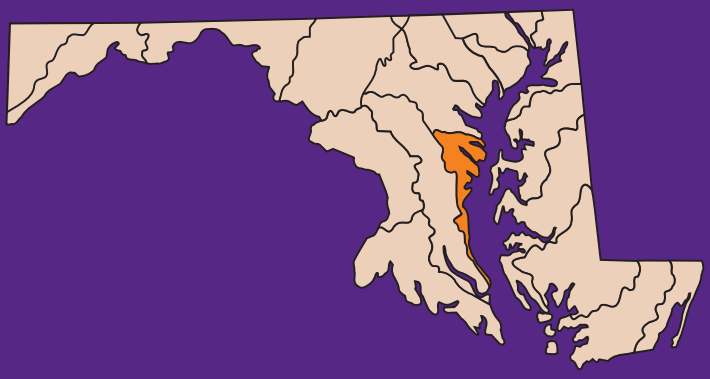
WEST CHESAPEAKE BASIN



ENVIRONMENTAL ASSESSMENT OF STREAM CONDITIONS

STATE OF MARYLAND
DEPARTMENT OF NATURAL RESOURCES

CHESAPEAKE BAY AND WATERSHED PROGRAMS
MONITORING AND NON-TIDAL ASSESSMENT

CBWP-MANTA- EA-99-9

Parris N. Glendening
Governor

Kathleen K. Townsend
Lieutenant Governor

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WEST CHESAPEAKE BASIN

ENVIRONMENTAL ASSESSMENT OF STREAM CONDITIONS

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September 1999

Maryland Department of Natural Resources
Resource Assessment Service
Monitoring and Non-Tidal Assessment Division
580 Taylor Avenue
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Sarah Taylor-Rogers, Secretary
Parris N. Glendening, Governor

FOREWORD

The Maryland Department of Natural Resources (MDNR) Monitoring and Non-tidal Assessment Division prepared this report for the National Oceanic and Atmospheric Administration's (NOAA) Coastal Zone Management Program under Contract No. C396-95-019. Eventually, basin reports will be prepared for each of the major drainage basins in the coastal zone region and elsewhere in the state.

The major source of data for this report is the Maryland Biological Stream Survey (MBSS), a statewide, acid-deposition monitoring and assessment program funded by the Maryland Power Plant Research Program and administered by the Department of Natural Resources. Field data for the West Chesapeake Basin was primarily collected by the University of Maryland's Wye Research and Education Center under Contract No. CB94-008-003 with MDNR. Chemical analysis of water samples was conducted by the University of Maryland's Appalachian Laboratory (AL) under Contract No. CB94-008-002 with MDNR. Much of the data analysis performed for this report was conducted by Versar, Inc. under Contract No. PR-91-047-001 with MDNR's Power Plant Research Division.

ACKNOWLEDGMENTS

We are grateful to Scott Stranko, Tony Prochaska, Marty Hurd, Chris Millard and Bill Rodney with Maryland Department of Natural Resources, and Bill Killen, Mark Scott, Jay Killian, and Cameron Speir, with the University of Maryland's Wye Research and Education Center for long hours spent in the field collecting the biological, chemical, and physical habitat data discussed in this report. We are also grateful to Katie Kline of the University of Maryland's Appalachian Laboratory for long hours and weekends spent in the water chemistry laboratory to ensure that holding times and quality control measures were met with water quality samples. We thank Janis Chaillou and the Versar landowner permission crew for long hours spent ensuring that permissions were obtained in a timely fashion. We also thank various MDNR staff: Marty Hurd for Geographic Information Systems (GIS) support, Lamar Platt for graphics suport, and Ron Klauda for editing this manuscript. We would also like to thank Janice Markusic of Anne Arundel County Office of Planning for her comments and edits, as well.

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EXECUTIVE SUMMARY

The primary purpose of this report is to describe existing aquatic resource conditions in first, second, and third order non-tidal streams of the West Chesapeake basin during 1997. This document also serves as an update to a previous Maryland Department of Natural Resources (MDNR) report on West Chesapeake basin conditions in 1994. Therefore, 1994 data is included in analysis and discussion where appropriate. All data were collected and analyzed using Maryland Biological Stream Survey (MBSS) protocols and techniques (Kazyak 1996).

The MBSS is a statewide survey of first, second, and third order streams conducted by the MDNR. The survey is used to characterize current biological, chemical, and habitat conditions and provide a basis for assessing future trends in Maryland streams.

The major findings of this report:

WATER QUALITY

- Seventeen percent (17%) of the stream miles were poorly-buffered, having acid neutralizing capacity (ANC) less than 200 *u*eq/l. In contrast, over three-quarters (76%) of the stream miles were well-buffered

- Relatively low nitrate levels (0.01-1 mg/l) were found in 66% of the stream miles sampled. Elevated nitrate levels (>1 mg/l) were found in 33% of the stream miles, indicating possible nutrient enrichment from groundwater and surface runoff.

- Eighty percent (80%) of the stream miles had dissolved organic carbon (DOC) levels less than 5mg/l, an indicator that wetlands do not play a major role in water quality of this basin. There were no measured DOC levels greater than 10 mg/l.

- Eighty-two percent (82%) of the stream miles in the basin had dissolved oxygen (DO) levels greater than 5 ppm (Maryland state standard).

PHYSICAL HABITAT

- Stream banks in 20% of the stream miles were badly eroded.

- Trash and other human refuse was abundant in approximately 20% of the stream miles in the basin.

- Eighty-two percent (82%) of the stream miles were well-shaded.

FISH

- Fish were collected at 32 out of 35 sites sampled by the MBSS in 1997.

- Thirty-seven fish species representing 16 families have been collected since 1994, including three gamefish species: rainbow trout, largemouth bass, and chain pickerel. None of the fish species collected are listed as rare, threatened, or endangered in Maryland.

- Total estimated population abundance of fish in first, second, and third order streams was 694,988.

- Fish species richness was low in many streams in the basin. The average number of fish species in each 75 m segment was 8.

- Fish density was estimated at 3,158 individuals per mile of stream.

- Basin-wide population estimates for individual species ranged from 19 for gizzard shad to 405,721 for eastern mudminnow.

- Six fish species taken in the West Chesapeake basin in 1997 (bluegill, green sunfish, largemouth bass, rainbow trout, goldfish, and black crappie) are not native to the Chesapeake Bay.

- Based on the MDNR fish Index of Biotic Integrity (IBI), about one-half of the stream miles were rated as Good or Fair, and one-half were rated as either Poor or Very Poor.

REPTILES AND AMPHIBIANS

- Reptiles and amphibians were found along 66% of the stream miles sampled in the basin. Frogs were the most common group, comprising 47% of the 12 species of herpetofauna collected.

BENTHIC MACROINVERTEBRATES

- Based on the MDNR benthic macroinvertebrate Index of Biotic Integrity, over 95% of the stream miles in the basin were rated Poor to Very Poor. Most of the benthic macroinvertebrates collected in the basin in 1997 were pollution tolerant.

- Development in the West Chesapeake Basin appears to be affecting some aspects of water quality and physical habitat. A total of 48.5% of the basin's land use is classified as forested (Figure 1), 25.1 % is urban, 17.0% is agricultural, and 0.7% is wetlands.

- Historical data is insufficient to determine how much or how recently fish abundance and distribution have changed. It is clear that there will be unprecedented population growth in the basin in the next 30 years. Diligent monitoring will be necessary to determine if the streams and rivers in the basin continue to degrade as more development occurs.

This report also includes appendices that describe the sampling methodology, water quality and physical habitat measurements, and fish population and density estimates used to generate results for this report. Maps showing the distribution of each fish species collected within the West Chesapeake Basin during 1994 and 1997 sampling are also included at the end of this report.

Maryland
Biological
Stream
Survey

Maryland
Biological
Stream
Survey

Introduction

Chapter One 1

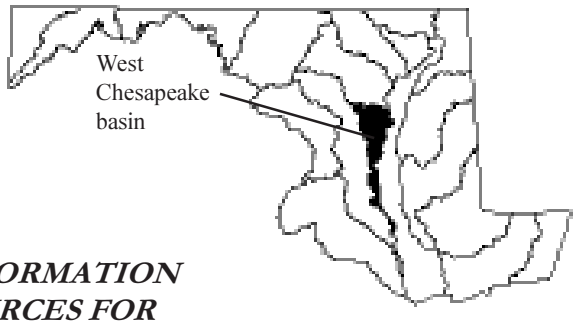
PURPOSE OF REPORT

The primary purpose of this report is to describe aquatic resource conditions in first, second, and third order non-tidal streams in the West Chesapeake basin in Maryland. It also serves to characterize water quality and habitat problems in the basin. Characterizations of this type will be useful as basin-specific strategies for protecting and restoring water quality in Chesapeake Bay are developed and refined.

STREAM RESOURCES

The flowing waters of Maryland represent a vital lifeblood to its residents. In addition to providing a source of drinking water and water for agricultural and industrial uses, Maryland's streams and rivers offer recreational opportunities, attract tourists, and support commercially important fish and shellfish species. The riparian corridors associated with streams and rivers contain some of the richest and most diverse plant and animal communities found anywhere in the state. They also temper the effects of heavy rainfall and storm water runoff. In many cases, the aesthetic attraction of streams and rivers has served as a catalyst for economic development. Nearly all of the rivers and streams in Maryland, including those in the West Chesapeake basin, drain into Chesapeake Bay. Therefore, the quality of streams and rivers in the basin has a direct impact on the health of Chesapeake Bay, one of Maryland's most important economic and natural resources.

Despite these values, Maryland's streams and rivers have often been abused and neglected, converted to flood routing systems, or used as receptacles for unwanted wastes. Increasingly, Marylanders are realizing that our mistreatment of natural resources is neither economically nor environmentally sustainable. Efforts are being made to restore degraded stream systems and to protect healthy streams.



INFORMATION SOURCES FOR THIS REPORT

This report uses 1997 and 1994 data collected by the Maryland Biological Stream Survey (MBSS) conducted by the Maryland Department of Natural Resources. Although the focus of the MBSS is on acid deposition impacts, the survey is being used for other purposes including basin characterizations, estimation of fish populations, and prioritization of restoration efforts.

To provide some comparison of present and past conditions, historical information is presented where appropriate. In addition, information on land use, hydrology, and other aspects of the basin are presented so that current stream conditions can be placed in context with other basin characteristics.

The MBSS is a statewide survey of first, second, and third order streams designed to characterize current biological and habitat conditions, identify major human stresses, and provide a basis for assessing future trends in aquatic resources in Maryland. The probabilistic design (all streams have a known probability of being sampled) used for the Survey allows unbiased estimates of stream characteristics and conditions. For example, the population of a given fish species in a basin can be validly estimated using the MBSS design. Because first, second, and third order streams represent close to 100% of the non-tidal stream miles in the West Chesapeake basin, MBSS results should accurately represent overall stream quality.

Maryland Biological Stream Survey

Basin Description

Chapter Two 2

HISTORY

The first colony of European settlers was established in the West Chesapeake around 1649. Further settlement of the West Chesapeake basin began soon after a land treaty was signed with the Susquehannock Indians in 1652. By 1700, a shipping port had developed at Annapolis and soon became an important hub for general commercial activity in the region as tobacco grown in the area was exported.

By the beginning of the twentieth century, deforestation and shoreline alteration began in earnest as more and more people moved into the region. Farming and urban development continued to increase, and expansion of the Baltimore/Washington area spawned development of highways and towns. Eventually, coves and wetlands were filled and progressively deeper channels were dredged to handle larger cargo ships and U.S. Navy vessels moving in and out of Baltimore Harbor and Annapolis (Davison and Rucker 1988).

BASIN CHARACTERISTICS

This section provides a brief overview of the ecological, recreational, and economic resources found in the West Chesapeake basin. It is intended to provide a context for the assessment of stream habitat and resource conditions presented in Chapter 4.

The West Chesapeake basin drains 313 square miles in Anne Arundel and Calvert counties, including the Magothy, Severn, South, West, and Rhode rivers. The downstream portions of these rivers are tidal and brackish. There is a total of 220 miles of 1st through 3rd non-tidal streams in the basin. First order streams make up 82% of the total stream miles; while second and third order streams constitute 13% and 5% of the stream miles, respectively.

The climate in the West Chesapeake basin is generally humid and temperate, with an average annual temperature of 56° F and an average daily maximum in the summer months of 87° F. The mean annual precipitation within the basin ranges from 39-44 inches (Maryland Office of Planning 1994).

The basin lies entirely within the Coastal Plain physio-province. The soils of the area originate from a wide variety of parent material including unconsolidated deposits of gravel, sand, silt, and clay . The steep topography and deeply cut stream valleys expose many different sedimentary layers, some of which are alluvial deposits laid down by rivers since the Cretaceous period, 65-145 million years ago. These deposits tend to be dominated by gravel, sand, and silt. Other layers were deposited under marine or estuarine conditions from the Miocene to the early Cretaceous Period. These sediments are comprised of fine sand, silt, and clay (Glaser 1976, USDA 1973). The marine deposits include glauconitic sediments which contain reduced sulfur compounds. Sulfates are released as part of natural weathering, but human influence accelerates this process by exposing highly acidic, sulfide-bearing sediments at road cuts and other excavations (Davis 1996).

Land Use and Human Population

Nearly one-half of the West Chesapeake basin is classified as forested (Figures 1 and 2). About one-quarter is urban, 17.0% is agricultural, and 0.7% is wetlands (MOP 1994).

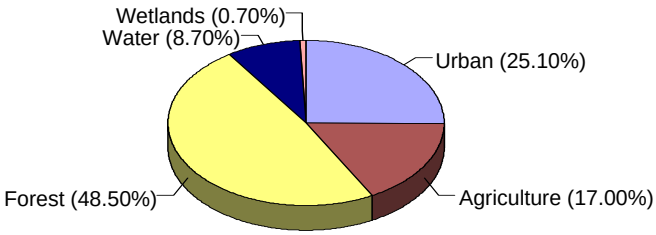


Figure 1. Land Use in the West Chesapeake basin, 1994.

Based on 1990 census data, 234,000 people live in West Chesapeake basin, making it the third most densely populated of the 18 major basins in Maryland. This basin is part of the high-growth area of southern Maryland where the population is expected to increase 80% by the year 2020. More houses are expected to be built in the next 30 years than were built in the preceding 300 years (MOP 1994).

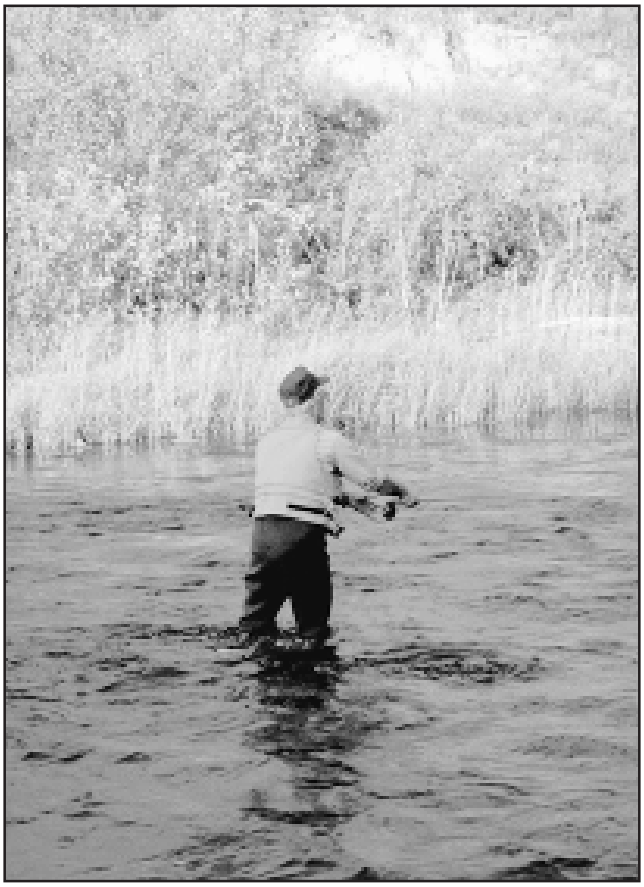
There are five municipal discharges and seven industrial discharges in the basin which have National Pollution Discharge Elimination System (NPDES) permits. While each of these point sources discharges to surface waters, only one of the industrial discharges is classified as major; all others are classified as minor. (USEPA 1998)

WATER QUALITY

For the period 1995-1997, MDNR reported that water quality in the West Chesapeake basin was generally good and showed no chronic exceedance of State water quality criteria (MDNR 1998). The basin partially supports water quality goals for swimability and fishability. Pollution in streams is considered to be minimal based on the presence of moderate numbers of pollution-sensitive benthic macroinvertebrates at fixed sampling stations.

Typically, the lower non-tidal and upper tidal portions of river embayments experience severe depressions in dissolved oxygen during summer due to algal blooms, poor flushing, and turnover. Low-oxygen water from Chesapeake Bay intrudes into the deeper regions of the tidal Magothy, South, and Severn rivers. Local restrictions on shellfish harvesting and swimming have occasionally occurred as a result of sewer overflows, particularly in tidal coves of the Severn River. Highway construction on routes I-97 and U.S. 50/301 has contributed to elevated sediment loads and water temperature increases in the Severn and South rivers.

Lake Waterford is the only significant, publicly owned lake in the basin. This 12-acre impoundment is listed as only partially supporting aquatic life, as a result of high, persistent turbidity levels resulsing from excessive waterfowl which denude the shoreline and permit uncontrolled erosion to the lake (MDNR 1998).



Recreational fishing is very popular in several areas throughout the West Chesapeake basin.

RESOURCE VALUES

Recreational and Ecological Resources

Maryland DNR annually stocks one area in the basin, Severn Run, with rainbow trout. Severn Run is a nine-mile long tributary to the Severn River. It is Maryland's southernmost Class IV (recreational trout) stream and most of the stocked trout are caught in the same year that they are stocked. Jabez Branch, which is Severn Run's largest tributary, has about 0.5 miles of native trout habitat (Class III) that supports a small naturally-reproducing brook trout population.

In addition to streams, tidal areas are also popular fishing areas in the West Chesapeake. Estuarine species like white perch, striped bass, spot, and Atlantic croaker mix with freshwater species such as largemouth bass and chain pickerel to keep the angler busy with a variety of catch.

The basin also has numerous parks, forest, and recreational areas such as the Severn Run Environmental Area, Thomas Point Park, and Sandy Point State Park.

Boating in the West Chesapeake basin is extremely popular, as it is throughout most of the Chesapeake Bay region. Because of the port of Annapolis and the high density of waterfront homes and communities, recreational boating is quite convenient and may have serious impacts on water quality and physical habitat within the basin.

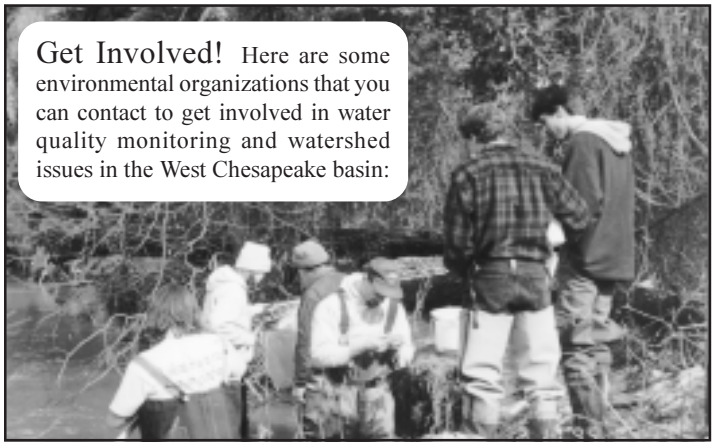
The Severn River Commission was established by Anne Arundel County and the City of Annapolis in 1985 to advise government on environmental issues in the watershed. One primary issue is addressed by the commission, development of land for residential or commercial purposes. Even minor, incremental amounts of development may have a cumulative impact on the ecological resources of the basin over time. The commission stresses the need to consider the eventual consequences of small development on ecological resources.

Extractable and Renewable Resources

The basin contains few mineral deposits of commercial value, although historically some sand and clay have been extracted for glass-making. Currently, sand and gravel are extracted from several areas, but these materials are used primarily to provide raw materials for local highway construction and maintenance. All forested areas in the basin are considered second growth timber.

Citizen Involvement

During the last decade, an increasing number of concerned citizens have become involved in organizations and programs working to protect Maryland's aquatic resources. Many such organizations focus their work on a particular river basin or stream and perform activities such as water quality monitoring and citizen education. In the West Chesapeake basin, citizen monitoring groups have been established on the Magothy, Severn, West, South, and Rhode rivers.



Get Involved! Here are some environmental organizations that you can contact to get involved in water quality monitoring and watershed issues in the West Chesapeake basin:

Alliance for the Chesapeake Bay
6600 York Road
Baltimore, MD 21212
410.377.6270

Chesapeake Bay Foundation
164 Conduit Street
Annapolis, MD 21401
410.268.8833

Trout Unlimited
2916 Trellis Lane
Abington, MD 21009
410.555.1212

Magothy River Assoc.
P.O. Box 550
Severna Park, MD 21146
410.544.7529

Magothy River Land Trust
P.O. Box 126
Severna Park, MD 21146
410.974.0756

Save Our Streams
258 Scotts Manor Drive
Glen Burnie, MD 21061
410.969.0138

South River Assoc.
3265 Harness Creek Road
Annapolis, MD 21043
410.267.9692

Severn River Assoc.
P.O. Box 146
Annapolis, MD 21404
410.263.0435

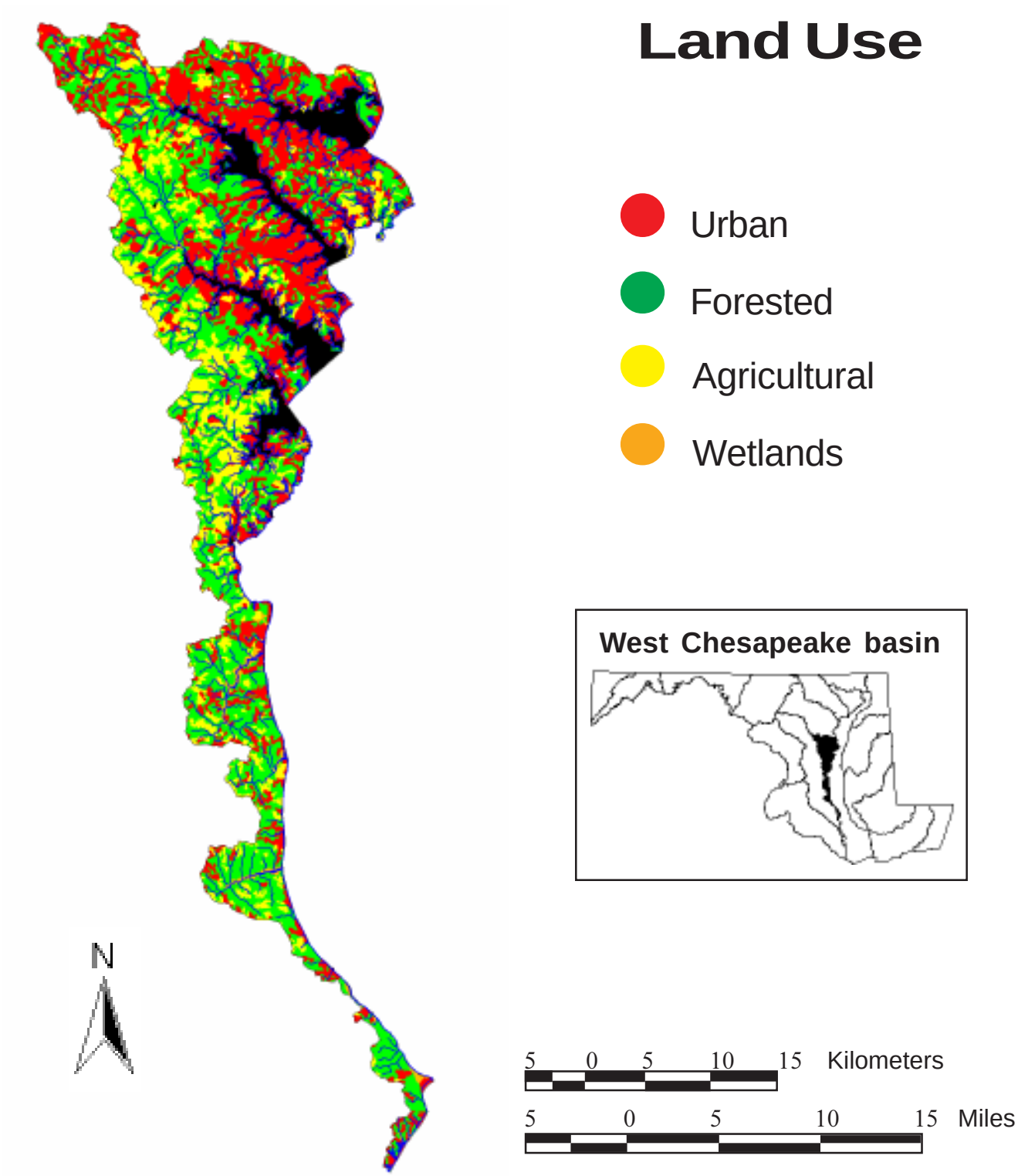


Figure 2. Land Use in the West Chesapeake basin during 1994 (MOP 1994). Inset map shows the basin's location within Maryland.

Maryland Biological Stream Survey

Survey Design and Methods

Chapter Three 3

This chapter briefly outlines the approach used to collect data for assessing the stream resources of the West Chesapeake basin during 1994 and 1997. The sampling design differed from other stream surveys that have been conducted in Maryland. Randomly selected sampling sites for the MBSS on first, second, and third order streams (Strahler 1964) were chosen by computer rather than hand-picked by the investigator. This approach allows estimates to be calculated for an array of ecological factors such as fish density and stream habitat condition. Non-randomly selected sites were also sampled to provide additional information on fish distributions. Figure 3 shows the random and non-random sampling sites from the 1994 and 1997 MBSS.

After landowner permissions were obtained, sample sites were located with Global Positioning System (GPS) receivers, fish and benthic macroinvertebrates were collected, and physical habitat features were evaluated using methods patterned after EPA's Rapid Bioassessment Protocols (Plafkin *et al.* 1989). Water quality was sampled using protocols previously established for acid rain studies in Maryland (MDNR 1988). Because the primary purpose of the MBSS is to assess the effect of acid rain on Maryland streams and rivers, other important water quality measures such as phosphorus and turbidity were not measured.

MBSS biologists take benthic samples during the spring.

MBSS crews use electrofishing backpacks and nets to stun and collect fish for identification and analysis.

Reptiles, amphibians, and mussels were also surveyed on a presence/absence basis. All catchments draining to MBSS sampling sites were delineated and land use percentages were determined for each (MOP 1994). Throughout all sampling and data management activities, an extensive Quality Control program was employed. Additional technical information about the methods used to survey streams and the survey results can be found in Volstad *et al.* 1995 and Kazyak 1996 and in the Appendices of this report.

Thanks Maryland!

91% of the landowners contacted in the West Chesapeake basin gave permission to have streams on their property sampled by the MBSS.

By allowing the Maryland DNR to sample biological communities in the streams on private property, citizens help ensure the quality of Maryland's aquatic resources. Thanks!

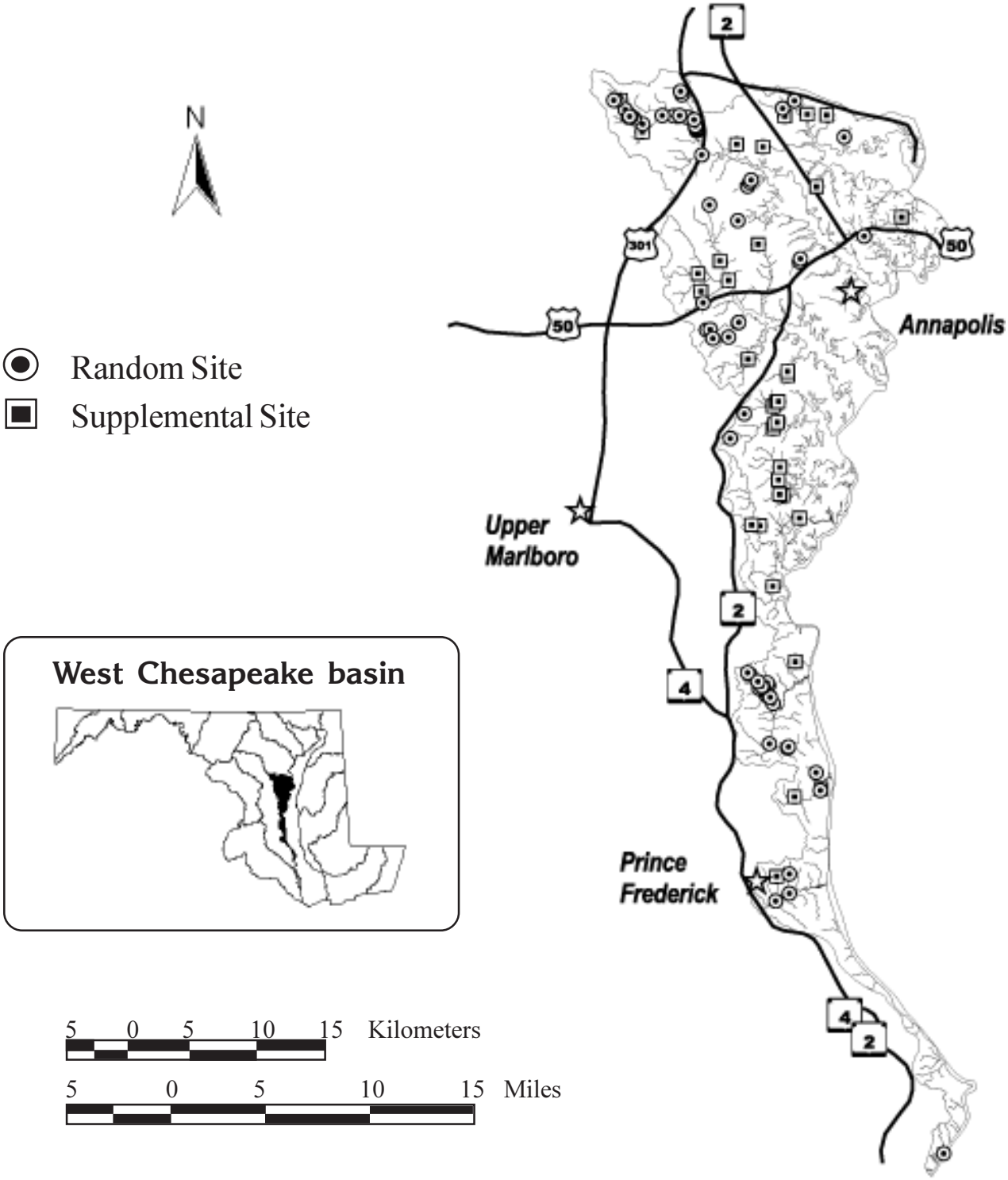


Figure 3. Locations of 1994 and 1997 sampling sites in the West Chesapeake basin. Major highways, population centers, and other features are shown for reference. Inset map shows the basin's location within Maryland.

Maryland Biological Stream Survey

Current State of Aquatic Resources

Chapter Four 4

This chapter uses 1997 MBSS data to describe the current status of first through third order non-tidal streams. A list of streams sampled is presented in Appendix B. Where appropriate, the inclusion of 1994 data is presented.

WATER QUALITY

pH and Buffering Capacity (ANC)

Eighty-four percent of the stream miles had spring and summer pH levels greater than 6.0 at the time sampling, suggesting that acid loading in the basin does not have a dominating effect on stream chemistry. (Figure 4). However, the remaining 16% of the stream miles have values less than 6.0. Significant adverse impacts on aquatic life are known to occur for some species when pH values drop below 6.0, and for most species at pH less than 5.0.

Acid neutralizing capacity (ANC) data show that *episodic* acidification may be a problem in the West Chesapeake basin. Approximately 10% of the stream miles had ANC values between 0 and 200 *u*eq/l (Figure 5). Streams with ANC values of less than 200 *u*eq/l are considered to be poorly-buffered and susceptible to episodic depressions in pH level. In addition, 7% of the stream miles had ANC values less than 0 *u*eq/l, and are severely impacted by acidification.

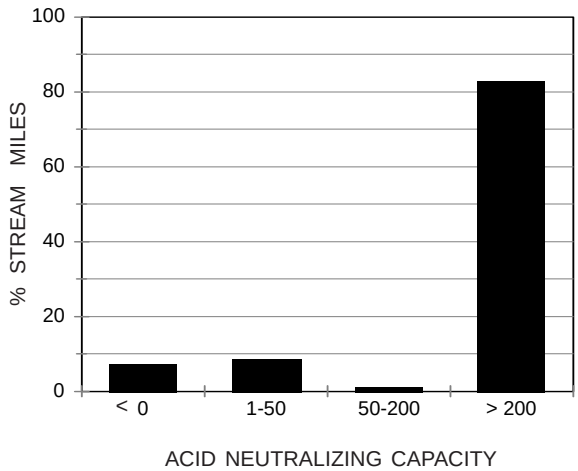


Figure 5. Acid Neutralizing Capacity (ANC) in non-tidal streams of the West Chesapeake basin, 1997.

Acidity in streams....

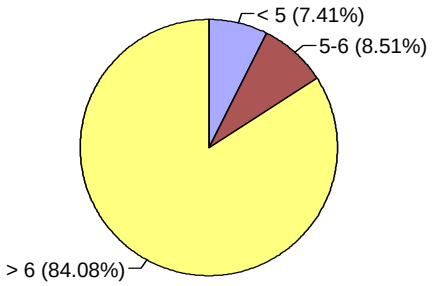


Figure 4. Spring pH levels in non-tidal streams of the West Chesapeake basin,1997. pH levels were above 6.0 for 84% of the stream miles at time of sampling.

An important aspect of water quality in streams of the West Chesapeake basin is acidity. The balance between free hydrogen ions (H+), and hydroxide ions (-OH) is measured as pH. The capacity of soil or water to absorb acids without changing the ion balance is known as its buffering capacity, measured as alkalinity in some studies but as acid neutralizing capacity (ANC) by the MBSS. Under acidic conditions, heavy metals such as aluminum are dissolved into stream water and can reach concentrations which are lethal to aquatic organisms. Acidity in streams is affected by rain, snow, atmospheric dust, geology, soil characteristics, and organic matter.

Acidification of streams can be either chronic (year-round) or episodic (storm event-related), depending on the capacity of the stream to buffer acid inputs. Chronically-acidified streams contain only those organisms that are highly tolerant of acid conditions (one example in the West Chesapeake basin is the eastern mudminnow), while streams which are episodically-acidified can and often do support less tolerant "invaders" from better-buffered downstream areas.

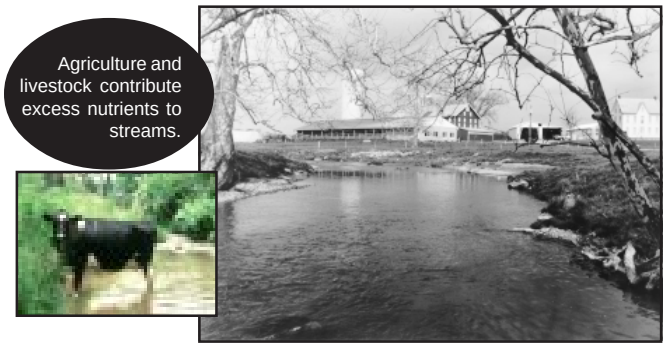
Nitrates and Dissolved Organic Carbon

Two important indicators of the sources of acidity in Maryland streams are nitrate and dissolved organic carbon (DOC).

One important source of nitrates in Maryland streams is deposition from the atmosphere. However, leaching into groundwater and direct runoff of fertilizers and animal wastes used on agricultural lands, discharges from sewage treatment plants, and leaking of septic systems are also important sources of nitrates to streams. Stream nitrate concentrations greater than 1 mg/L are elevated compared to undisturbed streams (Morgan 1995).

The primary source of DOC in streams is leachate from decaying leaves and other plant material that are natural sources of organic matter found within the stream drainage network itself, especially wetlands. DOC concentrations greater than 10 mg/L indicate that organic acids contribute significantly to overall acidity, but DOC levels between 5 and 10 mg/L also indicate that natural sources are contributing to overall acidity in a stream (Morgan 1995).

In 1997, 33% of the stream miles in the basin had elevated baseflow nitrate values (greater than 1 mg/l), while 66% of the stream miles had relatively low levels (0.01 to 1 mg/l) (Figures 6 and 8). As ongoing nutrient reduction strategies are implemented in the basin by Maryland Tributary Strategies Teams, these levels may decline.



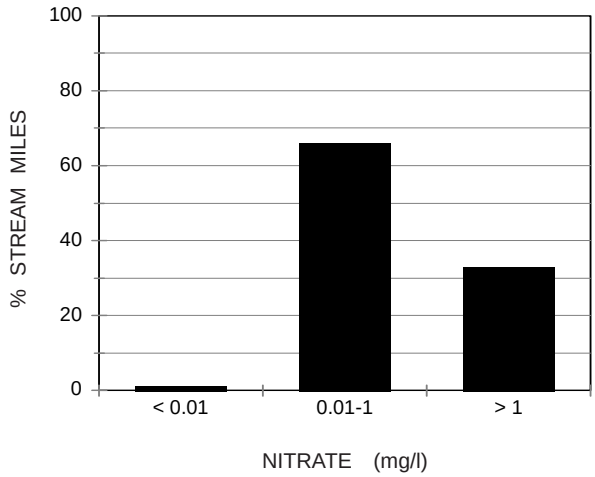


Figure 6. Nitrate levels in non-tidal streams of the West Chesapeake basin, 1997.

Eighty-eight percent of the stream miles had DOC levels below 5 mg/l, while the remaining 12% had levels ranging from 5 to 10 mg/l (Figure 7).

These data suggest that DOC is only a minor source of acidity in West Chesapeake basin streams. Relatively low DOC also indicates that relatively few wetlands are present in the basin.

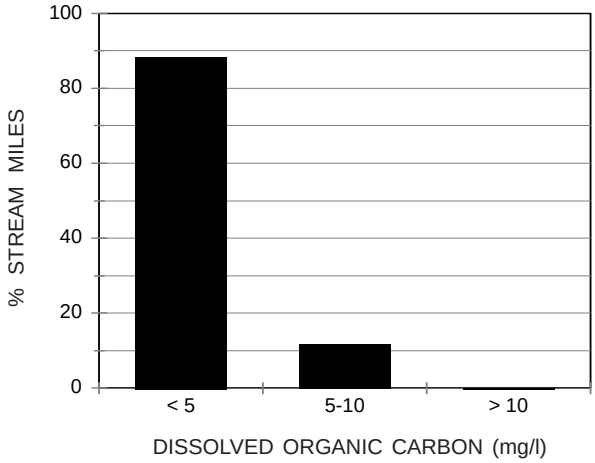


Figure 7. Dissolved organic carbon levels in non-tidal streams of the West Chesapeake basin, 1997.

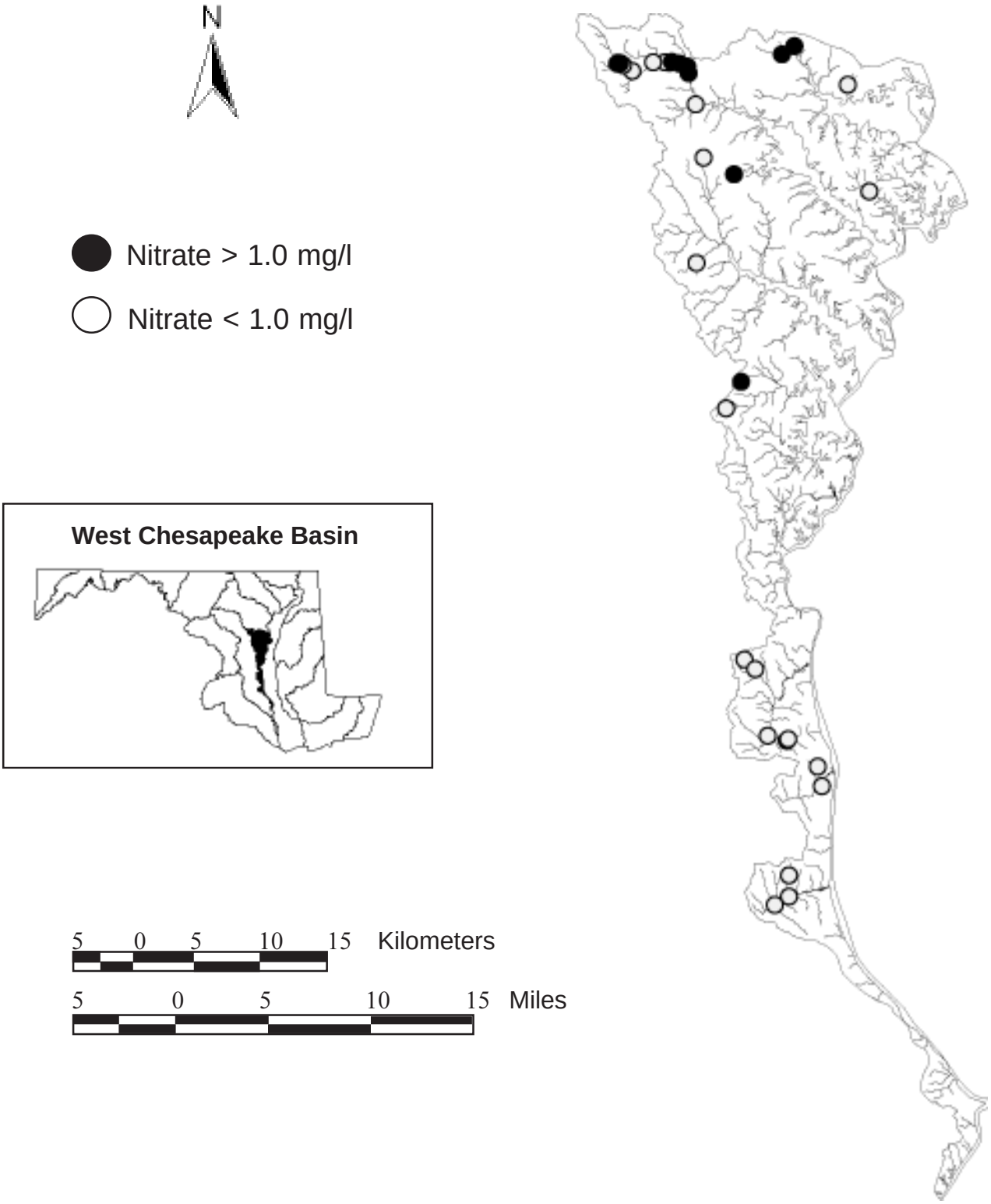


Figure 8. Nitrate concentrations in the West Chesapeake basin, 1997.

Dissolved Oxygen

An adequate amount of dissolved oxygen (DO) is one of the most basic requirements of aquatic organisms, thus DO levels play an important role in shaping biological communities in streams. DO in streams may be low due to nutrient-rich runoff and groundwater inputs from urban and agricultural areas, oxygen demanding organic chemicals in point source discharges, or the breakdown of naturally-occurring organic material such as leaves.

The State of Maryland has established a minimum surface water criterion of 5 milligrams per liter (mg/L, also known as parts per million) for DO. When DO is low (i.e., less than 5 mg/l), only those organisms adapted to low DO can persist. Streams typically have riffles, where water bubbles over rocks. Riffles help to keep DO levels high by aerating the water. During MBSS summer sampling, dissolved oxygen is measured only once during the day. In heavily impacted streams, DO may drop severely during the early morning hours because oxygen production from plants ceases at night while oxygen consumption by both plants and animals continues.

Eight-two percent of the stream miles had DO levels above the state water quality standard of 5 ppm (Figure 9) (COMAR 1995). This result indicates that biochemical oxygen demand (BOD) from the breakdown of organic matter is generally not high enough to depress DO to unhealthy levels.

Approximately, 1 in 5 stream miles had DO violations on the day that they were sampled, indicating that many more likely had low DO at some point during the summer. Given the relatively low levels of DOC measured in the streams of the basin and the relatively low percentage of agricultural land use (17%), low DO conditions are likely caused urban areas.

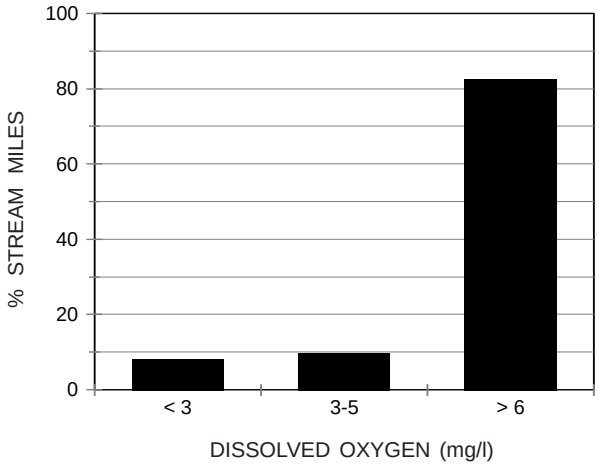


Figure 9. Dissolved oxygen levels in non-tidal streams of the West Chesapeake basin, 1997.

PHYSICAL HABITAT

Many physical habitat characteristics of streams are important determinants of ecosystem structure and function. Although a large number of habitat variables are measured by the MBSS, they can be grouped into four general categories: instream habitat; channel character; riparian zone; and aesthetics/remoteness. Most variables are classified as either: Good, Fair, Poor, or Very Poor. A description of selected habitat variables is included in Appendix D.

MBSS crew measure the **velocity** and **flow** of every stream sampled. Velocity and flow of a stream are important physical habitat characteristics used to characterize habitat in streams.

Instream Habitat

The complexity and stability of habitat in a stream typically has the strongest relationship to abundance and diversity of the biological communities that occur there. Important instream habitat characteristics include: 1) quality and composition of stream bottoms; 2) diversity of depth and flow; and 3) the amount and quality of stable habitat for fish and attachment sites for benthic macroinvertebrates.

Instream habitat data showed 41% of the stream miles rated as either Fair or Good, and 59% rated as either Poor or Very Poor (Figure 10). Most instream habitat problems in the basin result from: the removal or loss of woody debris from stream channels in agricultural and urban areas; little to no vegetative buffer between pastures, croplands, urban lands and streams; an increase in sediment loads; modification of stream channels because of increased runoff; and reductions in stream flow caused by groundwater withdrawal.

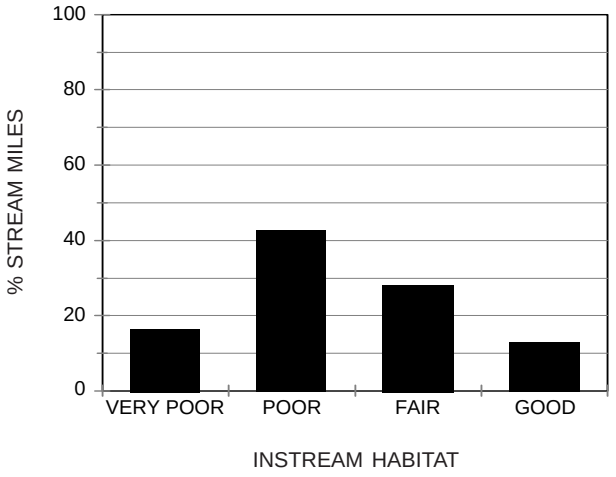


Figure 10. Instream habitat condition in non-tidal stream of the West Chesapeake basin, 1997.

Added sediment loads tend to reduce the complexity and stability of the stream bottom, resulting in loss of habitat for fish. Another result, measured by embeddedness, is the coating or burial of cobble and vegetation by silt. Because many benthic macroinvertebrates use gravel and vegetation as living quarters, sediment reduces the amount of available habitat and reduce the diversity and abundance of benthic macroinvertebrates. Most stream miles (98%) in this basin were rated as either in Fair or Good condition for embeddedness (Figure 11).

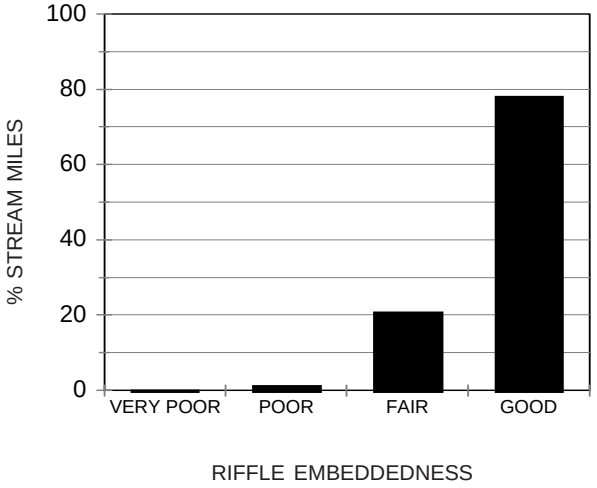


Figure 11. Riffle embeddedness rating in non-tidal stream of the West Chesapeake basin, 1997.

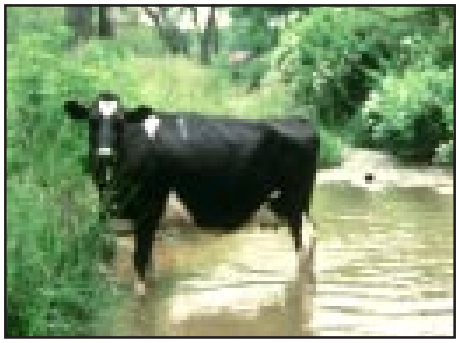
Wood in streams enhances habitat quality by providing a diverse array of shelter, depths, and velocities for both fish and benthic macroinvertebrates . Woody debris traps and retains leaves, providing a vital food supply for many benthic macroinvertebrates. By retaining organic matter in and near the stream channel, the export of nutrients to the Chesapeake Bay is also reduced. Therefore, removal of large woody debris such as logs, tree limbs, and rootwads along the stream banks and in stream channels is undesirable and can have an adverse impact on stream quality.

About 161 pieces of woody debris were found per stream mile in the West Chesapeake basin, while about 16% of the stream miles had no woody debris.. As a measure of comparison, wood often controls 80% or more of the stream channel in streams with old growth forests (Maser and Sedell 1994); thus woody debris densities in the basin prior to extensive human disturbance were likely to be much higher than even the least disturbed streams sampled in 1997.

Channel Characteristics

Large scale disturbance in the stream channel may result from logging, watershed development, or direct channel modification. Evidence of stream channel disturbance includes excessive bar formation, the presence of artificial structures (i.e., concrete armoring and rip-rap), channel dewatering for irrigation and other uses, and severe bank erosion.

Eighty-two percent (82%) of the stream miles in the basin were found to be artificially straightened and channelized. During channelization, trees in the riparian zone are often cut and wood is removed from the stream channel to allow for efficient movement of water away from agricultural fields or housing developments. As a result, heavily channelized streams are generally shallow, with little habitat for living organisms, while downstream areas suffer from increased flooding problems. Channelization also causes reduced retention and rapid transport of nutrients through the basin and into Chesapeake Bay.



The movement of cattle through streams can cause bank erosion and eventually produce sediment pollution.

Although very stable, concrete channels cause other problems such as loss of habitat and rapid changes in stream velocity and flow.

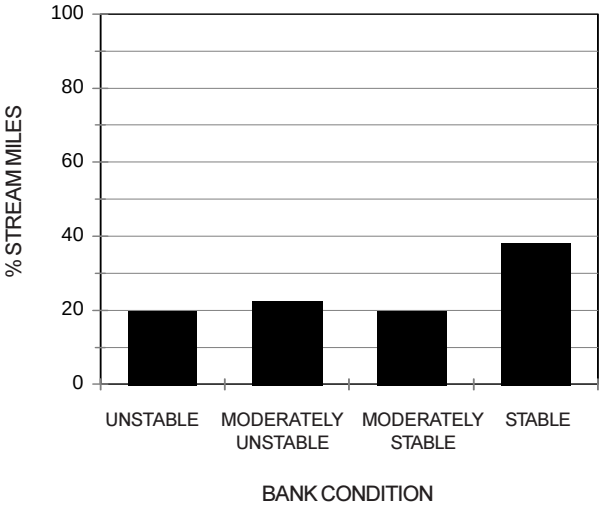


Figure 12. Bank condition in non-tidal streams of the West Chesapeake basin,1997.

Twenty percent of the stream miles in the basin had unstable stream banks, while 22% were rated as moderately unstable, and 38% were rated as stable (Figure 12). Unfortunately, unstable banks are difficult to repair and are a significant source of unwanted sediment and nutrients.

SEDIMENT POLLUTION is created when soil washes into the water from unstable stream banks, earthmoving, and poor agricultural practices. Loose soil particles enter the water and eventually settle to the stream floor, smothering bottom dwelling organisms and increasing flooding potential by forming large deposits of silt. By one estimate, every ton of sediment added to a stream can add 20 tons of additional sediment from additional bank erosion! We can protect our streams from sediment pollution by allowing vegetation to grow along stream banks and using cover crops on unused agricultural fields.

RIPARIAN ZONES

Riparian zone conditions along streams in the West Chesapeake Basin were generally Good (Figure 13), with vegetated buffers present along 83% of the stream miles, providing habitat for many corridor-dependent species. Forest buffers predominated in 57% of the stream miles.

Forest cover along basin streams greatly decreases the exposure of streams to direct sunlight and helps to prevent warming of stream waters above their natural conditions. When waters warm beyond their natural conditions, biological communities have a difficult time adjusting and can become stressed.

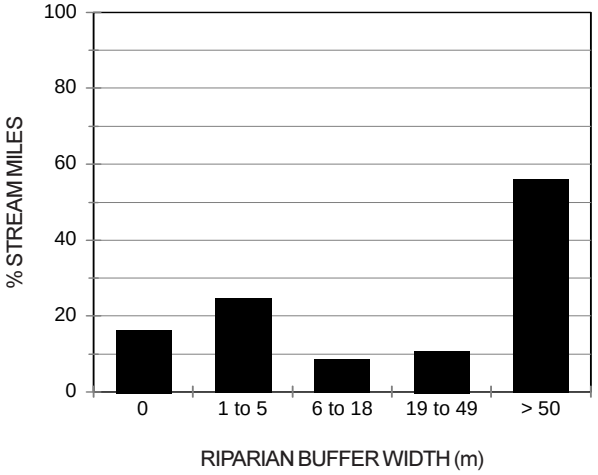
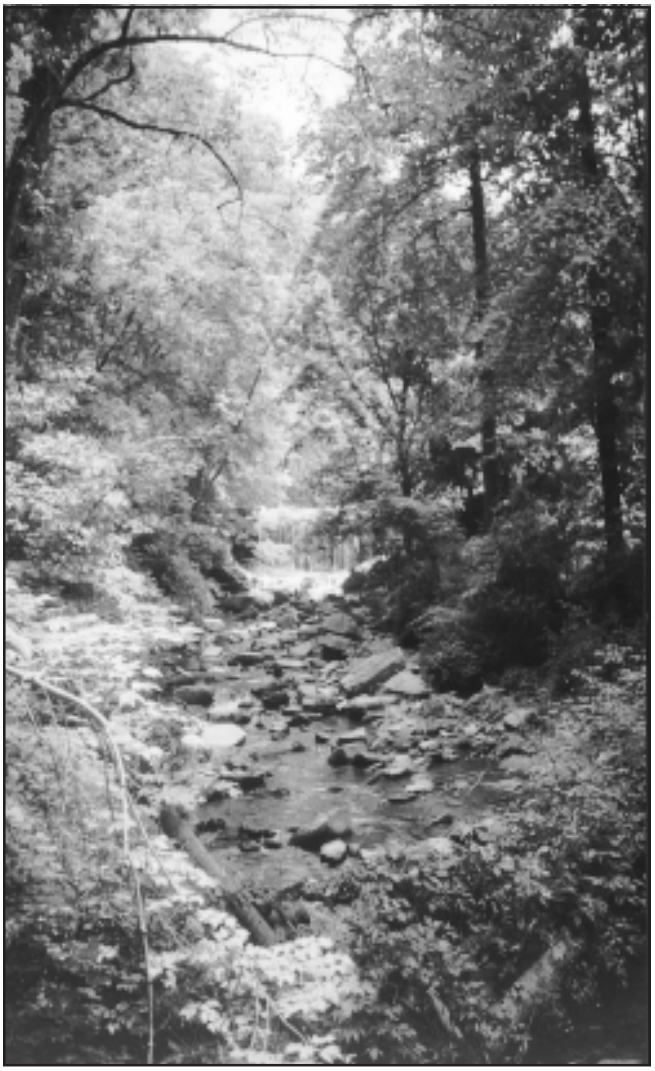


Figure 13: Riparian buffer width in non-tidal streams of the West Chesapeake basin, 1997.



Riparian Buffer Zone - when areas alongside streams and rivers are vegetated, they act as a protective buffer by decreasing the amount of run-off and pollutants entering the water. A healthy riparian zone also stabilizes the stream channel and provides food, shade, and instream cover for aquatic life.

RIPARIAN ZONES are the areas alongside streams, rivers, and other waterbodies. When these areas are vegetated, they play a vital role in structuring and maintaining physical habitat, energy flow, and aquatic community composition. *Vegetated* (trees, shrubs, and grasses) riparian zones act as buffers by decreasing runoff and preventing particulate pollutants from entering streams (Plafkin *et al.* 1989). Vegetation stabilizes stream channels; supplies overhead and instream cover for fishes and other aquatic life; moderates stream water temperature; and provides energy inputs to the stream in the form of leaf litter and woody debris.

Riparian Zones

Aesthetic Quality and Remoteness

What is the worst stream pollution problem? When asked this question, many people respond with one word, "trash." Although trash in and along streams is unsightly and undesirable, it is not the primary cause of stream degradation. However, it may be a good indicator of upstream watershed conditions.

The more people living in a watershed, the more likely trash will end up in the stream draining the watershed. Some groups conducting stream monitoring programs are developing indicies based on the number of trash items (such as shopping carts!) at a stream site. Quantifying stream characteristics such as trash will help us gauge our success in stormwater management, public education, and even recycling.

The aesthetic value of streams in the basin was scored according to the amount of human refuse found at a site. Only one-quarter of the stream miles received an aesthetic rating of Good, while approximately one-half were rated as Poor to Very Poor (Figure 14). The amount of excessive trash is consistent with the degree of urbanization in the basin.

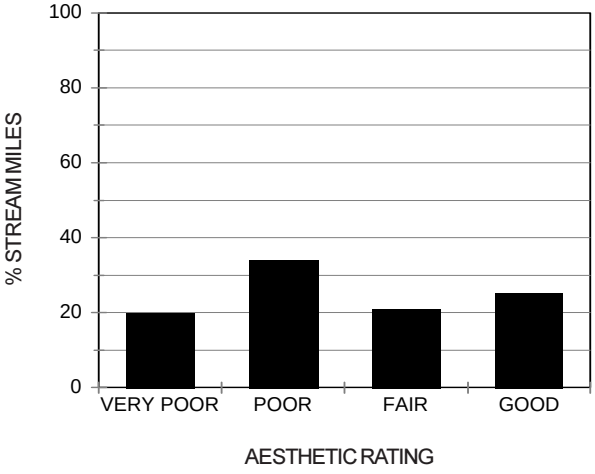


Figure 14. Aesthetic rating for non-tidal streams of the West Chesapeake basin,1997.

FISHERY RESOURCES

General Description

A total of 37 fish species representing 16 families were collected in the basin during 1994 and 1997 MBSS sampling. Table 1 shows a comprehensive list of all fish species collected during quantitative (random) and qualitative (non-random) sampling in these years. Consistent with the warmwater habitat in the basin, the **minnow family** (Cyprinidae) and **sunfish family** (Centrarchidae) were represented by the most species (8 each), followed by the **killifish family** (Fundulidae) with 3 species. All other families were represented by two or fewer species.

In 1997, fish were collected at 32 out of 35 random sites sampled by the MBSS. Sites with low species richness or no fish at all were primarily in the upper reaches of first order streams, where the likelihood of the stream drying up in summer is higher.

As is typical in streams throughout Maryland, more fish species were collected in larger streams. An average of 11 species per site were found in third order streams, 6 species in second order streams, and about 4 species in first order streams. The three species of fish most commonly found in 1997 were American eel, eastern mudminnow, and blacknose dace.

Based on 1997 data, the total estimated population of fish in first, second, and third order streams is 695,000 individuals. The average abundance of fish in 1997 was 3,200 per stream mile (Table 1). For individual species, densities ranged from less than 1 gizzard shad per stream mile to 1502 individuals per stream mile for eastern mudminnow.

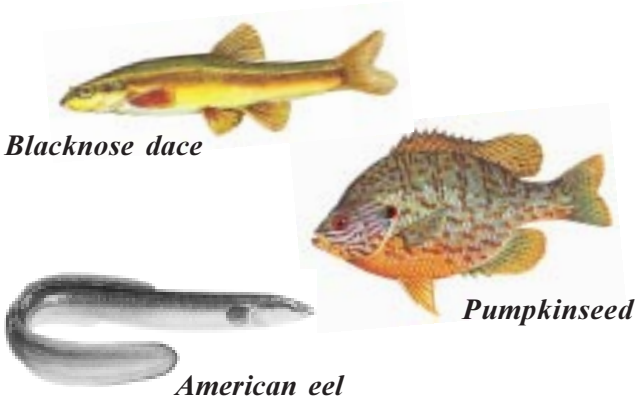


Table 1. Estimated total abundance and percentage occurrence of fish species collected in the West Chesapeake basin in 1997 (first, second, and third-order non-tidal streams combined). 1994 fish are also listed with no population estimates.

Family	Common Name	(*Scientific Name*)	Percentage Occurrence[1]	Population Estimate[2,3]	Standard Error
Petromyzontidae					
	Least Brook Lamprey	*(Lampetra aepyptera)*	6.67	88,726	87,371
	Sea Lamprey	*(Petromyzon marinus)*	0.95		
Anguillidae					
	American Eel	*(Anguilla rostrata)*	67.62	49,913	14,494
Clupeidae					
	Gizzard Shad	*(Dorosoma cepedianum)*	0.95	19	19
Esocidae					
	Chain Pickerel	*(Esox niger)*	20.00	673	206
	Redfin Pickerel	*(Esox americanus)*	17.14	1,015	447
Umbrida					
	Eastern Mudminnow	*(Umbra pygmaea)*	62.86	405,721	279,838
Cyprinidae					
	Blacknose Dace	*(Rhinichthys atratulus)*	36.19	50,434	34,097
	Fallfish	*(Semotilus corporalis)*	4.76	23,964	23,886
	Golden Shiner	*(Notemigonus crysoleucas)*	25.71	3,048	1,543
	Goldfish	*(Carassius auratus)*	0.95	125	125
	Rosyside Dace	*(Clinostomus funduloides)*	4.76	12,053	12,014
	Satinfin Shiner	*(Notropis analostana)*	2.86	154	123
	Spottail Shiner	*(Notropis hudsonius)*	1.90	590	569
	Swallowtail Shiner	*(Notropis procne)*	0.95	19	19
Catostomidae					
	Creek Chubsucker	(*Erimyzon oblongus*)	6.67	1,294	1,073
	White Sucker	(*Catostomus commersoni*)	16.19	3,056	935
Ictaluridae					
	Brown Bullhead	(*Ameiurus nebulosus*)	22.86	1,454	817
Salmonidae					
	Rainbow Trout	(*Oncorhynchus mykiss*)	0.95	39	27
Atherinidae					
	Inland Silverside	(*Menidia beryllina*)	0.95		
Fundulidae					
	Banded Killifish	(*Fundulus diaphanus*)	1.90		
	Mummichog	(*Fundulus heteroclitus*)	15.24	12,114	11,088
	Rainwater Killifish	(*Lucania parva*)	0.95		
Poeciliidae					
	Eastern Mosquitofish	(*Gambusia holbrooki*)	2.86	562	514
Moronidae					
	Striped Bass	(*Morone saxatilis*)	7.62		
	White Perch	(*Morone americana*)	0.95		

Table 1: Continued

Family	Common Name	(*Scientific Name*)	Percentage Occurrence[1]	Population Estimate[2,3]	Standard Error
Centrarchidae					
	Black Crappie	(*Pomoxis nigromaculatus*)	1.90	250	250
	Bluegill	(*Lepomis macrochirus*)	29.52	4,717	2,464
	Bluespotted Sunfish	(*Enneacanthus gloriosus*)	0.95		
	Banded Sunfish	(*Enneacanthus obesus*)	0.95	781	758
	Green Sunfish	(*Lepomis cyanellus*)	16.19	4,187	1,414
	Largemouth Bass	(*Micropterus salmoides*)	8.57	30,872	30,694
	Pumpkinseed	(*Lepomis gibbosus*)	34.29	11,146	6,626
	Redbreast Sunfish	(*Lepomis auritus*)	2.86	19	21
Percidae					
	Tessellated Darter	(*Etheostoma olmstedi*)	31.43	17,753	7,351
	Yellow Perch	(*Perca flavescens*)	12.38	1,181	498
Sciaenidae					
	Spot	(*Leiostomus xanthurus*)	0.95		

[1] Percent of all random and nonrandom sites where each species was collected.
[2] Total abundance (number per basin) adjusted for capture efficiency (Heimbuch et al. 1997).
[3] Nonrandom site information was not used in calculating population estimates.

Gamefish

Three species of gamefish were captured during 1997 sampling. Largemouth bass were the most common gamefish, averaging 140 individuals per stream mile. The estimated population of largemouth bass was 30,900 individuals. In contrast, chain pickerel averaged 3 individuals per stream mile and had an estimated population of 673. Even fewer rainbow trout were collected, likely because temperatures in most streams of the basin are too warm for stocked trout in summer. Other gamefish captured in 1994 MBSS sampling efforts included young striped bass. The only legal-sized gamefish species taken in the 1997 survey were rainbow trout.

Rainbow trout

Twenty percent of all fish captured in second order streams in 1997 were gamefish, although none were of legal size. Third order streams yielded considerably lower numbers of gamefish (2% of total catch) and no gamefish were taken from first order streams. The lower and middle portions of the major non-tidal tributaries in the basin provide suitable spawning habitat for largemouth bass, white perch, and yellow perch. Current regulations prohibit the taking of some gamefish in the Magothy, Severn, South, and West rivers.

Jabez Branch, in Severn Run has about 0.5 miles of natural **brook trout** habitat which was not randomly selected for sampling in 1997. Jabez Branch is sampled annually by MDNR Fisheries Service.

Migratory Species

There are three types of migratory fish in Maryland, anadromous, semianadromous, and catadromous. Anadromous species live as adults in estuarine or marine waters, moving into freshwater only to spawn. Semianadromous species, which also live as adults in estuarine or riverine waters, also move into freshwater to spawn, but generally migrate lesser distances. Catadromous species live as adults in freshwater, migrating to marine water to spawn.

Only two species of migratory fish were taken in the non-tidal portion of the West Chesapeake basin in 1997; American eel, and yellow perch. The catadromous American eel, which is catadromous, was the most abundant migratory species, with an average density of more than 200 individuals per stream mile and was collected at 68% of the sites sampled. Yellow perch, which are semianadromous, had an average abundance of 8 individuals per stream mile and were collected at 12% of the sampled sites.

Yellow perch

FISH INDEX OF BIOTIC INTEGRITY

Maryland DNR recently developed an Index of Biotic Integrity (IBI) for non-tidal stream fish communities (Roth et al. 1997) that is an effective tool for evaluating ecological conditions in streams. Using this IBI, various characteristics of the fish community are compared to results from high quality reference streams. The IBI score is then used to assess ecological conditions of streams in the basins Good, Fair, Poor, or Very Poor.

Based on the Maryland DNR's fish Index of Biotic Integrity (IBI), about one-half of the stream miles were rated as Good or Fair, and half were rated as either Poor or Very Poor in 1997 (Figures 15 and 16).

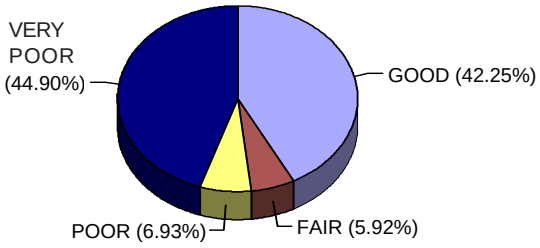


Figure 15: Fish Index of Biotic Integrity ratings for West Chesapeake basin, 1997

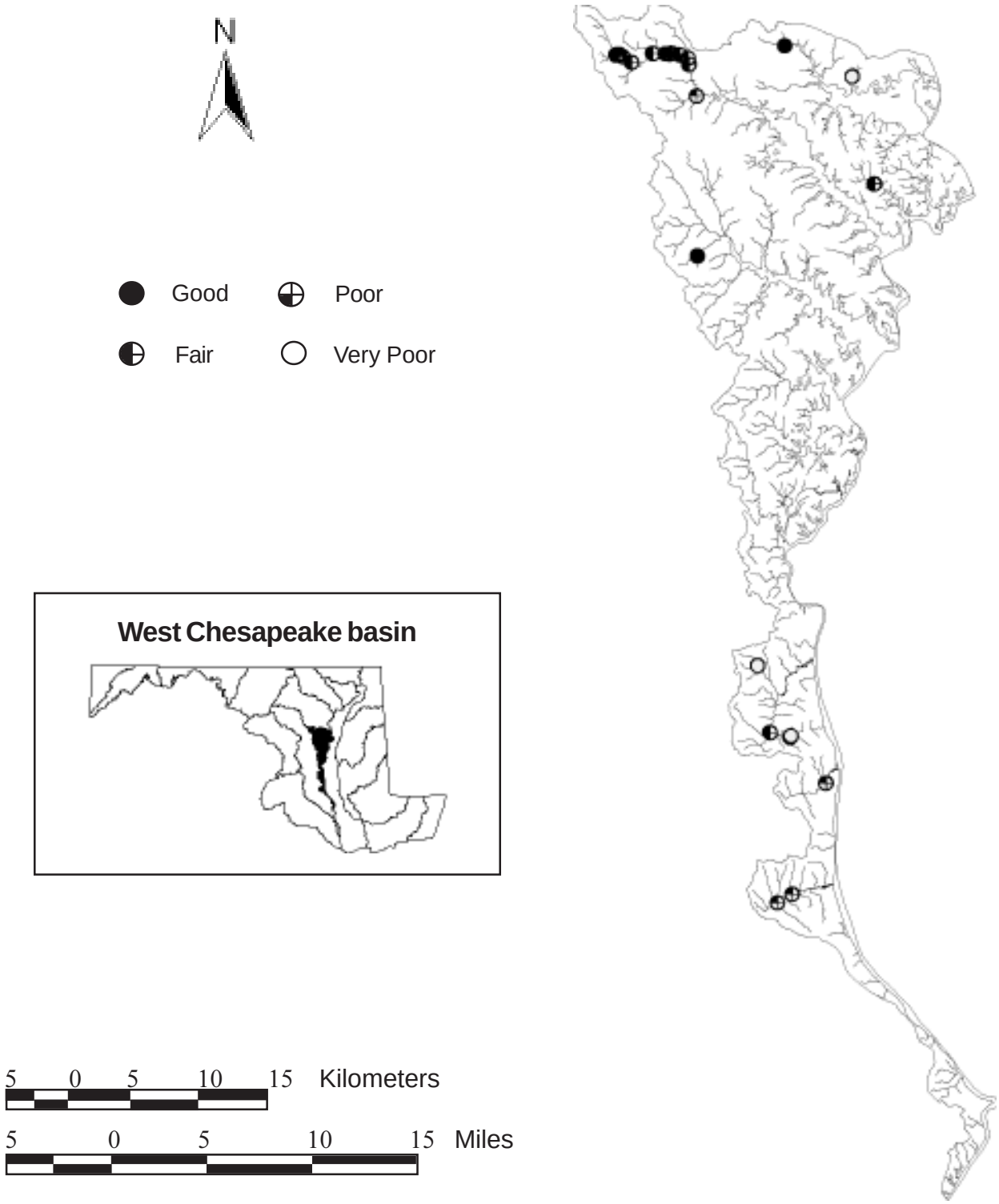
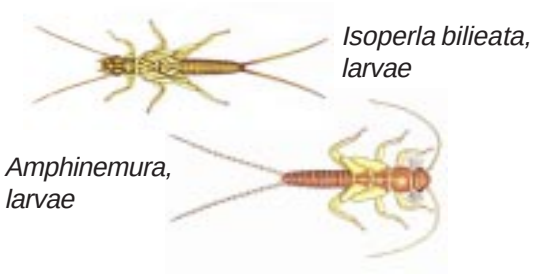


Figure 16. Fish Index of Biotic Integrity ratings, 1997.

Benthic Macroinvertebrates

Of the more than 350 taxa of stream dwelling benthic macroinvertebrates in Maryland, about one-third (118) were found in the West Chesapeake basin, and the total number of taxa per site ranged from 1 to 35. Dominant taxa and their respective percentage occurrence among all sites in the basin were: *Cricotopus/Orthocladius* (82%), *Conchapelopia* and *Amphinemura* (both 51%), *Parametriocnemus* (45%) and *Rheocrictopus* (45%). In contrast, there were 48 individual macroinvertebrate taxa that were found only at a single site, an indication that many tax in the basin are rare. A list of all benthic taxa collected is found in Appendix F.

Most benthic macroinvertebrates collected in the basin in 1997 are considered pollution tolerant. The percentage of the macroinvertebrate taxa which are mayflies (Ephemeroptera), stoneflies (Plecoptera), or caddisflies (Trichoptera), collectively referred to as EPT, is an indicator of stream health. Generally, the higher the percentage of EPT, the better the stream health. EPT comprised 24% of the benthic macroinvertebrates collected in the basin in 1997, which is a low to intermediate value for Maryland streams.



BENTHIC INDEX OF BIOTIC INTEGRITY

Similar to the fish Index of Biotic Integrity (IBI) described earlier, DNR has developed a benthic macroinvertebrate IBI for Maryland streams. The IBI used in the West Chesapeake basin includes several metrics that measure taxa richness, pollution sensitivity, feeding modes, and habit. IBI scores range from 1 (Very Poor) to 5 (Good).

Based on Maryland DNR's benthic IBI, less than 5% of the stream miles were rated as Good or Fair (Figures 17 and 18). Close to 95% were rated as Poor or Very Poor.

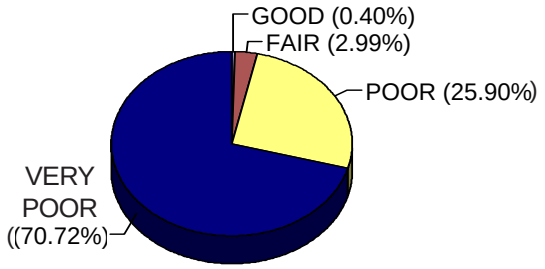


Figure 17: Benthic Index of Biotic Integrity ratings for West Chesapeake basin, 1997.

Benthic macroinvertebrates, or simply "benthos", are animals without backbones larger than 0.5 millimeter (the size of a pencil dot). These animals live on rocks, logs, sediment, debris, and aquatic plants during some period of their life. Benthos include crustaceans, such as crayfish; mollusks, such as clams and snails; aquatic worms; and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

A Maryland DNR Biologist uses a **D-Net** to take samples of benthic macroinvertebrates from Jabez Branch, Anne Arundel County.

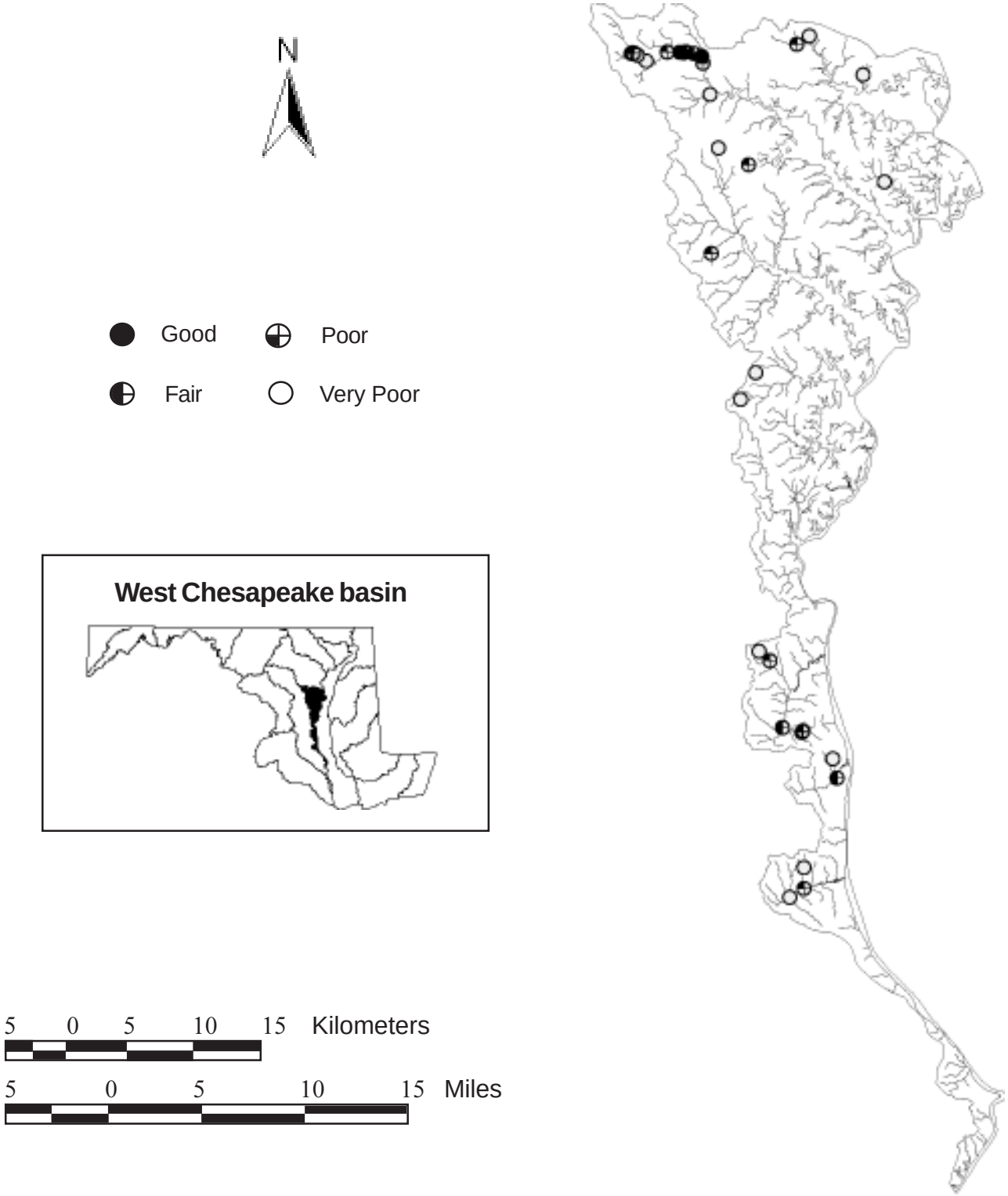


Figure 18. Benthic macroinvertebrate Index of Biotic Integrity rating, 1997.

Fish IBI vs. Benthic macroinvertebrate IBI

When comparing the fish IBI with the benthic macroinvertebrate IBI, one will notice that nearly 50% of the stream miles were rated as fair or good using the fish IBI, and that less than 5% of the stream miles were given these two ratings when assessed with the benthic macroinvertebrate IBI (Figure 19). The discrepancy between the indicies may be partially attributed to the number of sites assessed. No fish IBIs were calculated for those sites having upstream watersheds less than 300 acres because small, shallow streams may naturally support few fish species. In these small streams the IBI may indicate natural conditions rather than anthropogenic stresses. Benthic IBIs, however, were calculated for all sites in the basin. Another possible explanation is that habitat requirements for the fish are different than benthos.

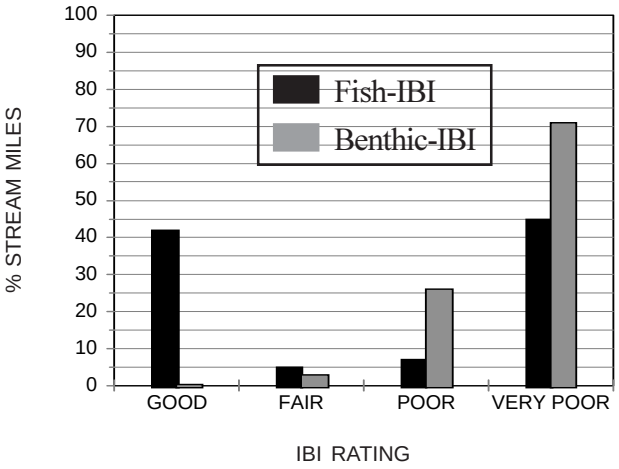


Figure 19. Fish and benthic macroinvertebrate Index of Biotic Integrity ratings for non-tidal streams of the West Chesapeake basin,1997.

Reptiles and Amphibians

Reptiles and amphibians were present at 66% of the sampling sites. Frogs and Toads were the most common taxa present, found at 47% of the sites sampled in the basin. Reptiles appeared at 31% of the sites, and salamanders at 21%. Seven species of frogs were collected, including; bullfrog, green frog, spring peeper, northern leopard frog, southern leopard frog, pickerel frog, and wood frog. Three species of salamanders were captured; northern-dusky, red salamander, and northern two-lined salamander. Four species of reptiles were collected: eastern box turtle, common musk turtle, eastern painted turtle, and northern water snake (Table 2).

Table 2: List of reptiles and amphibians found in the West Chesapeake basin, 1994 and 1997.

Frogs and Toads
- Bullfrog (*Rana catesbeiana*)
- Fowler's Toad (*Bufo woodhousii fowleri*)
- Green Frog (*Rana clamitans melanota*)
- Northern Leopard Frog (*Rana pipiens*)
- Northern Spring Peeper (*Pseudacris crucifer crucifer*)
- Pickerel Frog (*Rana palustris*)
- Southern Leopard Frog (*Rana utricularia*)
- Wood Frog (*Rana sylvatica*)

Turtles
- Common Musk Turtle (*Sternotherus odoratus*)
- Eastern Box Turtle (*Terrapene carolina carolina*)
- Eastern Painted Turtle (*Chrysemys picta picta*)

Salamanders
- Northern Dusky Salamander (*Desmognathus fuscus fuscus)*
- Northern Two-Lined Salamander (*Eurycea bislineta*)
- Red Salamander (*Pseudotriton ruber*)

Snakes
- Northern Water Snake (*Nerodia sipedon sipedon*)

Maryland
Biological
Stream
Survey

Summary of Stream Resource Conditions

Chapter Five 5

Information from the Maryland Biological Stream Survey has provided us with a snapshot of living resources, stream conditions, and major stressors to the aquatic habitat in the West Chesapeake basin.

Like most Maryland watersheds, the West Chesapeake basin consists of streams that range in quality from extremely degraded to relatively healthy. Every stream in the basin has been altered in a negative way by human activity; this fact is important for the reader to note when interpreting results which may at times seem contradictory. An example is the fact that fish IBI results paint a brighter picture of stream conditions than the benthic IBI. Because of their increased mobility, fish may be able to avoid temporarily stressful conditions simply by moving to a more tolerable area. Consequently, stream quality assessments should be based on more than one living resource.

During more than three centuries of European habitation, the streams of the West Chesapeake basin have been subject to repeated clearing of all forests and elimination of many non-tidal wetland areas. At present, about 25% of the basin has been urbanized. As urbanization continues its sprawl throughout the basin, further degradation of aquatic resources is inevitable because mitigation efforts are often unsuccessful (Schueler 1997), and can never fully correct the many types of impacts associated with human disturbance. This increased degradation of streams will at least partially offset progress made towards restoring the living resources of Chesapeake Bay and its tributaries.

Based on MBSS characterizations, most streams were rated as having Poor habitat; thus, reduced quality of physical habitat appears to be an important limiting factor to living resources in the basin. Although 83% of stream miles in the basin had relatively good riparian zones, about 17% of the stream miles were rated as having no functional riparian buffer, thereby reducing the ability of streams in the basin to function as a natural system. When there is a lack of functional riparian zone next to a stream, nutrients are not retained where they are needed, and essential habitat for many species is not present.

More than one-half of the streams in the basin contain large amounts of human refuse- an indication that other, more harmful additions are being made to streams. The frequency at which trash was observed is clearly an indication that environmental stewardship efforts need to be increased.

Smothering of stream bottoms by silt is widespread in the basin, reducing habitat available for benthos and food supplies for fish. Although overland run-off from new construction projects and agricultural fields may be a significant problem in some streams, one potentially important and overlooked source of silt in the West Chesapeake basin may be from streambanks. An estimated 42% of streambanks are eroded, with severe problems in 20% of streams. Each ton of soil eroded from a stream bank can generate as much as 20 tons of additional eroded soil in dowstream areas. The lack of bank stability may be due to logging practices, ongoing urbanization, and cultivation of lands immediately adjacent to streams. In each of these cases, the abundance of trees and tree roots in the stream channel has been reduced or eliminated altogether, reducing the ability of streams to dissipate the erosive power of water during storms. The lack of wood in streams also contributes to the generally poor habitat for fish found in the basin.

At present, baseflow nitrate-nitrogen levels in about one-third of the streams of the basin are elevated well above natural levels, and activities such as agriculture, lawn care, sewage plant effluent, and is the chief source of this nutrient. Because this condition represents current and historical nutrient additions, it may be years to decades before the benefits of nutrient reduction efforts begin to be realized. Further, reducing nutrient levels in just a few target streams will be unlikely to correct the overall problem A general reduction in nitrogen loading throughout the basin will be necessary. Although the effects of widespread overenrichment are reflected in low DO levels in about 18% of West Chesapeake stream miles, low DO in the tidal portions of the basin result in significant problems for living resources.

Elevated nitrate-nitrogen levels were present in 99% of the stream miles indicating that land use in the basin is clearly increasing nutrient loads to streams. Although urban runoff may be a contributor of excess nitrate, agricultural lands are probably the largest contributor to the source of nitrate-nitrogen in the basin's streams. Forested buffers, however, have been shown to aid in the retention of nutrients. As forested buffers increase along side streams, nitrate levels decrease (Figure 20).

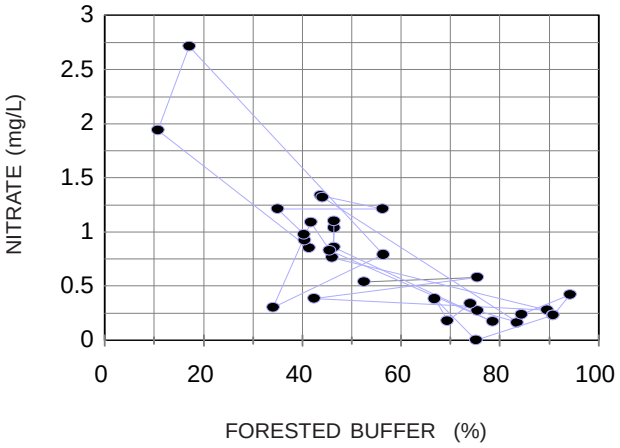


Figure 20: Percent forested buffer vs. nitrate concentrations in West Chesapeake basin, 1997.

Because lime is routinely applied to agricultural fields in the basin, most streams are protected from the effects of acid rain. However, 15% of the streams in the basin may suffer biological losses during large runoff events. Although these types of events may be infrequent, they can have a large and often lasting effect on stream conditions and should not be dismissed as being too infrequent to impact natural resources. In addition, species adapted to the relatively acidic conditions in the coastal plains are often displaced by cosmopolitan species when pH is increased too far.

In 1997, precipitation in the basin was generally lower than average (Figure 21) . Extremely dry periods during summer baseflow may have caused considerable stress in fish and benthic communities, thus potentially lowering IBI scores. Unfortunately, there is little historical information on the basin's fish and benthic communities. Thus, it is difficult to determine how stream health has changed over time. When the MBSS is repeated in future years, more information will be available to assess trends.

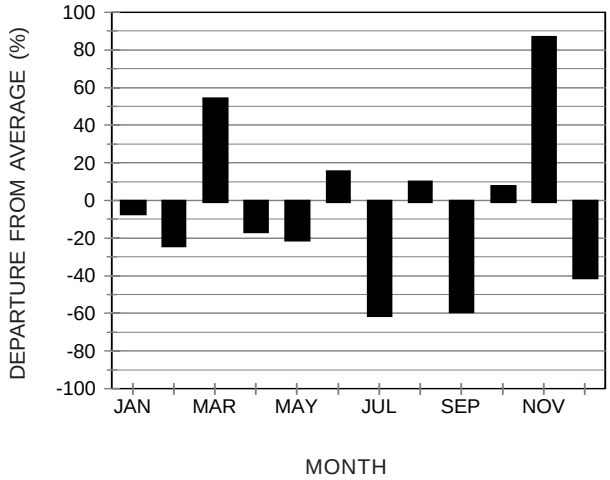


Figure 21: Monthly rainfall in West Chesapeake basin, 1997. Bars indicate the departure, as percent, from average monthly rainfall amounts for the period 1967-1997.

Although relatively few violations of state water quality criteria were observed during sampling in 1997, the living resources of the basin clearly indicate that problems exist. About one-half of the streams in the basin were rated as Poor or Very Poor by the fish IBI, while the benthic IBI rated more than three-quarters of all streams in Poor or Very Poor condition. Considering that overall ratings from the physical habitat index were somewhat lower than ratings from fish and about the same ratings from benthic macroinvertebrate communities, there may be periodic water quality problems that were not present at the time water chemistry samples were collected by the MBSS.

In addition to identifying impaired areas, the IBI results also indicate areas of higher biological integrity areas that should receive protection from disturbance. One approach endorsed by a number of prominent scientists is to conduct restoration activities to reconnect areas of high integrity via forested corridors along streams and defer restoration work on highly degraded areas until the higher quality resource areas are adequately secured (Doppett, *et al.* 1993). Although more characterization work is necessary to more fully define higher quality areas, the MBSS has provided a template upon which to build.

The native fish community is moderately diverse in the West
Chesapeake basin, but at least two species appear to be at risk of extirpation because of low numbers and historical and ongoing loss of habitat. In addition to the native fishes, six species collected were introduced (bluegill, green sunfish, largemouth bass, rainbow trout, goldfish, and black crappie), and most, if not all, of these were introduced by fishery managers or anglers. From a recreational standpoint, some of these introductions have been beneficial, but ecological impacts to the fish community have likely occurred and will continue to occur. Unfortunately, there is little historical information about fish communities in streams of the basin, so it is difficult to determine the extent to which the introduction of non-native fish has influenced the distribution and abundance of native species.

At one time, many of the streams in the West Chesapeake basin flowed slowly through wetland areas. As a result of prolonged contact with leaves, wood, and other vegetation, the waters were tea-stained and laden with weak acids. Only a small group of species was able to live in this naturally acidic environment, and productivity was low. Today, the elimination of wetlands and addition of lime to croplands has allowed many cosmopolitan species to invade the streams of the basin, increasing competition and predation within this unique community of acid-endemic fishes.

The story of migratory fish in the West Chesapeake basin is not unlike the history of blackwater streams. Early colonization of the basin included construction of dams to supply waterpower for mills, and more recent activities included construction of culverts under roads. With each new barrier, habitat for migratory fish species such as blueback herring, American shad, yellow perch, and American eel was reduced or restricted. Today, 73 man-made barriers to migratory fish have been documented. Fortunately, efforts are underway to provide fish passage and restore spawning runs.

The information from the MBSS identifies a clear need for restoration and protection activities in streams of the West Chesapeake basin, not only to reduce nutrient loading to Chesapeake Bay, but for the upstream aquatic resources as well. The wide variety of problems documented is an indication of the array of activities that will be necessary to maintain or improve our aquatic resources and Chesapeake Bay heritage. Given the projected expansion of human activity in the basin in the future, it is imperative that restoration and protection be aggressively pursued.

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Appendix A: Synopsis of Maryland Biological Stream Survey (MBSS) survey design and sampling methods.

The MBSS is intended to provide unbiased estimates of the condition of streams and rivers of Maryland on a local (e.g., drainage basin or county) as well as a statewide scale. To date, the MBSS has focused on wadeable, headwater streams. The survey is based on a probabilistic stream sampling approach where random selections are made from all sections of streams in the state which can physically be sampled. The approach supports statistically-valid population estimation of variables of interest (e.g., largemouth bass densities, miles of streams with degraded physical habitat, etc.). When repeated, the MBSS will also provide a basis for assessing future changes in ecological condition of flowing waters of the state. At present, plans are to repeat the MBSS at five year intervals and develop a quantitative sampling approach for larger streams and rivers.

The study area for the MBSS includes each of the 18 major drainage basins of the state, and a total of three years is required to sample all 18 basins. For logistical reasons, the state was divided into three geographic regions (east, west, and central) with five to seven basins in each region. Each basin is sampled at least once during a given three year cycle, and one basin in each region is sampled twice so that data collected in different years can be combined into a single statewide estimate for each of the variables of interest.

The sampling frame for the MBSS was constructed by overlaying basin boundaries on a map of all blueline stream reaches in the state as digitized on a U.S. Geological Survey 1:250,000 scale map. Sampling within basins is restricted to non-tidal, first, second and third-order (Strahler 1964) stream reaches, excluding unwadeable or otherwise unsampleable areas. An additional restriction is that only public lands or privately-owned sites where landowner permissions have been obtained are sampled.

During 1995 the MBSS sample sites were selected from a comprehensive list of headwater stream reaches in 6 of the 18 drainage basins. In 1997, sample sites were selected from 7 of the drainage basins. To provide adequate information about each size of stream, an approximately equal number of first, second, and third order streams were sampled during spring and summer, with the number of sites of each order in a basin being proportional to the number of stream miles (of an order) in the entire state.

Benthic macroinvertebrates and water quality samples were collected during the spring index period from March through early May, while fish, herpetofauna, *in situ* stream chemistry and physical habitat sampling were conducted during the low flow period in the summer, from June through September.

In the spring, water samples were collected and analyzed for pH, acid-neutralizing capacity (ANC), sulfate (SO_4), nitrate (NO_3), conductivity, and dissolved organic carbon (DOC) in the laboratory. These variables primarily characterize the sensitivity of the streams to acid deposition, and to other anthropogenic stressors to a lesser extent. Benthic macroinvertebrates collected in the spring were identified to family and genus level in the laboratory.

Habitat assessments were conducted in the summer using metrics largely patterned after EPA's Rapid Bioassessment Protocols and Ohio EPA's Qualitative Habitat Evaluation Index (QHEI) described by Rankin (1989),

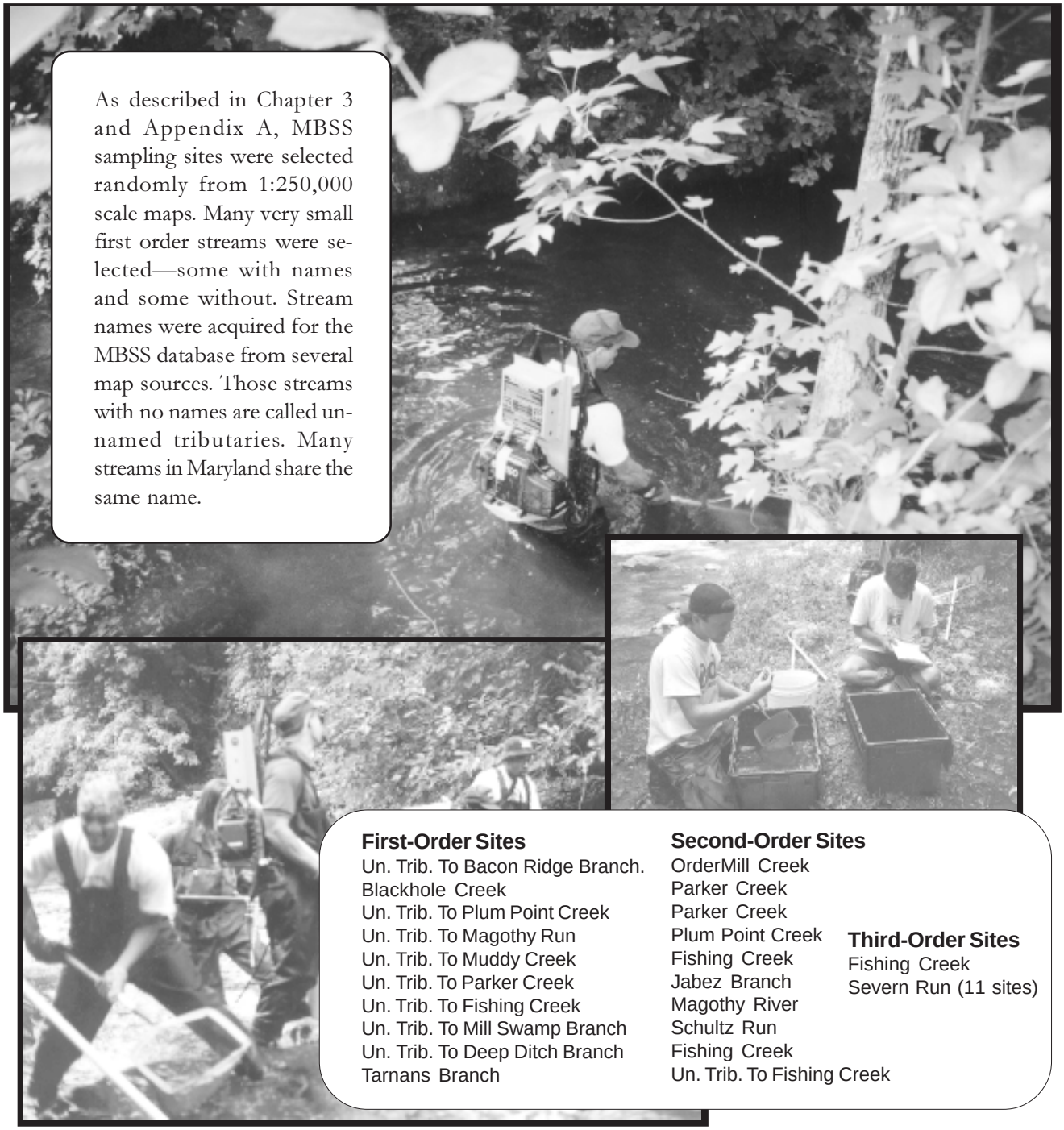
(Cont) Appendix A: Synopsis of Maryland Biological Stream Survey (MBSS) survey design and sampling methods.

Plafkin *et al.* (1989), and Platts *et al.* (1983) in the designated 75 m length of the stream segments; riparian habitat measurements were based on the surrounding area within 20 m of the segment. Other qualitative measurements included (1) aesthetic value, based on evidence of human refuse; (2) remoteness, based on the absence of detectable human activity and difficulty in accessing the segment; (3) land use, based on the surrounding area immediately visible from the segment; (4) general stream character, based on the shape, substrate, and vegetation of the segment; and (5) bank erosion, based on the kind and extent of erosion present. Quantitative measurements at each segment included flow, depth, wetted width, and stream gradients.

Fish and herpetofauna were sampled during the summer index period using quantitative, double-pass electrofishing of the 75 m stream segments. Blocking nets were placed at each end of the segment, and one or more direct-current, backpack electrofishing units were used to sample the entire segment. All fish captured during each electrofishing pass were identified, counted, weighed in aggregate, and up to 100 individuals of each species were examined for external anomalies such as lesions and tumors. All gamefish captured were also measured for length. Any amphibians, reptiles, freshwater molluscs, submerged aquatic vegetation either in or near the stream segment were collected and identified.

For all phases of the MBSS, there was a ongoing, documented program of quality assurance/quality control (QA/QC). The QA/QC program used by the MBSS allows for generation of data with known confidence.

Appendix B. MBSS Streams sampled in the West Chesapeake River basin in 1997.



As described in Chapter 3 and Appendix A, MBSS sampling sites were selected randomly from 1:250,000 scale maps. Many very small first order streams were selected—some with names and some without. Stream names were acquired for the MBSS database from several map sources. Those streams with no names are called unnamed tributaries. Many streams in Maryland share the same name.

First-Order Sites
Un. Trib. To Bacon Ridge Branch.
Blackhole Creek
Un. Trib. To Plum Point Creek
Un. Trib. To Magothy Run
Un. Trib. To Muddy Creek
Un. Trib. To Parker Creek
Un. Trib. To Fishing Creek
Un. Trib. To Mill Swamp Branch
Un. Trib. To Deep Ditch Branch
Tarnans Branch

Second-Order Sites
OrderMill Creek
Parker Creek
Parker Creek
Plum Point Creek
Fishing Creek
Jabez Branch
Magothy River
Schultz Run
Fishing Creek
Un. Trib. To Fishing Creek

Third-Order Sites
Fishing Creek
Severn Run (11 sites)

Appendix C. Location and water quality data for MBSS sites in the West Chesapeake basin (1997). Temperature and Dissolved Oxygen (DO) were measured in the summer while all other parameters were measured during the spring. Units of measure for temperature are degrees celcius. DO, nitrate nitrogen (NO_3), sulfate (SO_4), and dissolved organic carbon (DOC) are presented in mg/l, and acid neutralizing capacity (ANC) is measured as *u*eq/l)

Stream Name	Latitude	Longitude	Temp Field	DO Field	pH Lab	DOC	ANC Lab	NO3 Lab	SO4 Lab
UT to Muddy Creek	38.8680	76.6080	21.0	7.8	6.8	2.5	555.7	0.54	31.37
Mill Creek	39.0180	76.4800	23.4	5.6	6.7	4.7	301.0	0.58	5.52
Tarnans Branch	38.9690	76.6330	24.4	7.5	6.6	3.9	226.4	0.39	18.06
UT to Bacon Ridge Branch	39.0422	76.6264	19.2	7.6	5.6	1.5	43.8	0.28	16.92
Severn Run	39.1080	76.6600	18.0	7.9	7.0	4.8	463.0	0.76	14.76
Severn Run	39.1090	76.6540	19.1	8.2	7.1	3.2	453.0	1.04	15.17
Severn Run	39.1080	76.6480	18.5	8.7	7.3	3.6	447.0	1.10	15.36
Severn Run	39.1081	76.6566	20.9	8.4	7.0	5.2	513.9	0.86	13.26
Blackhole Creek	39.0920	76.4980	19.0	0.7	4.0	4.6	-108.0	0.18	15.87
Severn Run	39.1090	76.6710	20.6	7.6	7.1	4.5	598.7	0.83	14.18
Magothy Run	39.1140	76.5560	25.8	7.7	6.9	5.7	422.7	1.09	19.28
Schultz Run	39.1080	76.7030	19.0	4.9	6.9	8.5	555.1	0.30	15.38
Jabez Branch	39.0790	76.6330	17.7	8.5	6.9	7.9	589.9	0.79	10.80
UT to Magothy Run	39.1190	76.5450	17.3	8.2	6.2	2.8	210.9	2.71	23.31
UT to Mill Swamp Branch	38.8870	76.5940	16.4	3.6	6.9	4.8	764.3	1.94	20.90
Severn Run	39.1030	76.6900	17.4	8.7	6.9	5.1	424.9	0.85	17.51
Severn Run	39.1070	76.6980	17.8	8.7	6.7	4.1	369.0	0.93	17.19
Severn Run	39.1080	76.7000	18.3	8.3	6.6	4.2	357.1	0.98	17.46
Severn Run	39.1082	76.7020	19.0	8.2	6.5	3.7	339.8	1.22	17.09
UT to Deep Ditch Branch	39.0305	76.5995	18.1	8.7	6.6	1.1	282.7	1.21	18.25
Severn Run	39.1050	76.6410	21.8	8.2	7.1	3.4	398.2	1.34	16.08
Severn Run	39.1010	76.6400	20.7	7.7	7.0	3.4	389.6	1.32	16.07
UT to Parker Creek	38.5444	76.5536	17.4	9.1	7.2	2.8	897.2	0.17	8.19
UT to Fishing Creek	38.6940	76.5920	22.5	6.8	6.9	3.0	396.2	0.27	21.54
Parker Creek	38.5300	76.5540	22.0	8.0	7.2	3.2	680.7	0.34	10.20
Parker Creek	38.5242	76.5664	20.1	7.5	7.0	3.6	624.9	0.18	8.70
Fishing Creek	38.6410	76.5720	18.8	8.2	7.2	2.8	477.7	0.39	19.39
Plum Point Creek	38.6060	76.5240	19.1	7.4	7.3	3.2	760.3	0.00	16.21
Fishing Creek	38.6390	76.5540	22.8	7.5	6.8	2.5	323.7	0.23	16.87
Fishing Creek	38.6380	76.5550	21.0	7.7	6.9	2.2	323.4	0.23	16.89
UT to Plum Point Creek	38.6200	76.5280	19.8	7.7	7.0	3.7	873.6	0.42	19.52
UT to Fishing Creek	38.6880	76.5830	21.6	7.8	6.8	3.1	442.4	0.24	20.56

*** UT = Unnamed Tributary**

Appendix D: Physical Habitat conditions measured by Maryland Biological Stream Survey

I. SUBSTRATE AND INSTREAM COVER

Instream Habitat is rated according to the perceived value of habitat to the fish community. Higher scores are assigned to sites with a variety of habitat types and particle sizes. In addition, higher scores are assigned to sites with a high degree of uneven substrate. In streams where substrate types are favorable but flows are so low that fish are essentially precluded from using the habitat, low scores are assigned. If none of the habitat within a segment is useable by fish, a score of zero is assigned.

Epifaunal Substrate is rated based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. Because they inhibit colonization, flocculent materials or fine sediments surrounding otherwise good substrates are assigned low scores. Scores are also reduced when substrates are less stable.

Velocity/Depth Diversity is rated based on the variety of velocity/depth regimes present at a site (slow-shallow, slow-deep, fast-shallow, and fast-deep). As with embeddedness, this metric may result in lower scores in low-gradient streams but will provide statewide information on the physical habitat found in Maryland streams.

Pool/Glide/Eddy Quality is rated based on the variety and spatial complexity of slow or still water habitat within the sample segment. In high-gradient streams, functionally important slow water habitat may exist in the form of larger eddies. Within a category, higher scores are assigned to segments which have undercut banks, woody debris or other types of cover for fish.

Riffle/Run Quality is based on the depth, complexity, and functional importance of riffle/run habitat in the segment, with highest scores assigned to segments dominated by deeper riffle/run areas, stable substrates, and a variety of current velocities.

Embeddedness is a percentage of surface area of larger particles that is surrounded by fine sediments on the stream bottom. In low gradient streams, embeddedness may be high even in unimpaired streams.

II. CHANNEL CHARACTER

Channel Alteration is a measure of large-scale changes in the shape of the stream channel. Channel alteration includes: concrete channels, artificial embankments, obvious straightening of the natural channel, rip-rap, or other structures, as well as recent bar development. Ratings for this metric are based on the presence of artificial structures as well as the existence, extent, and coarseness of point bars, side bars, and mid-channel bars which indicate the degree of flow fluctuations and substrate stability. Evidence of channelization may sometimes be seen in the form of berms which parallel the stream channel.

Bank Stability is rated based on the presence/absence of riparian vegetation and other stabilizing bank materials such as boulders and rootwads, and frequency/size of erosional areas. Sites with steep slopes are not penalized if banks are composed solely of stable materials.

Channel Flow Status is the percentage of the stream channel that has water, with subtractions made for exposed substrates and dewatered areas.

III. RIPARIAN CORRIDOR

Shading is rated based on estimates of the degree and duration of shading at a site during summer, including any effects of shading caused by land forms.

Riparian Buffer is rated according to the size and type of the vegetated riparian buffer zone at the site. Cultivated fields for agriculture which have bare soil to any extent are not considered as riparian buffers. At sites where the buffer width is variable or direct delivery of storm runoff or sediment to the stream is evident or highly likely, the narrowest representative buffer width in the segment (e.g., 0 if parking lot runoff enters directly to the stream) is measured and recorded even though some of the stream segment may have a well developed riparian buffer.

IV. AESTHETICS/REMOTENESS

Aesthetics are rated according to the visual appeal of the site and presence/absence of human refuse, with highest scores assigned to stream segments with no human refuse and visually outstanding character.

Remoteness is rated based on the absence of detectable human activity and difficulty in accessing the segment.

MBSS Habitat Assessment Guidance Sheet

Habitat Parameter	Optimal 16-20	Sub-Optimal 11-15	Marginal 6-10	Poor 0-5
1. Instream Habitat[a]	Greater than 50% mix of a variety of cobble, boulder, submerged logs, undercut banks, snags, rootwads, aquatic plants, or other stable habitat	30-50% mix of stable habitat. Adequate habitat	10-30% mix of stable habitat. Habitat availability less than desirable	Less than 10% stable habitat. Lack of habitat is obvious
2. Epifaunal Substrate[b]	Preferred substrate abundant, stable, and at full colonization potential (riffles well developed and dominated by cobble; and/or woody debris prevalent, not new, and not transient)	Abund. of cobble with gravel &/or boulders common; or woody debris, aquatic veg., under-cut banks, or other pro-ductive surfaces common but not prevalent /suited for full colonization	Large boulders and/or bedrock prevalent; cobble, woody debris, or other preferred surfaces uncommon	Stable substrate lacking; or particles are over 75% surrounded by fine sediment or flocculent material
3. Velocity/Depth Diversity[c]	Slow (<0.3 m/s), deep (>0.5 m); slow, shallow (<0.5 m); fast (>0.3 m/s), deep; fast, shallow habitats all present	Only 3 of the 4 habitat categories present	Only 2 of the 4 habitat categories present	Dominated by 1 velocity/depth category (usually pools)
4. Pool/Glide/Eddy Quality[d]	>50% pool/glide/eddy habitat; both deep (>.5 m)/shallows (<.2 m) present; complex cover/&/or depth >1.5 m	10-50% pool/glide/eddy habitat, with deep (>0.5 m) areas present; or >50% slow water with little cover	<10% pool/glide/eddy habitat, with shallows (<0.2 m) prevalent; slow water areas with little cover	Pool/glide/eddy habitat minimal, with max depth <0.2 m, or absent completely
5. Riffle Quality[e]	Riffle/run depth generally >10 cm, with maximum depth greater than 50 cm (maximum score); substrate stable (e.g. cobble, boulder) & variety of current velocities	Riffle/run depth generally 5-10 cm, variety of current velocities	Riffle/run depth generally 1-5 cm; primarily a single current velocity	Riffle/run depth < 1 cm; or riffle/run substrates concreted
6. Channel Alteration[f]	Little or no enlargement of islands or point bars; no evidence of channel straightening or dredging; 0-10% of stream banks artificially armored or lined	Bar formation, mostly from coarse gravel; and/or 10-40% of stream banks artificially armored or obviously channelized	Recent but moderate deposition of gravel and coarse sand on bars; and/or embankments on both banks; and/or 40-80% of banks artificially armored; or channel lined in concrete	Heavy deposits of fine material, extensive bar development; OR recent channelization or dredging evident; or over 80% of banks artificially armored
7. Bank Stability[g]	Upper bank stable, 0-10% of banks with erosional scars and little potential for future problems	Moderately stable. 10-30% of banks with erosional scars, mostly healed over. Slight potential in extreme floods	Moderately unstable. 30-60% of banks with erosional scars and high erosion potential during extreme high flow	Unstable. Many eroded areas. "Raw" areas frequent along straight sections and bends. Side slopes >60° common
8. Embeddedness[h]	Percentage that gravel, cobble, and boulder particles are surrounded by line sediment or flocculent material.			
9. Channel Flow Status[i]	Percentage that water fills available channel			
10. Shading[j]	Percentage of segment that is shaded (duration is considered in scoring). 0% = fully exposed to sunlight all day in summer; 100% = fully and densely shaded all day in summer			
11. Riparian Buffer[k]	Minimum width of vegetated buffer in meters; 50 meters maximum; see back of Habitat Assessment Data Sheet for buffer type and land cover immediately adjacent to buffer			

Habitat Parameter	Optimal (16-20)	Sub-Optimal (11-15)	Marginal (6-10)	Poor (0-5)
12. Aesthetic Rating[l]	Little or no evidence of human refuse present; vegetation visible from stream essentially in a natural state	Human refuse present in minor amounts; and/or channelization present but not readily apparent; and/or minor disturbance of riparian vegetation	Refuse present in moderate amounts; and/or channel-ization readily apparent; and/or moderate disturbance of riparian vegetation	Human refuse abundant and un-sightly: and/or extensive unnatural channelization; and/or nearly complete lack of vegetation
13. Remoteness[m]	Stream segment more than 1/4 mile from nearest road; access difficult and little or no evidence of human activity	Stream segment within 1/4 of but not immediately accessible to roadside access by trail; site with moderately wild character	Stream within 1/4 mile of roadside and accessible by trail; anthropogenic activities readily evident	Segment immediately adjacent to roadside access; visual , olfactory, and/or auditory displeasure experienced

a) **Instream Habitat** Rated based on perceived value of habitat to the fish community. Within each category, higher scores should be assigned to sites with a variety of habitat types and particle sizes. In addition, higher scores should be assigned to sites with a high degree of hypsographic complexity (uneven bottom). In streams where ferric hydroxide is present, instream habitat scores are not lowered unless the precipitate has changed the gross physical nature of the substrate. In streams where substrate types are favorable but flows are so low that fish are essentially precluded from using the habitat, low scores are assigned. If none of the habitat within a segment is useable by fish, a score of zero is assigned.

b) **Epifaunal Substrate** Rated based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. Because they inhibit colonization, floculent materials or fine sediments surrounding otherwise good substrates are assigned low scores. Scores are also reduced when substrates are less stable.

c) **Velocity/Depth Diversity** Rated based on the variety of velocity/depth regimes present at a site (slow-shallow, slow-deep, fast-shallow, and fast-deep). As with embeddedness, this metric may result in lower scores in low-gradient streams but will provide a statewide information on the physical habitat found in Maryland streams.

d) **Pool/Glide/Eddy Quality** Rated based on the variety and spatial complexity of slow- or still-water habitat within the sample segment. It should be noted that even in high-gradient segments, functionally important slow-water habitat may exist in the form of larger eddies. Within a category, higher scores are assigned to segments which have undercut banks, woody debris or other types of cover for fish.

e) **Riffle/Run Quality** Rated based on the depth, complexity, and functional importance of riffle/run habitat in the segment, with highest scores assigned to segments dominated by deeper riffle/run areas, stable substrates, and a variety of current velocities.

f) **Channel Alteration** Is a measure of large-scale changes in the shape of the stream channel. Channel alteration includes: concrete channels, artificial embankments, obvious straightening of the natural channel, rip-rap, or other structures, as well as recent bar development. Ratings for this metric are based on the presence of artificial structures as well as the existence, extent, and coarseness of point bars, side bars, and mid-channel bars which indicate the degree of flow fluctuations and substrate stability. Evidence of channelization may sometimes be seen in the form of berms which parallel the stream channel.

g) **Bank Stability** Rated based on the presence/absence of riparian vegetation and other stabilizing bank materials such as boulders and rootwads, and frequency/size of erosional areas. Sites with steep slopes are not penalized if banks are composed solely of stable materials.

h) **Embeddedness** Rated as a percentage based on the fraction of surface area of larger particles that is surrounded by fine sediments on the stream bottom. In low gradient streams with substantial natural deposition, the correlation between embeddedness and fishability or ecological health may be weak or non-existent, but this metric is rated in all streams to provide similar information from all sites statewide.

i) **Channel Flow Status** Rated based on the percentage of the stream channel that has water, with subtractions made for exposed substrates and islands.

j) **Shading** Rated based on estimates of the degree and duration of shading at a site during summer, including any effects of shading caused by landforms.

k) **Riparian Buffer Zone** Based on the size and type of the vegetated riparian buffer zone at the site. Cultivated fields for agriculture which have bare soil to any extent are not considered as riparian buffers. At sites where the buffer width is variable or direct delivery of storm runoff or sediment to the stream is evident or highly likely, the smallest buffer in the segment. (e.g., 0 if parking lot runoff enters directly to the stream) is measured and recorded even though some of the segment may have a well developed buffer. In cases where the riparian zone on one side of the stream slopes away from the stream and there is no direct point of entry for runoff, the buffer on the other side of the stream should be measured and recorded and a comment made in comments section of the data sheet.

l) **Aesthetic Rating** Rated based on the visual appeal of the site and presence/absence of human refuse, with highest scores assigned to stream segments with no human refuse and visually outstanding character.

m) **Remoteness** Rated based on the absence of detectable human activity and difficulty in accessing the segment.

Stream Name	Latitude	Longitude	Instream Habitat	Epifaunal Substrate	Velocity Depth	Pool Quality	Riffle Quality
UT to Muddy Creek	38.8680	76.6080	6	4	4	6	7
Mill Creek	39.0180	76.4800	15	16	12	17	17
Tarnans Branch	38.9690	76.6330	12	11	10	12	14
UT to Bacon Ridge Branch	39.0422	76.6264	5	3	3	3	6
Severn Run	39.1080	76.6600	16	17	14	18	16
Severn Run	39.1090	76.6540	10	11	17	15	17
Severn Run	39.1080	76.6480	17	16	17	18	16
Severn Run	39.1081	76.6566	13	15	10	17	16
Blackhole Creek	39.0920	76.4980	9	6	1	8	0
Severn Run	39.1090	76.6710	10	10	10	13	14
Magothy Run	39.1140	76.5560	18	18	15	15	17
Schultz Run	39.1080	76.7030	13	11	5	10	7
Jabez Branch	39.0790	76.6330	12	13	10	10	11
UT to Magothy Run	39.1190	76.5450	10	5	10	10	11
UT to Mill Swamp Branch	38.8870	76.5940	2	1	2	2	1
Severn Run	39.1030	76.6900	8	7	13	13	10
Severn Run	39.1070	76.6980	10	10	14	13	10
Severn Run	39.1080	76.7000	17	15	15	17	10
Severn Run	39.1082	76.7020	14	11	15	15	10
UT to Deep Ditch Branch	39.0305	76.5995	9	5	5	7	10
Severn Run	39.1050	76.6410	18	18	17	17	17
Severn Run	39.1010	76.6400	17	17	16	17	18
UT to Parker Creek	38.5444	76.5536	12	11	10	7	10
UT to Fishing Creek	38.6940	76.5920	9	11	2	5	6
Parker Creek	38.5300	76.5540	13	11	6	16	0
Parker Creek	38.5242	76.5664	16	13	5	10	15
Fishing Creek	38.6410	76.5720	15	12	10	14	16
Plum Point Creek	38.6060	76.5240	15	12	10	10	12
Fishing Creek	38.6390	76.5540	11	12	4	7	8
Fishing Creek	38.6380	76.5550	11	11	4	8	10
UT to Plum Point Creek	38.6200	76.5280	16	11	5	6	7
UT to Fishing Creek	38.6880	76.5830	15	13	5	9	8

***UT = Unnamed Tributary**

Stream Name	Latitude	Longitude	Channel Alteration	Bank Stability	Embedded	Channel Flow	Shading
UT to Muddy Creek	38.8680	76.6080	7	8	90	85	50
Mill Creek	39.0180	76.4800	10	13	85	95	80
Tarnans Branch	38.9690	76.6330	6	3	70	75	70
UT to Bacon Ridge Branch	39.0422	76.6264	5	18	100	80	90
Severn Run	39.1080	76.6600	9	12	95	90	70
Severn Run	39.1090	76.6540	10	10	100	99	75
Severn Run	39.1080	76.6480	4	11	95	95	65
Severn Run	39.1081	76.6566	9	7	100	90	70
Blackhole Creek	39.0920	76.4980	16	18	98	50	90
Severn Run	39.1090	76.6710	10	14	100	99	50
Magothy Run	39.1140	76.5560	14	16	65	98	85
Schultz Run	39.1080	76.7030	9	6	60	70	90
Jabez Branch	39.0790	76.6330	5	5	60	70	80
UT to Magothy River	39.1190	76.5450	9	13	95	90	65
UT to Mill Swamp Branch	38.8870	76.5940	1	6	100	20	50
Severn Run	39.1030	76.6900	10	4	50	70	80
Severn Run	39.1070	76.6980	16	6	50	90	85
Severn Run	39.1080	76.7000	11	9	55	90	75
Severn Run	39.1082	76.7020	11	8	50	80	80
UT to Deep Ditch Branch	39.0305	76.5995	7	5	95	50	90
Severn Run	39.1050	76.6410	10	13	95	90	60
Severn Run	39.1010	76.6400	11	11	100	90	70
UT to Parker Creek	38.5444	76.5536	17	17	100	95	85
UT to Fishing Creek	38.6940	76.5920	10	16	100	70	90
Parker Creek	38.5300	76.5540	17	18	100	95	80
Parker Creek	38.5242	76.5664	16	17	100	95	70
Fishing Creek	38.6410	76.5720	3	5	100	75	80
Plum Point Creek	38.6060	76.5240	3	16	100	65	70
Fishing Creek	38.6390	76.5540	6	3	98	50	80
Fishing Creek	38.6380	76.5550	8	10	98	70	80
UT to Plum Point Creek	38.6200	76.5280	16	11	60	75	75
UT to Fishing Creek	38.6880	76.5830	8	6	100	60	70

***UT = Unnamed Tributary**

Riparian Width	Aesthetic Rating	Max Depth	Gradient	Segment Length	Woody Debris
5	9	9	1	69	0
50	5	75	0.8	67	6
21	10	42	1	73	4
50	3	6	1	71	0
50	17	98	0.6	59	20
50	18	91	0.9	71	15
50	19	120	0.9	41	13
50	17	100	0.6	29	17
15	8	45	0.6	59	2
50	9	85	0.8	55	8
21	4	70	0.9	71	10
50	11	40	2.2	63	5
50	19	35	0.3	54	9
0	12	32	0.5	73	2
0	12	16	0.3	69	1
50	1	94	0.4	60	8
50	6	81	0.6	65	8
10	5	114	0.6	63	7
50	8	141	0.4	68	7
50	5	40	1.2	60	3
50	16	83	0.9	56	11
50	19	122	0.9	57	17
50	19	15	0.6	65	11
50	16	6	0.3	68	11
50	19	110	0.4	70	8
50	16	30	0.4	60	12
50	14	84	0.4	69	9
50	16	23	0.4	64	9
50	18	16	0.9	61	8
50	12	28	0.9	70	5
50	10	16	1.1	62	11
40	13	25	0.6	46	11

ECOLOGY AND DISTRIBUTION OF FISH SPECIES COLLECTED IN THE WEST CHESAPEAKE BASIN

The species descriptions (Jenkins and Burkhead 1994, Rohde et al. 1994) and distributional maps which follow (Pages E5-E41) include those fish species collected during both random and non-random sampling in theWest Chesapeake basin as part of the 1994 and 1997 MBSS.

Common Name	*Family*	*Tolerance*	*Feeding Group*	*Page*	*Interesting Facts*
Least brook lamprey	Lamprey	Intolerant	Filter Feeder	E-5	The larvel stage of this species may last a decade or more, but the adult stage is short with death occuring after spawning.
Sea lamprey	Lamprey	Moderate	Filter Feeder	E-6	Adults live in the ocean and use freshwater streams to spawn and grow to maturity (anadromous)
American eel	Eel	Tolerant	Generalist	E-7	Although most of their life is spent in fresh water streams (up to 20 years or more), adults become silver in color and journey to the Sargasso sea to spawn (catadromous).
Gizzard shad	Herring	Moderate	Filter Feeder	E-8	Attempts have been made to stock this species as a forage base for game fish but they are only small enough to be taken by predators for a short time due to their rapid growth rate.
Chain pickerel	Pike	Moderate	Top Predator	E-9	This ambush predator feeds almost exclusively on other fish.
Redfin pickerel	Pike	Moderate	Top Predator	E-10	This member of the pike family is able to survive in small streams and ditches with extremely low dissolved oxygen.
Eastern mudminnow	Mudminnow	Tolerant	Invertivore	E-11	As the name implies, this species buries itself into the mud during the day and is active at night.
Blacknose dace	Minnow	Tolerant	Omnivore	E-12	This species is tolerant of a wide range of environmental conditions and pollutants. It is the most abundant fish in Maryland streams.
Fallfish	Minnow	Moderate	Generalist	E-13	The male fallfish may build a large nest of gravel over three feet high to protect its mate's eggs.
Golden shiner	Minnow	Tolerant	Omnivore	E-14	This species is a favorite food of largemouth bass. It has been transported throughout the United States as a result of bait bucket introductions.
Goldfish	Minnow	Tolerant	Omnivore	E-15	This well known Asian fish was the first exotic fish species introduced to North America. Unfortunately, many new introductions still occur from tropical fish hobbyists.

Common Name	Family	Tolerance	Feeding Group	Map	Interesting Facts
Rosyside dace	Minnow	Intolerant	Invertivore	E-16	This minnow is considered to be sensitive to heavy siltation.
Satinfin shiner	Minnow	Moderate	Invertivore	E-17	This species is considered a good aquarium fish because of its active nature and ready acceptance of dried food.
Spottail shiner	Minnow	Moderate	Omnivore	E-18	This species is found in a wide range of habitats, including tidal freshwater areas where it can be highly abundant.
Swallowtail shiner	Minnow	Moderate	Invertivore	E-19	This species seems to use both minnow and sunfish nests for spawning, unlike other minnows which only spawn on other minnow nests.
Creek chubsucker	Sucker	Moderate	Invertivore	E-20	This species lacks a lateral line and therefore is easily distinguishable from other suckers in Maryland.
White sucker	Sucker	Tolerant	Omnivore	E-21	Large white suckers have been reported to reach 17 years of age and lengths of over 23 inches. This is the most widely distributed sucker species in Maryland.
Brown bullhead	Catfish	Tolerant	Omnivore	E-22	Although considered native to Maryland, this species has been widely introduced throughout the United States to provide fishing opportunities.
Rainbow trout	Trout	Moderate	Top Predator	E-23	Although ranked among the top five sought after gamefish in North America, hatchery-reared fish are not considered desirable by many fishing purists.
Inland silverside	Atherinidae	Moderate	Planktivore	E-24	The inland silverside is an abundant year-round resident of Chesapeake Bay, inhabiting tidal creeks and grass flats in the summer but retreating to deeper water in the winter.
Banded killifish	Killifish	Moderate	Invertivore	E-25	As a result of its hardy nature and general abundance this species is often used as live bait.
Mummichog	Killifish	Moderate	Invertivore	E-26	This species is more commonly found in estuaries and can tolerate salinities up to 32 parts/thousand.
Rainwater killifish	Killifish	Moderate	Invertivore	E-27	Found mostly in brackish waters, the rainwater killifish will tolerate both freshwater and seawater, and during the summer it is abundant in all brackish-water habitats where vegetation is present. During the winter it burrows into the bottom silt in low-salinity tidal pools.
Mosquitofish	Topminnow	Moderate	Invertivore	E-28	As the name implies, this species has been known to control mosquito populations by feeding on pupal and larval stages of the insect.

Common Name	*Family*	*Tolerance*	*Feeding Group*	*Map*	*Interesting Facts*
Striped bass	Temperate bass	Moderate	Top Predator	E-29	Although quite common in some non-tidal streams, this species rarely ventures into small streams. The striped bass attains weights of over 100 pounds and is valued highly by both sport and commercial fishermen.
White perch	Temperate bass	Moderate	Invertivore	E-30	This species spawns from late March through May, migrating from the lower portions of the Chesapeake Bay upstream to freshwater (semi-anadromous). It is abundant in tidal waters of the Susquehanna River.
Black crappie	Sunfish	Tolerant	Generalist	E-31	Considered an excellent game and food fish, the black crappie is pursued by many freshwater anglers. They are most abundant in well-vegetated lakes and clear backwaters of rivers.
Banded sunfish	Sunfish	Moderate	Invertivore	E-32	This sunfish is known to live in streams with pH values of less than 4. However, this species is out-competed and preyed upon by larger members of the sunfish family.
Bluegill	Sunfish	Tolerant	Invertivore	E-33	This species has been widely introduced throughout the United States, and has flourished as a result of its tolerance to a variety of conditions.
Bluespotted sunfish	Sunfish	Moderate	Invertivore	E-34	This species is distinguished by long, spotted fins and iridescent silver to blue body spots. Because of its small size and timid character, this Maryland native is often out competed by introduced fish such as largemouth bass and bluegill.
Green sunfish	Sunfish	Tolerant	Generalist	E-35	This species is intolerant of low pH streams, but tolerant of many other types of stress. The lowest pH stream site in the basin where this sunfish was collected at was 7.1.
Largemouth bass	Sunfish	Moderate	Top Predator	E-36	This species is considered the most popular gamefish in the United States and has been known to reach weights of over 20 pounds.
Pumpkinseed	Sunfish	Moderate	Invertivore	E-37	This sunfish is tolerant of darkly-stained acidic waters and is a regular visitor to brackish waters.
Redbreast sunfish	Sunfish	Moderate	Generalist	E-38	Often found with smallmouth bass and other “cool water” species, this sunfish has been found in water warmer than 100° F.
Tessellated darter	Perch	Moderate	Invertivore	E-39	The male tessellated darter has a curious behavior of frequently caring for nests containing eggs that it did not fertilize.

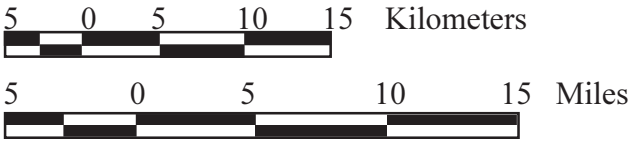
Common Name	*Family*	*Tolerance*	*Feeding Group*	*Map*	*Interesting Facts*
Yellow perch	Perch	Moderate	Generalist	E-40	The yellow perch population in Chesapeake Bay is unique because it winters in areas of moderate salinity; all other populations spend their entire life cycle in freshwater.
Spot	Drum	Tolerant	Benthivore	E-41	Spot migrate seasonally between coastal and estuarine waters, and is one of Chesapeake Bay's most important commercial and recreational species.

● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **leastbrook lamprey** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin

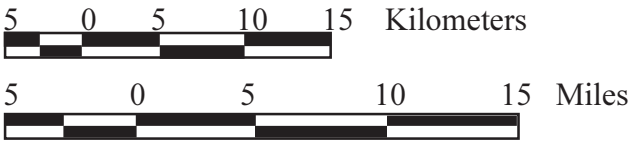


● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **sea lamprey** in the West Chesapeake basin, 1994 and 1997.

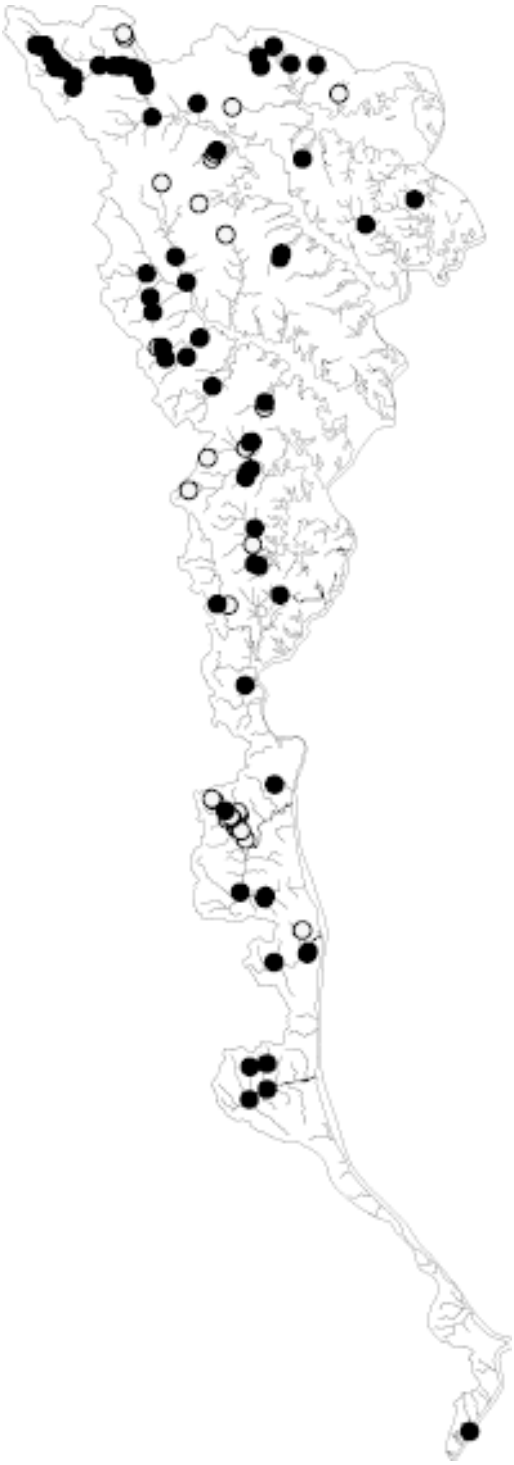
West Chesapeake Basin

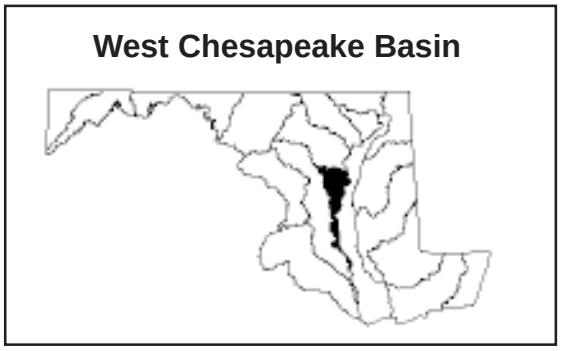


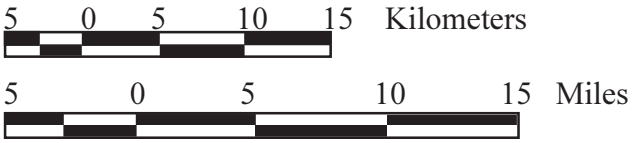
● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **American eel** in the West Chesapeake basin 1994 and 1997.

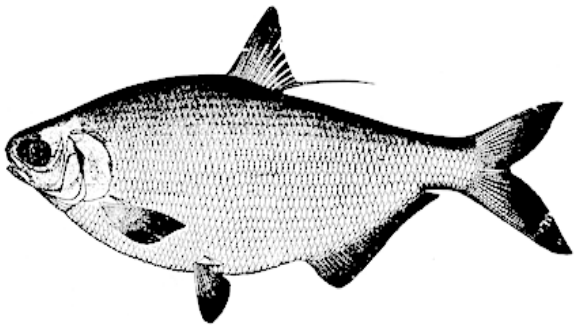






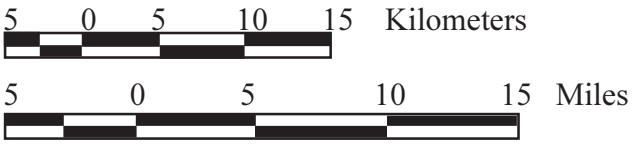
● **Species PRESENT at site**

○ **Species ABSENT at site**



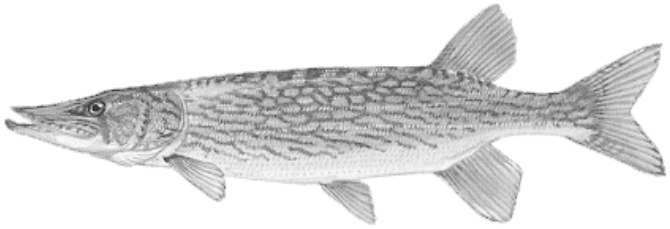
Distribution of **gizzard shad** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin



● **Species PRESENT at site**

○ **Species ABSENT at site**

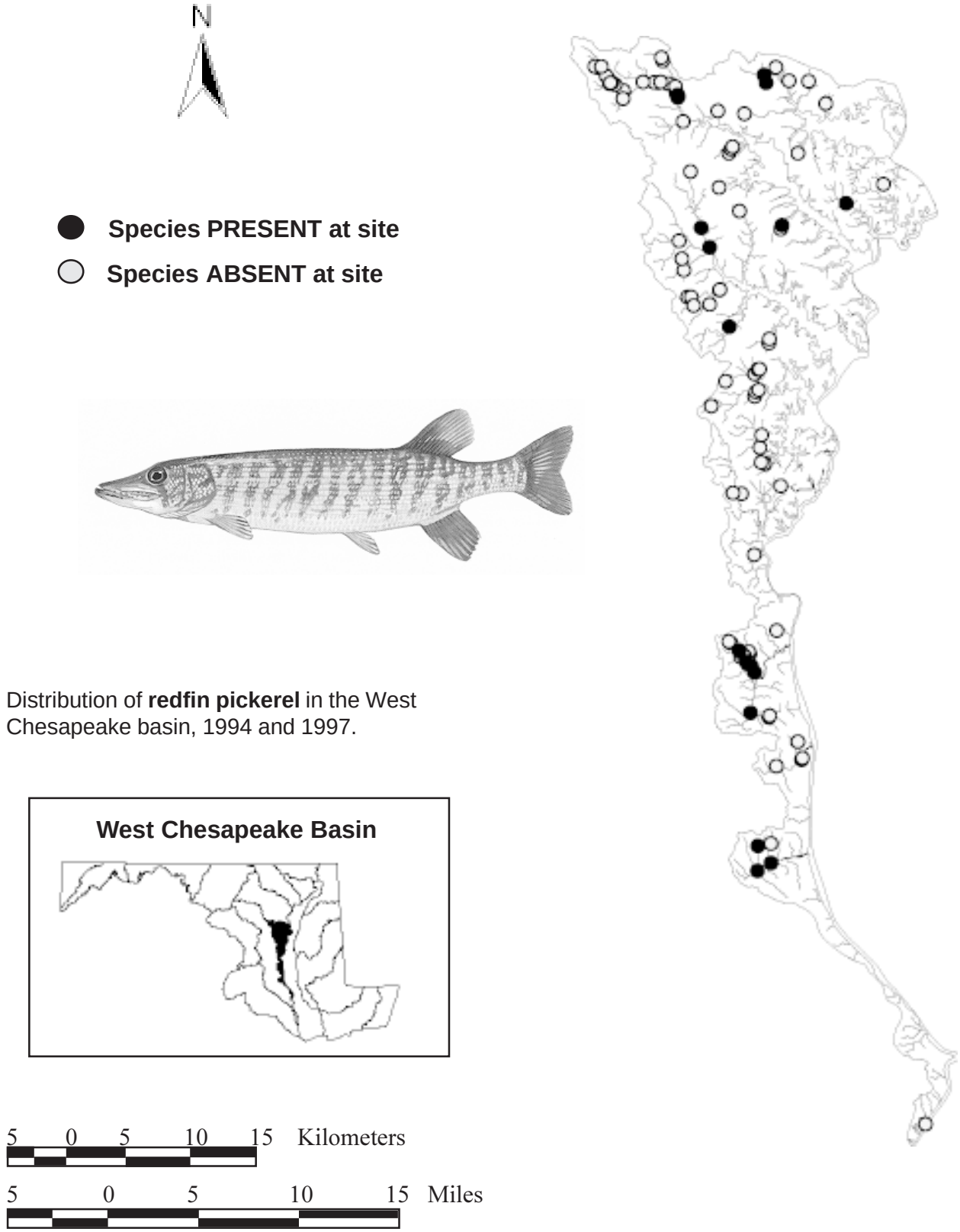


Distribution of **chain pickerel** in the West Chesapeake basin, 1994 and 1997.

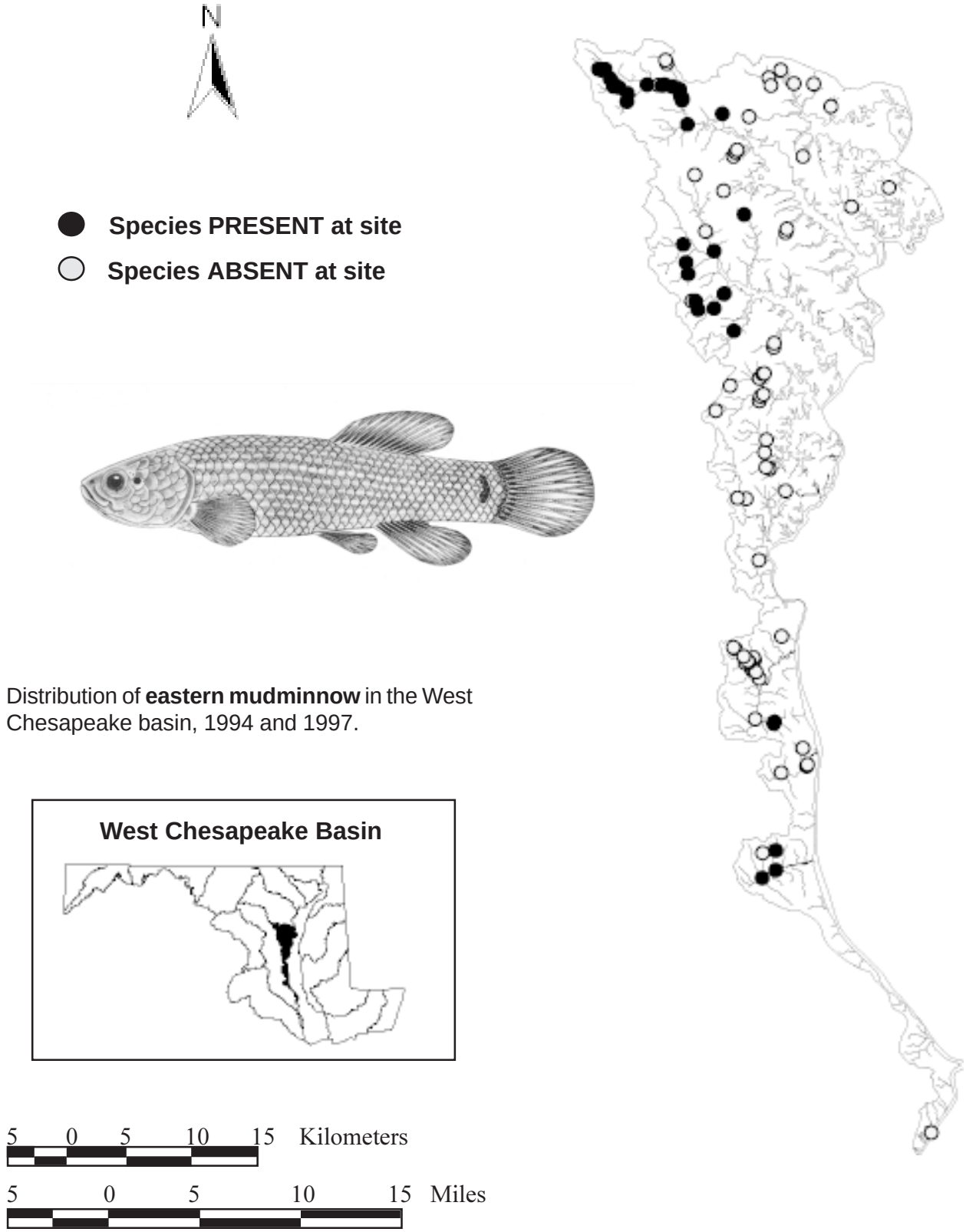
West Chesapeake Basin

5 0 5 10 15 Kilometers

5 0 5 10 15 Miles



Distribution of **redfin pickerel** in the West Chesapeake basin, 1994 and 1997.



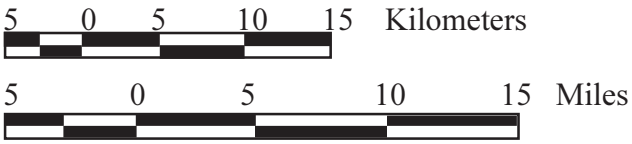
Distribution of **eastern mudminnow** in the West Chesapeake basin, 1994 and 1997.

● **Species PRESENT at site**

○ **Species ABSENT at site**

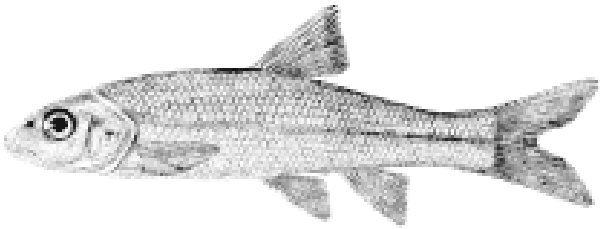
Distribution of **blacknose dace** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin



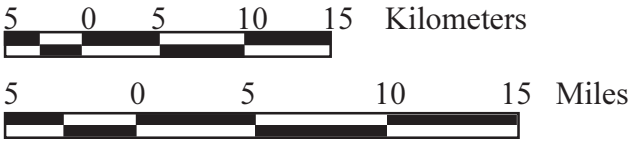
● **Species PRESENT at site**

○ **Species ABSENT at site**



Distribution of **fallfish** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin



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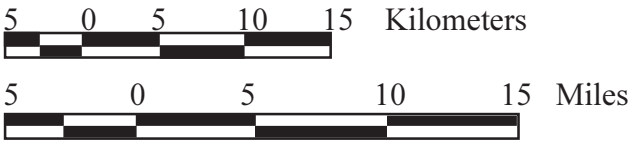
Distribution of **golden shiner** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin



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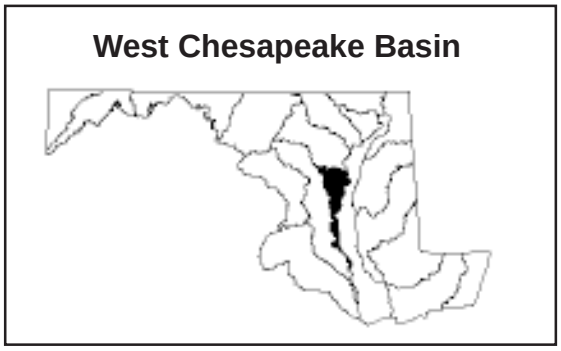
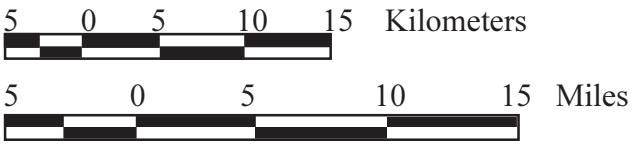
○ **Species ABSENT at site**

Distribution of **goldfish** in the West Chesapeake basin, 1994 and 1997.





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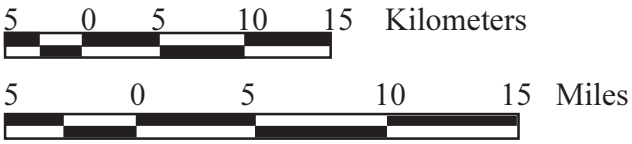
○ **Species ABSENT at site**

Distribution of **rosyside dace** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin

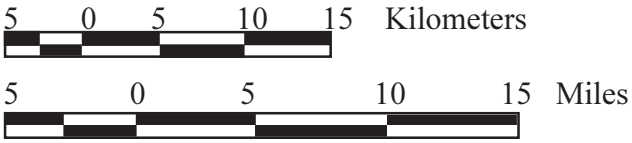


● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **satinfin shiner** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin

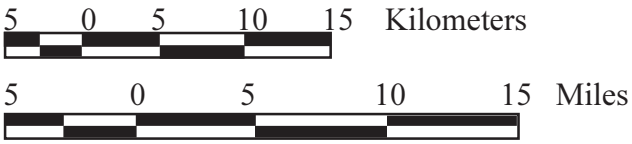


● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **spottail shiner** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin

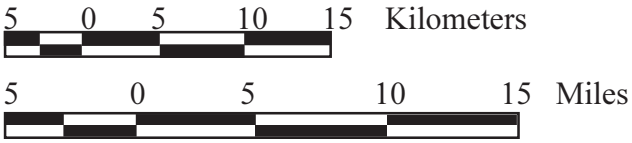


● **Species PRESENT at site**

○ **Species ABSENT at site**

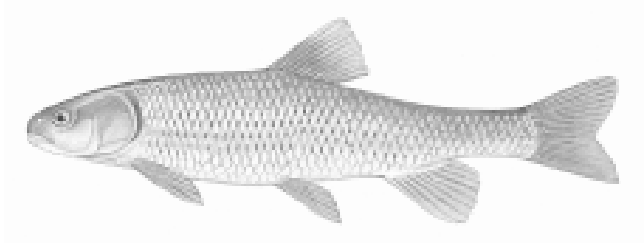
Distribution of **swallowtail shiner** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin



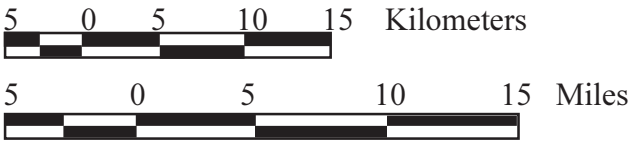
● **Species PRESENT at site**

○ **Species ABSENT at site**



Distribution of **creek chubsucker** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin



● **Species PRESENT at site**

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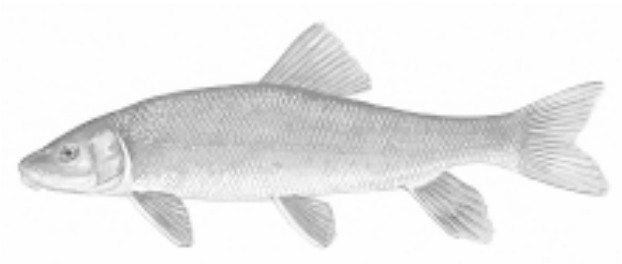


Distribution of **white sucker** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin

5 0 5 10 15 Kilometers

5 0 5 10 15 Miles

● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **brown bullhead** in the West Chesapeake basin, 1994 and 1997.

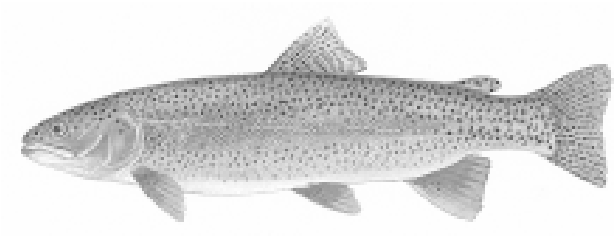
West Chesapeake Basin

5 0 5 10 15 Kilometers

5 0 5 10 15 Miles

● **Species PRESENT at site**

○ **Species ABSENT at site**



Distribution of **rainbow trout** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin

5 0 5 10 15 Kilometers

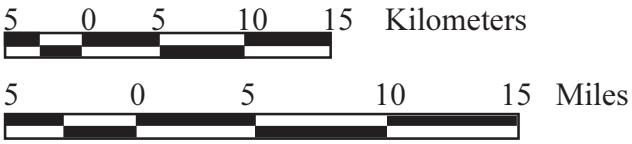
5 0 5 10 15 Miles

● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **inland silverside** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin



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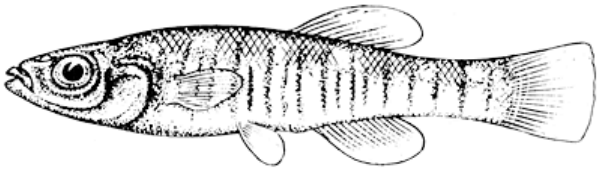
○ **Species ABSENT at site**



Distribution of **banded killifish** in the West Chesapeake basin, 1994 to 1997.

West Chesapeake Basin

5 0 5 10 15 Kilometers

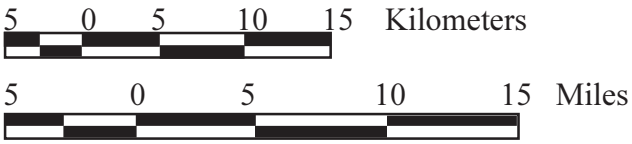
5 0 5 10 15 Miles

● **Species PRESENT at site**

○ **Species ABSENT at site**

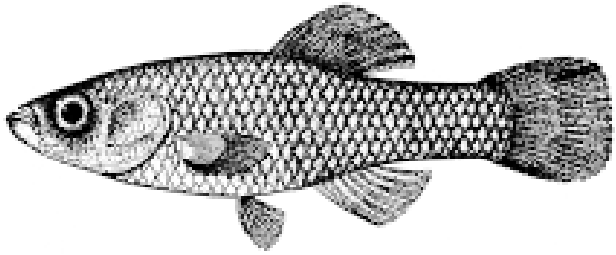
Distribution of **mummichog** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin



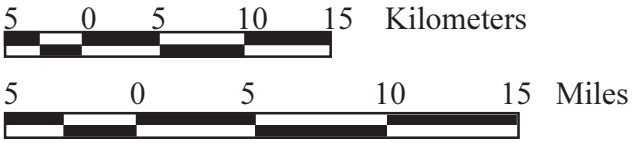
● **Species PRESENT at site**

○ **Species ABSENT at site**



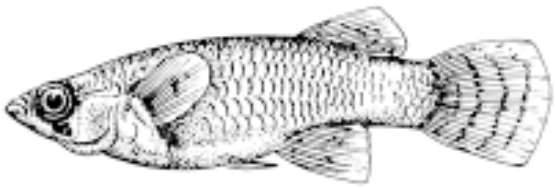
Distribution of **rainwater killifish** in the West Chesapeake basin, 1994 to 1997.

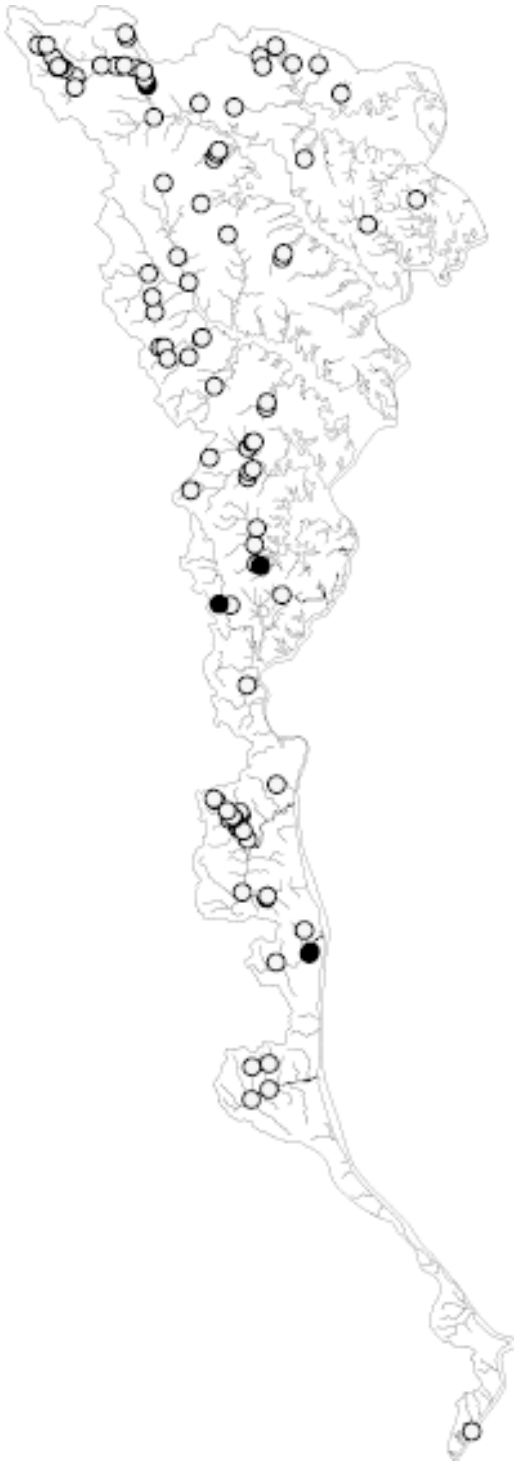
West Chesapeake Basin



● **Species PRESENT at site**

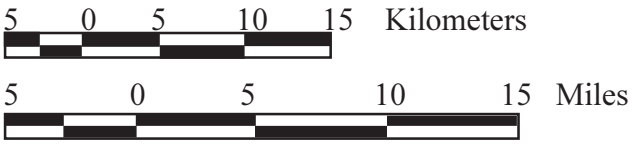
○ **Species ABSENT at site**

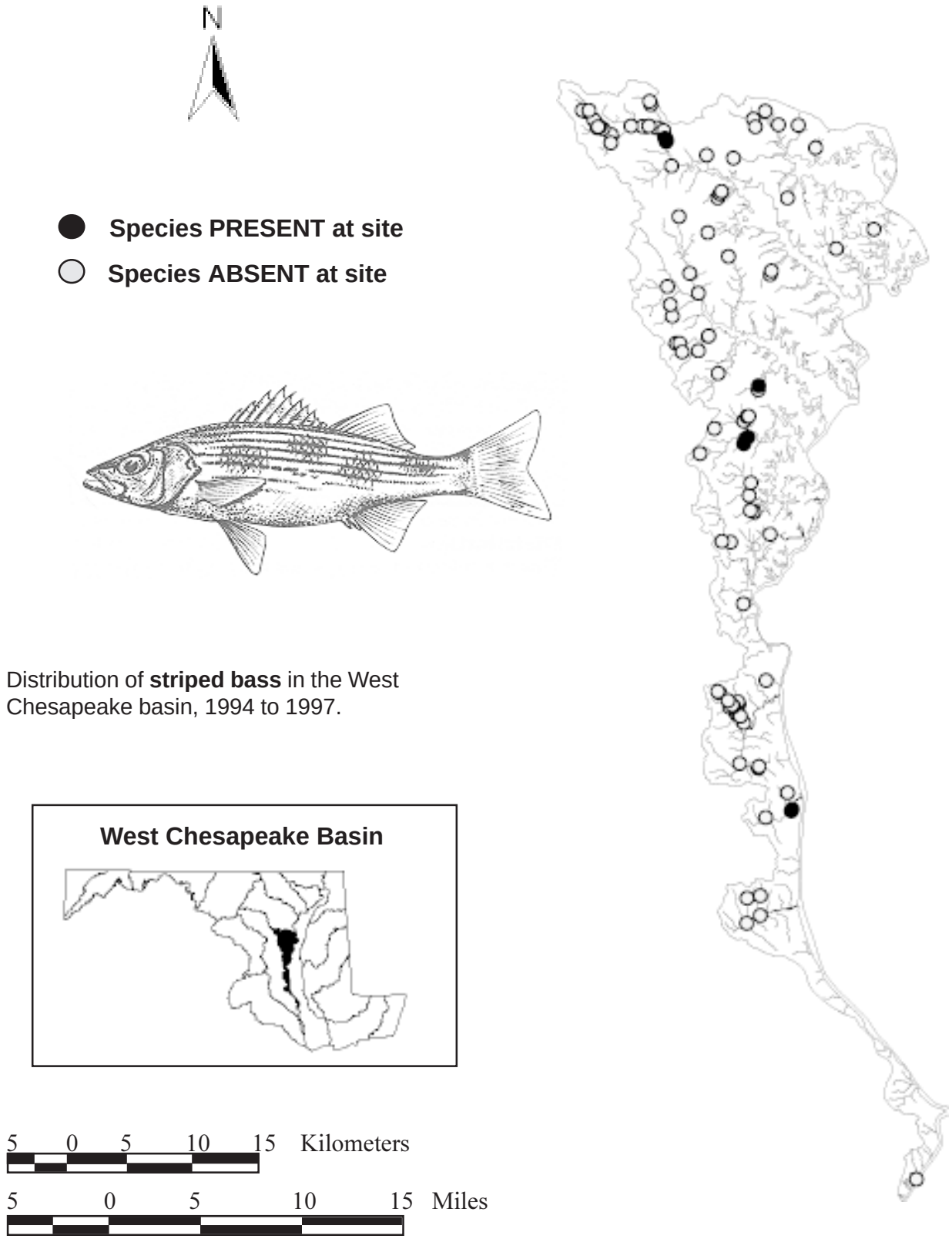




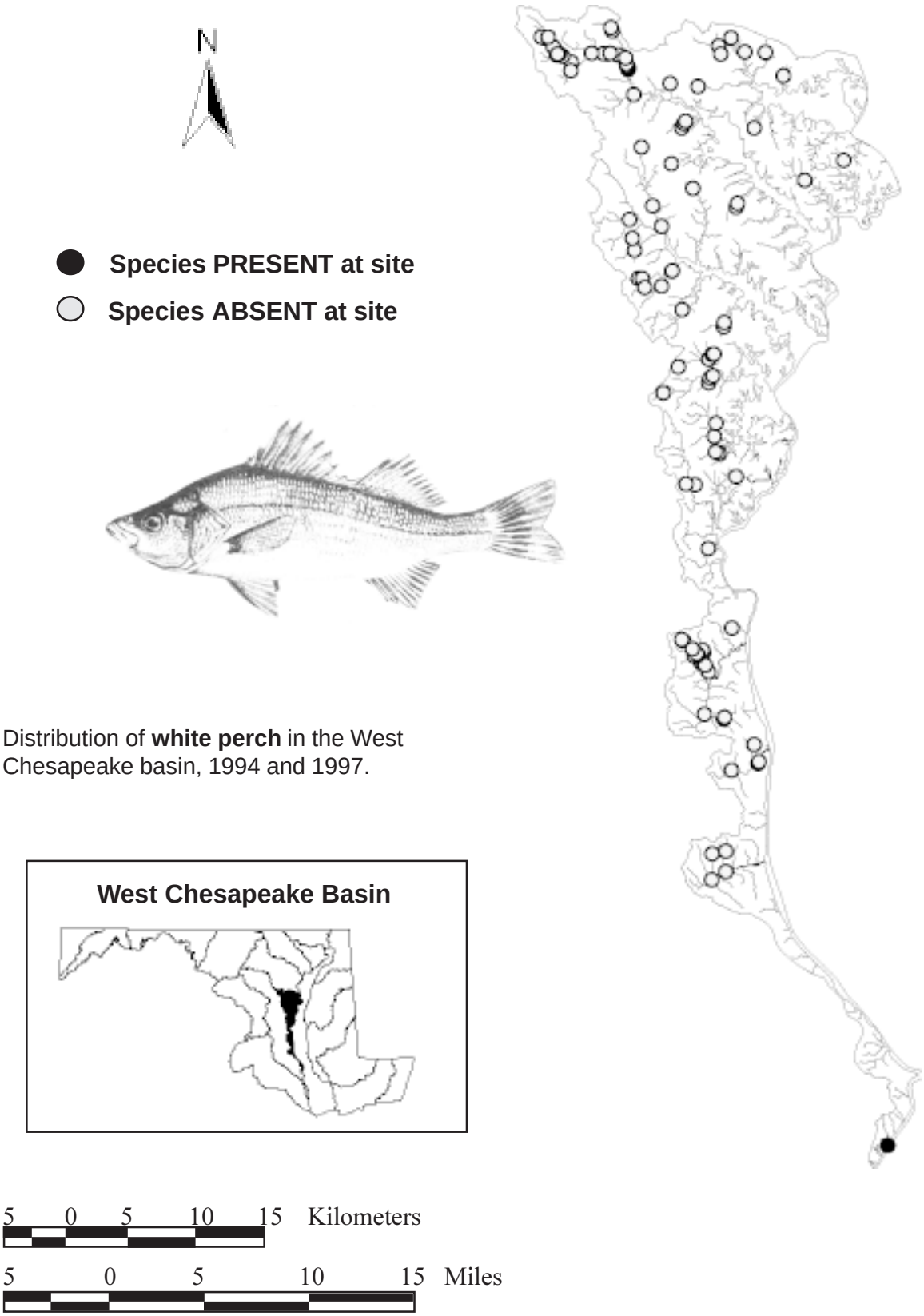
Distribution of **mosquitofish** in the West Chesapeake basin, 1994 to 1997.

West Chesapeake Basin





Distribution of **striped bass** in the West Chesapeake basin, 1994 to 1997.



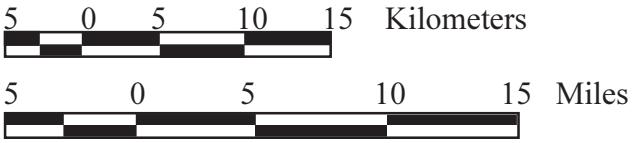
Distribution of **white perch** in the West Chesapeake basin, 1994 and 1997.

● **Species PRESENT at site**

○ **Species ABSENT at site**

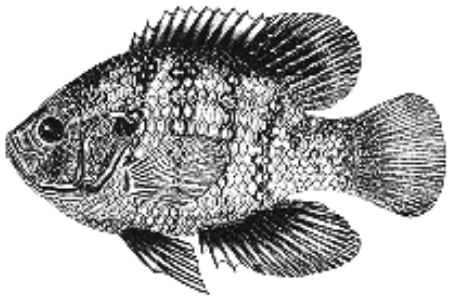
Distribution of **black crappie** in the West Chesapeake basin, 1994 to 1997.

West Chesapeake Basin

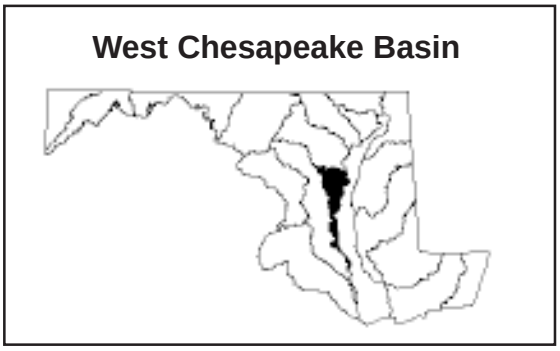


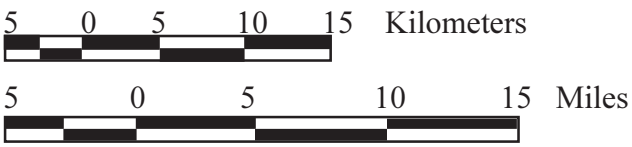
● **Species PRESENT at site**

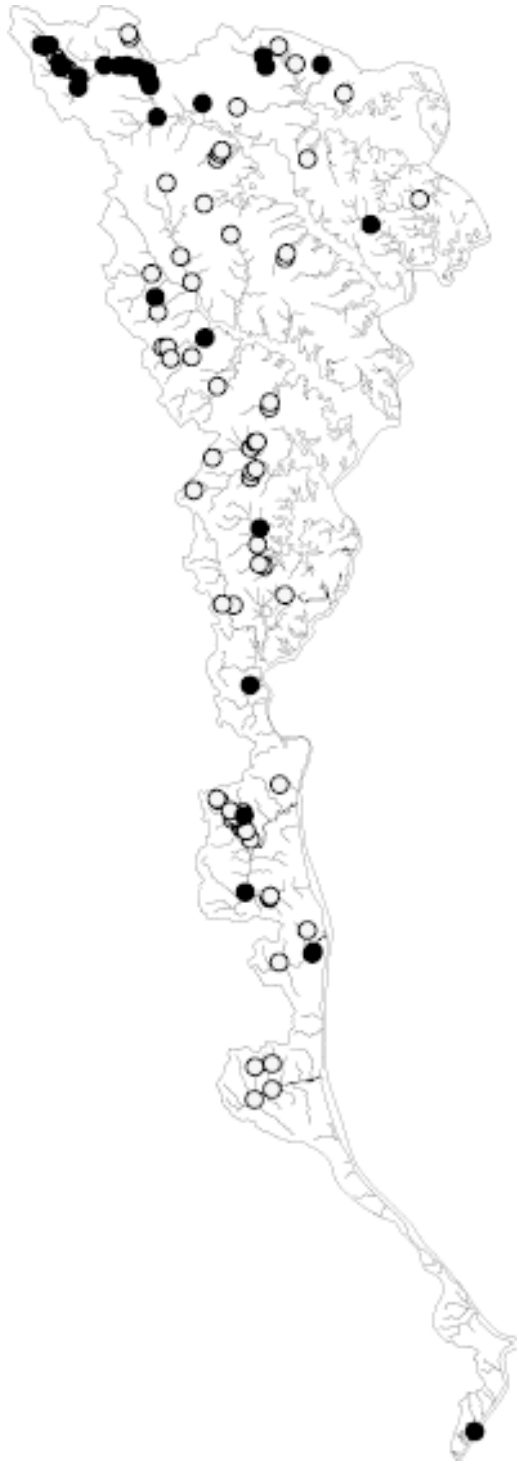
○ **Species ABSENT at site**



Distribution of **banded sunfish** in the West Chesapeake basin, 1994 and 1997.





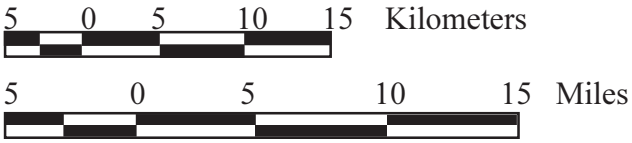


● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **bluegill** in the West Chesapeake basin, 1994 to 1997.

West Chesapeake Basin

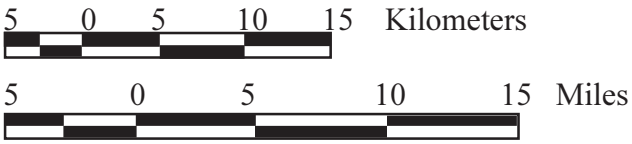


● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **bluespotted sunfish** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin



● **Species PRESENT at site**

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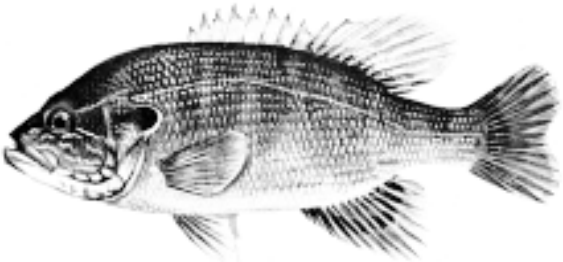
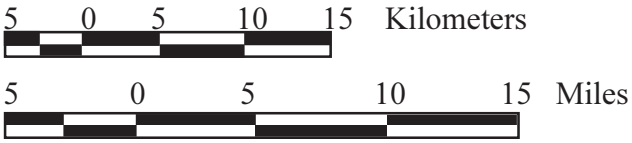


Distribution of **green sunfish** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin

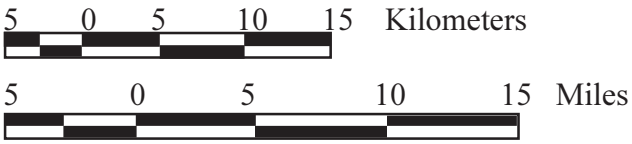


● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **largemouth bass** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin



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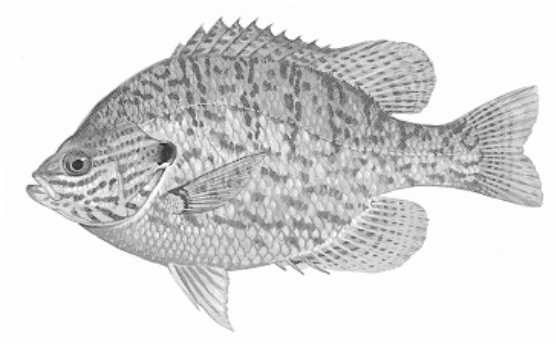
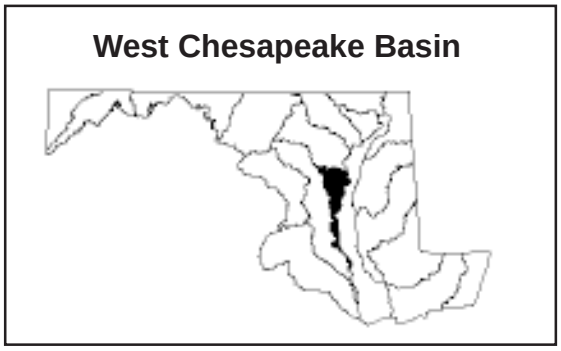
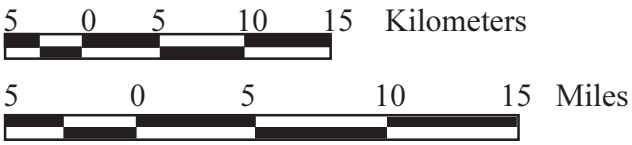
○ **Species ABSENT at site**



Distribution of **pumpkinseed** in the West Chesapeake basin, 1994 and 1997.





● **Species PRESENT at site**

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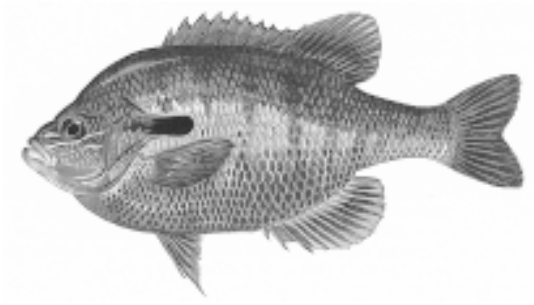
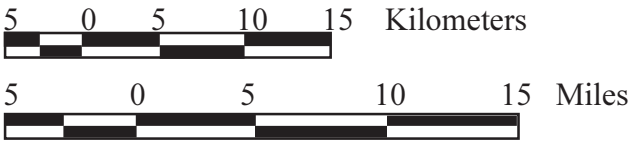


Distribution of **redbreast sunfish** in the West Chesapeake basin, 1994 and 1997.

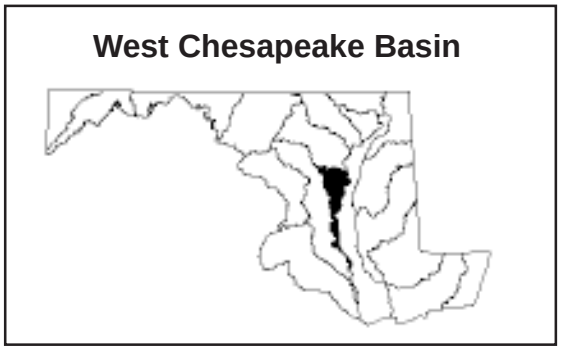
West Chesapeake Basin

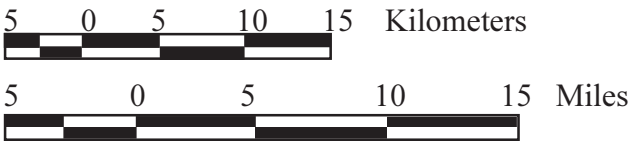


● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **tessellated darter** in the West Chesapeake basin, 1994 and 1997.



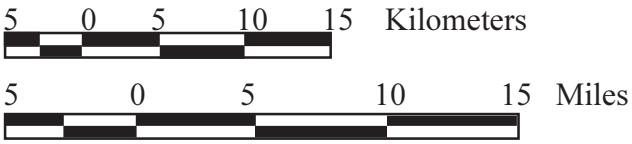


● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **yellow perch** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin

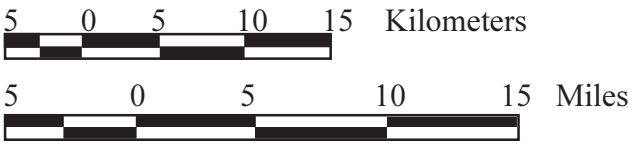


● **Species PRESENT at site**

○ **Species ABSENT at site**

Distribution of **spot** in the West Chesapeake basin, 1994 and 1997.

West Chesapeake Basin



Appendix F: List of benthic macroinvertebrates captured in the West Chesapeake basin during 1997. Tolerance value (TolVal), functional feeding group (FFG), habitat, and percent occurance (Per Occ) are shown. Abbreviations of habits are: bu - burrower, cn - clinger, cb - climber, sp - sprawler, dv - diver, and sk - skater. Adapted from Stribling et. al 1998.

Class	Order	Family	Taxon	Tol Val	FFG	Habit	Per Occ
Enopla	Hoplonemertea	Tetrastemmatidae	*Prostoma*		Predator	unknown	14.3
Turbellaria	Tricladida	Planariidae	*Cura*		Unknown	sp	5.7
			Dugesia	7	Predator	sp	5.7
Oligochaeta	Lumbriculida	Lumbriculidae		10	Collector	bu	22.9
	Tubificida	Enchytraeidae		10	Collector	bu	11.4
		Tubificidae	*Limnodrilus*	10	Collector	cn	8.6
		Naididae		10	Collector	bu	40.0
Gastropoda	Basommatophora	Lymnaeidae	*Pseudosuccinea*	6	Collector	cb	2.9
		Physidae	*Physella*	8	Scraper	cb	14.3
		Planorbidae	*Gyraulus*	8	Scraper	cb	2.9
			Helisoma	6	Scraper	cb	2.9
			Menetus	8	Scraper	cb	2.9
Pelecypoda	Veneroida	Corbiculidae	*Corbicula*	6	Filterer	bu	2.9
		Sphaeriidae	*Pisidium*	8	Filterer	bu	34.3
			Sphaerium	8	Filterer	bu	2.9
Malacostraca	Amphipoda	Crangonyctidae	*Crangonyx*	4	Collector	sp	45.7
		Gammaridae	*Gammarus*	6	Shredder	sp	37.1
			Stygonectes	6	Shredder	sp	2.9
		Hyalellidae	*Hyalella*	6	Shredder	sp	8.6
	Isopoda	Asellidae	*Caecidotea*	8	Collector	sp	40.0
Insecta	Ephemeroptera	Baetidae	*Acentrella*	4	Collector	sw, cn	25.7
			Acerpenna	4	Collector	sw, cn	2.9
		Ephemerellidae	*Eurylophella*	4	Scraper	cn, sp	20.0
		Heptageniidae	*Stenonema*	4	Scraper	cn	22.9
	Odonata	Aeshnidae	*Boyeria*	2	Predator	cb, sp	28.6
		Calopterygidae	*Calopteryx*	6	Predator	cb	14.3
		Cordulegastridae	*Cordulegaster*	3	Predator	bu	5.7
	Plecoptera	Leuctridae	*Leuctra*	0	Shredder	cn	14.3
		Nemouridae	*Amphinemura*	3	Shredder	sp, cn	51.4
		Nemouridae	*Prostoia*		Shredder	sp, cn	11.4
		Perlidae	*Acroneuria*	0	Predator	cn	2.9
			Eccoptura		Predator	cn	8.6
		Perlodidae	*Isoperla*	2	Predator	cn, sp	22.9
		Taeniopterygidae	*Taeniopteryx*	2	Shredder	sp, cn	17.1
	Hemiptera	Veliidae	*Microvelia*	6	Predator	sk	2.9
	Megaloptera	Corydalidae	*Nigronia*	0	Predator	cn, cb	17.1
	Trichoptera	Brachycentridae	*Micrasema*	2	Shredder	cn, sp	2.9
		Calamoceratidae	*Heteroplectron*	3	Shredder	sp	2.9
		Hydropsychidae	*Cheumatopsyche*	5	Filterer	cn	28.6
			Diplectrona	2	Filterer	cn	2.9
			Hydropsyche	6	Filterer	cn	28.6

Class	Order	Family	Taxon	TolVal	FFG	Habit	PerOcc
Insecta	Tricoptera	Lepidostomatidae	*Lepidostoma*	3	Shredder	cb, sp, cn	2.9
		Leptoceridae	*Oecetis*	8	Predator	cn, sp, cb	8.6
		Limnephilidae	*Hydatophylax*	2	Shredder	sp, cb	2.9
			Ironoquia	3	Shredder	sp	8.6
			Pycnopsyche	4	Shredder	sp, cb, cn	8.6
		Philopotamidae	*Wormaldia*		Filterer	cn	2.9
		Phryganeidae	*Ptilostomis*	5	Shredder	cb	5.7
		Polycentropodidae	*Polycentropus*	5	Filterer	cn	2.9
		Psychomyiidae	*Lype*	2	Scraper	cn	11.4
		Uenoidae	*Neophylax*	3	Scraper	cn	8.6
	Lepidoptera	Pyralidae			Shredder	cb	2.9
	Coleoptera	Dryopidae	*Helichus*	5	Scraper	cn	2.9
		Dytiscidae	*Agabus*	5	Predator	sw, dv	2.9
			Hydroporus	5	Predator	sw, cb	5.7
		Elmidae	*Ancyronyx*	2	Scraper	cn, sp	2.9
			Dubiraphia	6	Scraper	cn, cb	11.4
			Macronychus	4	Scraper	cn	5.7
			Oulimnius	2	Scraper	cn	2.9
			Stenelmis	6	Scraper	cn	8.6
		Gyrinidae	*Dineutus*	4	Predator	sw, dv	5.7
		Haliplidae	*Peltodytes*	5	Shredder	cb, cn	2.9
		Hydrophilidae	*Sperchopsis*	5	Collector	cn	2.9
		Ptilodactylidae	*Anchytarsus*	4	Shredder	cn	2.9
		Ceratopogonidae	*Bezzia*	6	Predator	bu	2.9
			Culicoides	10	Predator	bu	11.4
			Mallochohelea		Predator	bu	2.9
			Probezzia	6	Predator	bu	2.9
	Diptera	Chironomidae	*Ablabesmyia*	8	Predator	sp	2.9
			Apsectrotanypus	5	Predator	bu, sp	2.9
			Brillia	5	Shredder	bu, sp	2.9
			Cladotanytarsus	7	Filterer	Unknown	2.9
			Clinotanypus	8	Predator	bu	2.9
			Conchapelopia	6	Predator	sp	51.4
			Corynoneura	7	Collector	sp	5.7
			Cricotopus	7	Shredder	cn, bu	2.9
			Cricotopus/Orthocladius		Shredder	Unknown	82.9
			Diamesa	5	Collector	sp	11.4
			Eukiefferiella	8	Collector	sp	25.7
			Heterotrissocladius		Collector	sp, bu	5.7
			Hydrobaenus	8	Scraper	sp	5.7
			Krenopelopia		Predator	sp	2.9
			Labrundinia	7	Predator	sp	2.9
			Microtendipes	6	Filterer	cn	2.9
			Nanocladius	3	Collector	sp	8.6
			Natarsia	8	Predator	sp	2.9
			Odontomesa	4	Collector	sp	2.9

Class	Order	Family	Taxon	TolVal	FFG	Habit	PerOcc
Insecta	Diptera	Chironomidae	Orthocladiinae A	6	Collector	sp, bu	14.3
			Parametriocnemus	5	Collector	sp	45.7
			Paraphaenocladius	4	Collector	sp	5.7
			Paratanytarsus	6	Collector	sp	5.7
			Polypedilum	6	Shredder	cb, cn	37.1
			Psectrocladius	8	Shredder	sp, bu	2.9
			Pseudorthocladius	0	Collector	sp	2.9
			Rheocricotopus	6	Collector	sp	45.7
			Rheotanytarsus	6	Filterer	cn	14.3
			Stenochironomus	5	Shredder	bu	8.6
			Symposiocladius		Predator	sp	20.0
			Tanytarsus	6	Filterer	cb, cn	34.3
			Thienemanniella	6	Collector	sp	8.6
			Thienemannimyia		Predator	sp	5.7
			Tribelos	5	Collector	bu	5.7
			Trissopelopia		Predator	sp	2.9
			Xylotopus	2	Shredder	bu	2.9
			Zavrelimyia	8	Predator	sp	11.4
		Empididae	*Chelifera*		Predator	sp, bu	22.9
			Hemerodromia	6	Predator	sp, bu	11.4
		Simuliidae	*Simulium*	7	Filterer	cn	25.7
			Stegopterna	7	Filterer	cn	20.0
		Tabanidae	*Chrysops*	7	Predator	sp, bu	5.7
		Tipulidae	*Dicranota*	4	Predator	sp, bu	2.9
			Erioptera	7	Collector	bu	2.9
			Hexatoma	4	Predator	bu, sp	2.9
			Limonia	6	Shredder	bu, sp	2.9
			Pseudolimnophila	2	Predator	bu	8.6
			Tipula	4	Shredder	bu	17.1