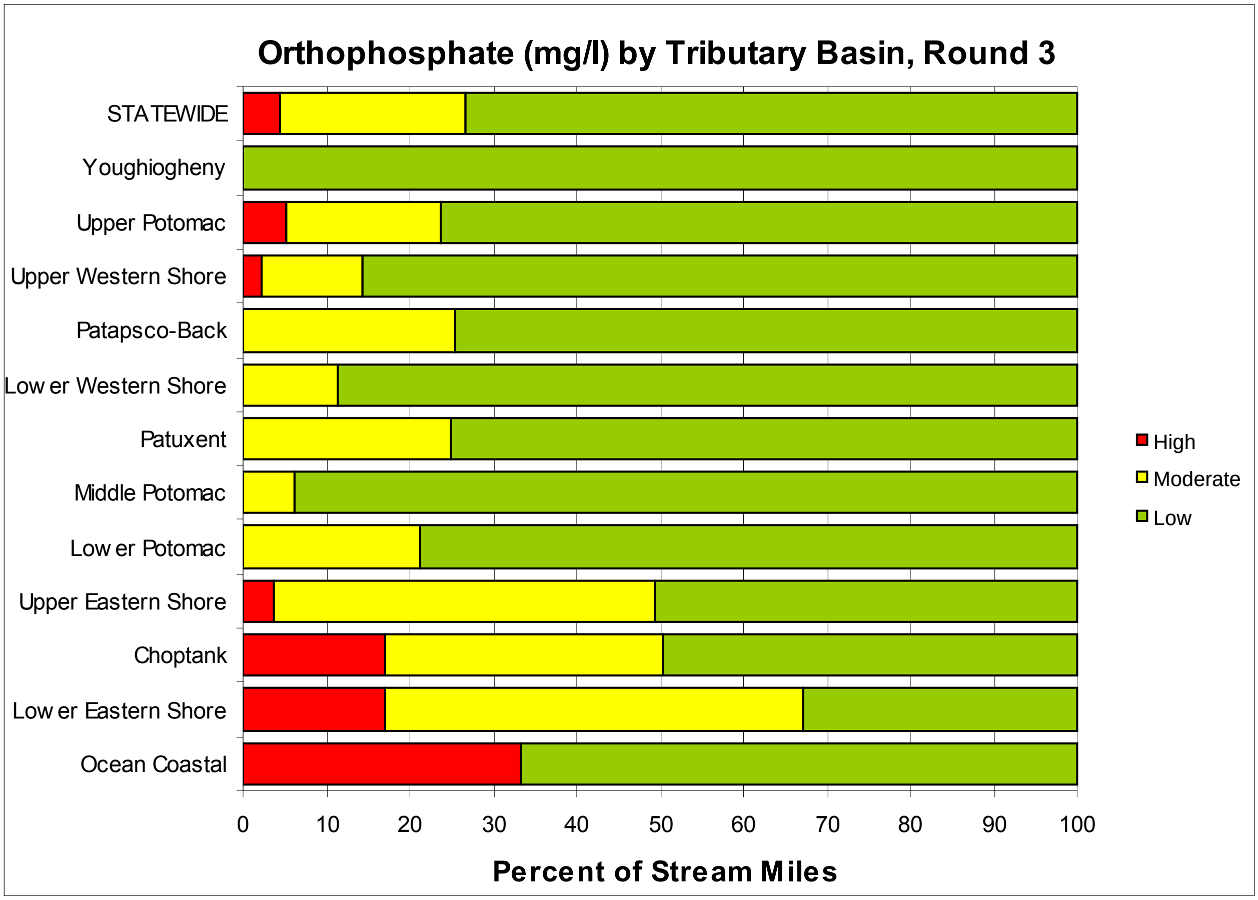
Total phosphorus concentrations less than 0.025 mg/l were rated Low, between 0.025 mg/l and 0.07 mg/l were rated Moderate, and those concentrations greater than 0.07 mg/l were rated High.



Results from Round 3 of the MBSS indicate that 61% of stream miles in Maryland have Low concentrations of total phosphorus and only 13% of stream miles had High total phosphorus concentrations (see above chart). The Tributary Basins with the greatest number of stream miles with high (greater than 0.07 mg/l) concentrations of total phosphorus are located on the Eastern Shore and include the Upper Eastern Shore, Lower Eastern Shore, Choptank River, and Ocean Coastal Basins (35%, 34%, 33%, and 33%, respectively). This geographic pattern is similar to that seen with orthophosphate (as described below).

Phosphorus in the Form of Orthophosphate

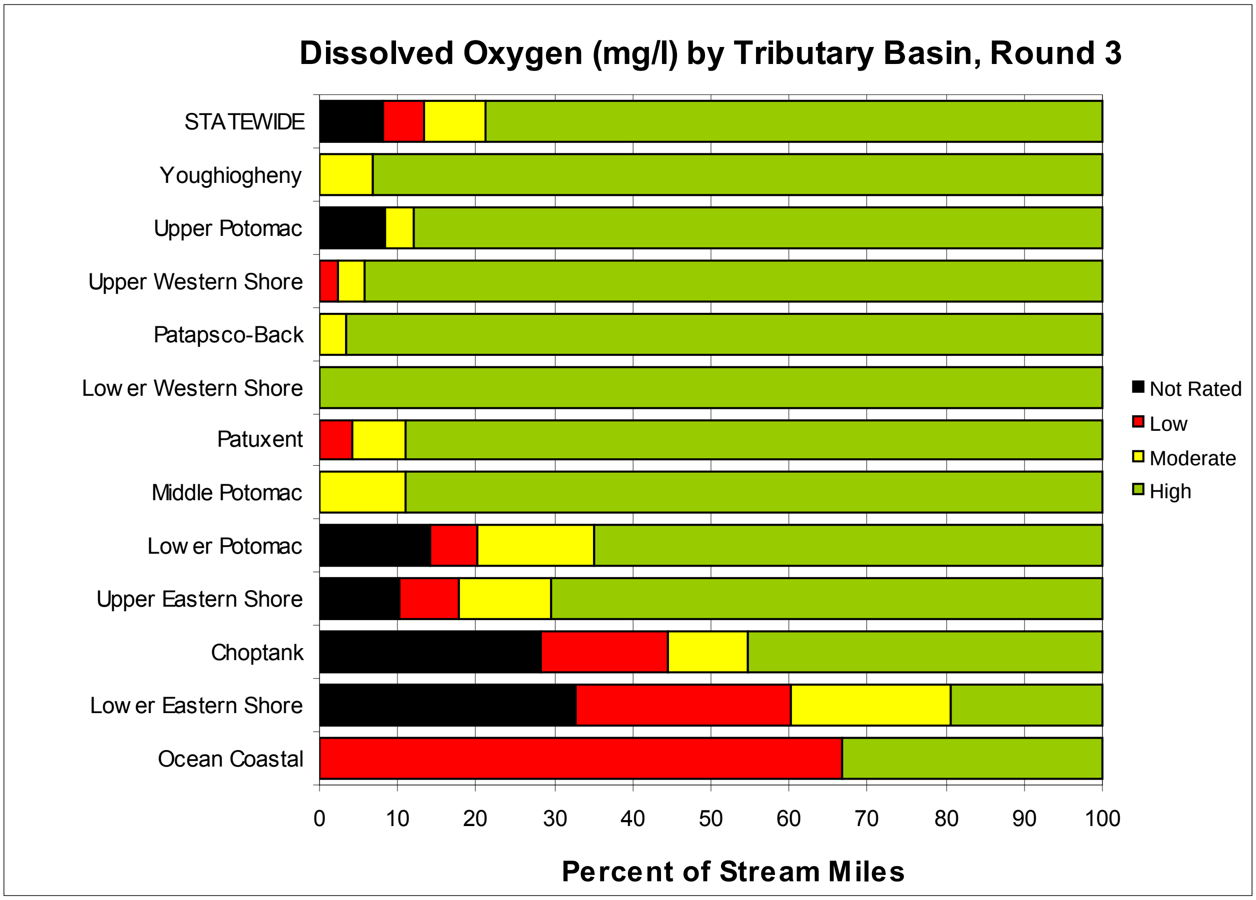
Orthophosphate concentrations less than 0.008 mg/l were rated Low, between 0.008 mg/l and 0.03 mg/l were rated Moderate, and those concentrations greater than 0.03 mg/l were rated High.



Results from Round 3 of the MBSS indicate that 73% of stream miles in Maryland have Low orthophosphate concentrations and only 4% of stream miles had High orthophosphate concentrations (see above chart). Similar to the geographic pattern seen with total phosphorus, the Tributary Basins with the greatest number of stream miles with high concentrations (greater than0.03 mg/l) of orthophosphate are located on the Eastern Shore and include the Ocean Coastal Basin (33% of stream miles), Lower Eastern Shore Basin (17% of stream miles), and Choptank River Basin (17% of stream miles).

4.9 DISSOLVED OXYGEN

Fish and other aquatic organisms need oxygen to live. As water moves past their gills (or other breathing apparatus), microscopic bubbles of oxygen gas in the water, called dissolved oxygen (DO), are transferred from the water to their blood. Pollution tends to cause a decrease in stream oxygen concentrations. The Code of Maryland Regulations (COMAR) states that concentrations greater than 5 mg/l are the standard and the minimum DO concentration needed to sustain aquatic life. In Round 3 of the MBSS, DO concentrations greater than 5.0 mg/l were rated High, between 3.0 mg/l and 5.0 mg/l were rated Moderate, and those concentrations less than 3.0 mg/l were rated Low. Streams are Not Rated when they cannot be sampled owing to lack of flow.



Results from Round 3 of the MBSS indicate that 79% of stream miles in Maryland have concentrations of dissolved oxygen greater than 5 mg/l (the COMAR standard) (see the above chart). Only 5% of stream miles had Low DO concentrations. As expected, the greatest number of stream miles with Low DO (less than 3 mg/l) concentrations occurs on the Eastern Shore in the Ocean Coastal Basin (67% of stream miles), and the Lower Eastern Shore and Choptank River Basins (27% and 16%, respectively). This is an area of the state where swampy blackwater streams and sluggish waters are naturally lower in dissolved oxygen, but also susceptible to biological oxygen demand (BOD) loading from human-related sources.

5. What is the Trend in the Condition of Streams in Maryland?

The Maryland Biological Stream Survey (MBSS) is unique in that the probability-based survey provides statistically valid estimates of condition for each year that random sampling is conducted. When a statewide round of random sampling is completed in three (1995-1997 and 2007-2009) or five years (2000-2004), all parts of the state can be assessed.

One of the most important questions for managing water resources is how is the condition of streams changing over time? Detection of trends in condition requires that comparable assessments be completed with enough precision to determine if differences are real. Natural variability within and across years is large enough that we do not expect to detect meaningful trends over a period of less than 10 years and perhaps longer. The ability to detect trends also depends on the number of assessments that are completed.

The MBSS is designed to detect trends in stream condition in three ways:

- Changes across multiple-year rounds of statewide sampling
- Annual changes in statewide assessments with partial coverage of watersheds
- Annual changes at sentinel sites

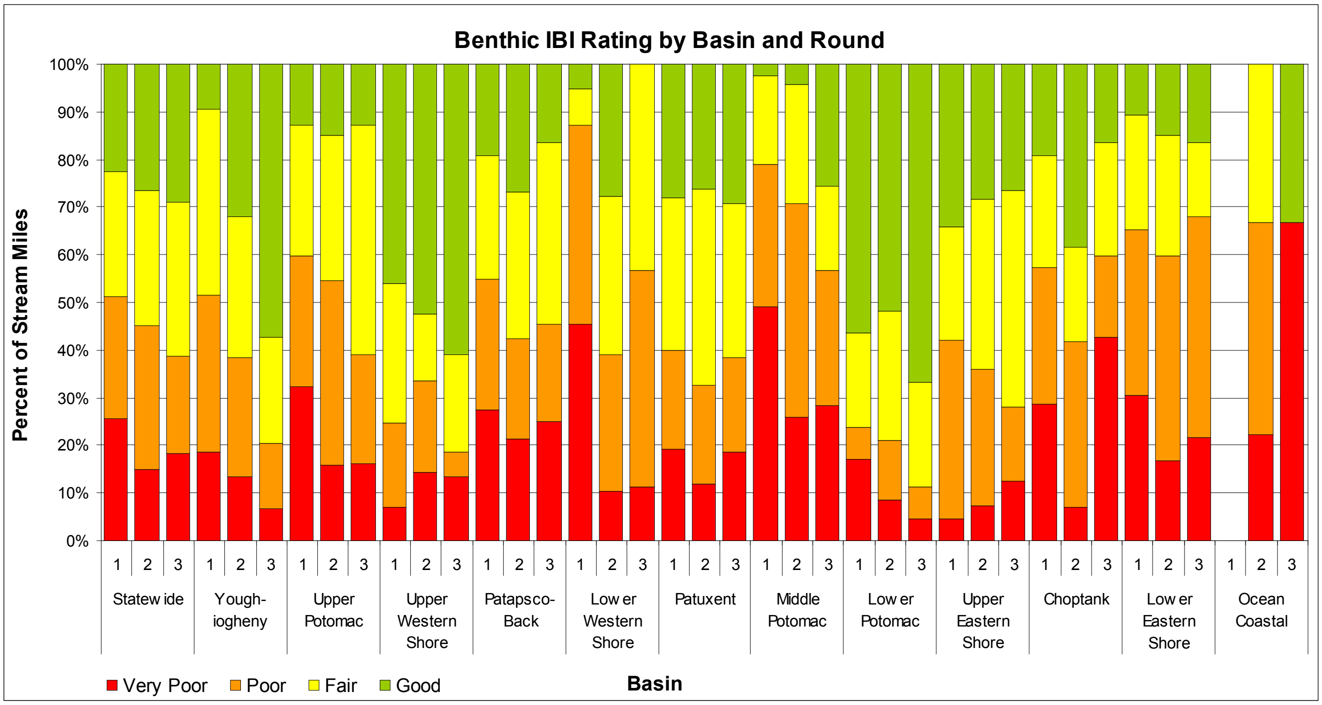
5.1 CHANGES ACROSS MULTIPLE-YEAR ROUNDS OF STATEWIDE SAMPLING

Statistical standards for trends detection generally require five points in time. Therefore, we only provide a visual comparison of the three single statewide assessments of condition from each multi-year round in the figures below. Each figure shows the percentage of stream miles in each stream condition class (Good, Fair, Poor, and Very Poor) for each of the three statewide sampling rounds: Round 1 (1995-1997), Round 2 (2000-2004), and Round 3 (2007-2009).

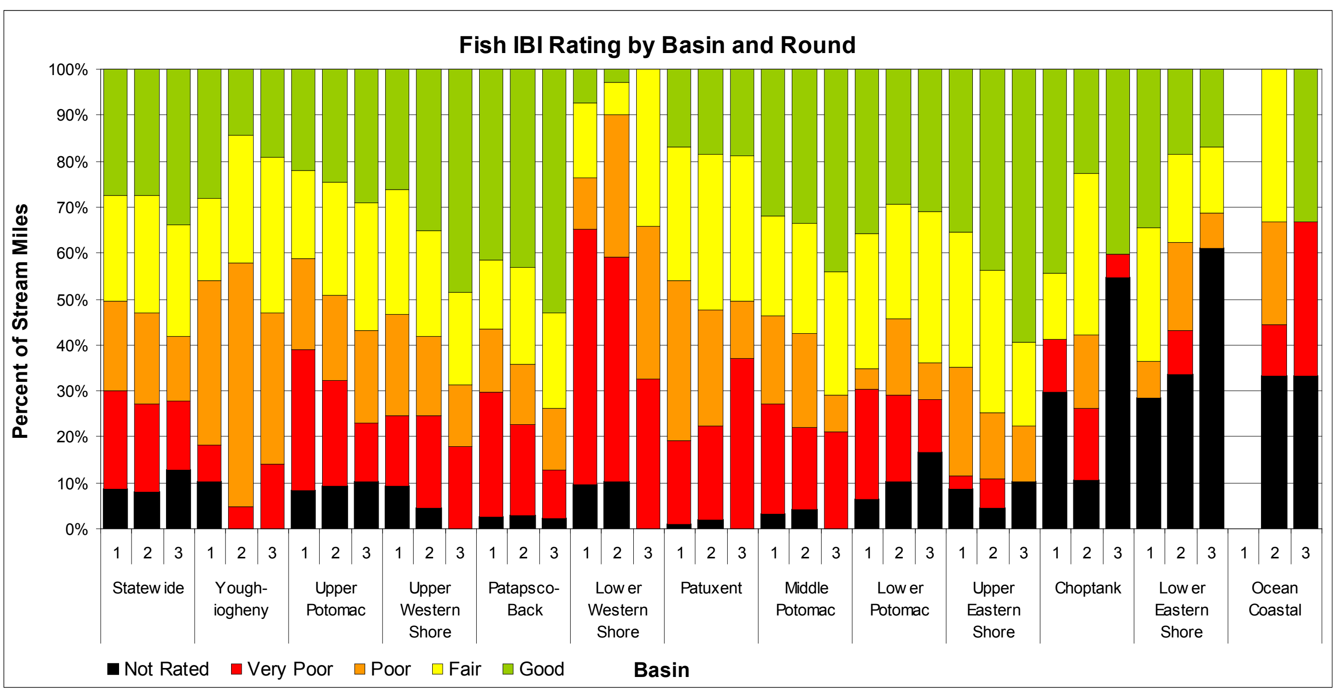
Both the benthic and fish indices of biotic integrity (IBIs) show a variable, but consistent, relative proportion of stream miles in each condition class for each major drainage basin. Statewide, the percentage of stream miles in Good condition increased by 5-7% from Round 1 to Round 3, while the percentage of stream miles in Very Poor condition decreased by a comparable amount. The improvement in condition based on the benthic macroinvertebrate IBI (BIBI) was greatest for the Youghiogheny basin. As expected, the trend in CIBI (average of benthic and fish IBIs) was similar, while the change in physical habitat index (PHI) was not consistent across all three rounds.

The figures below shows percent of stream miles in each condition for BIBI, FIBI, CBI, and PHI by Round (1, 2, 3) in each Tributary Basin and Statewide as sampled in the Maryland Biological Stream Survey.

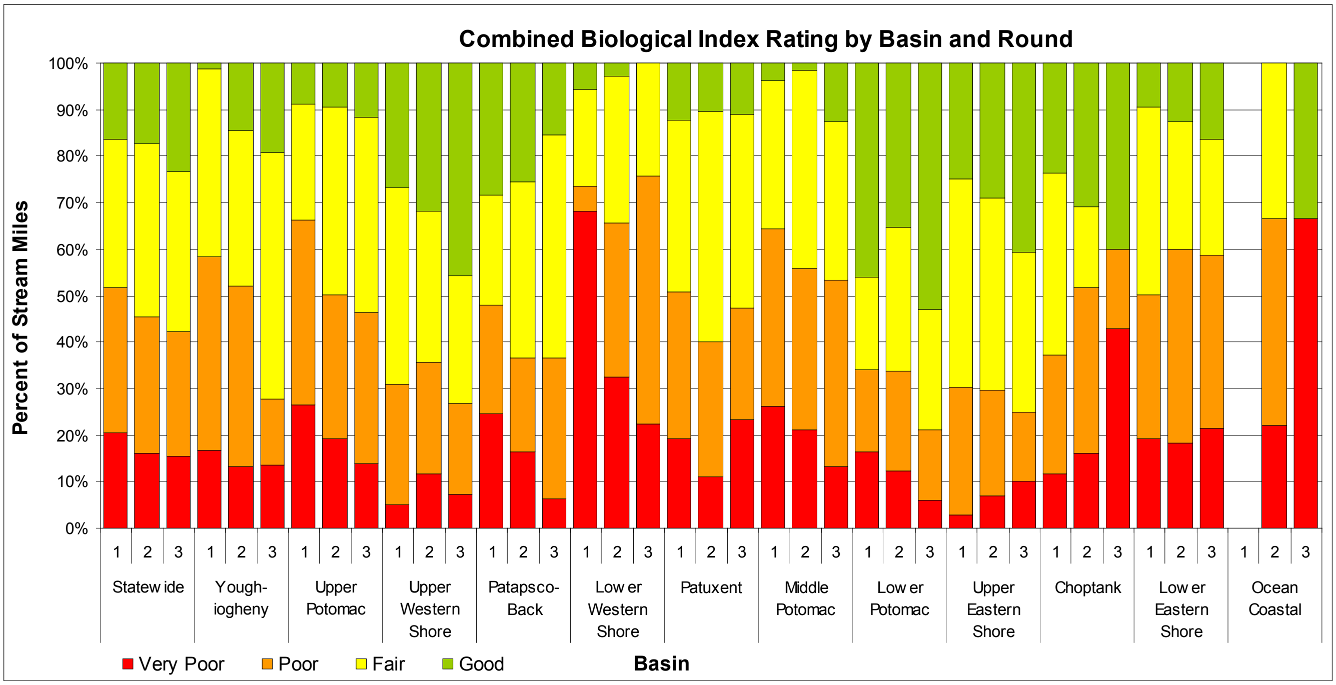
Pie charts for the MBSS Rounds can be viewed for each tributary basin clicking on the basin name.



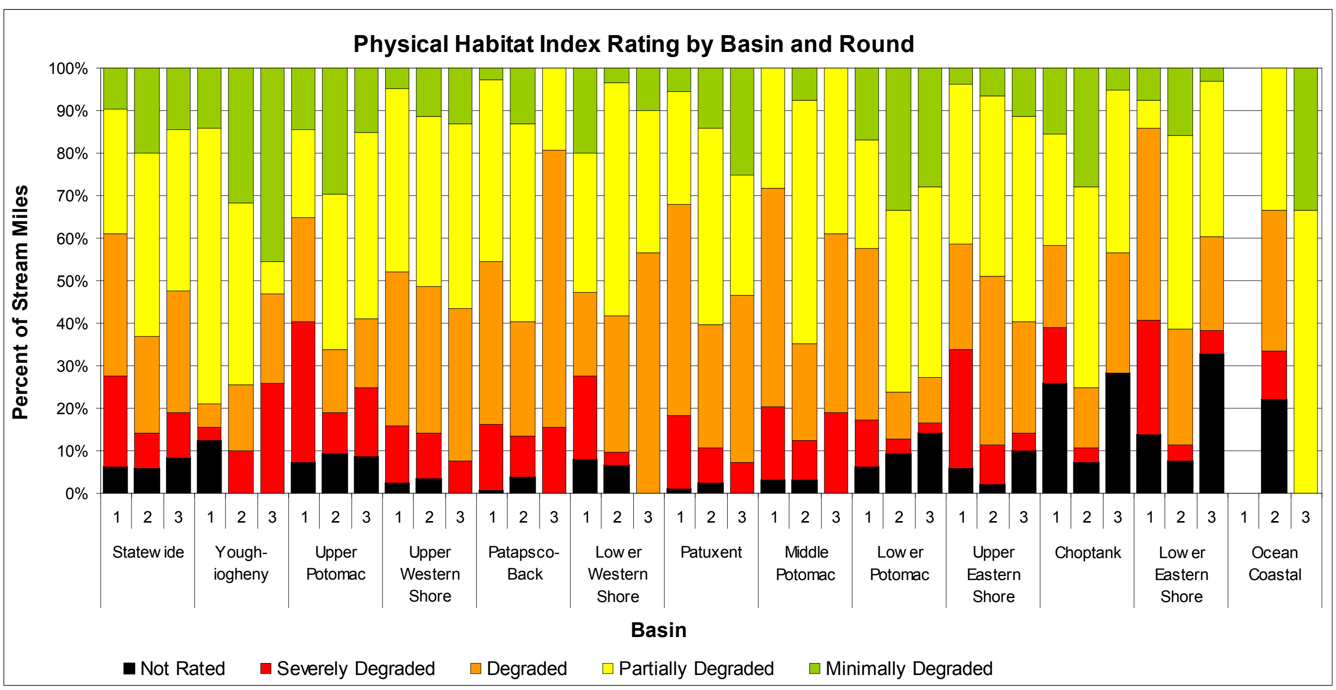
Pie charts for the MBSS Rounds can be viewed for each tributary basin clicking on the basin name.



Pie charts for the MBSS Rounds can be viewed for each tributary basin clicking on the basin name.



Pie charts for the MBSS Rounds can be viewed for each tributary basin clicking on the basin name.

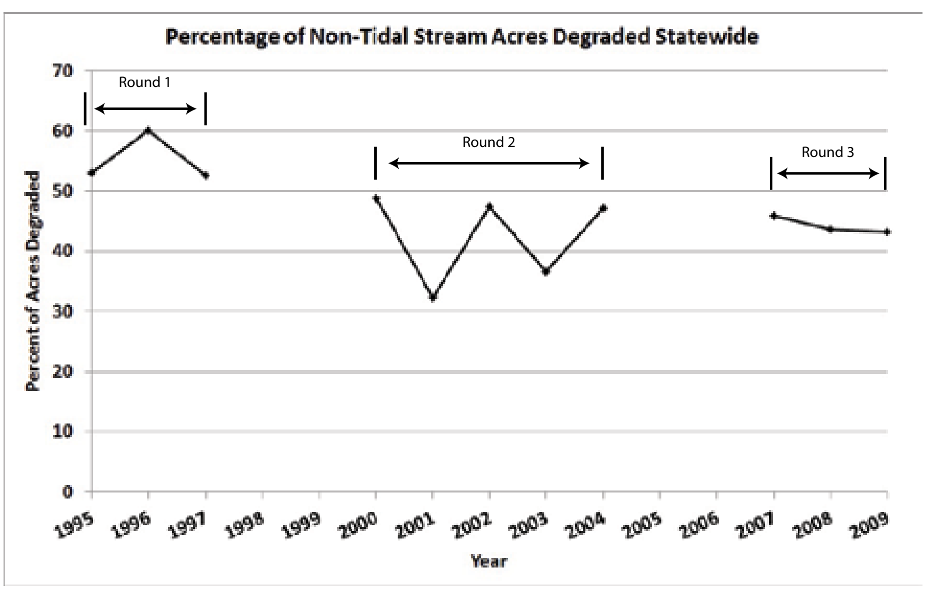


5.2 ANNUAL CHANGES IN STATEWIDE ASSESSMENTS OF STREAM CONDITION

Since 1995, the MBSS has sampled the condition of Maryland streams statewide in three separate rounds of monitoring. Specifically, the MBSS sampled non-tidal streams in 84 Primary Sampling Units (PSUs) that were equivalent to individual or combined 8-digit watersheds throughout Maryland during Rounds 2 and 3 (18 drainages basins were used as PSUs in Round 1). Each year of the survey used a stratified random (2-stage stratification by PSU and stream order for Round 1) sampling design. This design allows annual estimates of the statewide percentage of degraded streams for the individual years 1995, 1996, 1997 (Round 1); 2000, 2001, 2002 2003, 2004 (Round 2); and 2007, 2008, 2009 (Round 3). The total stream acres failing to meet or exceed the 3.0 threshold BIBI score and the percentage of total acres that these represent are given in the table below. For this assessment, failing acres are defined as non-tidal streams in a degraded condition.

Total non-tidal stream acres failing, percentage of acres failing, and the number of sites sampled each year by the MBSS. ND = no data

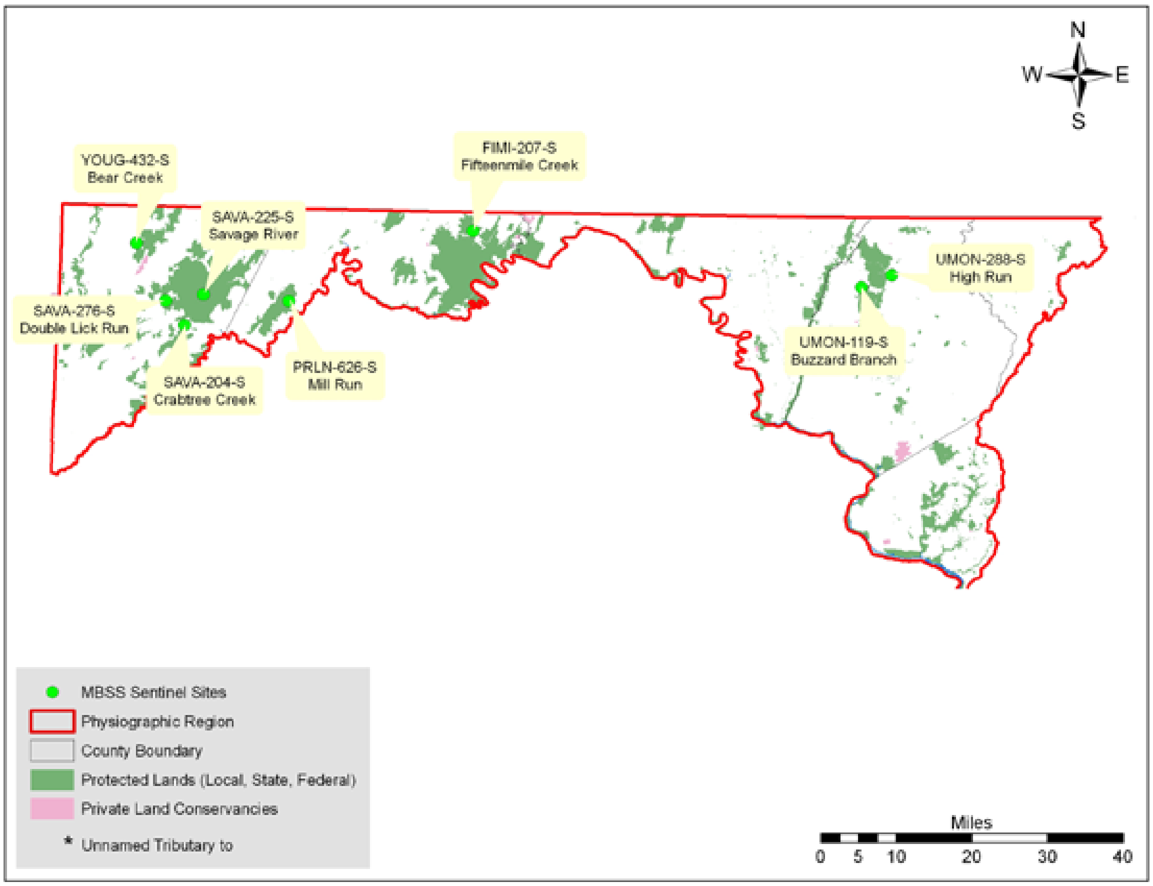
Year	Total Acres Failing	Percentage Failing	Number of Sites
1995	8,666	53.09	284
1996	9,807	60.07	343
1997	8,580	52.55	328
1998	ND	ND	ND
1999	ND	ND	ND
2000	7,976	48.85	210
2001	5,274	32.31	212
2002	7,737	47.4	216
2003	5,979	36.62	219
2004	7,692	47.11	207
2005	ND	ND	ND
2006	ND	ND	ND
2007	7,478	45.81	88
2008	7,121	43.62	90
2009	5,523	43.21	84



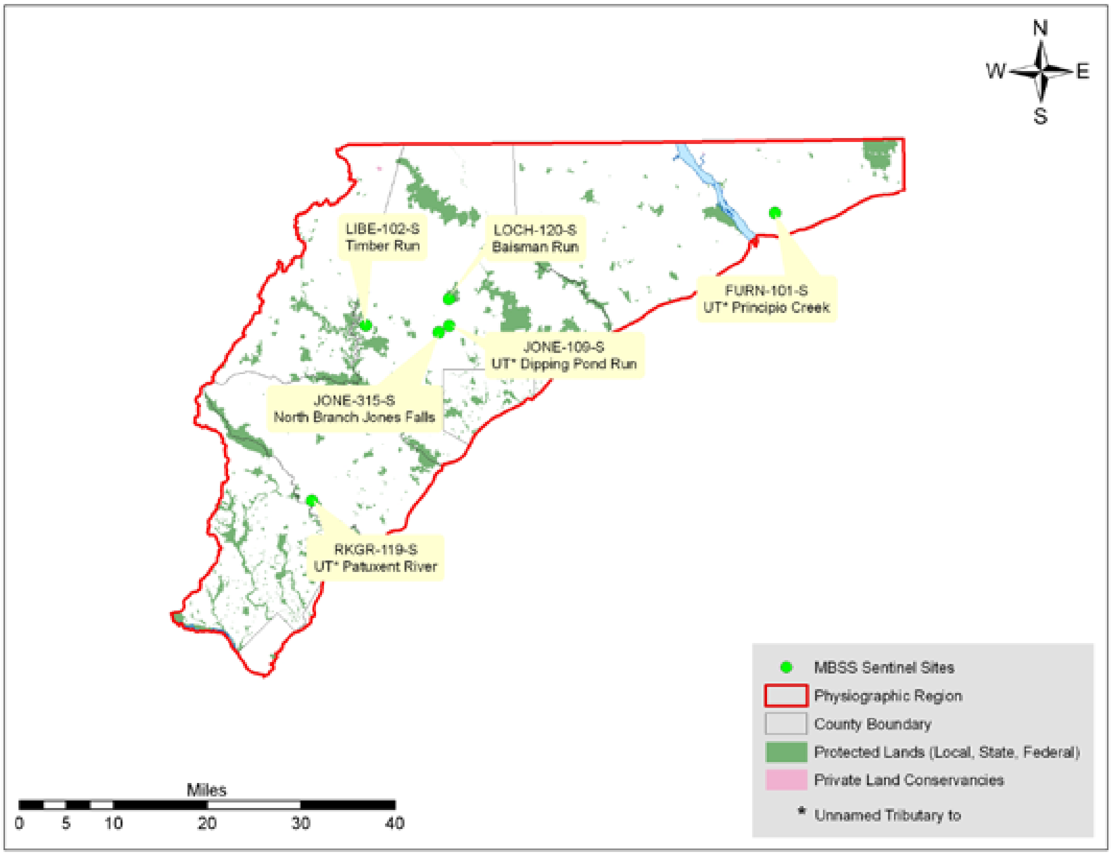
5.3 ANNUAL CHANGES AT SENTINEL SITES

Another way to look at annual changes in Maryland stream conditions associated mostly with short-term weather variations (e.g., droughts and floods) is to measure benthic macroinvertebrate and fish community indicator scores at the MBSS Sentinel Sites. The Sentinel Site Network (SSN) was established by Maryland DNR in 2000. The network initially included 25 minimally-disturbed streams that are sampled every year using MBSS protocols. The current network includes 27 sites, with two additional candidate sites being evaluated in 2010 for potential inclusion in the network in 2011. If the SSN can be continued (and expanded) for several decades, the data should also be useful for tracking the long-term effects of climate change on non-tidal streams.

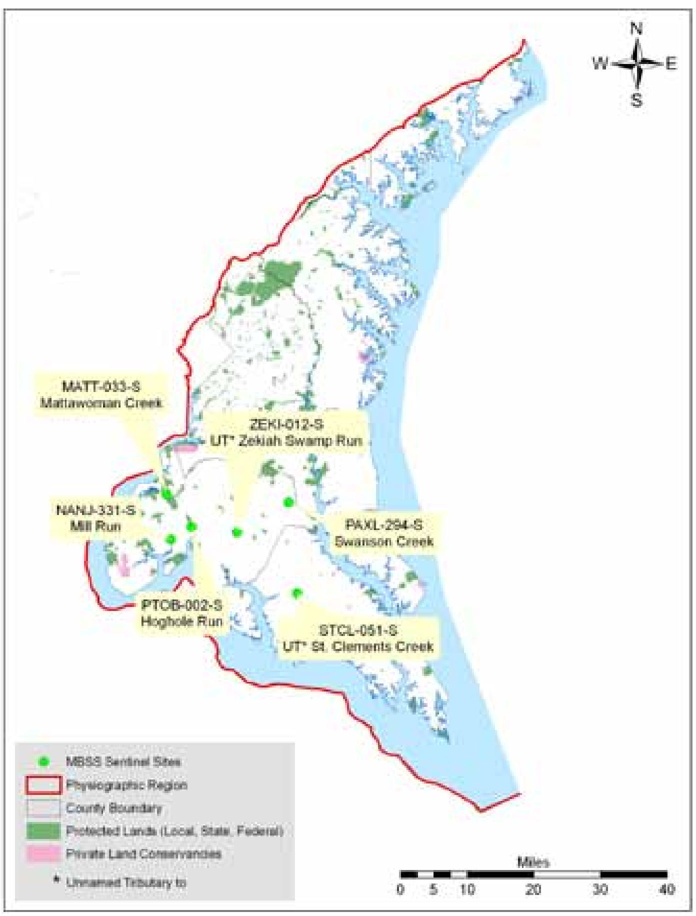
Maps of the fixed sentinel sites are shown below by region - Highlands, Piedmont, Western Coastal Plain, and Eastern Coastal Plain.



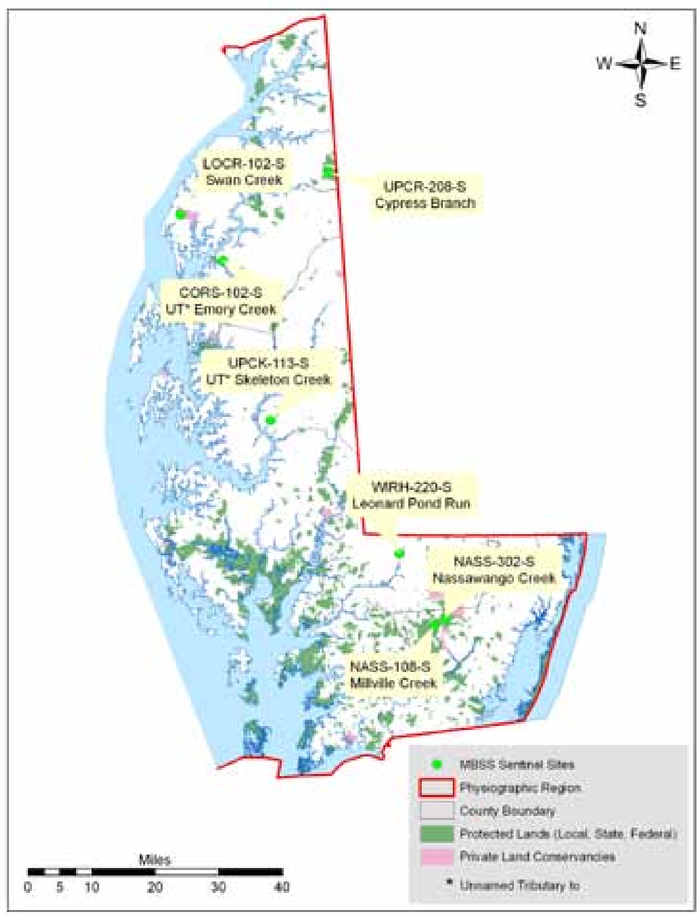
Highlands Area Sentinel Sites



Piedmont Area Sentinel Sites



Western Coastal Plain Sentinel Sites



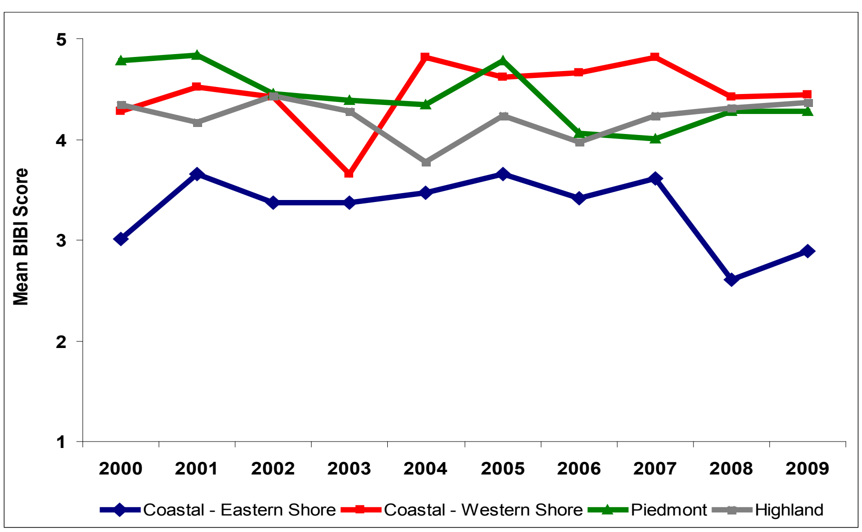
Eastern Coastal Plain Sentinel Sites

Site UPCK-101-R-2007 in the Upper Choptank watershed, during the 2007 spring sampling.

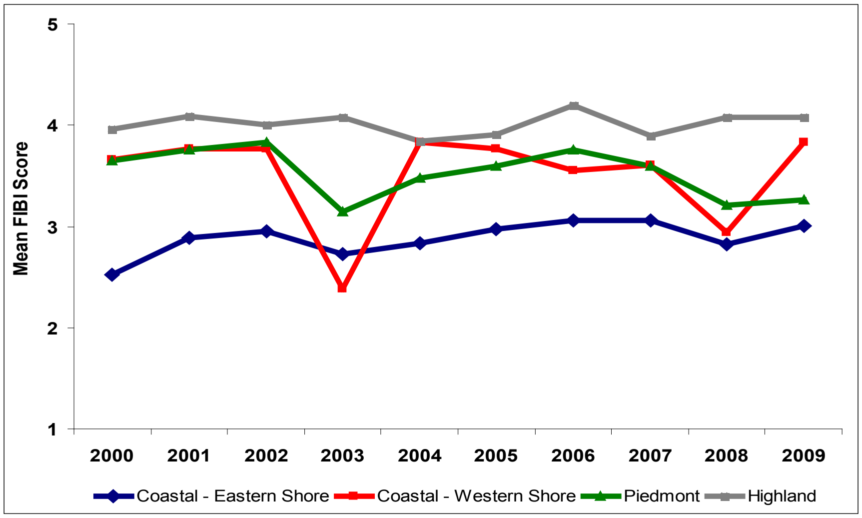
The same site during the 2007 summer sampling season which was a drought year.

Between 2000 and 2009, drought conditions occurred in Maryland during 2001, 2002, and 2007. As a result, water levels in many streams were abnormally low. Conversely, 2003 was wetter than normal and many streams experienced higher water levels and elevated flows. Precipitation amounts and stream flows were near normal in the other six years. For more details, view the 2010 Sentinel Site Report.

Biological indicator scores (indices of biotic integrity, or IBI) decreased in 2003 at Sentinel Sites in the Coastal Plain – western shore and Piedmont regions, presumably in response to drought conditions in 2001 and 2002. However, these scores were significantly lower in only one of the four geographic regions: the Coastal Plain – western shore region. By 2004, benthic macroinvertebrate and fish IBI scores returned to near normal numbers. In 2008, one year after the drought of 2007, fish IBI scores dipped significantly in the Coastal Plain – western shore region and non-significantly in the Eastern Piedmont. Benthic macroinvertebrate IBI scores also responded negatively (but non-significantly) in 2008 to the 2007 drought, but only in the Coastal Plain – eastern shore region.



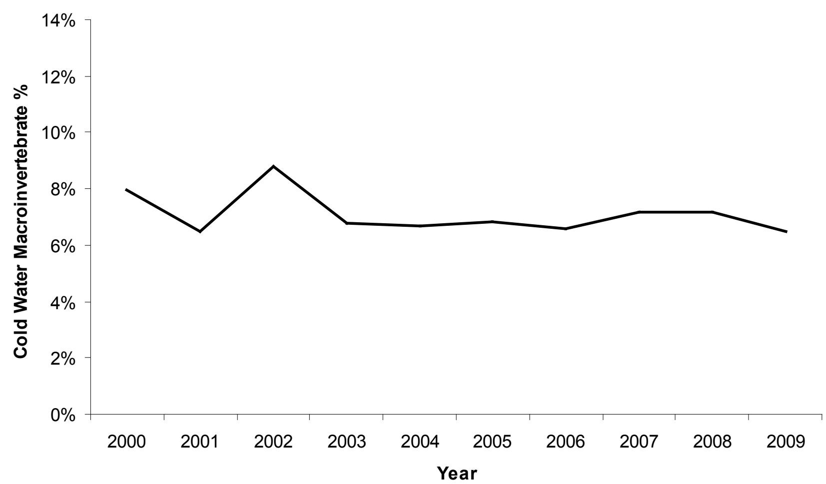
Mean Annual BIBI Score for the Sentinel Sites by Geographic Regions



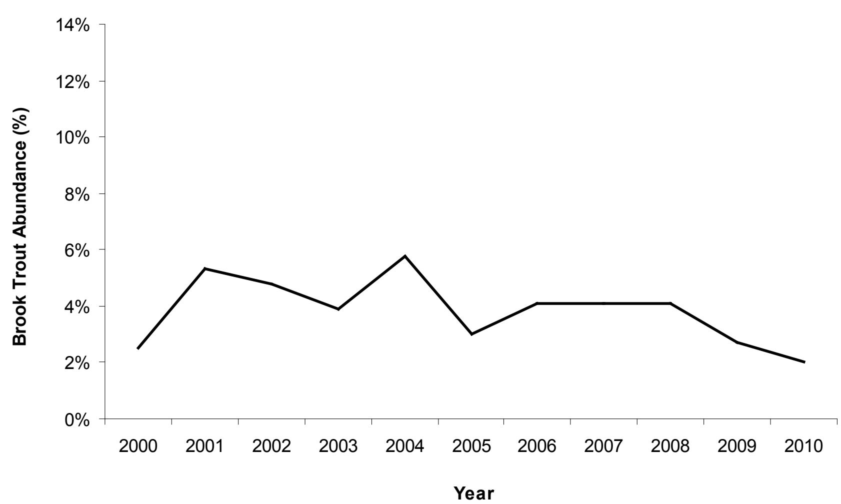
Mean Annual FIBI Score for the Sentinel Sites by Geographic Regions

To further evaluate short-term changes in coldwater-preference biota and also develop baseline conditions for tracking longer-term climate change effects, we compiled a list of 16 benthic macroinvertebrates plus one fish species, brook trout. Any observed decreases in coldwater taxa richness or abundances over time at the Sentinel Sites, accompanied by increases in stream water temperatures, could yield evidence of climate change effects.

Percent Coldwater-preference Benthic Macroinvertebrate Taxa Richness at 27 MBSS Sentinel Sites Sampled Between 2000 and 2009



Percent Brook Trout Abundance at 27 MBSS Sentinel Sites Sampled Between 2000 and 2009



The percentages of coldwater-preference benthic macroinvertebrate taxa richness and percent brook trout (a coldwater obligate) at the Sentinel Sites were negatively associated with year. However, these apparent decreases were not statistically significant. Most likely these decreases in coldwater-obligate and coldwater-preference aquatic organisms are not associated with increases in stream temperatures. Water temperatures collected by in-situ data loggers at all Sentinel Sites did not vary significantly between 2000 and 2009, at any spatial scale (site, region, or statewide).

Working through the Maryland Water Monitoring Council, DNR will strive to extend the current 10-year baseline period for the SSN and implement a maintenance strategy that will continue the network from many decades. DNR is also seeking funding and partners to develop a long-term network, using the SSN as a core component, that can be used to track changes in non-tidal streams. Information coming from such a collaborative monitoring network should help us document climate change-associated effects on non-tidal streams, and also develop adaptive strategies to protect ecosystem integrity.

6. What is Degrading Maryland Streams?

The ecological condition of streams includes their physical, chemical, and biological integrity. Biological integrity is the best indicator of the overall condition of streams, while physical and chemical integrity provide evidence of specific stressors. Water quality criteria under the Clean Water Act require attainment of all three elements of integrity. Each of the sections below provides answers to specific questions about the factors affecting ecological integrity from the results of Round 3 (2007-2009) of the Maryland Biological Stream Survey (MBSS).

- 6.1 What stressors are primarily responsible for degrading Maryland streams?
- 6.2 Has the number of acidic and acid-sensitive streams in Maryland increased or decreased since 1995 and what are the sources of acidity?
- 6.3 What impacts do nutrients and sediment have on Maryland streams?
- 6.4 Do Maryland streams show any warming trends?
- 6.5 How many Maryland streams have been channelized?
- 6.6 How many Maryland streams have adequate riparian buffers?
- 6.7 How many miles of Maryland streams have at least one non-native fish species?
- 6.8 What non-native plants occur most commonly along Maryland Streams?
- 6.1 What stressors are primarily responsible for degrading Maryland streams?

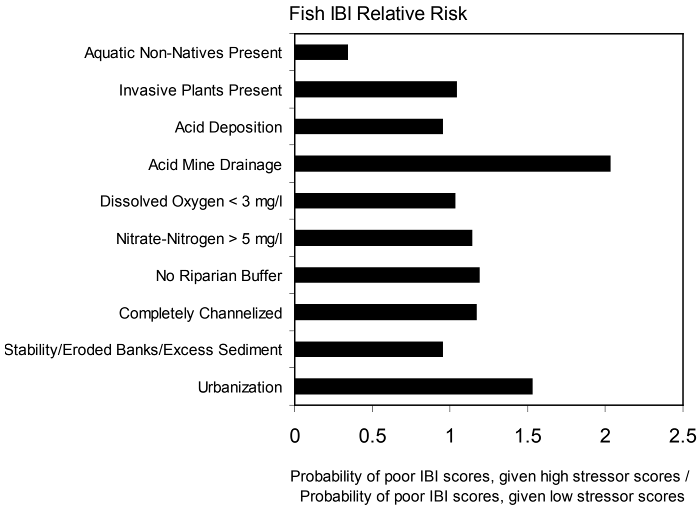
6.1 WHAT STRESSORS ARE PRIMARILY RESPONSIBLE FOR DEGRADING MARYLAND STREAMS?

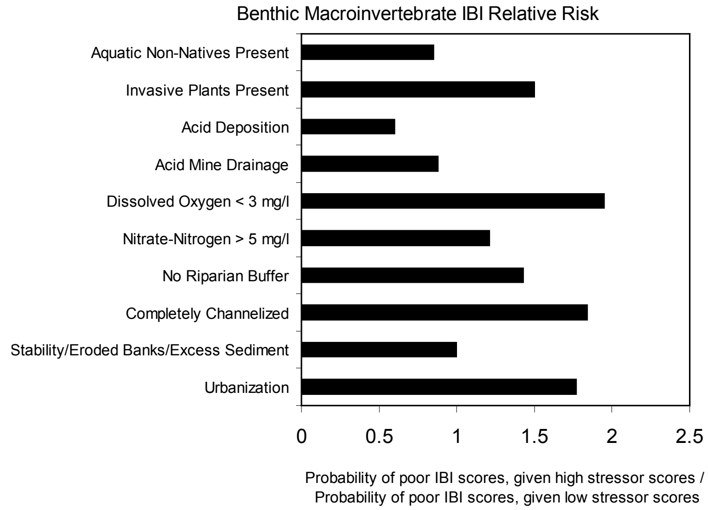
The ten stressors primarily responsible for degrading Maryland streams are urban land use greater than 5%, no riparian buffer, channelization, nitrate-nitrogen greater than 5 mg/l, dissolved oxygen less than 3 mg/l, acid deposition, acid mine drainage, poor bank stability (eroded banks), invasive plants, and invasive aquatic species. While the presence of one stressor may be insufficient to cause a significant decline in stream condition, many streams in Maryland have multiple stressors and the cumulative effect of these stressors results in a degraded biological community and a dysfunctional ecosystem.

The degradation of streams in Maryland results from both the importance (or severity) and the prevalence (or extent) of each stressor. The severity of a stressor is portrayed by relative risk scores that describe how much biota are degraded when affected by that stressor. The figures below show the relative risk scores for 10 stressors affecting fish and macroinvertebrates benthos. Acid mine drainage and low dissolved oxygen have the most severe effects on fish and macroinvertebrates benthos, respectively.

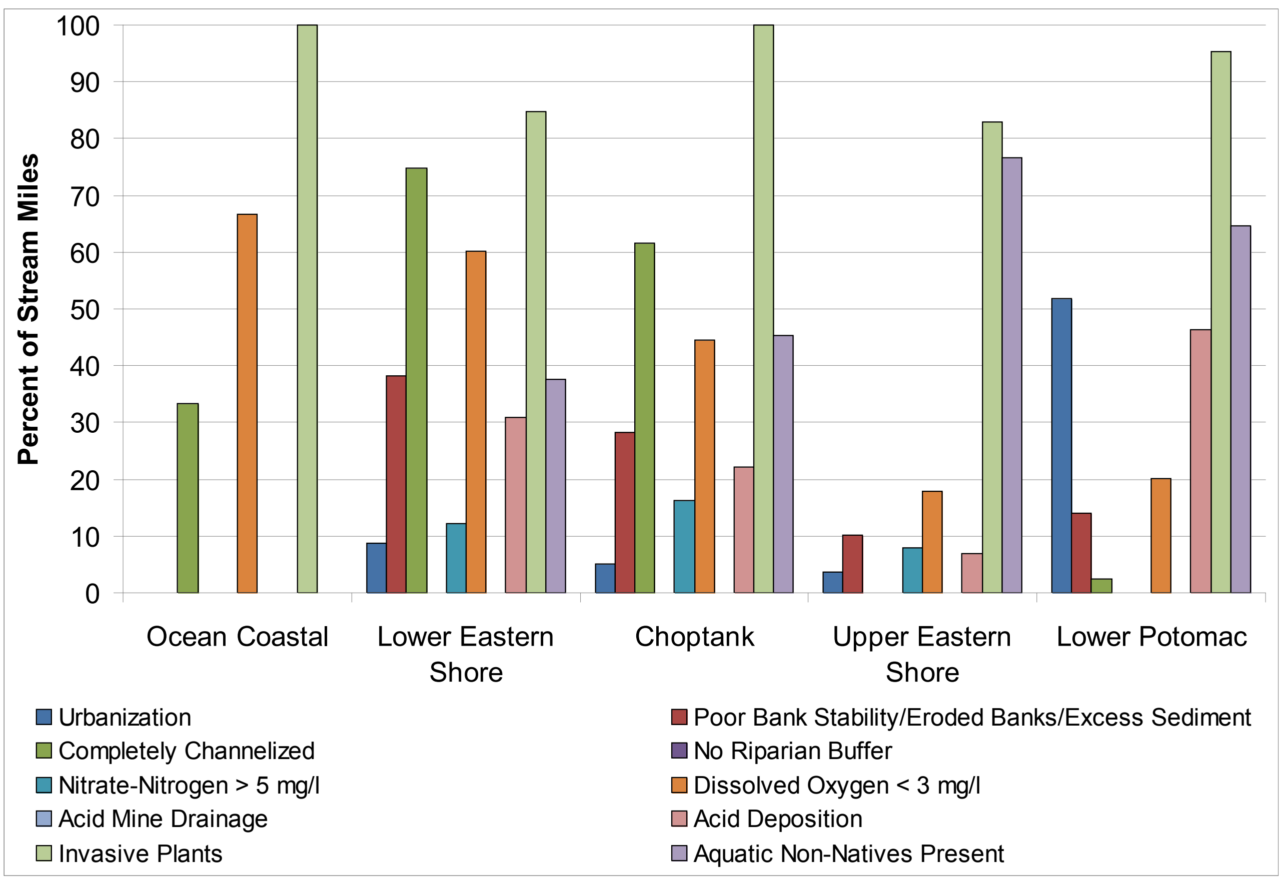
Ten Common Stressors

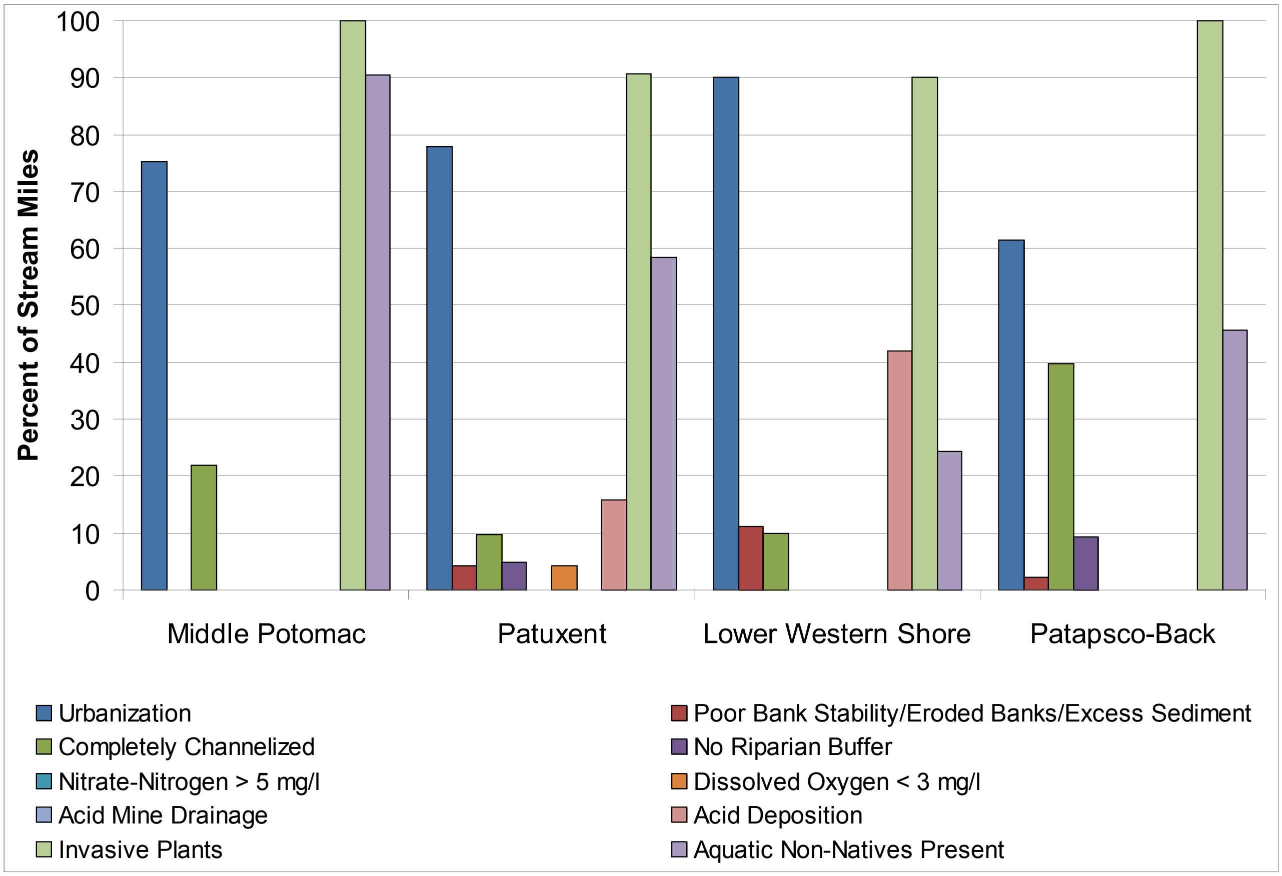
- Urban Land Use Greater Than 5%
- No Riparian Buffer
- Channelization
- NO_3 Greater Than 5 mg/l
- DO less than 3 mg/l
- Acid Deposition
- Acid Mine Drainage
- Poor Bank Stability/Eroded Banks/Excess Sediment
- Invasive Plants
- Invasive Fish, Mussels, and Crayfish

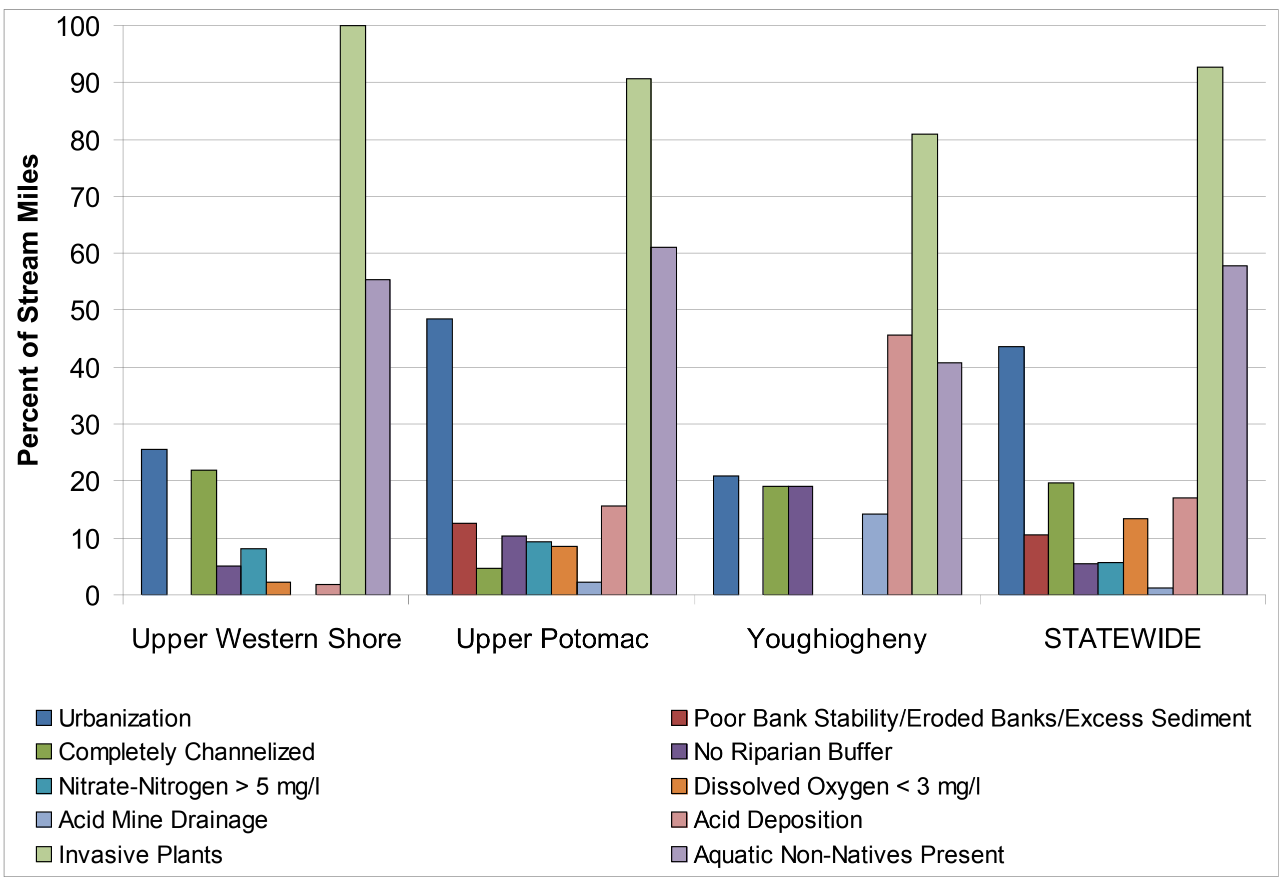




The extent of a stressor is portrayed by the percentage of stream miles affected by that stressor. The figures below show how many stream miles in each Maryland Tributary Basin and statewide are affected by each stressor.



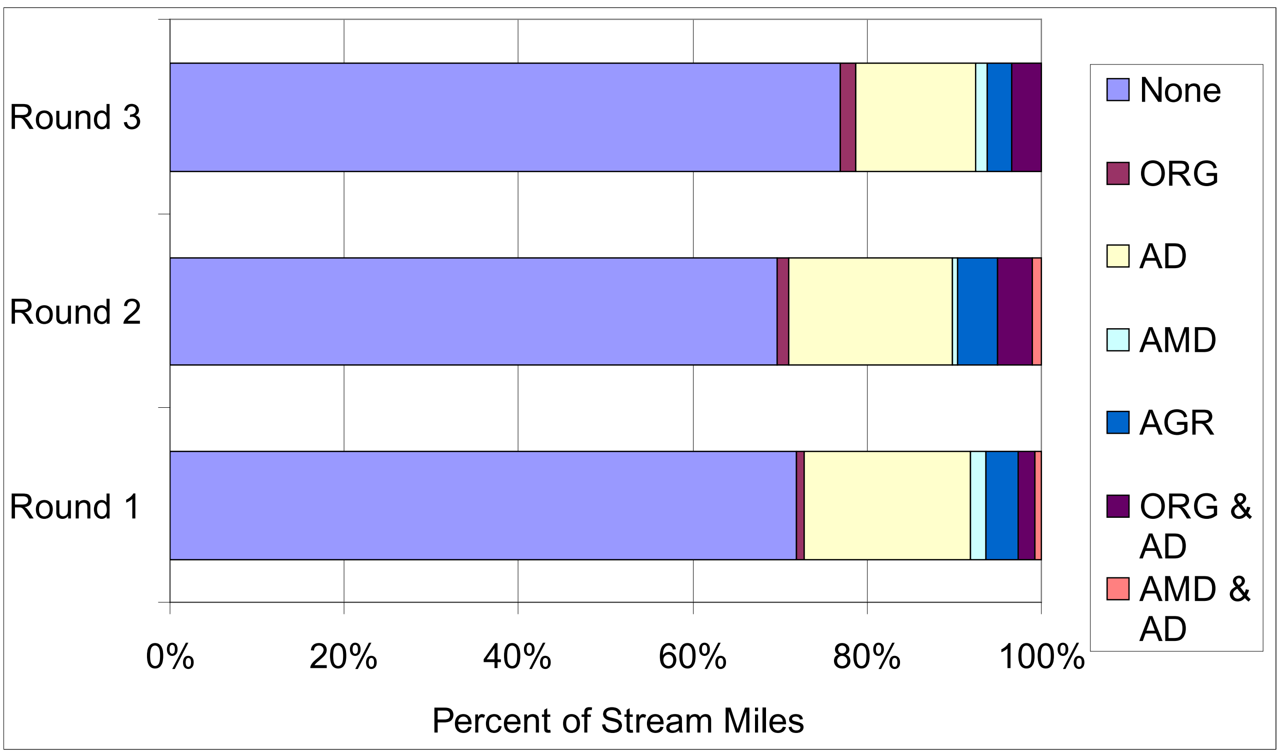

Percent of Stream Miles
100
90
80
70
60
50
40
30
20
10
0
Middle Potomac
Patuxent
Lower Western Shore
Patapsco-Back
Urbanization
Poor Bank Stability/Eroded Banks/Excess Sediment
Completely Channelized
No Riparian Buffer
Nitrate-Nitrogen > 5 mg/l
Dissolved Oxygen < 3 mg/l
Acid Mine Drainage
Acid Deposition
Invasive Plants
Aquatic Non-Natives Present


Percent of Stream Miles
100
90
80
70
60
50
40
30
20
10
0
Upper Western Shore
Upper Potomac
Youghiogheny
STATEWIDE
Urbanization
Poor Bank Stability/Eroded Banks/Excess Sediment
Completely Channelized
No Riparian Buffer
Nitrate-Nitrogen > 5 mg/l
Dissolved Oxygen < 3 mg/l
Acid Mine Drainage
Acid Deposition
Invasive Plants
Aquatic Non-Natives Present

MBSS data are also used by the Maryland Department of the Environment (MDE) to identify watersheds impaired by specific stressors through their Biological Stressor Identification (BSID) analysis. The BSID was developed by examining relationships among MBSS biological, water chemistry, and habitat data and is an example of how risk assessment can be used to identify the streams that have the most potential for targeted management strategies, such as protection or restoration.

6.2 HAS THE NUMBER OF ACIDIC AND ACID-SENSITIVE STREAMS IN MARYLAND INCREASED OR DECREASED SINCE 1995 AND WHAT ARE THE SOURCES OF ACIDITY?

Atmospheric deposition has consistently been the largest source of acid input to Maryland streams since 1995. However, fewer stream miles (13%) were acidified by atmospheric deposition in Round 3 sampling compared to Rounds 1 (19%) and 2 (19%). Agricultural lands are the second most common source of acid in Maryland streams and have contributed to the acidification of Maryland streams. Other sources of acidity, including organic pollutants, acid mine drainage, and combinations of sources, were each responsible for acidification of no more than 4% of Maryland stream miles in each of the rounds.



The percentage of stream miles affected by various sources of acidity as shown in the above chart. Data from MBSS Rounds 1, 2 and 3 are shown. ORG=organic pollutants, AD=atmospheric deposition, AMD=acid mine drainage, AGR=agricultural, ORG & AD=a combination of organic pollutants and atmospheric deposition, and AMD & AD=a combination of acid mine drainage and atmospheric deposition.

6.3 WHAT IMPACTS DO NUTRIENTS AND SEDIMENT HAVE ON MARYLAND STREAMS?

The nutrients phosphorous and nitrogen are some of the most significant pollutants affecting Maryland's waters, especially the Chesapeake Bay. These pollutants often enter waterways from non-point sources, meaning that they are flushed into streams and rivers as runoff during rain or snow melt events instead of being discharged directly from a pipe. Nitrogen and phosphorous are necessary for plant growth, but in large quantities they stimulate algal blooms that can cause problems for fish and other aquatic life and make treatment of drinking water difficult and expensive.

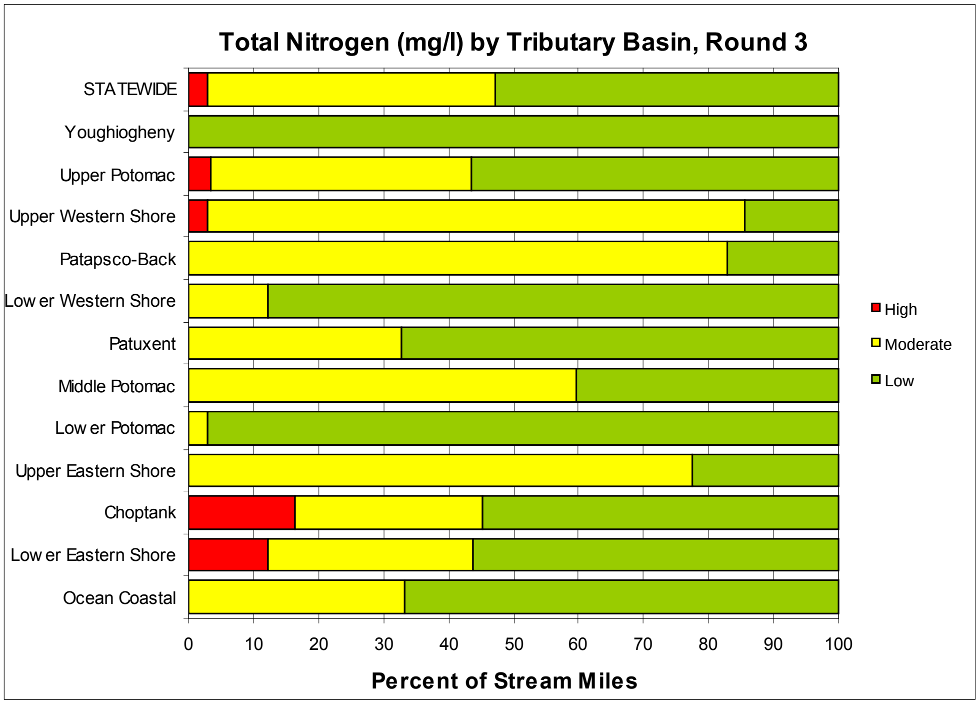
Nutrients come from a wide range of sources in both urban and rural environments. In Maryland, agriculture is the largest source of nutrients, but stormwater runoff from urban areas is the only source that continues to increase. Agriculture is a source of phosphorous and nitrogen entering waterways from both livestock and croplands. Best management practices, such as no-till agriculture, riparian buffer strips, and stormwater management, can be used to reduce the amount of nutrients entering water bodies.

Phosphorous tends to become bound to soil particles while nitrogen is more easily transported by water. High levels of phosphorous are often associated with sediment and erosion. In urban and suburban areas, stormwater, wastewater systems, and atmospheric deposition of nitrogen are the primary sources of nutrients. Septic systems, common in rural areas, may also contribute to elevated nutrient levels in water bodies.

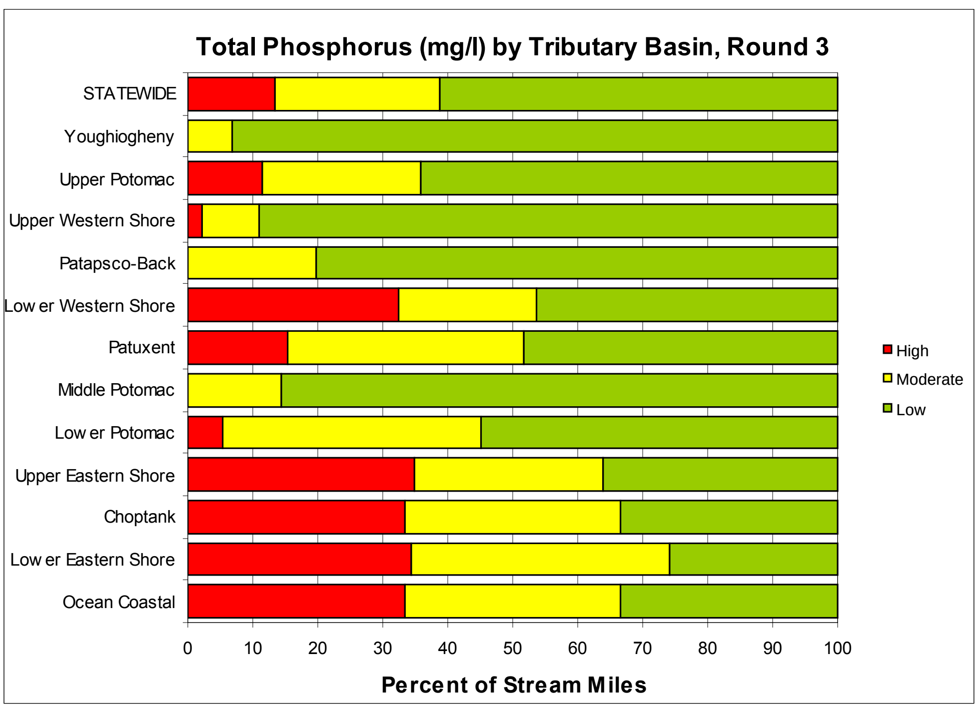
When nutrients enter a water body in high levels they may lead to algal blooms. Excess algae growth can block light for aquatic plants and decomposing algae removes oxygen from the water, resulting in dead zones. Excess nutrients can also cause a shift in the types of algae present from those that many organisms eat to those that are not desirable and may even be toxic.

MBSS collects water samples at each site that are analyzed for phosphorous and nitrogen during the summer sampling period. These data are reported as concentrations of nitrates, nitrites, total nitrogen, total phosphorous, and organic phosphorous. Samples are collected during low or base flow, at a single point in time. Therefore, they provide useful assessments of nutrient conditions over areas with a number of random sites, but yield limited information at the level of individual streams. The data are also limited for characterizing nutrient loads being transported to receiving waters. More frequent and expensive sampling, under a range of measured flow conditions, is necessary to quantify the nutrient load for a particular area. Large-scale analysis of nutrient transport is usually a modeling exercise based on established flow regimes and land use, such as the Sparrow and Chesapeake Bay models.

MBSS data are useful for characterizing conditions within a region because of the random distribution of sites and are being used by MDE to identify watersheds that are impaired by nutrients through their BSID analysis: http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/BSID_Studies.asp.



Total nitrogen (TN) concentrations less than 1.5 mg/l were rated Low, between 1.5 mg/l and 7.0 mg/l were rated Moderate, and those concentrations greater than 7.0 mg/l were rated high.



Total phosphorus (TP) concentrations less than 0.025 mg/l were rated Low, between 0.025 mg/l and 0.07 mg/l were rated Moderate, and those concentrations greater than 0.07 mg/l were rated High.

The graphs above show the percentage of streams in each Maryland tributary basin and statewide, that have low, medium, and high levels of TN and TP.

Many of Maryland's streams have low to moderate levels of both phosphorous and nitrogen. High values for both tend to be in tributary basins with high urban development or large amounts of agriculture.

Even nutrient levels that do not degrade individual streams can contribute to excessive nutrients reaching the Chesapeake Bay. Combined with excessive sediment, the algae fed by these nutrients lead to turbidity levels that block light for important sea grasses. Without the sea grass, many animals lack the necessary habitat to live, feed and reproduce. Additionally, the nutrients lead to algal blooms that deplete oxygen as they respire at night and decompose, contributing to the growing "dead zones" of the Bay. Because there are many small nutrient and sediments sources in urban, suburban and rural areas throughout the state, all Maryland citizens can take actions to reduce their impact on the Bay.

6.4 DO MARYLAND STREAMS SHOW ANY WARMING TRENDS?

Based on analyses of data from the MBSS Sentinel Site Network collected between 2000 and 2009, stream temperature do not seem to be increasing. water temperatures measured by in-situ, continually recording data loggers at all sentinel sites did not vary significantly over time at any spatial scale (site, region, or statewide). More information on this can be found in the 2010 Sentinel Site Network report.

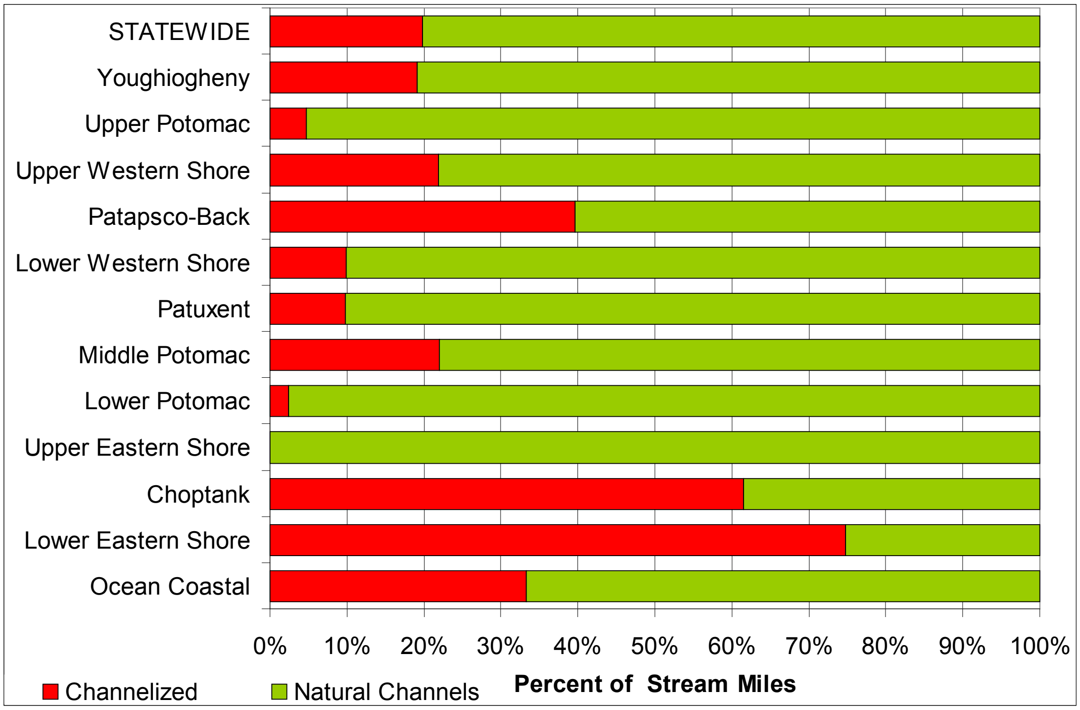
6.5 HOW MANY MARYLAND STREAMS HAVE BEEN CHANNELIZED?

"Natural" streams usually have a sinuous pattern that slowly dissipates the energy of the water flowing through the channel. Under natural conditions, streams undergo a process of erosion and deposition that is balanced, resulting in the migration of bends and curves in the channel within the floodplain. However, as humans changed the landscape, we also manipulate streams and rivers to accommodate our needs.

In urban and agricultural areas, streams are often channelized to move water more conveniently away from an area. "Channelization" refers to straightening and modifying the stream channel. In urban areas, streams may be converted to concrete-lined channel, or they may be straightened and the banks stabilized using gabions (rock filled baskets) or riprap (large boulders). Many small urban streams have been "buried" becoming part of the stormwater system and are piped underground. Often, agricultural streams were channelized in order to expedite the land draining for more productive use. Channelizing streams negatively affects stream biota by limiting available habitat and disrupting flow regimes. The act of channelizing a stream also usually disrupts the riparian buffer which normally provides shade, erosion protection, and other benefits to the stream (link to riparian buffer page).

In Maryland, 20% of non-tidal stream miles are channelized. These primarily occur in areas with active agriculture or large amounts of urban development. For example, the Lower Eastern Shore, an area with considerable agriculture, has almost 75% of its stream miles channelized. Channelization is a practice no longer widely used because it degrades overall stream condition. Channelized streams often lack the habitat and food resources necessary to support diverse aquatic biota. Hydrologists have also found that channelization can lead to larger problems, such as erosion and sedimentation, throughout the watershed. Scientists are beginning to recognize the benefits of allowing streams to establish a more natural pattern, and many local governments are making the effort to restore some of the most degraded streams in Maryland.

The percentage of channelized and natural stream channels statewide and in each tributary basin are shown in the chart below.



6.6 HOW MANY MARYLAND STREAMS HAVE ADEQUATE RIPARIAN BUFFERS?

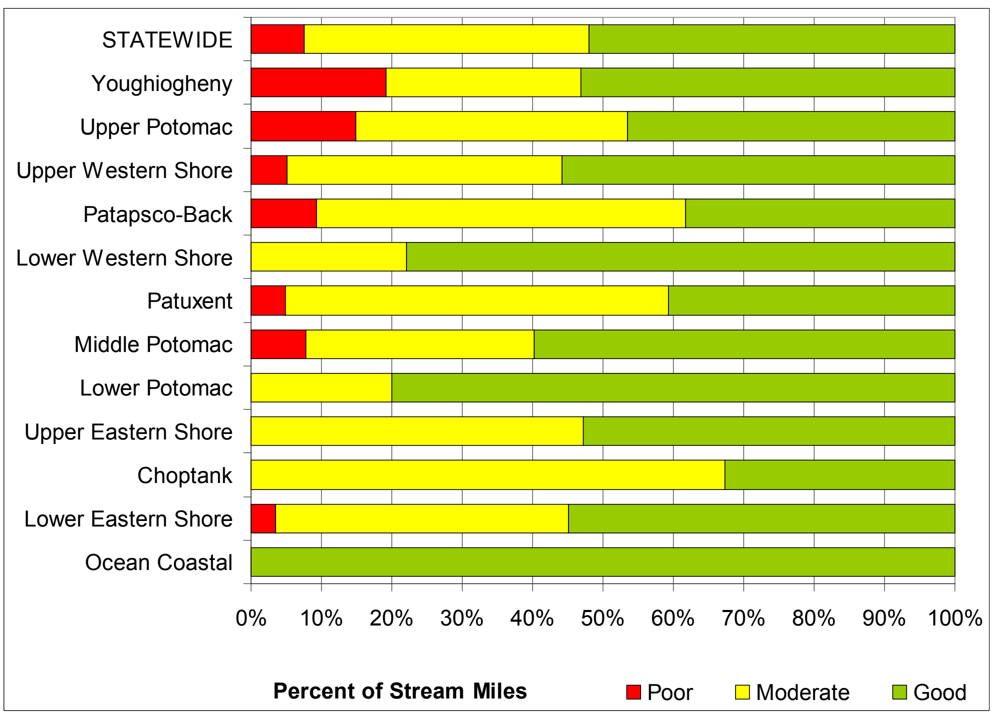
The riparian zone is the area at the margins of a stream or river, an area that has a significant influence on water quality. Vegetated riparian zones, particularly those that are forested, provide a buffer that can mitigate many anthropogenic disturbances within the watershed. Although wide, forested riparian buffers are necessary to protect ecological integrity in streams, buffers alone may not be sufficient. Many streams in Maryland with intact riparian buffers can still have degraded physical habitat and impaired aquatic biota because of extensive urban/suburban development or intensive agriculture throughout the rest of the watershed. A vegetated "riparian buffer" provides a number of functions including terrestrial habitat, erosion prevention, removal of pollutants from stormwater, shading and temperature control, woody debris for in-stream habitat and channel stability, and input of leaves used by some stream organisms for food. Forested buffers best support stream ecosystems. Buffers with only shrubs and grasses can help reduce nutrient and sediment input during storm flows.

While some erosion is natural, human activities have altered the flow of water in ways that often accelerate erosion around streams and rivers. Vegetated riparian buffers prevent erosion by slowing the runoff, minimizing exposed soil, and by providing a root structure that helps hold soil and stream banks in place. Erosion leads to instability in streambed materials and results in sedimentation transported further down the watershed. Sedimentation can increase the costs of water treatment and can degrade habitat for fish and other aquatic organisms. As runoff moves through a riparian buffer, it slows down and has time to percolate into the soil. As it percolates, nutrients and other pollutants may be bound to soil particles, taken up by plants, or processed by microbes. In this way, the riparian buffer acts to filter some of the pollutants before the stormwater recharges the groundwater or enters the stream.

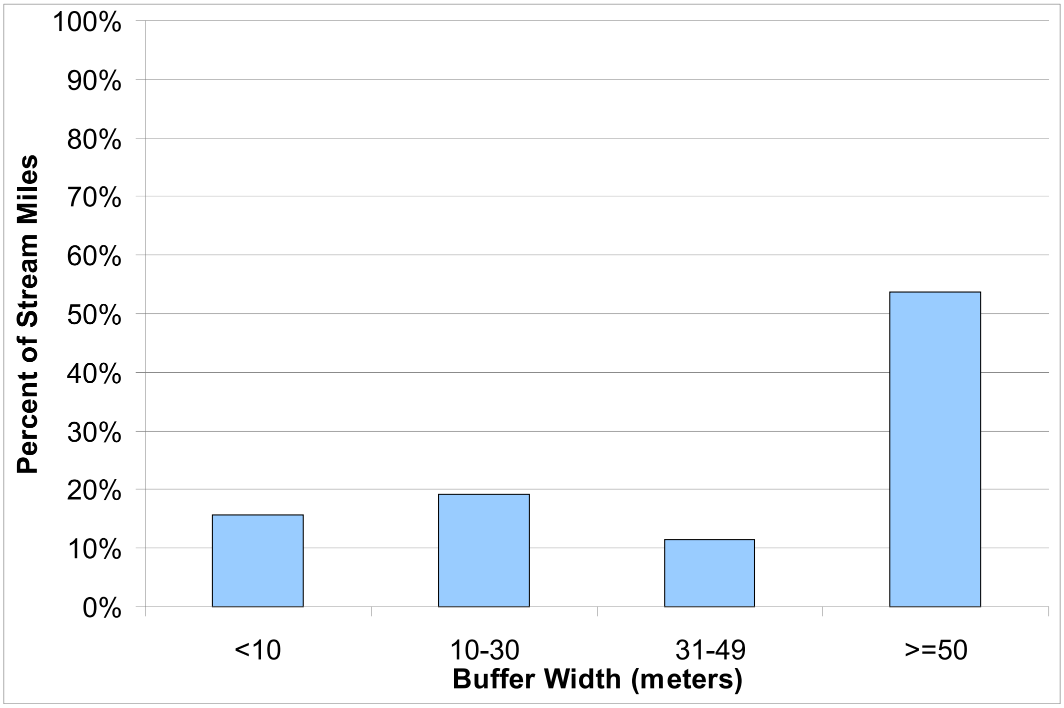
A forested riparian buffer provides shade to the stream as well as woody debris and leaf inputs. Shade keeps the water temperature low and relatively stable. Many fish, such as brook trout, and most aquatic biota prefer cool water. The amount of dissolved oxygen in a stream is related to water temperature, and cooler water can hold more dissolved oxygen. Fallen trees that land in the stream, and even tree limbs, help stabilize the banks and provide habitat. Leaves are used for food by many aquatic organisms.

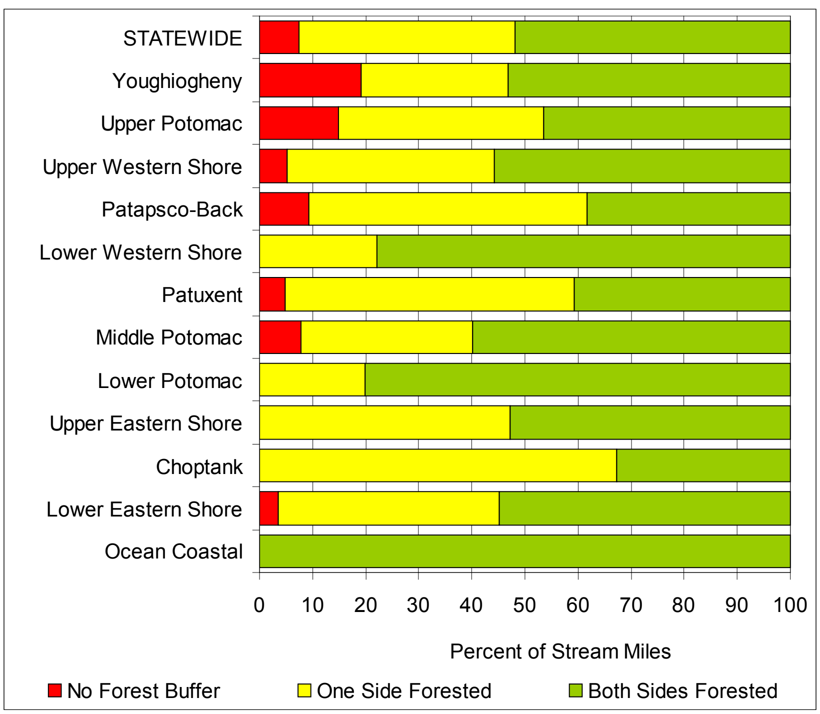
There is some debate as to the optimal width of a vegetated riparian buffer. The most accepted minimum width is 50 meters, though smaller buffers provide some benefits. Narrow buffers can provide erosion control and bank stability, but wider buffers are necessary for nutrient removal, pollutant removal, and to provide habitat for terrestrial animals.

Round 3 of the MBSS measured the width, cover type, and dominant vegetation of riparian buffers throughout Maryland. The overwhelming majority of Maryland streams had some sort of riparian buffer on both sides. Approximately 50% of Maryland streams have good riparian buffers (see charts below). The Youghiogheny and Upper Potomac tributary basins have the largest proportion of streams with no riparian buffer . Fewer than 20% of streams throughout the state have buffers less than 10 meters wide and more than half of the riparian buffers are at least 50 meters wide, based on the side of the stream with the narrowest buffer. Most of the buffers were forested on at least one side of the stream, while the other buffers were shrubs and grasses, lawns or not vegetated. While the results reflect effective protection and restoration efforts, there is room for improvement.



A Poor riparian buffer is defined as either side or both sides of the stream having no vegetated riparian buffer. A Good riparian buffer is defined as having both sides of the stream have 50 meters or greater of vegetated riparian buffer. Moderate riparian buffer is defined as everything else between Poor and Good.



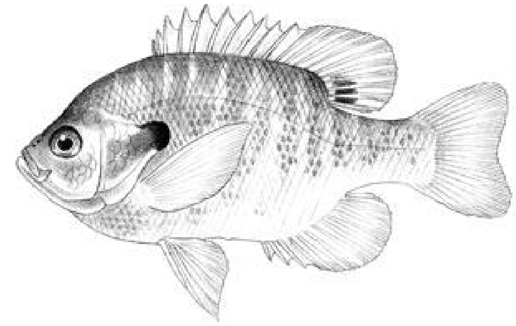


6.7 HOW MANY MILES OF MARYLAND STREAMS HAVE AT LEAST ONE NON-NATIVE FISH SPECIES?

Non-native species are plants, animals, or other organisms that have been transported from one geographic region to an area where they did not live before. Human actions are the primary means of non-native species introductions. These introductions may be intentional, or unintentional, and the full effect of their introduction on an ecosystem is often unpredictable. The introduction of these animals can cause harm to the ecosystem because these animals can use up limited food or space resources or they can prey on native species. They are often referred to as invasive species because they "invade" the habitat of other resident species. Sometimes, they are called introduced, exotic, nuisance, or alien species. Not all non-native species become invasive, but many do.

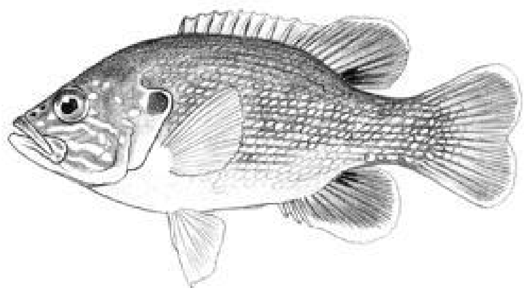
What Non-Native Fish Species Live in Maryland's Streams?

The Maryland Biological Stream Survey (MBSS) conducts monitoring of the state's streams to provide the best possible information for ensuring the protection and restoration of Maryland's stream ecological resources. At each stream sampled, biologists identify numbers and kinds of fish present in the 75-meter stream segment. These include both native and non-native species. During Round 3 of sampling (2007–2009), the MBSS sampled for fish at 225 randomly-selected stream sites distributed throughout the state of Maryland, including the three primary ecoregions –Highlands, Eastern Piedmont, and Coastal Plain.



Bluegill

Round 3 results indicate that the bluegill is the most widely-distributed non-native fish species in Maryland, occurring in approximately 37% of all stream miles in the state (See table below). These fish are extremely common in the Coastal Plain, occupying 48% of the stream miles in this ecoregion, the highest percentage of any of the non-native species. Bluegill are also the most commonly found non-native species in the Eastern Piedmont region, occupying 39% of the stream miles.



Green Sunfish

In the Highlands ecoregion of Maryland, the Green Sunfish is the most widely-distributed non-native fish species, occupying 31% of the stream miles in this ecoregion. The Green Sunfish is the second most widely-distributed non-native fish species in the state. Statewide, Green Sunfish are present in approximately 24% of the stream miles in Maryland (See table below).

Non-native fish obtained in MBSS Round 3 sampling (2007 – 2009) throughout the state of Maryland					
Non-Native Fish Species	Number of Maryland Stream Miles where Non-Native Fish is Found				Percentage of Maryland Stream Miles Where Non-Native Fish is Found
	Highlands	Eastern Piedmont	Coastal Plain	Statewide	
BLUEGILL	697.63	826.46	1849.02	3373.11	36.65
GREEN SUNFISH	998	378.91	820.54	2197.44	23.88
LARGEMOUTH BASS	304.79	373.45	832.3	1510.55	16.41
SMALLMOUTH BASS	328.78	368.03	143.5	840.31	9.13
BROWN TROUT	180.83	551.17	0	732	7.95
ROCK BASS	385.57	192.31	0	577.88	6.28
RAINBOW TROUT	150.65	97.67	25.4	273.72	2.97
RAINBOW DARTER	169.71	0	0	169.71	1.84
BLACK CRAPPIE	0	0	113.22	113.22	1.23
CHAIN PICKEREL	29.5	0	0	29.5	0.32
BANDED DARTER	0	29.38	0	29.38	0.32
PUMPKINSEED	26.94	0	0	26.94	0.29
GOLDFISH	0	0	25.05	25.05	0.27
CHANNEL CATFISH	0	14.69	9.81	24.5	0.27
FATHEAD MINNOW	0	0	23.4	23.4	0.25
ORIENTAL WEATHERFISH	0	22.42	0	22.42	0.24
COMMON CARP	0	14.69	0	14.69	0.16
WALLEYE	0	14.69	0	14.69	0.16

How many miles of Maryland streams have at least one non-native fish species?

Statewide, the MBSS found at least one non-native fish in 56% of the stream miles sampled during Round 3 (that is, at least one non-native fish species was present in 5,196 stream miles of Maryland). The percentage of stream miles with at least one non-native fish was similar across the ecoregions of Maryland, as seen in table below.

Number and percentage of stream miles with at least one non-native fish species obtained in MBSS Round 3 sampling (2007-2009) throughout the state of Maryland			
Ecoregion	Total Number of Miles	Number of Stream Miles with Non-Native Fish Species	Percentage of Stream Miles with Non-Native Fish Species
Highlands	3256.8	1987.7	61.03
Eastern Piedmonts	2105.5	1115.9	53
Coastal Plain	3841.2	2092.7	54.48
Statewide	9203.4	5196.3	56.46

6.8 CASE STUDY

INVASIVE CRAYFISHES IN MARYLAND

During Round 3, the Maryland Biological Stream Survey collected 14 crayfish species in the state, including five non-natives. These non-natives are the Rusty Crayfish (*Orconectes rusticus*), Virile Crayfish (*O. virilis*), Red Swamp Crawfish (*Procambarus clarkii*), Southern White River Crawfish (*P. zonangulus*), and the Little Brown Mudbug (*Cambarus thomai*). Some of these non-native species are invasive and have the capacity to cause harm by altering species composition, food webs, and habitat in streams. These invasive species represent the largest threat to Maryland's nine native crayfishes.

Virile Crayfish (*O. virilis*) was first reported from the Patapsco River in the early 1960s and is now widespread in Central and Western Maryland, as a result of its use as bait by anglers.

Rusty Crayfish (*O.rusticus*) is now known to occur in the Lower Susquehanna, Middle Potomac, and Upper Potomac basins. This species can attain high densities in streams. At one site, MBSS field crews collected more than 900 individual rusty crayfish in only 250 feet of stream.

How Did They Get Here?

Our actions intentionally and inadvertently introduce and spread non-native crayfish to waters where they don't belong. The five non-native crayfish found their way to Maryland through the live trade as bait, as pets, in classrooms, and in commercial aquaculture. Once introduced, the use and release of live crayfish as bait by anglers is responsible for the spread of several species, including the Virile Crayfish, the most widespread in Maryland.

Invasive crayfishes have become a large problem in many Maryland watersheds as a result of their use as bait. Live crayfishes are either purchased or caught and transported in bait buckets by many Maryland anglers. The release of live, unused crayfishes by anglers has resulted in introductions throughout much of Maryland. Possession or use of live crayfish as bait is now banned by MD/DNR in waters where rusty crayfish are found.

Invasive crayfishes have become a large problem in many Maryland watersheds as a result of their use as bait. Live crayfishes are either purchased or caught and transported in bait buckets by many Maryland anglers. The release of live, unused crayfishes by anglers has resulted in introductions throughout much of Maryland. Possession or use of live crayfish as bait is now banned by MD/DNR in waters where rusty crayfish are found.

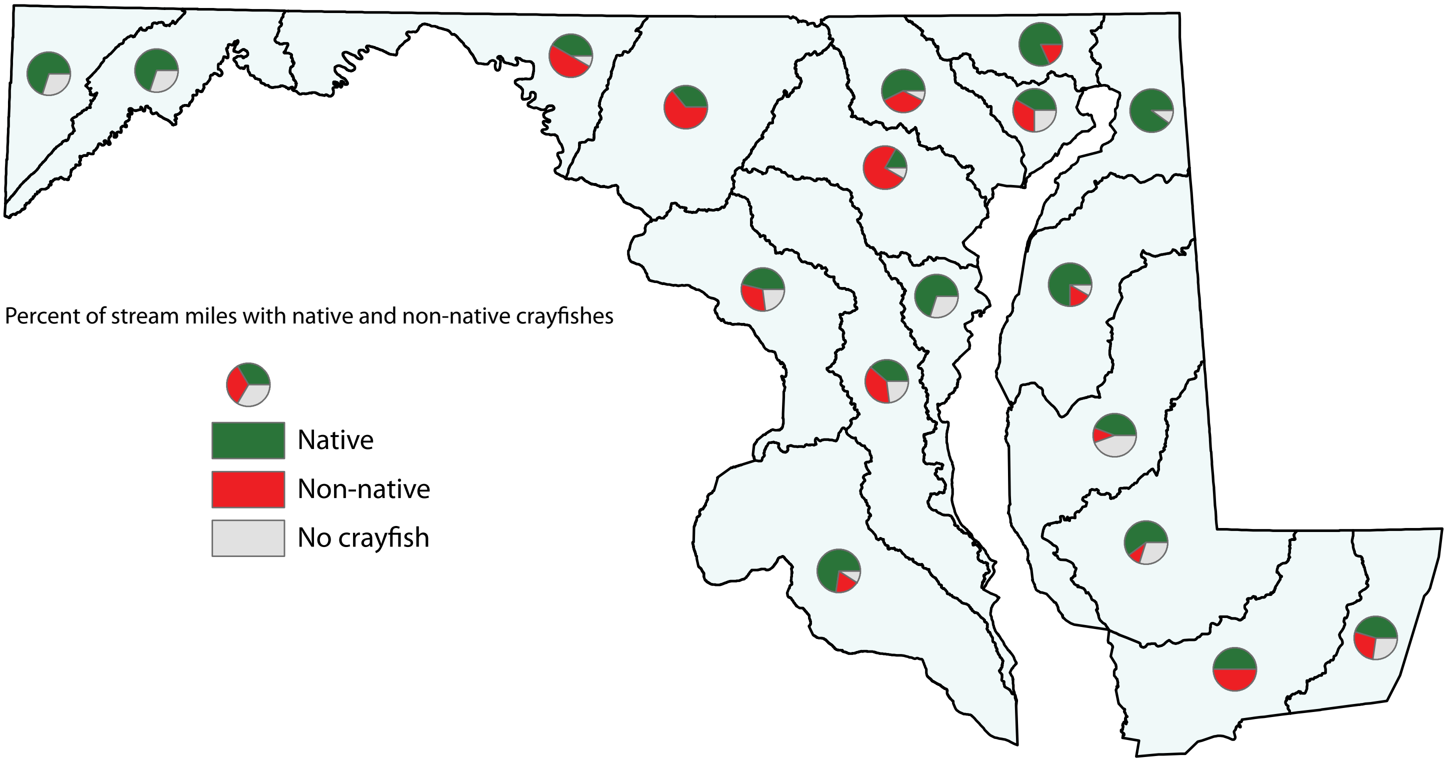
How Have Invasive Crayfishes Affected Maryland's Native Species?

The most obvious effect of the introduction and spread of non-native, invasive crayfishes in Maryland is the concomitant decline of native crayfish species. Once introduced, non-native, invasive crayfishes tend to quickly colonize and become highly abundant in affected waters. These species are aggressive and can compete with and displace native crayfish species. The ranges of two native species, the Spinycheek Crayfish (*O. limosus*) and Allegheny Crayfish (*O. obscurus*) dramatically declined as the invasive Virile Crayfish spread over the past 50 years. The Spinycheek Crayfish is now absent from several watersheds in Central Maryland where it was once common.

Spinycheek Crayfish is a native species that dramatically declined as the invasive Virile Crayfish spread in Central Maryland. Spinycheek Crayfish disappeared from many Maryland watersheds as the Virile Crayfish expanded its range.

So How Big is the Problem?

We estimated the percent of stream miles occupied by native and non-native crayfishes in each of the 18 major drainage basins in Maryland. We also estimated the mean abundance of both native and non-native crayfishes per stream mile in each basin. Based on these estimates, it is clear that non-native crayfishes are widespread in many basins, and are more abundant than native species in the Upper Potomac River, Middle Potomac River, Potomac Washington Metro, Patuxent, Patapsco, Bush, Lower Susquehanna River, and Pocomoke River basins. Native and non-native crayfishes were found together in the same stream at only 16% of sites sampled, clear proof that when non-natives arrive, natives soon disappear.



Estimated mean abundance of native and non-native crayfishes per stream mile in Maryland's 18 major drainage basins.		
Drainage Basin	**Native crayfish**	**Non-native crayfish**
Lower Susquehanna River	135.9	381.5
Ocean Coastal	16.1	10.7
Pocomoke River	51	96.6
Nanticoke River	75.1	5.4
Choptank River	392.4	36.8
Chester River	291.2	29.1
Elk River	414.2	0
Bush River	67.1	667.9
Gunpowder River	220	130.5
Patapsco River	13.3	1352
West Chesapeake Bay	92.9	0
Patuxent River	60.8	483.7
Lower Potomac River	182.88	14.3
Potomac Washington Metro	59.6	165.7
Middle Potomac River	282.1	3634.4
Upper Potomac River	187.2	1262.6
North Branch Potomac River	89.6	0
Youghiogheny River	386.3	0

What Other Effects Do Invasive Crayfishes Have on Maryland Streams?

Owing to their size, ability to achieve large population densities, and importance as both prey and predator, invasive crayfishes have the capacity to affect more than just native crayfish diversity. Unfortunately, not much is known about the effects of these invasives on other components of Maryland's aquatic ecosystems. However, invasive crayfishes in other states have altered the abundance and diversity of native aquatic plants, invertebrates, amphibians, and fishes, thereby causing dramatic changes to aquatic food webs. Their ability to eliminate aquatic vegetation can also reduce the quantity and quality of important nursery habitats for fishes and other aquatic animals.

6.8 WHAT NON-NATIVE PLANTS OCCUR MOST COMMONLY ALONG MARYLAND STREAMS ?

Between 2007 and 2009 (Round 3), the MBSS identified a total of 35 non-native plant species growing along Maryland streams. The ten most common* non-native plants include multiflora rose, Japanese stiltgrass, Japanese honeysuckle, garlic mustard, mile-a-minute, Japanese barberry, wineberry, Oriental bittersweet, privet, and tree of heaven. All of these species are well-suited to taking advantage of disturbed soils. Eroded stream banks and streams near roadways or other construction areas are particularly susceptible to non-native plant colonization. Streams also provide a means of transport for seed, stem, and root debris, processes which non-native plants use to colonize new riparian areas.

Multiflora rose is native to eastern Asia. It was intentionally introduced to the U.S. in 1866 as rootstock for ornamental roses, and was later recommended for erosion control, "living fences," cover for wildlife, highway crash barriers and headlight glare control. Multiflora rose poses a medium threat to native flora. It has the ability to move into field, forest, wetland, and other habitats, produces a large number of fruits, and forms large, dense thickets that exclude native vegetation.

Japanese stiltgrass originates in Asia. It was inadvertently introduced to the U.S. around 1919 from use as a packing material for porcelain objects. Japanese stiltgrass poses a large threat to native flora. It forms thick patches in forests, fields, and in mowed, trampled, or otherwise disturbed soils.

Japanese honeysuckle is native to eastern Asia. It was intentionally introduced to the U.S. in 1806 for ornamental, erosion control, and wildlife habitat purposes. Japanese honeysuckle poses a medium threat to native flora. It smothers low-lying vegetation and can girdle small trees as it climbs into the tree canopy.

Garlic mustard is native to Europe. It was intentionally introduced to the U.S. around 1868 for food and medicinal purposes. Garlic mustard poses a large threat to native flora. It displaces native wildflowers in floodplain and forest habitat, and takes advantage of disturbed soils. Chemicals released by the roots suppress native fungal and seedling growth.

Mile-a-minute originates in Asia. It was probably inadvertently introduced to the U.S. in the 1930s, possibly imported with other plants for the nursery trade. Mile-a-minute poses a medium threat to native flora. It can inhabit fields, forest edges, stream banks, wetlands, roadsides and wetlands, and kills native flora by smothering. Japanese barberry is native to Japan. It was intentionally introduced to the U.S in 1875 as an ornamental. Japanese barberry poses a large threat to native flora. It can grow in most habitat types and displaces native herbaceous and woody plants. Japanese barberry leaf litter can alter the surrounding soil chemistry.

Plant Taxa	Overall		Highlands		Eastern		Coastal	
	Rank	# Sites	Rank	# Sites	Rank	# Sites	Rank	# Sites
Multiflora Rose	1	449	1	100	1	141	2	208
Japanese Stiltgrass	2	412	2	81	2	133	3	198
Japanese Honeysuckle	3	393	4	49	3	117	1	227
Garlic Mustard	4	234	3	80	4	108	5	46
Mile-A-Minute	5	168	8	13	5	107	4	48
Japanese Barberry	6	114	5	30	7	63	10	21
Wineberry	7	111	6	27	8	59	8	25
Oriental Bittersweet	8	93			6	69	9	24
Privet	9	66			9	32	6	34
Tree of Heaven	10	44	9	12	11	18	11	14
Canada Thistle	11	32	7	16	15	10	14	6
Japanese Knotweed	12	32	10	11	13	15	15	6
Autumn Olive	13	30	12	3	12	17	13	10
Common Reed (Phragmites)	14	27			23	1	7	26
Japanese Hops	15	24	13	2	10	19	17	3
English Ivy	16	23			14	11	12	12
Shrub Honeysuckle	17	23	11	10	16	8	16	5
Mimosa	18	9			17	6	18	3
Vinca Vine	19	9			18	6	20	3
Bamboo	20	6			19	4	21	2
Norway Maple	21	6	14	2	20	4		
Porcelainberry	22	5			22	2	19	3
Paulowinia	23	3			21	2	25	1
White Mulberry	24	3			32	1	22	2
Callery Pear	25	1					23	1
Field Bindweed	26	1			24	1		
Giant Hogweed	27	1			25	1		
Hydrilla Verticillata	28	1			26	1		
Japanese Spiraea	29	1			27	1		
Wisteria	30	1					24	1
Kudzu	31	1			28	1		
Purple Loosestrife	32	1			29	1		
Reed Canary Grass	33	1			30	1		
Wavy Leaf Basket Grass	34	1			31	1		
Winter Creeper	35	1					26	1
**Note: Additions were made to the MBSS list of non-native plants in 2008. The presence of the three additional species (vinca vine, wavyleaf basketgrass, and mimosa) may be underrepresented in the above data.								

Wineberry originates in eastern Asia. It was intentionally introduced to the U.S in the 1890s as breeding stock for new raspberry cultivars. Wineberry poses a medium threat to native flora. It prefers edge habitats and can form dense thickets.

Oriental bittersweet originates in eastern Asia. It was intentionally introduced to the U.S. in 1860s as an ornamental. Oriental bittersweet poses a large threat to native flora. It can smother low plants, girdle trees as it climbs to the canopy, and can topple the trees from excessive weight at the canopy level.

Privet originates in Europe and Asia. It was intentionally introduced in or before the 1800s for use as hedges and landscaping ornamentals. Privet poses a low threat to native flora. When growing in dense thickets, privet shades out and displaces native plants.

Tree of heaven is native to China and Taiwan. It was intentionally introduced to the U.S. in 1748 by a gardener. Tree of heaven poses a medium threat to native flora. It is able to adapt to a wide range of soil types and conditions, can form dense stands, is drought-tolerant, seeds prolifically, and releases allelopathic chemicals into the surrounding soil.

7. Where are the Best and Worst Streams in Maryland?

Streams in Maryland vary from those in Very Good condition (minimally disturbed by human activities) to those in Very Poor condition. We can better appreciate this wide range of condition by listing the streams sampled in Round 3 of the MBSS that represent the best and worst conditions sampled from 2007-2009.

The 21 streams had the best conditions and 26 streams had the worst conditions based on the Combined Biotic Index (CBI) are listed in the tables below (more than 20 streams are listed for each category because of ties in scores). The CBI is the average of the fish and benthic macroinvertebrate Indices of Biotic Integrity (IBIs) and ranges from 1.0 to 5.0.

Site SAVA-225-S-2007 (Savage Run), ranked "best" by the CBI for MBSS Round 3

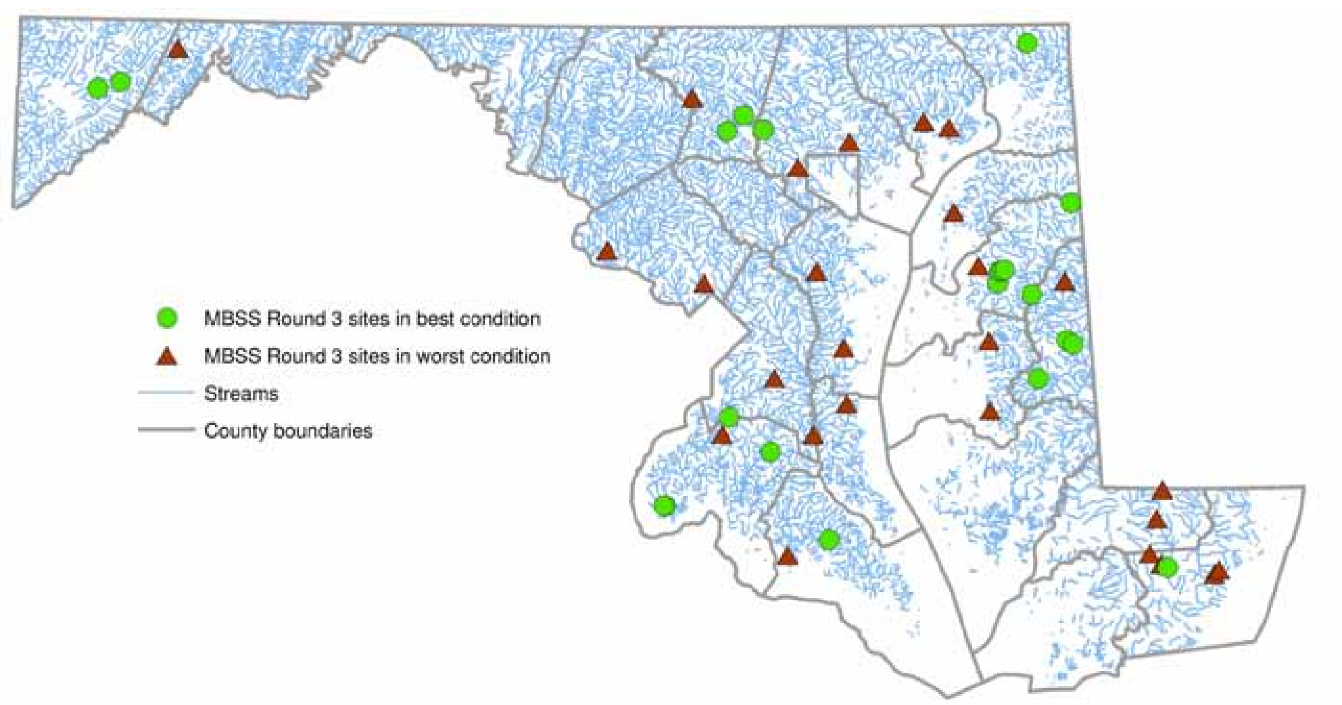
Site BUSH-104-R-2007 (Sod Run), one of the sites ranked "worst" by the CBI for MBSS Round 3

The location of each of these 20 best-condition and 20 worst-condition streams from MBSS Round 3, based on the Combined Biotic Index (CBI) is shown in the figure below.

Top twenty (21 with tie scores) streams in best condition (highest scoring sites) from MBSS Round 3, based on the Combined Biotic Index (CBI)

Site	Stream Name	County	CBI
SAVA-225-S-2007	Savage River	Garrett	4.88
NASS-204-R-2007	Nassawango Creek	Worcester	4.86
UPCK-210-R-2007	Hog Creek	Caroline	4.86
BRET-404-R-2007	McIntosh Run	St. Mary's	4.83
CORS-216-X-2009	Mill Stream Branch	Queen Anne's	4.83
NANJ-304-R-2008	Nanjemoy Creek	Charles	4.83
TUCK-450-H-2007	Tuckahoe Creek	Caroline	4.83
UPCK-212-X-2007	Watts Creek	Caroline	4.83
SAVA-276-S-2009	Double Lick Run	Garrett	4.75
MATT-316-A-2007	Mattawoman Creek	Prince George's	4.71
UPCK-211-X-2007	Herring Run	Caroline	4.71
CORS-250-H-2007	Three Bridges Branch	Queen Anne's	4.69
ZEKI-202-A-2008	Mill Dam Run	Charles	4.69
CORS-104-H-2007	Three Bridges Branch UT2	Queen Anne's	4.67
CORS-122-X-2008	Three Bridges Branch	Queen Anne's	4.67
LIBE-102-S-2008	Timber Run	Baltimore	4.67
LIBE-202-A-2007	Middle Run	Carroll	4.67
LIBE-262-A-2007	Little Morgan Run	Carroll	4.67
NANJ-301-H-2008	Nanjemoy Creek	Charles	4.67
NEAS-103-R-2008	Northeast Creek	Cecil	4.67
UPCR-306-R-2008	Andover Branch	Queen Anne's	4.67

Bottom twenty (26 with tie scores) streams in worst condition (lowest scoring sites) from MBSS Round 3, based on the Combined Biotic Index (CBI)			
Site	Stream Name	County	CBI
BUSH-104-R-2007	Sod Run	Harford	1.14
CORS-106-B-2008	Unnamed Tributary (UT) to Tilghman Cove	Queen Anne's	1.14
LPAX-101-R-2009	UT Towsers Branch	Anne Arundel	1.14
MILE-105-B-2009	UT Miles River	Talbot	1.14
ROCK-101-R-2009	Rock Creek	Montgomery	1.17
DOUB-105-R-2007	Dickenson Run UT1 (Five Daughters Run)	Carroll	1.25
PRMO-209-R-2008	Horsepen Branch	Montgomery	1.25
DIVI-107-R-2007	Pusey Branch	Worcester	1.29
LOWI-104-B-2008	Horsebridge Creek	Wicomico	1.29
BUSH-102-R-2007	Ha Ha Branch	Harford	1.33
LOGU-104-R-2007	Minebank Run	Baltimore	1.33
LOCK-104-R-2009	UT Island Creek	Talbot	1.43
NASS-108-S-2007	Millville Creek	Worcester	1.43
PAXL-107-R-2008	UT Summerville Creek	Prince George's	1.43
UPCK-101-R-2007	Forge Branch UT2	Caroline	1.43
WCHE-106-R-2007	Fishing Creek UT3 UT2	Calvert	1.43
UPPC-110-R-2009	Five Mile Branch	Worcester	1.45
GEOR-103-R-2008	George's Creek	Allegany	1.5
GWYN-102-R-2007	Gwynns Falls UT2	Baltimore	1.5
MATT-110-A-2009	Unnamed Tributary (UT) to Old Woman's Creek	Charles	1.57
NEWP-125-B-2009	UT to UT Marshall Creek	Worcester	1.57
PISC-102-B-2007	Dower House Branch	Prince George's	1.57
PRLT-107-B-2008	UT Whites Neck Creek	St. Mary's	1.57
STIL-104-B-2008	UT Fairlee Creek	Kent	1.57
WEST-103-B-2008	UT Smith Creek	Anne Arundel	1.57
WIRH-103-B-2009	Figgs Ditch	Wicomico	1.57



8. How are Maryland’s Fish Doing?

Maryland has a diverse freshwater fish fauna including 96 species living across the Highlands, Eastern Piedmont, and Coastal Plain regions of the state. Monitoring by the Maryland Biological Stream Survey (MBSS) provides a robust inventory of the distribution and abundance of Maryland fishes based on estimates from its probability-based design. It also provides critical information on the status of rare species and game fish, as well as which fishes are most and least sensitive to human activities. Each of these topics is discussed below:

- 8.1. How many kinds (species) of fish live in Maryland’s streams and what are the State’s most common stream fish?
- 8.2. What stream fishes are most and least sensitive to habitat degradation and water pollution?
- 8.3. Where do young bass and other game fish live and grow and how can they be protected? In addition, we provide the following three case studies on Maryland fishes:

    1. Where were species found that were previously believed to be extirpated in Maryland streams?
    2. Do brook trout live in more streams, less streams, or about the same number of streams than they did 30 years ago?
    3. What streams in Maryland would probably have American eels if not for dams and other blockages?

8.1 HOW MANY KINDS (SPECIES) OF FISH LIVE IN MARYLAND’S STREAMS AND WHAT ARE THE STATE’S MOST COMMON STREAM FISH

The table that follows list the fish species collected during Round 3 (2007-2009) of the MBSS based on the number of streams they were found in statewide and by each of four ecological stream types: Highlands coldwater, Highlands warmwater, Eastern Piedmont, and Coastal Plain.

In the Coastal Plain, eastern mudminnows and American eels are each found in about 2/3 of all streams. Blacknose dace are the most common fish in the other three stream types, occurring in 90% of both East Piedmont and Highlands warmwater streams and nearly half of all Highlands coldwater streams. The Coastal Plain has the most fish species (60), compared to the East Piedmont (55 species), the Highlands warmwater (46 species), or the Highlands coldwater streams (24 species). Sixteen (16) of Maryland’s freshwater fish species are on the list of Rare, Threatened, and Endangered (RTE) species. Of these, 10 occur in the Coastal Plain, 3 each in the Eastern Piedmont and Highland warmwater, and 2 in the Highlands coldwater streams. To learn more about RTE species, please see a href=”http://www.dnr.state.md.us/wildlife/Plants_Wildlife/rte/rteanimals.asp”>DNR’s Natural Heritage website or US Fish and Wildlife Service website.

Fish species in each region of Maryland and the percentage of stream sites within each region in which they were collected by MBSS. An "X" in the RTE column indicates that this species is rare, threatened, or endangered.						
Fish Species	RTE Species	Statewide	Highlands coldwater	Highlands warmwater	East Piedmont	Coastal
Eastern Blacknose Dace		59.2	45.8	90	90.6	31.4
Creek Chub		45.1	37.5	72.5	79.7	15.2
American Eel		42.1		5	43.8	64.8
Tessellated Darter		41.2		20	59.4	47.6
Bluegill		40.3	4.2	32.5	37.5	53.3
White Sucker		33.9	20.8	55	62.5	11.4
Eastern Mudminnow		30.5			1.6	66.7
Longnose Dace		27.5	12.5	50	54.7	5.7
Rosyside Dace		26.6		25	65.6	9.5
Pumpkinseed		25.3	4.2	10	14.1	42.9
Green Sunfish		24		45	18.8	24.8
Redbreast Sunfish		21		17.5	29.7	21.9
Largemouth Bass		19.3	4.2	15	21.9	22.9
Creek Chubsucker		18			3.1	38.1
Margined Madtom		16.7		12.5	31.3	13.3
Fallfish		15.9		10	25	16.2
Blue Ridge Sculpin		15.5	4.2	27.5	35.9	1
Cutlip Minnow		15.5		17.5	40.6	2.9
Common Shiner		14.6	4.2	27.5;	32.8	1
Brown Bullhead		14.2	4.2	2.5	9.4	23.8
Swallowtail Shiner		14.2		5	28.1	12.4
Central Stoneroller		13.3	4.2	37.5	20.3	1.9
Golden Shiner		13.3		5	1.6	26.7
Yellow Bullhead		13.3	4.2	27.5	6.3	14.3
Fantail Darter		12.4	4.2	70		
Redfin Pickerel		12.4				27.6
Bluntnose Minnow		12	4.2	45	12.5	1
Northern Hogsucker		11.6	8.3	17.5	28.1	
Least Brook Lamprey		11.2			1.6	23.8
Eastern Mosquitofish		10.7			1.6	22.9
River Chub		9.9	4.2	10	28.1	
Satinfin Shiner		9		2.5	17.2	8.6
Smallmouth Bass		9		17.5	20.3	1
Pirate Perch		8.6				19
Spottail Shiner		8.6		12.5	7.8	9.5
Potomac Sculpin		8.2		42.5	3.1	
Banded Kilifish		7.7		10	6.3;	9.5
Greenside Darter		7.3		37.5	3.1	
Brown Trout		6.9	8.3	2.5	20.3	
Bluespotted Sunfish	X	6.4				14.3
Spotfin Shiner		6.4		17.5	3.1	5.7
Sea Lamprey		6			9.4	7.6
Rock Bass		5.6	4.2	17.5	7.8	
Tadpole Madtom		5.6				12.4
Chain Pickerel		4.7	4.2			9.5
Rosyface Shiner		4.3		5	12.5	
Shield Darter	X	3.9		2.5	12.5	
Mummichog		3.4			4.7	4.8
Brook Trout	X	3	25		1.6	
Silverjaw Minnow		2.6		12.5		1
Banded Sunfish	X	2.1				4.8
Black Crappie		2.1				4.8
Mottled Sculpin	X	2.1	20.8			
Rainbow Trout		2.1		5	3.1	1
Sunfish (Hybrid)		2.1		5	3.1	1
Pearl Dace		1.7		10		
Rainbow Darter		1.7		10		

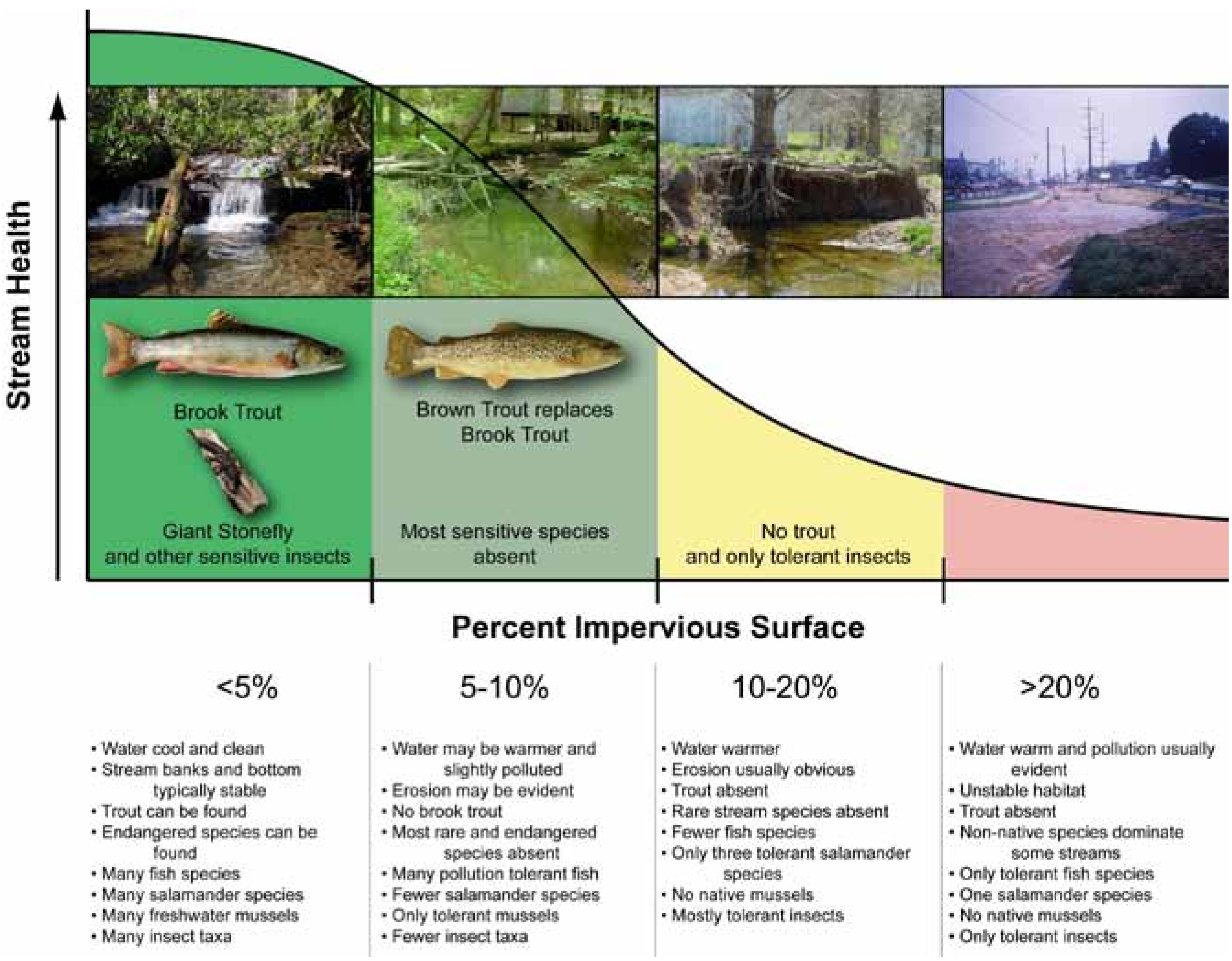
Fish species in each region of Maryland and the percentage of stream sites within each region in which they were collected by MBSS. An "X" in the RTE column indicates that this species is rare, threatened, or endangered.						
Fish Species	RTE Species	Statewide	Highlands coldwater	Highlands warmwater	East Piedmont	Coastal
American Brook Lamprey	X	1.3				2.9
Johnny Darter	X	1.3	12.5			
Swamp Darter	X	1.3				2.9
Warmouth	X	1.3				2.9
Western Blacknose Dace		1.3	12.5			
Yellow Perch		1.3				3.9
Banded Darter		0.9			3.1	
Channel Catfish		0.9			1.6	1
Chesapeake Logperch	X	0.9			3.1	
Comely Shiner	X	0.9		2.5		1
Gizzard Shad		0.9			1.6	1
White Catfish	X	0.9			1.6	1
Alewife	X	0.4				1
Checkered Sculpin	X	0.4		2.5		
Common Carp		0.4			1.6	
Fathead Minnow		0.4				1
Glassy Darter	X	0.4				1
Golden Redhorse		0.4			1.6	
Goldfish		0.4				1
Ironcolor Shiner	X	0.4				1
Oriental Weatherfish		0.4			1.6	
Walleye		0.4			1.6	

8.2 WHAT STREAM FISHES ARE MOST AND LEAST SENSITIVE TO HABITAT DEGRADATION AND WATER POLLUTION?

There are about 130 species of fish living in Maryland's streams. Each of these species tolerates habitat degradation and water pollution differently. Some species, like blacknose dace, adapt very well to stream habitat degradation and most types of water pollution. However, the blacknose dace is very sensitive to acidity and tends to be absent from streams that are even mildly acidic. Other fish, like brook trout, appear to be sensitive to nearly all types of stream habitat degradation and water pollution, although they can tolerate acidic water better than many stream fish. Those fish species (and other stream biota) that are more sensitive to habitat degradation and water pollution tend to become extirpated first, leaving the least sensitive or most pollution-tolerant species (as illustrated in the graph and table below) in the stream. We use this knowledge, along with other information, to help rate the health of streams.

The table to the right lists those species that are generally most and least sensitive to habitat degradation and water pollution.

Most sensitive to pollution	Least sensitive to pollution
Sea Lamprey	Eastern Blacknose Dace
Central Stoneroller	Bluntnose Minnow
Comely Shiner	Creek Chub
Common Shiner	Golden Shiner
Fallfish	Bluegill
Ironcolor Shiner	Green Sunfish
Blue Ridge Sculpin	Largemouth Bass
Mottled Sculpin	Pumpkinseed
Flier	Tessellated Darter
Banded Darter	
Shield Darter	
Swamp Darter	



8.3 WHERE DO YOUNG BASS AND OTHER GAME FISH LIVE AND GROW AND HOW CAN THEY BE PROTECTED?

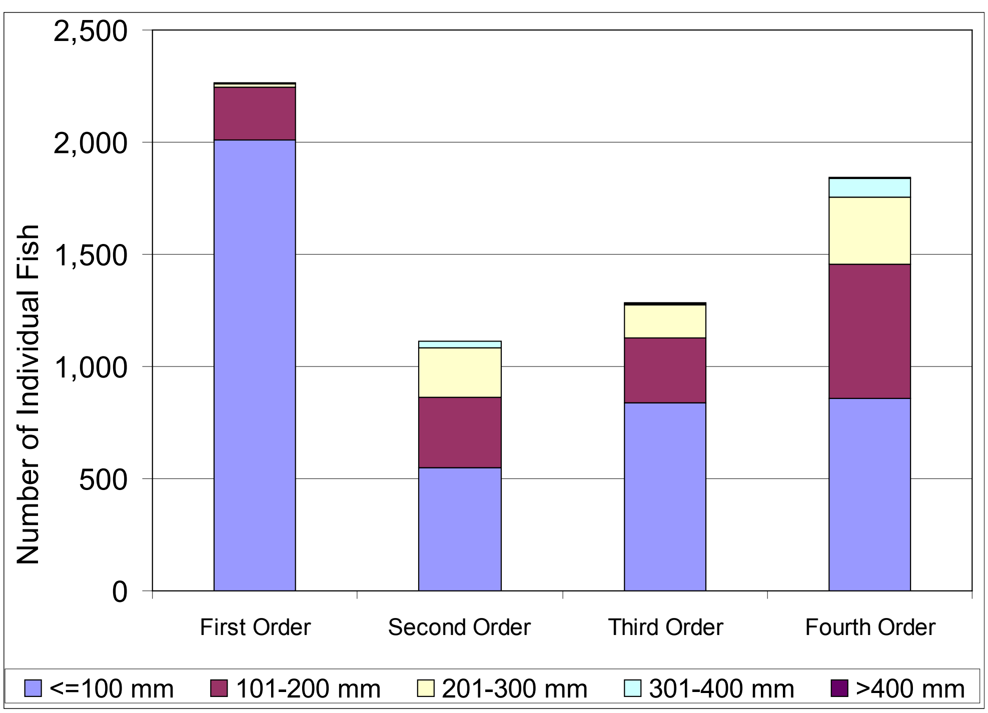
Maryland has a range of freshwater recreational fishing opportunities including cold water trout streams in the western part of the state and warmer water bass fishing in the middle and eastern counties. Maryland's sport fisheries provide both economic and recreational benefits to the state. While most anglers are focused on catching the large, mature fish, the habitat and resources required by the young, small fish must also be protected to ensure a thriving game fish population.

MBSS samples fish populations throughout Maryland. Since 2000, the MBSS has measured the length of every game fish collected. To date, the MBSS has recorded the lengths of more than 6,000 game fish. There are nine species of freshwater game fish found in Maryland. Brook trout, followed by smallmouth, largemouth bass, and brown trout, were most commonly collected.

Freshwater Game Fish in Maryland Collected by MBSS

Species	# Collected
Brook Trout	1,870
Brown Trout	1,215
Chain Pickerel	425
Cutthroat Trout	1
Largemouth Bass	1,328
Rainbow Trout	100
Smallmouth Bass	1,551
Striped Bass	10
Walleye	2

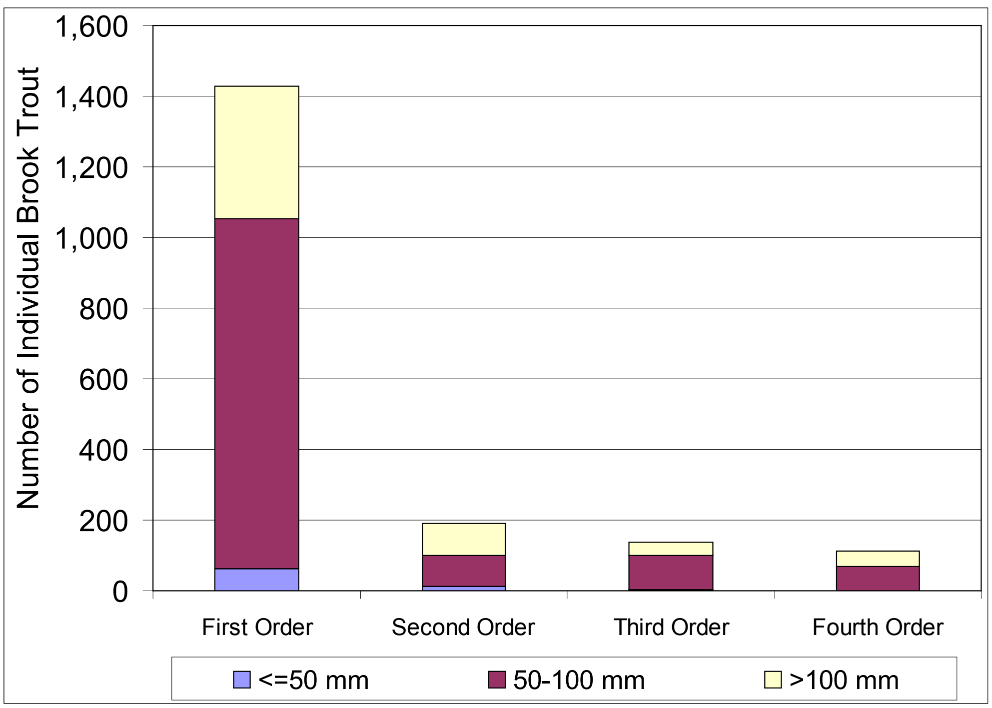
Surprisingly, many of these fish, even some large individuals, are found in small, first-order streams (defined as first-order because they have no perennial upstream tributaries). In the chart below shows that more game fish were collected in first order streams than in any other size stream. Large predators are often absent from small streams, and young fish can find habitat and food in these waters. Small streams also tend to be cooler because vegetation on the banks usually shades the entire stream channel. Cool temperatures, high surface-to-volume ratios, and turbulence caused by rocky substrate lead to high levels of dissolved oxygen which many species prefer. These characteristics make small streams an ideal refuge for sensitive species and young fish.



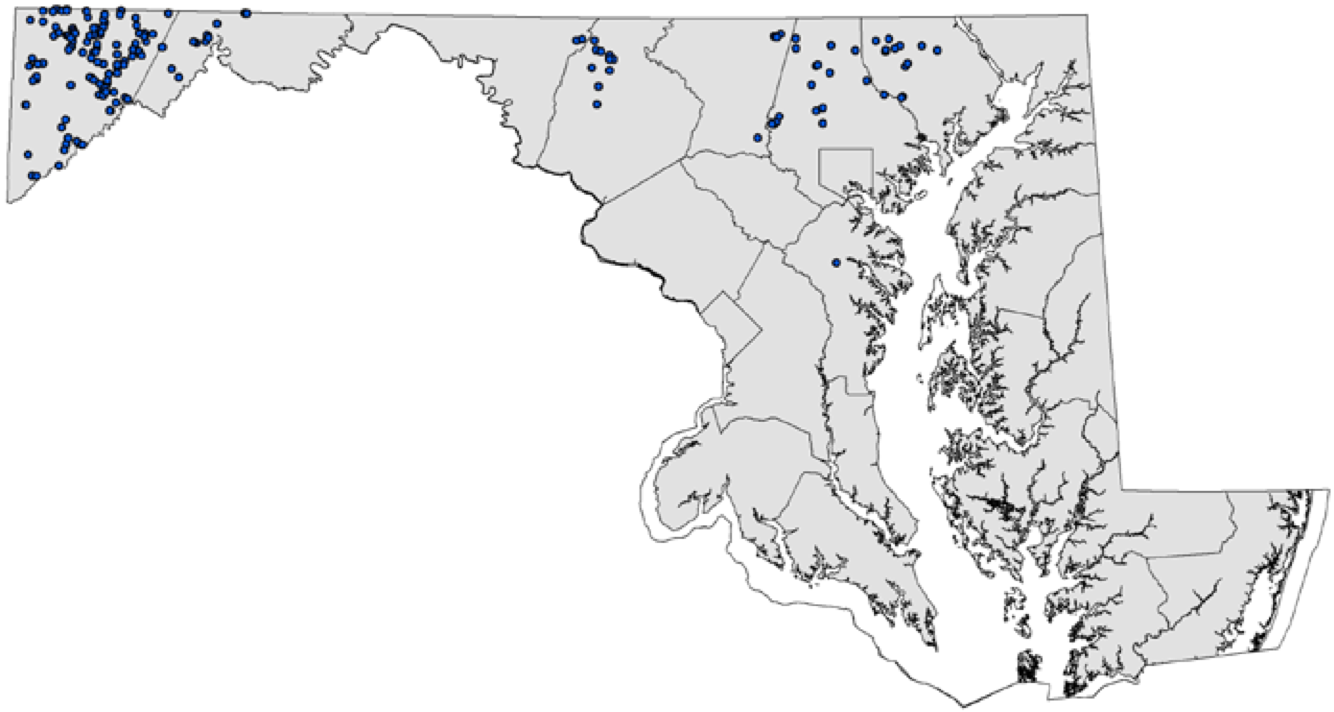
Game Fish Size (mm) Distribution by Stream Order

What can you do to protect game fish habitat? Streams throughout the state are threatened by housing developments, new roads, agriculture, and other human activities. Marylanders must work together to protect these streams that support healthy game fish populations. Providing for effective stormwater management, best management practices, and riparian buffers are tools that must be employed to facilitate the growth of our state's economy and still maintain healthy waterways. On an individual level, we can each take steps to ensure that our activities have minimal negative effects on nearby streams. The stormwater drains throughout our communities are connected to the streams so we should keep trash, oils, and other hazardous household materials out of storm drains. Riparian buffers 50 meters wide or more provide critical protection for streams. If you have a stream on your property, you can help protect and improve its condition by establishing a wide forested buffer along both banks.

Brook trout are the only trout native to Maryland, and both adults and juveniles are predominantly found in small streams (See chart below). Brook trout have a low tolerance for pollution or disturbance and favor cold temperatures, clear water, and gravely stream bottoms. Brook trout are most common in Western Maryland, but can also be found in good quality coldwater streams in central, northern Maryland (See map below). Aquatic insects and terrestrial insects that fall into the water are the primary food source for brook trout. They reach maturity around age 3 and between 130-250 mm long.

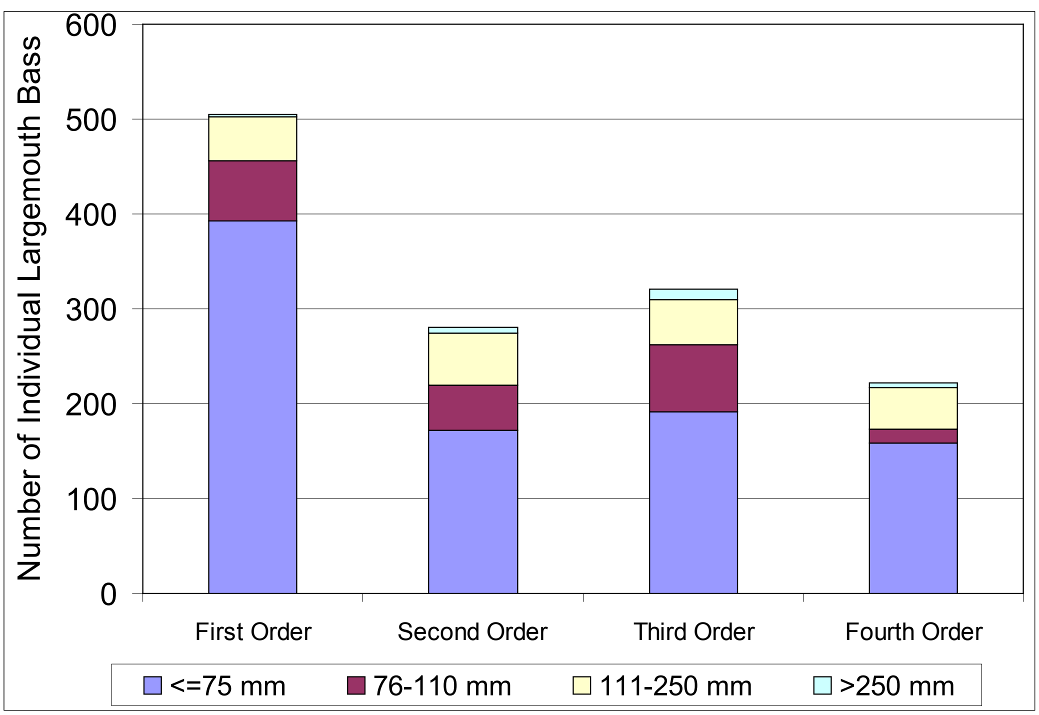


Brook Trout Size (mm) Distribution by Stream Order

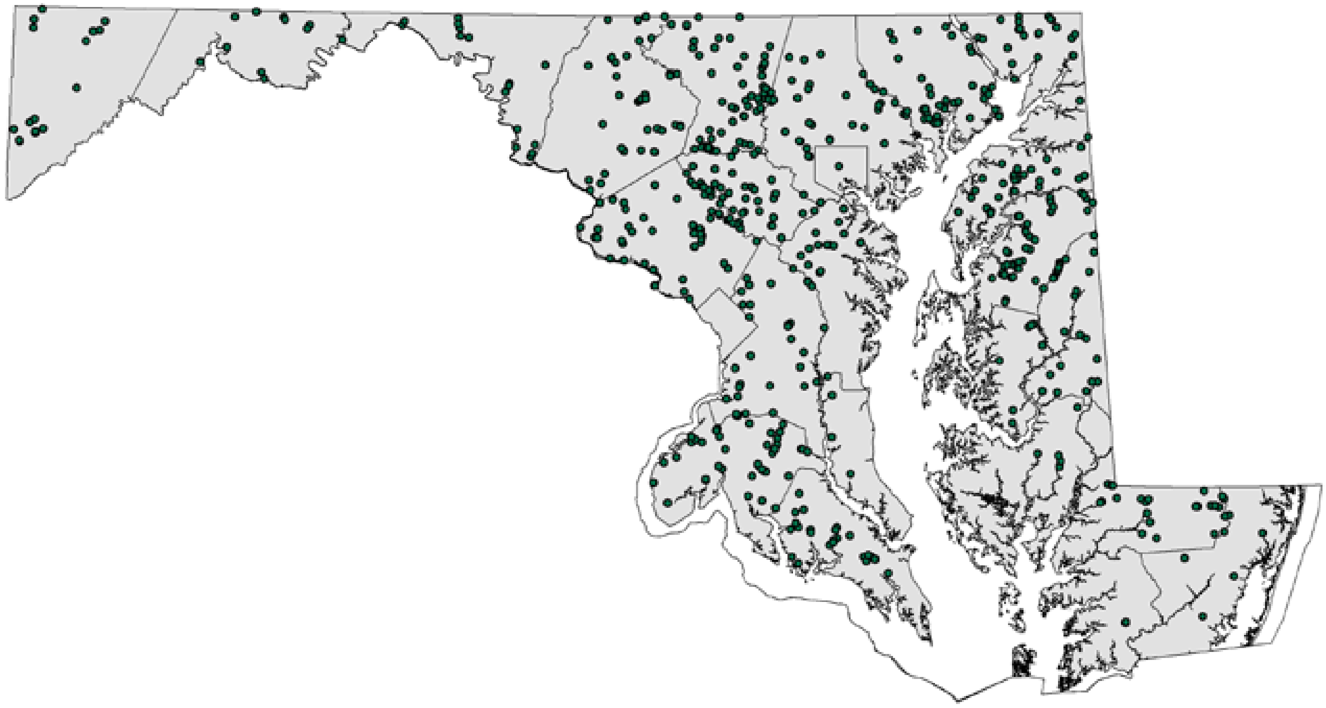


Locations Where Brook Trout Were Collected by MBSS

Largemouth bass are found throughout Maryland. While larger individuals are found in small to large streams (see map below), small fish are most common in first-order streams. Largemouth bass are predators and prefer smaller fish, frogs, and insects. They reach maturity around 4 years of age at an average length of 251-475 mm (see chart below).

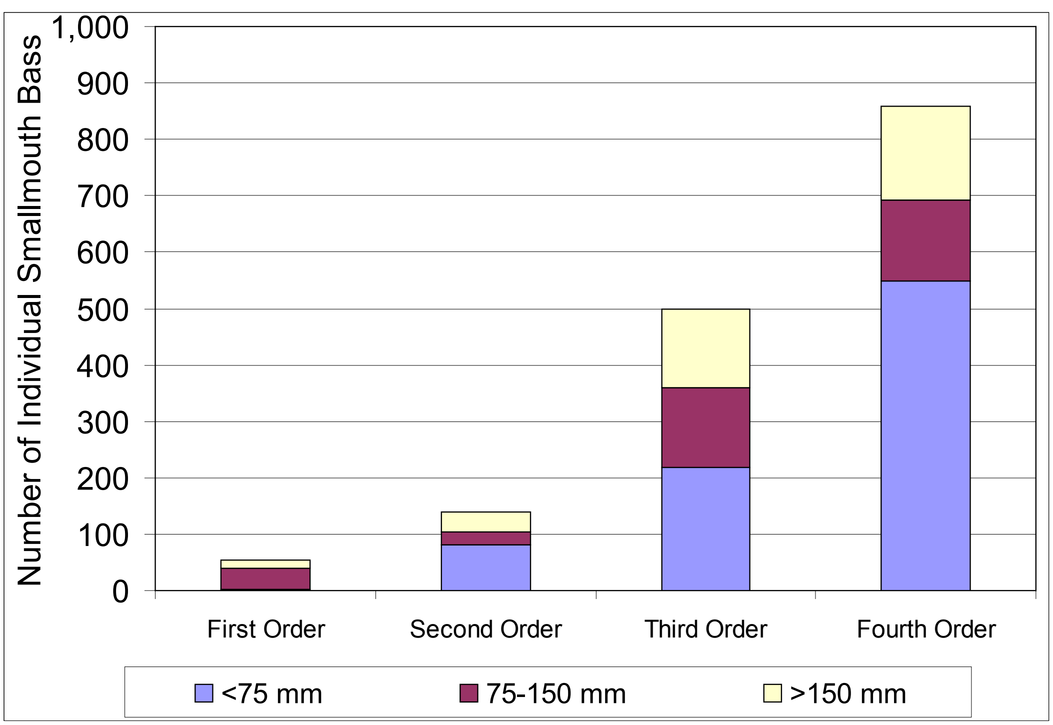


Largemouth Bass Size (mm) Distribution by Stream Order

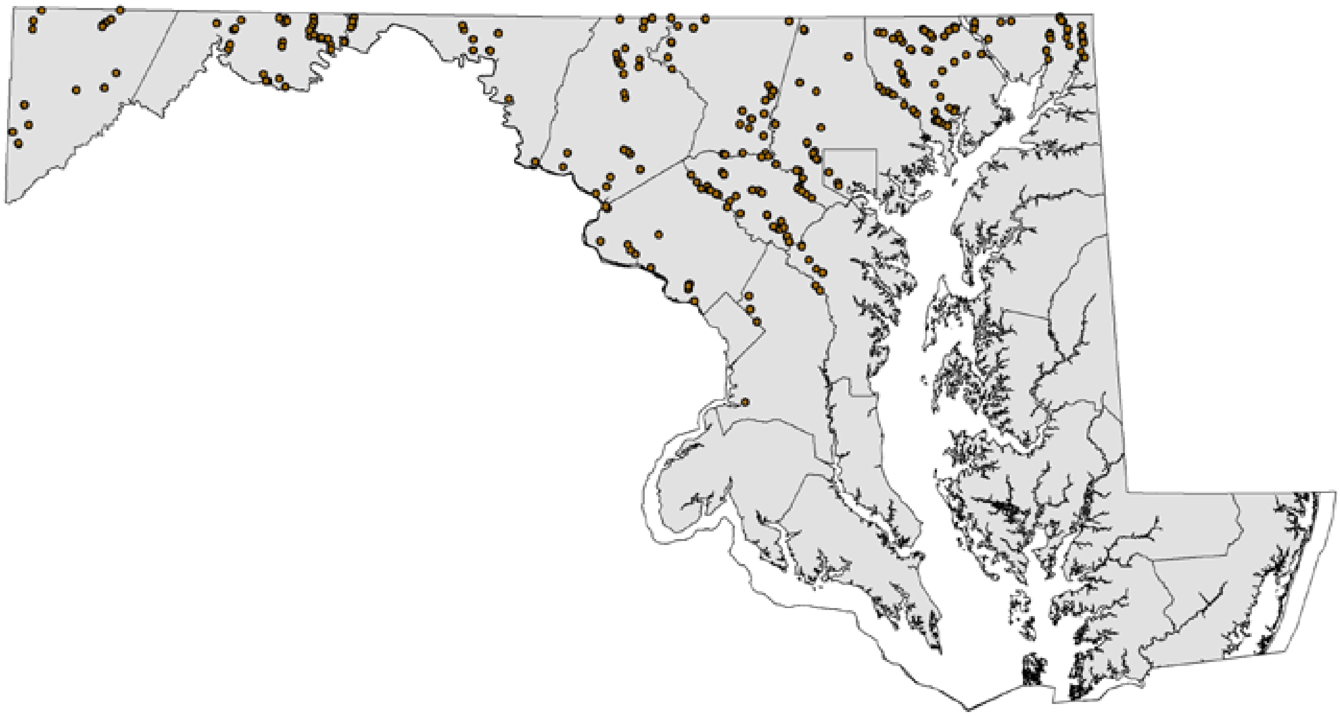


Locations Where Largemouth Bass Were Collected by MBSS

Smallmouth bass mature in two to four years, longer in smaller streams. Adults average 200-430 mm in length (see chart below). Smallmouth bass are predators from a young age and eat small crustaceans, insects, and small fish. Smallmouth bass prey size increases as they increase in size (mm). Smallmouth bass are found throughout Maryland and prefer cool, clear water. The MBSS survey found Smallmouth bass of all sizes primarily in third and fourth order streams (see map below). Very few smallmouth bass were found in first and second order streams.



Smallmouth Bass Size (mm) Distribution by Stream Order



Locations Where Smallmouth Bass Were Collected by MBSS

Case Study 1:

Where were species found that were previously believed to be extirpated in Maryland streams?

We know much more about the distribution of stream animals in Maryland than we did before the MBSS began in 1994. Sampling at randomly-selected sites is an excellent way to get an unbiased characterization of stream animal distributions and abundance estimates. Another advantage of a random sampling design is that sampling tends to occur in places that were not surveyed previously and might never be sampled otherwise. Based on MBSS sampling at random sites, many species of fish, freshwater mussels, salamanders, and crayfish are now known to live in watersheds and streams where biologist had not previously known. One example is the federally-endangered dwarf wedgemussel. They are now known from four more Maryland streams and two more watersheds based on MBSS sampling. These findings increased the number of known streams in Maryland with dwarf wedgemussel from six to ten.

MBSS random sampling has also found established populations of non-native stream animals that were not known to exist in Maryland before the MBSS. Examples include the rusty crayfish and the Oriental weatherfish (see pictures below). Over the last two years, the weatherfish has been found in two streams in the Baltimore area. The fish are commonly sold for food or as an aquarium species. This species may have the capacity to reproduce and spread in Maryland's streams as it has in other places around the country when introduced. The rusty crayfish was first discovered in a tributary to the Monocacy River in 2007. It has since been found throughout much of the northern portion of the Monocacy River watershed and exists in very large numbers in some streams. An MBSS sampling crew found enough rusty crayfish to fill two five-gallon buckets from a single 75 meter stretch of stream. Most recently rusty crayfish were collected in Antietam Creek and the mainstem of the Potomac River.

Rusty Crayfish

Oriental Weatherfish

While random stream sampling by the MBSS has helped to describe more comprehensively the distributions of many species, this sampling has likely also missed places where species live in very restricted areas or unique habitats. Beginning in 2002, the MBSS teamed up with Dr. Richard Raesly of Frostburg State University to determine if certain species that had not been seen for many years may still live in Maryland. The MBSS focused on three fish species: Maryland darter, bridle shiner, and blackbanded sunfish. This effort focused on exact locations where these species had been previously collected. Two of these species, Maryland darter and bridle shiner, have yet to be found. Searches will continue in the hopes of finding them in places near where they had been last collected many years ago.

While searches for bridle shiner and Maryland darter have not been encouraging, we were much more successful with searches for blackbanded sunfish. Staff from DNR's Fisheries Service reported collecting a blackbanded sunfish while seining in 1999. Upon returning to the same area in the Nanticoke River basin where the single sunfish was found, several individuals were found by MBSS crews and Dr. Raesly in six distinct locations. Since then, MBSS staff have teamed up with other Maryland and Delaware biologists to promote region-wide conservation of the few remaining populations of this species.

The ability to conduct effective stream biodiversity conservation has been substantially improved by inventories of aquatic species conducted by the MBSS. Protection of rare species, like blackbanded sunfish or dwarf wedgemussel, and efforts to control non-native species, like the rusty crayfish and Oriental weatherfish, would not have been possible without this information.

Case Study 2:

Do brook trout live in more streams, less streams, or about the same number of streams than they did 30 years ago?

The brook trout is an icon of cold, clean streams. Brook trout were probably widely distributed throughout Maryland at one time but now inhabit only a fraction of their former habitat. Many brook trout streams were probably lost over a hundred years ago due to widespread logging, farming, stream channelization, and other human activities. During the early 1970s DNR's Fisheries Service began a detailed inventory of trout streams. This survey indicated that brook trout still lived in many western and central Maryland streams at that time. This information provided the basis for tracking brook trout occurrences through time. Subsequent surveys by the Fisheries Service and the MBSS documented the loss of brook trout from several central Maryland streams. These losses were coincident with urban development in every case (see example from Goodwin Run below).

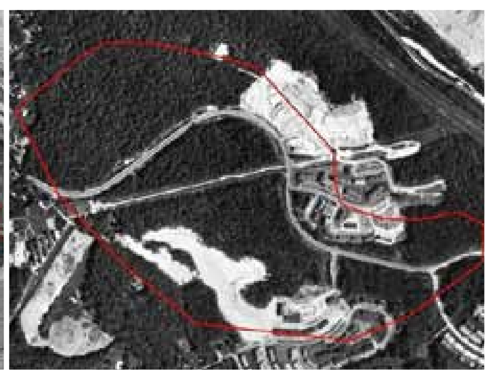
Even small developments were associated with brook trout disappearance. Covering less than 5% of the drainage area of a stream with roof tops and pavement was typically sufficient to eradicate brook trout.

Brook trout is an important stream fish to Maryland. It is a game fish, is listed as a "watch list" species on Maryland's list of rare, threatened, and endangered species, and is an indicator of good water quality. DNR is actively working on brook trout conservation. Limiting urban development within watersheds where this species still lives is an important aspect of this conservation effort.

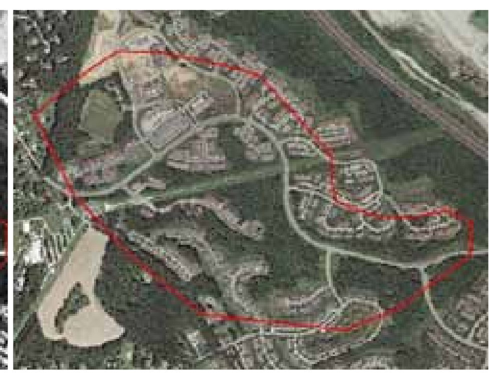
Brook Trout

Below is an example of brook trout loss associated with urban development in the Goodwin Run watershed of central Maryland.

Goodwin Run Watershed in 1972, when brook trout still lived there



Goodwin Run Watershed in 1992, when brook trout were no longer found there



Goodwin Run Watershed in 2004, when development was complete

Case Study 3:

What streams in Maryland would probably have American eels if not for dams and other blockages?

The American eel has a life history unique among Maryland fish species. In contrast to anadromous fish (such as American shad) that spawn in Maryland's freshwater rivers and grow to maturity in the ocean, the catadromous eel spawns in the tropical Atlantic Ocean and grows to maturity in estuarine and freshwater habitats. Juvenile eels (or elvers) must migrate upstream through estuaries, rivers, and streams to reach habitats that will support them (for 20 years or more) before reaching sexual maturity and migrating to their spawning area in the Sargasso Sea.

European colonization of Maryland was accompanied by the construction of numerous small dams to supply water power for mills. Later, dams on larger streams and rivers were added for transportation, water supply, flood control, and hydroelectric projects. Today, the more than 1,000 man-made barriers to migratory fish in Maryland have reduced access of American eel and other fish to their historical habitats. It is likely that the American eel was abundant in virtually all the estuaries, rivers, streams, and lakes of Maryland and other coastal states prior to the colonization of North America.

The American eel has had an interesting history in Maryland fisheries. In the nineteenth century, the species was considered so destructive of other fish that the legislature passed an act in 1888 appropriating a quarter of the state fish commission's budget for destruction of the eel. From the two-year period of 1892 to 1893, over $3,400 was spent harvesting eels in baited pots, but the sale of the captured eels only brought $80, and the practice was discontinued.

Current American eel regulations in Maryland (including the lower Susquehanna River) permit commercial and recreational fishing for eels with no restrictions for eels larger than six inches. For eels less than six inches, there is a limit of 25 per person, per day. Commercial harvest of American eels in Maryland peaked at 1.3 million pounds in 1945, and then declined to 110,000 pounds in 1962. Harvest peaked again in 1981 at more than 700,000 pounds, but declined to an average of 100,000 pounds from 1982 to 1988. According to Keith Whiteford, total Maryland eel landings averaged nearly 300,000 pounds annually between 1989 and 2007, and now comprise over 40 percent of total Atlantic coastal landings.

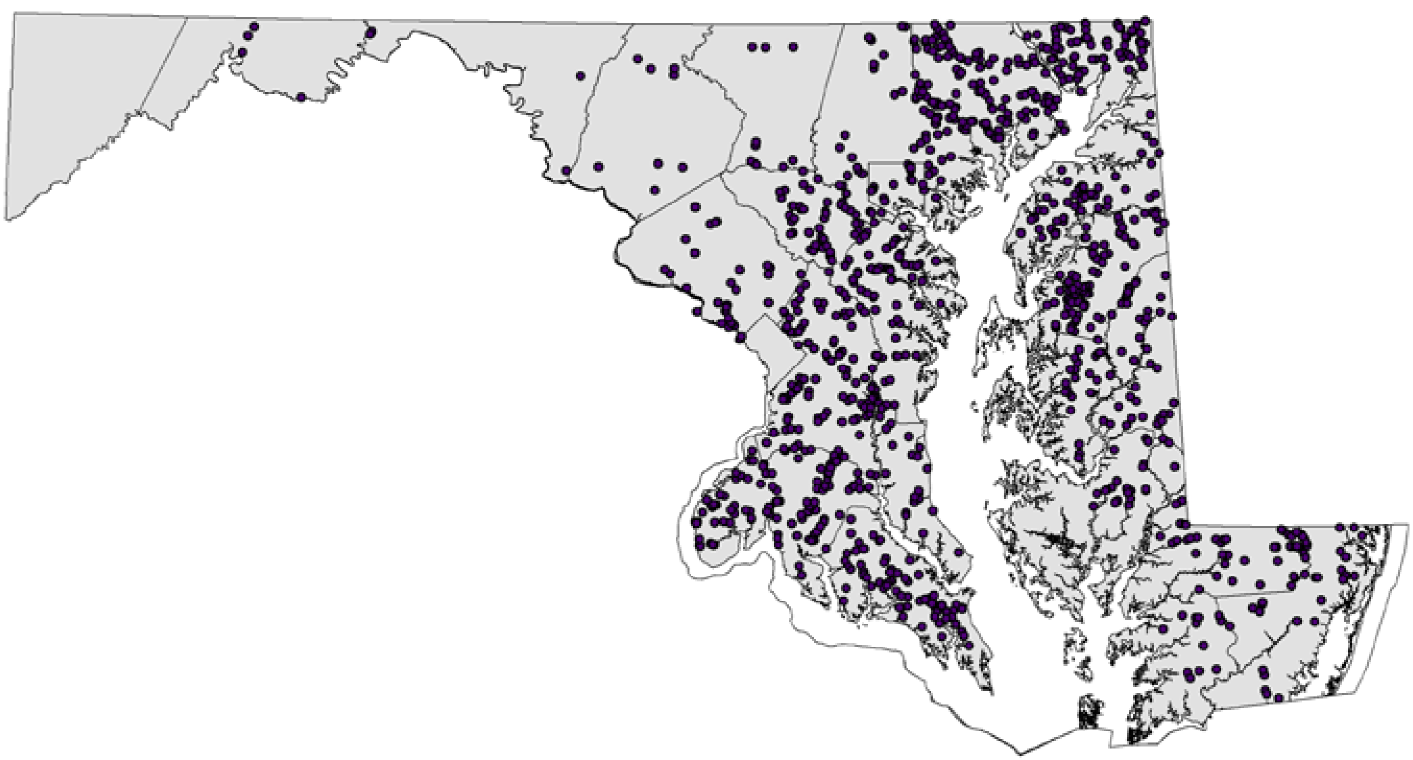
The most dramatic evidence for the impact of major dams on eel abundance can be found in the Susquehanna River basin. Prior to completion of four mainstem dams on the lower Susquehanna (the last, Conowingo Dam, was built in 1928), eels were common throughout the Susquehanna basin and were popular with anglers in Pennsylvania lakes. Annual harvests of eels in the Susquehanna were nearly 1 million pounds at that time. For many decades, there have been no recreational or commercial harvests of this species in Pennsylvania.

Since 1997, DNR's Fisheries Service has conducted an American eel study. Major components of this study include collection of harvest data from the commercial eel fishery, monitoring of the eel fishery through representative subsampling of commercial catches, the development of American eel size and age structure in selected tributaries of the Chesapeake Bay, an eel pot study in the Sassafras River, and an annual young of year abundance survey in the Coastal Bays.

Results to date indicate that the juvenile eel index marked its high in 2007, but catches in 2008 slipped below the nine-year average. The overall nine-year juvenile index shows no apparent trend. Yellow eel relative abundance indices based on commercial landings continued to show a positive trend through 2007. Commercial eeling effort continued to decline, but landings have remained stable. The yellow eel relative abundance index from eel pot sampling has shown slight improvements with 2008 catches ranking second over the past six sampled years.

DNR also participates in multi-state management of the American eel through multiple technical committees established by the Atlantic States Marine Fisheries Commission (ASMFC). ASMFC, which was formed 65 years ago by the 15 Atlantic coastal states, has management authority for 22 inter-jurisdictional species groups.

In September 2004, the U.S. Fish and Wildlife Service and the National Marine Fisheries Service reviewed the status of the American eel at the request of the ASMFC in light of an apparent decline in the commercial eel harvest. In December 2004, the two Services announced their intention to consider extending Endangered Species Act protection to the American eel. In January 2007, it was announced that endangered status was not needed for the species. The Services noted that while the eel population has declined in some areas, the species' overall population is not in danger of extinction or likely to become so in the foreseeable future. They continued, stating that "The eel population as a whole shows significant resiliency. If we look at eels over time, we see fluctuations in the population numbers, so a decreasing number of eels right now does not necessarily forecast an irreversible trend".



MBSS Round 3 Sites (2007-2009) Where the Eels Were Sampled During Electrofishing Efforts.

The most dramatic evidence for the impact of major dams on eel abundance can be found in the Susquehanna River basin. Prior to completion of four mainstem dams on the lower Susquehanna (the last, Conowingo Dam, was built in 1928), eels were common throughout the Susquehanna basin and were popular with anglers in Pennsylvania lakes. Annual harvests of eels in the Susquehanna were nearly 1 million pounds at that time. For many decades, there have been no recreational or commercial harvests of this species in Pennsylvania.

Data from Round 3 of the MBSS (2007-2009) indicate that 7615 individuals were found at 290 sites in 72 watersheds. The map above shows the obvious absence of individuals in areas above dams. American eels were found at only a few sites sampled beyond the Fall Line.

The most dramatic evidence for the impact of major dams on eel abundance can be found in the Susquehanna River basin. Prior to completion of four mainstem dams on the lower Susquehanna (the last, Conowingo Dam, was built in 1928), eels were common throughout the Susquehanna basin and were popular with anglers. For many decades, there have been no recreational or commercial harvests of this species in Pennsylvania. Round 3 of the MBSS found a total of 987 eels at 12 sites in the Susquehanna basin. None of these sites were located in the watersheds above the dam. Eels were only found in Deer Creek, Octoraro Creek, and the Lower Susquehanna River.

9. How are the Other Freshwater Animals Doing in Maryland ?

Maryland's freshwater streams also support a diverse fauna of animals other than fish. Unlike fish, where sampling of the stream according the Maryland Biological Stream Survey (MBSS) methods has a very high probability of capture, other animals use streams part time or are harder to sample. Nonetheless, the electrofishing and visual searching of streams by the MBSS does record many animals, such as frogs, toads, salamanders, turtles, snakes, lizards, crayfish, mussels and clams, and provide useful information on their distribution. In addition to sampling and searching the stream itself, the MBSS conducts systematic searches of the riparian zone adjacent to the stream for seasonal (or vernal) pools and notes the animals seen or heard in these pools.

There are eight species of mussels and clams found in Maryland streams by the MBSS. The non-native Asian clam is the most common in both the Eastern Piedmont and the Highlands regions, whereas the Eastern elliptio freshwater mussel is the most common species in the Coastal Plain. The Coastal Plain has the most species at eight, followed by the Highlands with three species, and the Eastern Piedmont with two species. The majority of Maryland streams sampled by MBSS do not have mussels and clams.

Five species of mussels found in Maryland streams are listed as rare, threatened, or endangered (RTE). All of these species occur in the Coastal Plain, only one in the Highlands, and none in the Eastern Piedmont. None of the amphibians and reptiles found in the streams of Maryland sampled by the MBSS are listed as rare, threatened, or endangered.

Bivalve species in each region of Maryland and the percentage of sites in each region in which they occur. An "X" in the RTE column indicates that this species is rare, threatened or endangered.

Species	RTE Species	Statewide	Coastal	East Piedmont	Highlands
Asian Clam		12.7	10.7	18.3	10.4
Eastern Elliptio		8.5	13.1	5.6	3
Northern Lance	X	2.7	5.7		
Eastern Floater		1.5	3.3		
Atlantic Spike	X	1.2	0.8		
Eastern Lampmussel	X	0.8	1.6		
Alewife Floater	X	0.4	0.8		
Dwarf Wedgemussel	X	0.4	0.8		

Reptile and amphibian species in each region of Maryland and the percentage of sites within each region in which they occur. No species found was rare, threatened or endangered.				
Species	**Statewide**	**Coastal**	**East Piedmont**	**Highlands**
Northern Green Frog	43.5	48.8	35.7	40.6
Northern Two-Lined Salamander	26.6	13.8	52.4	25
American Bullfrog	20.8	22.5	26.2	9.4
Pickerel Frog	20.8	18.8	35.7	6.3
Northern Spring Peeper	20.1	26.3	14.3	12.5
Eastern American Toad	11.7	3.8	26.2	12.5
Northern Watersnake	10.4	7.5	14.3	12.5
Gray Treefrog	8.4	10	9.5	3.1
Eastern Box Turtle	6.5	7.5	9.5	
Fowler's Toad	6.5	8.8	4.8	3.1
New Jersey Chorus Frog	6.5	12.5		
Wood Frog	6.5	2.5	9.5	12.5
Eastern Red-Backed Salamander	5.2	3.8	11.9	
Common Five-Lined Skink	4.5	7.5	2.4	
Eastern Snapping Turtle	4.5	2.5	7.1	6.3
Eastern Cricket Frog	3.2	6.3		
Northern Dusky Salamander	3.2		2.4	12.5
Spotted Salamander	3.2	5		3.1
Upland Chorus Frog	3.2	6.3		
Eastern Gartersnake	2.6	2.5	2.4	3.1
Northern Ring-Necked Snake	2.6	2.5	4.8	
Southern Leopard Frog	2.6	5		
Eastern Painted Turtle	1.9	1.3	2.4	3.1
Eastern Ratsnake	1.3	2.5		
Marbled Salamander	1.3	2.5		
Spotted Turtle	1.3	2.5		
Stinkpot	1.3	2.5		
Wood Turtle	1.3			6.3
Allegheny Mountain Dusky Salamander	0.6			3.1
Broad-Headed Skink	0.6	1.3		
Cope's Gray Treefrog	0.6	1.3		
Eastern Hog-Nosed Snake	0.6	1.3		
Eastern Mud Turtle	0.6	1.3		
Mole Kingsnake	0.6	1.3		
Northern Black Racer	0.6			3.1
Northern Spring Salamander	0.6			3.1
Red Spotted Newt	0.6	1.3		
Red-Eared Slider	0.6		2.4	
Valley And Ridge Salamander	0.6			3.1

9.1 WHAT ARE SEASONAL (VERNAL) POOLS AND WHAT ANIMALS ARE FOUND IN THESE UNIQUE HABITATS?

Seasonal pools (often called vernal pools, vernal ponds, or ephemeral pools) are temporary pools of water. These pools usually fill with rain and snow melt during the fall, winter, and spring, and then dry completely by summer. Seasonal pools are typically small and shallow. While these pools are too temporary to support fish, they teem with life in the spring with frogs, toads, salamanders, and invertebrates like fairy shrimp. Seasonal pools have been declining in numbers in recent years, inspiring scientists to conduct more research into these important aquatic habitats.

Spotted Salamander

Seasonal Pools in Forest

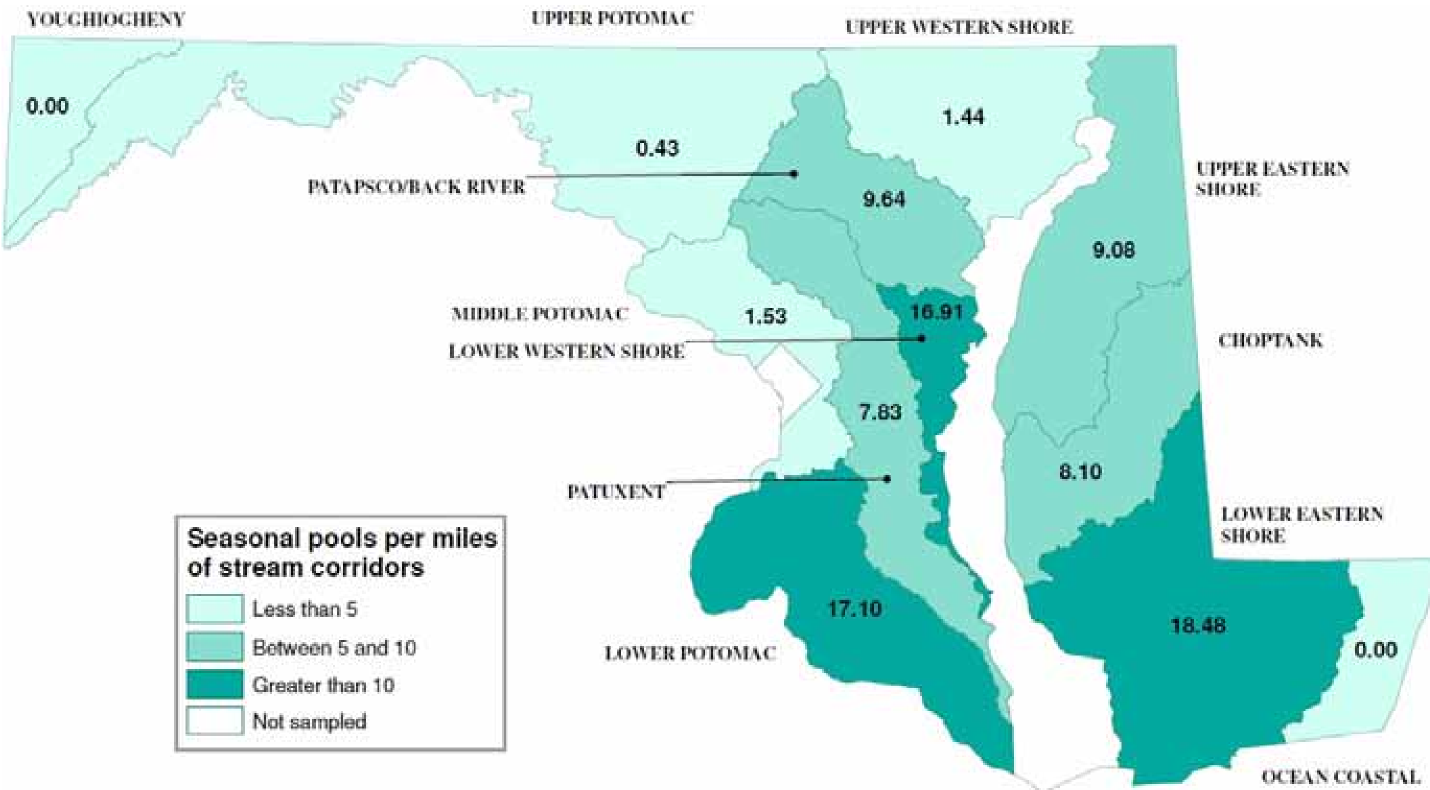
Beginning in 2007, the MBSS added searches for seasonal pools to their statewide stream monitoring protocol. Survey teams look for seasonal pools, mostly in the 50-m wide forested area along either side of each stream (i.e., basically the flood plain), but also along the access routes to each stream segment. Pool size, depth, and location are recorded, as well as the kinds of animals living in each pool. Between 2007 and 2009, all watersheds in the state of Maryland were visited as part of the Round 3 MBSS.

How Many Riparian-zone Pools are There in Maryland?

The total number of seasonal pools found within the 100-m wide stream corridors varied with the location of each watershed and with each year of MBSS sampling. During each year, 84 stream segments (sites) were sampled.

From these results, it is estimated that there are 6.25 pools per stream mile, or 57,521 seasonal pools in Maryland stream corridors.

The number of pools increases as you move east across the state. The density of pools throughout Maryland is shown in the map below as number of pools per mile of stream.



What are Some of the Pool Characteristics ?

Most seasonal pools were small in area and shallow. Thirty-one percent (31%) of pools had areas less than 20 m2, while 47% of pools were less than 20 cm deep. The majority of seasonal pools (88%) were adjacent to forested land.

Spring Peeper

Wood Frog

What Animals Live in the Pools?

About one-quarter of the pools in the State were occupied by one or more frog, toad, salamander, turtle, or fairy shrimp species (23% of the random sites sampled). Only about 10% of the pools had animals considered to be “obligates,” that is, animals that need seasonal pools to survive. The list of species seen or heard in seasonal pools during MBSS sampling is given in the table below:

Animals found in Maryland seasonal pools and the number and percentage of seasonal pools in which they occurred		
Species	**Number of Occurrences**	**Percentage of Pools Where Present**
Wood Frog	26	8.1
Spotted Salamander	15	4.7
Northern Spring Peeper	10	3.1
Eastern Cricket Frog	5	1.6
Marbled Salamander	5	1.6
New Jersey Chorus Frog	5	1.6
Northern Green Frog	4	1.2
Pickerel Frog	3	0.9
Eastern Red-Backed Salamander	2	0.6
Eastern American Toad	1	0.3
Four-Toed Salamander	1	0.3
Southern Leopard Frog	1	0.3
Spotted Turtle	1	0.3
Upland Chorus Frog	1	0.3
Fairy Shrimp	1	0.3

10. What Can Marylanders Do to Help Their Streams?

There are countless ways Marylanders can get involved in protecting and restoring our freshwater streams. Marylander homeowners, farmers, and businesspeople are fortunate to have a wealth of information at their fingertips (just an internet click, email, or phone call away). Below are some easy ways to learn more and get involved.

10.1 CONTROL STORMWATER AT HOME

Stormwater running off rooftops, sidewalks and driveways eventually reaches a stream or river or the Chesapeake Bay. Stormwater may pick up debris, sediment, nutrients, heavy metals, and toxicants. By installing rain barrels and rain gardens, or even just disconnecting downspouts from impervious surfaces, we can reduce the volume of stormwater as well as the pollutant loads that degrade our waterways, by slowing the flow and purifying it as it infiltrates into our lawns and gardens. Planting trees and other native plants in place of impervious surfaces or traditional lawns also helps capture and clean stormwater in your yard.

Replanting riparian buffers is one of many ways we can work together to restore our streams

The Herring Run Watershed Association in Baltimore City has lots of information on how to disconnect your downspout and thus help keep our streams a little bit cleaner. The Chesapeake Bay Foundation website provides documents on simple ways to:

- Build a rain barrel
- Install a rain garden
- Create a truly "green" lawn by using natural soil amenities, planting locally adapted grass, watering deeply, and cutting back on fertilizer

10.2 GET CONNECTED WITH A LOCAL ORGANIZATION

Maryland has many active and well-established watershed organizations working to protect and restore our streams. Opportunities abound to help plant trees, monitor frog habitat, investigate illicit discharges, remove invasive plants, clean up trash, and more! The Maryland Tributary Strategies website contains a comprehensive list of watershed organizations from the Lower Eastern Shore to the Upper Potomac River.

10.3 GET YOUR FEET WET IN YOUR LOCAL STREAM

Many watershed organizations provide opportunities to monitor water and biological quality of streams. For example, The Chester River Association's Chester Testers measure nutrients and other indicators of water quality throughout the watershed. Results are used in an annual Watershed Report Card. The Jug Bay Wetlands Sanctuary sponsors an amphibian and reptile survey that helps track the habitat quality of many species that depend on clean water. Lastly, DNR's Stream Waders volunteers sample aquatic macroinvertebrates to help assess stream health statewide. After completing a one-day training session each February, volunteers grab their GPS units, don waders and sample up to 12 sites per sampling team in the same watersheds being sampled by MBSS crews. Results are used in watershed reports and volunteer findings can be found alongside those of the Maryland Biological Stream Survey. To get the latest Stream Waders updates, call the Stream Waders hotline at 410-260-8623 or find us on Facebook (Maryland Stream Waders)!

Students from Salisbury State University sample stream invertebrates during a Maryland Stream Waders training near Centerville. Photo by Dan Boward

10.4 GET FINANCIAL ASSISTANCE FOR YOUR ACTIONS

Maryland has several programs available through which private landowners can help protect the health of streams on their property. For example, the Conservation Reserve Program provides technical and financial assistance to eligible landowners to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner. CRP encourages landowners to convert highly erodible cropland and other environmentally sensitive areas to permanent cover, such as introduced or native grasses, trees, filter strips, riparian forest buffers, wetlands, and shallow water habitats.

The Maryland Agricultural Water Quality Cost Share Program (MACS) provides grants to help farmers protect natural resources such as freshwater streams. Since 1984, the MACS Program has been helping farmers maintain farm productivity and comply with a growing number of federal, state, and local environmental requirements. MACS provides farmers with grants that cover up to 87.5 percent of the cost to install best management practices (BMPs) on their farms to control soil erosion, manage nutrients, and safeguard water quality in streams, rivers, and the Chesapeake Bay. Cover crops planted after the fall harvest to soak up unused fertilizers, streamside buffers of grasses and trees planted to protect waterways from sedimentation and agricultural runoff, and animal waste storage systems designed to help farmers safely handle and store manure resources are among more than 30 BMPs currently eligible for funding.

The vision of the Maryland Environmental Trust (MET) is to provide landowners with information and tools to permanently protect natural, historic, and scenic resources in the state. As one of the oldest and most successful land trust in the country, MET holds over 1,000 conservation easements preserving over 125,000 acres statewide. From the Chesapeake Bay to the mountains of Garrett County, MET's Land Conservation, Monitoring and Stewardship, and Land Trust Assistance Program promote the protection of open land. MET also provides grants to environmental education projects through the Keep Maryland Beautiful Program. The MET website contains a directory of Land Trusts / Land Conversation Organizations in Maryland and Washington DC.

11. Will there be a Round Four of the Maryland Biological Stream Survey?

Yes. A Round 4 MBSS will begin in 2013, or possibly in 2014. The Round 4 survey will include the core component of randomly-selected sampling sites that will yield estimates of stream conditions and aquatic resource status with known levels of precision. As with the Round 3 sampling design, Round 4 will also include a targeted site selection component to answer several specific questions. Planning for the Round 4 MBSS was only recently started, so the final survey design is not complete. MD/DNR anticipates expanding the collection of physical habitat parameters to include more hydrogeomorphological measurements during Round 4. The Round 4 design will also likely add a third biological indicator, a stream salamander index of biotic integrity (IBI), to supplement the benthic macroinvertebrate and fish IBI's currently being used.

In 2012, much of DNR's stream sampling activities will be focused on a partial repeat, 25 years later, of the 1987 Maryland Synoptic Stream Chemistry Survey (or MSSCS). This chemistry survey was designed to estimate the percentages of headwater stream reaches in MD that were either acidic or very sensitive to acidic inputs from acid deposition (or more commonly, 'acid rain'). Acid rain was a major environmental issue in the 1970's and 1980's that is rarely talked about these days. With passage of amendments to the federal Clean Air Act in 1990, emission of sulfur and nitrogen oxides (precursors to the formation of acid rain) were expected to decrease. Repeating the 1987 MSSCS in the Appalachian Plateau – Western Valley and Ridge and Southern Coastal Plain, the two regions of MD with the largest percentages of acidified or acid-sensitive stream reaches in 1987, will enable MD/DNR to determine if federal (and state) mandates intended to reduce acidifying emissions have been effective and stream quality has improved as a result.