State of Baltimore Harbor's Ecological and Human Health 2010

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Editors

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Science communication

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EcoCheck is a partnership group between the University of Maryland Center for Environmental Science (UMCES) and the National Oceanic and Atmospheric Administration (NOAA). Comprised of a collection of scientists interested in solving, not just studying, environmental problems, EcoCheck has extensive experience in developing ecosystem health assessments, including the annual Chesapeake Bay Report Card and numerous report cards for tributaries in the Mid-Atlantic region.

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Table of contents

History and geography shape Baltimore's Harbor

This baseline condition assessment was produced by EcoCheck (NOAA-UMCES Partnership) for the Waterfront Partnership of Baltimore, Inc. This report assesses the current ecosystem health status of Baltimore's Inner Harbor—future health can be assessed through annual Harbor ecosystem health report cards. An introduction to Baltimore Harbor's geophysical conditions, methods to evaluate individual indicators, and results of data analysis are all presented, along with suggestions for future monitoring and research needs.

Baltimore is an historic city

Baltimore was founded as a port city in the early 1700's for the tobacco trade and evolved into a leading port for sugar from the Caribbean. Baltimore continued to be a major manufacturing and shipping city throughout the 18th and 19th centuries, and due to its importance as a center of commerce, Baltimore's population grew rapidly. By the 20th century, the Harbor's waterfront was run down, with warehouses and businesses occupying the downtown area. In the late 20th century, the Inner Harbor area was revitalized as a tourist and shopping center, and this revitalization continues today. The National Aquarium, the Maryland Science Center, and a variety of restaurants and shops draw both residents and tourists to the Inner Harbor each day.

Baltimore is an urban river city

Two river systems run through the city and drain into two, separate branches of the Harbor. Jones Falls Creek and Gwynns Falls Creek run northwest to southeast, emptying into the Inner Harbor and the Middle Branch, respectively (Figure 1, next page). The Patapsco River flows just south of the city limits, draining the area from Eldersburg through Ellicott City south to Lansdowne-Baltimore Highlands. Historical records show that the Jones Falls outlet was bulkheaded as early as the mid-1800's. This means that the creeks and streams were funneled directly into the Harbor. Eventually these streams were paved over to make way for a growing city (Figures 1 and 2, next page). The Jones Falls Expressway (Interstate 83) now runs parallel and over top of Jones Falls Creek. The Jones Falls Creek outfall is between Pier 6 and Falls Avenue at the Inner Harbor.

Baltimore: When She Was What She Used to Be (University Press 1983)

The Jones Fall outlet was bulkheaded as early as the mid-1800s.

Geographical setting

The Patapsco River is a tidal tributary of Chesapeake Bay. The tidal portion of the Patapsco River reaches to the Inner Harbor (Northwest Branch) and the Middle Branch, where it mixes with the freshwater from the watershed (Figures 1 and 2, next page). The boundary between the Coastal Plain ecoregion and the Piedmont Uplands ecoregion runs northeast to southwest, through the very bottom parts of the Jones Falls and Gwynns Falls watershed. The Direct Harbor watershed is completely within the Coastal Plain ecoregion.

The Jones Falls Creek and Gwynns Falls Creek watersheds (150.8 km² or 58.2 mi² and 168.8 km² or 65.2 mi²,

Baltimore: When She Was What She Used to Be (University Press 1983)

This view from Federal Hill shows the Harbor waterfront was completely developed by the Civil War.

J. Thomas

An aerial view of Baltimore, facing northwest, with the Northwest Branch of the Patapsco River in the bottom left.

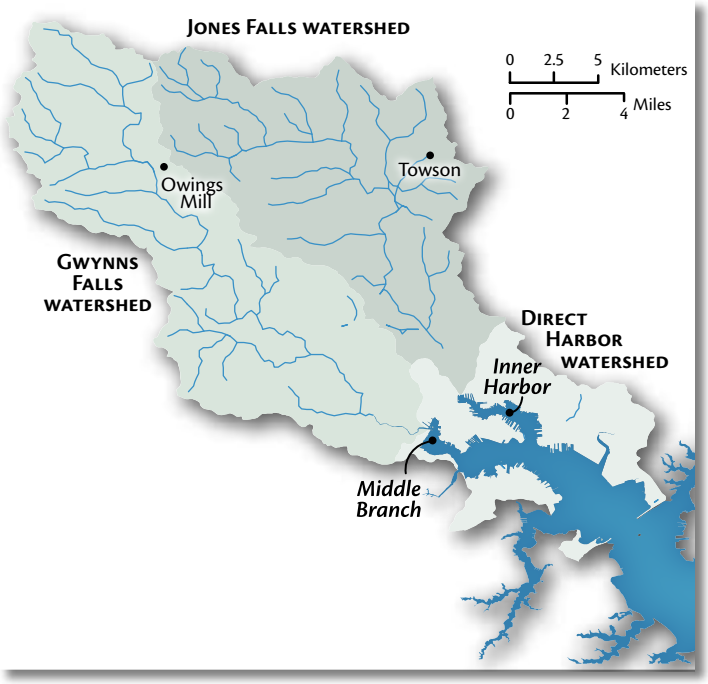


Figure 1. Map of streams in the Inner Harbor watershed. Notice that there are no aboveground streams closer to the Inner Harbor because they flow underground, through storm drains.

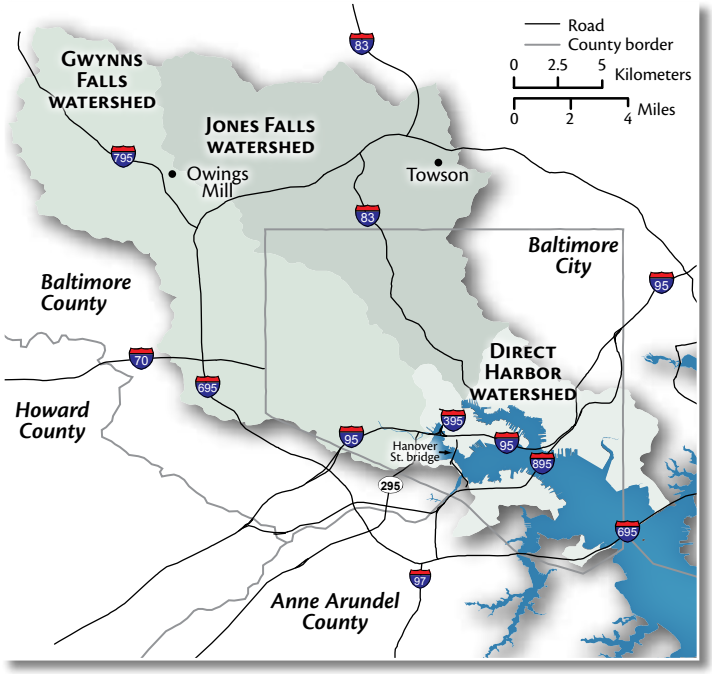


Figure 2. Map of Baltimore City, surrounding counties, pertinent watersheds, and the major road system.

respectively) contribute fresh water into the tidal Patapsco River. Jones Falls Creek delivers its freshwater via storm drains underneath the city and outfalls directly into the Inner Harbor. Gwynns Falls Creek delivers its freshwater via storm drains and streams and outfalls into the Middle Branch.

Figure 2 shows the pertinent major roadways, county and city boundaries, and three major watersheds. In addition to the Jones Falls Creek and Gwynns Falls Creek watersheds, there is also a Direct Harbor watershed, which drains directly into the Harbor. The Baltimore Beltway, I-695, encircles the city proper; however, residential suburbs of Baltimore stretch northwest into Baltimore County and even into Pennsylvania.

Natural water depths in the Harbor are generally less than 20 feet except for the main navigation channel, which is maintained at a depth of 52 feet (as permitted) through periodic dredging. The tidal range in the Harbor is approximately one foot (MDE 2006).

What does 'Harbor' mean?

The Inner Harbor can be defined in many ways. For visitors and residents of downtown Baltimore, the Inner Harbor refers to the area of waterfront along Pratt Street that has been revitalized and turned into a tourist destination (Figure 3 left). For others, the Inner Harbor refers to the areas adjacent to the waterfront promenade, stretching to Fells Point and Canton, along the northern edge of the water and to Federal Hill and Locust Point along the southern edge (Figure 3 middle). For the purposes of this study, water quality indicators were assessed within the area from the Inner Harbor waterfront (Aquarium, etc.) out to Fort McHenry, thereby encompassing the entire Baltimore Harbor area. This is an area that is relevant to the Waterfront Partnership of Baltimore's Healthy Harbor Initiative, but also is a geographically distinct area that is influenced by the Jones Falls Creek and Direct Harbor watersheds. The Middle Branch region was assessed because a large portion of the population of Baltimore City and County live in the Gwynns Falls watershed and around the Middle Branch area (Figure 3 right). These

Figure 3. Illustration of different geographical areas that are pertinent to this study.

communities also use and influence Baltimore Harbor, and are included in the target audience of the Waterfront Partnership of Baltimore's Healthy Harbor Initiative.

Tidally and nontidally (watershed) influenced

Because the Patapsco River is a tidal river, it is influenced both by its watershed, and by tides pushing saltier water up the river from the mainstem (i.e., the main, or central section) of the Chesapeake Bay. The mainstem of the Patapsco River is also influenced by the mainstem Chesapeake Bay via the force of freshwater coming from the Susquehanna River at the northern extent of the mainstem Bay (Schubel and Pritchard 1986, Jin 2004). The freshwater of the Susquehanna River and the saltwater of the Atlantic Ocean mix in the mainstem Chesapeake Bay adjacent to the mouth of the Patapsco River. The Patapsco River is characterized as mesohaline (salinity falls between 5 and 18 ppt on average). Furthermore, as saltwater moves up the mainstem tidal Patapsco (due to tides and wind), it is diluted by freshwater from the tributaries, such as Bear Creek, the Patapsco River, Gwynns Falls Creek, and Jones Falls Creek. The effect of freshwater from these creeks is localized. When less rainfall occurs, the salinity of the Inner Harbor and Middle Branch regions increases.

These complex processes affect the hydrological and physicochemical properties of the Inner Harbor waters. While the Inner Harbor is influenced by the mainstem tidal Patapsco, it is also influenced by freshwater streams. This results in a three-layer circulation pattern, where less salty waters from the Susquehanna float on top of the saltier (and therefore more dense) water from the Atlantic Ocean while moving into the Harbor. These waters mix and move out of the Harbor in the middle layer (Figure 4; Schubel and Pritchard 1986). This pattern is reliant on seasonal patterns of river flow and is easily disrupted by freshwater input from the Jones Falls Creek. A typical two-layer circulation pattern, where fresh, less dense waters float on top of saltier, more dense waters, results when freshwater input from Jones Falls Creek increases (Jin 2004).

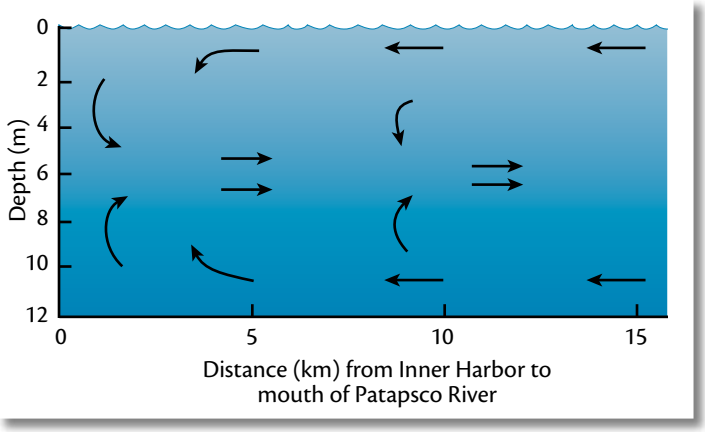


Figure 4. This figure describes the three-layer circulation that occurs in Baltimore Harbor. This can change to a two-layer circulation when there is strong freshwater flow, such as after a storm. Adapted from Schubel and Pritchard 1986.

Impervious surface and land use

The watersheds that drain into the Inner Harbor and Middle Branch are highly urbanized (Figure 5). The percentage of impervious cover (e.g., parking lots, houses, roads) which is the amount of area that does not allow rain to soak in, is a measure of how urbanized an area is and is related to the degree of stream degradation that occurs (Schueler et al. 2009). Many studies have confirmed the relationship between impervious cover and stream quality (Schueler et al. 2009). Jones Falls Creek, Gwynns Falls Creek, and the Direct Harbor watersheds have varying levels of impervious surface: 17.8%, 26.2%, and 67.0%, respectively. Based on a revised model of impervious cover (ICM) and stream degradation (Schueler et al. 2009), the Jones Falls watershed should exhibit stream quality from Good to Poor, Gwynns Falls watershed should exhibit stream quality from Fairly Good to Poor, and the Direct Harbor watershed should exhibit Poor stream quality. The amount of impervious coverage in the Direct Harbor watershed is considered urban drainage and is not categorized in the ICM.

Furthermore, each watershed has varying levels of developed land (e.g., housing, buildings). While areas of impervious surface and development are related, it is not a one to one relationship. Developed land is the most prevalent land use type in each subwatershed (Figure 6).

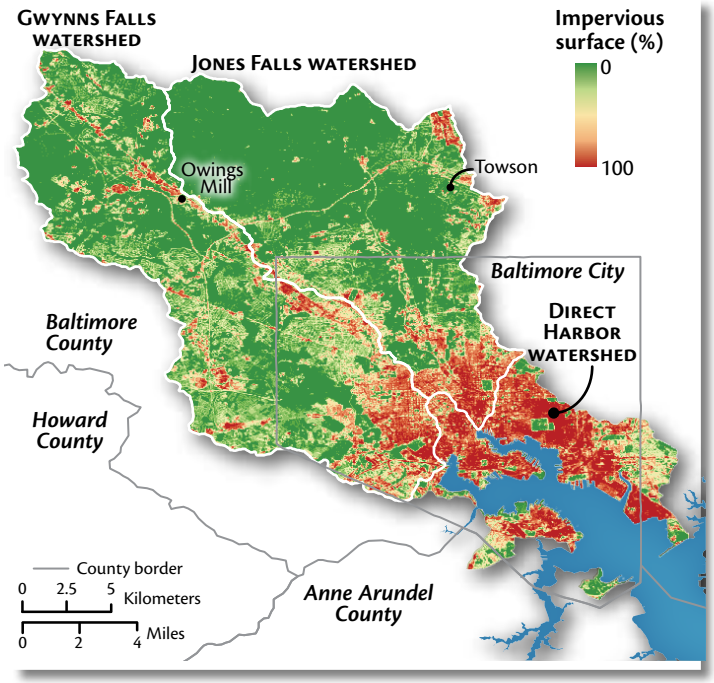


Figure 5. Impervious surface coverage in the Jones Falls Creek, Gwynns Falls Creek, and Direct Harbor watersheds. The Direct Harbor watershed is almost completely impervious surfaces.

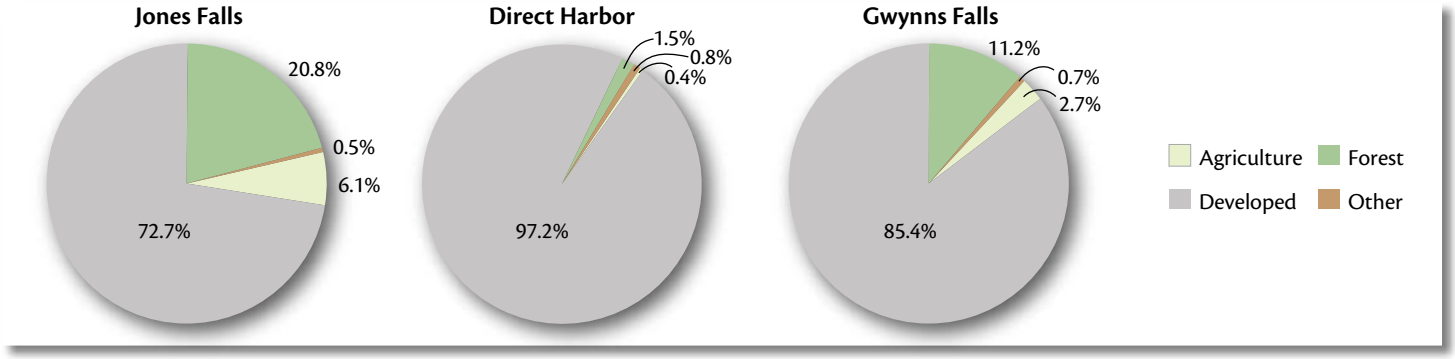


Figure 6. Developed land is the primary land use type in the Inner Harbor subwatersheds, with the highest amount (97.2%) in the Direct Harbor watershed, which is adjacent to the Inner Harbor.

There is some forested and agricultural land, mostly in the Jones Falls and Gwynns Falls watersheds. The Direct Harbor watershed has the highest percentage of developed land (97.2%), with very little forested land (1.5%).

Many agencies oversee management of Baltimore Harbor

Baltimore Harbor has historically been a commercially-focused waterway. The shipping industry has used the Harbor for hundreds of years. Shipping channels are maintained by the U.S. Army Corps of Engineers and by the Maryland Port Administration. Discharge into the Harbor waters is regulated by the federal National Pollutant Discharge Elimination System (NPDES), which is a state-administered, federal permitting program. The state grants permits to industry, such as wastewater treatment plants and factories, to discharge wastewater into local waters. Cities and counties are required to monitor the water quality of these discharges, to ensure they meet federal standards.

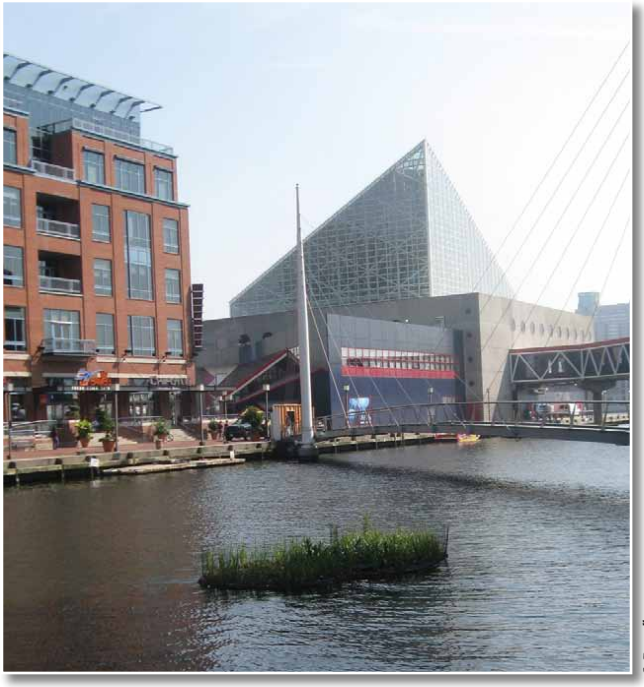
The Clean Water Act of 1972 established a structure that regulates pollutant discharges into local waters and quality standards for surface waters. Baltimore Harbor has been on the Clean Water Act's Impaired Waters list for many years due to nutrient, toxicant, and metal impairment. For the entire Patapsco River watershed (including areas not addressed in this report), the estimated average load of total nitrogen delivered to the tidal Patapsco River is 7,583,700 $lbs \cdot yr^{-1}$. The estimated average load of total phosphorus is 397,300 $lbs \cdot yr^{-1}$, and the estimated average load of sediment is 56,700 $tons \cdot yr^{-1}$. These loads indicate that these waters are too high in nutrients and sediment and a Total Maximum Daily Load (TMDL) for nitrogen, phosphorus, and sediment was calculated. A TMDL is the amount of a pollutant that a receiving water can accommodate and still meet water quality standards.

The recently approved Chesapeake Bay Total Maximum Daily Load (TMDL) and corresponding Watershed Implementation Plans (WIPs) will address the degraded conditions of the Baltimore Harbor and its watershed, as well (EcoCheck 2011). The TMDL and WIP process includes all relevant government agencies—the U.S. EPA, Maryland Department of the Environment, Maryland Department of Natural Resources, Maryland Department of Agriculture, Baltimore County, Baltimore City, and local municipalities.

Despite many years of government oversight, the water quality and habitat of the Harbor have not yet improved. The Harbor water is still filled with trash coming down the storm drains and blowing off the streets of Baltimore. Water quality is negatively impacted by nutrients, sediment, and bacteria transported into the Harbor. In recent years, private citizens, advocacy groups, and interested corporations have organized to take action against the pollution and neglect that has befallen Baltimore's Inner Harbor. These groups include neighborhood associations, the Baltimore Harbor WATERKEEPER®, Blue Water Baltimore, and the


National Aquarium, Baltimore

Trash piles up along the shoreline at Fort McHenry. The National Aquarium organizes a trash clean up four times a year to clean up this marsh.



S. Powell

The Waterfront Partnership and the National Aquarium partnered with several local groups to construct and install a pilot floating wetland project in Baltimore's Inner Harbor, with the goal of testing the ability of the system to clean the water and provide habitat for fish and other organisms. Watch underwater video of the wetlands at *www.youtube.com/watch?v=vFn142ciD7g* Waterfront Partnership of Baltimore.

The Waterfront Partnership of Baltimore, Inc. (*waterfrontpartnership.org*) is dedicated to improved maintenance, beautification, and visitor services for Baltimore Inner Harbor. The Partnership has launched Healthy Harbor 2020 (*healthyharborbaltimore.org*), an initiative to restore the Harbor and assure a vibrant, safe, sustainable future. This initiative includes an initial baseline conditions assessment of the ecological and human health of the Inner Harbor and its watershed. Furthermore, an annual report card will be produced in subsequent years and will be based on the same indicators as the baseline conditions assessment.

Integrated assessments can be achieved through annual report cards

Annual report cards are an excellent way to develop rigorous assessments and communicate results to the public, local decision makers, interest groups, and the scientific community. In order to achieve a regular cycle of report card production, monitoring of a comprehensive suite of relevant indicators is required. In some cases, additional research and monitoring needs may need to be identified before regular assessments are realistic.

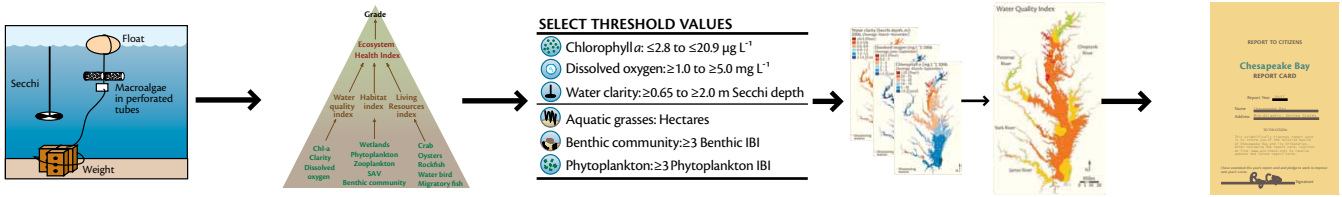
Typically, the process of producing a report card takes five steps, from creating indicators and establishing a monitoring program, to printing and disseminating the report card to the target audience (Figure 7).

Purpose of this document

Previous reports on the Patapsco River have not directly addressed the health of Baltimore Harbor. This is primarily because the Harbor is one small part of the larger Patapsco River. However, it is an important cultural and ecological area of the river that needs to be addressed, and is the focus of recent improvement efforts by the Waterfront Partnership of Baltimore and other organizations.

The current report is presented to the Waterfront Partnership of Baltimore as a baseline conditions assessment of Baltimore Harbor and Middle Branch health.

Five Step Process for Developing a Report Card



Step 1—Create new indicators and novel techniques for effective reporting and rigorous data analysis. Development of indicators is often based on available data, while recognizing and assessing additional data needs.

Step 2—Select indicators that convey meaningful information and can be measured reliably. Selection is normally based on factors such as sampling location and frequency and representativeness of the system. Indicators are grouped and structured to improve clarity to the intended audience.

Step 3—Define benchmarks against which data is compared (i.e., thresholds), reporting regions, and method of measuring threshold attainment. Threshold values are often based on values obtained from scientific literature and additional data analysis.

Step 4—Calculate indicator scores and combine into overall grades. Where it is appropriate, scores for different regions can be combined into overarching index values and converted to report card letter grades. Detailed maps of index and indicator scores are produced.

Step 5—Communicate results using mass media. Report cards include a variety of visual elements, such as photos, maps, figures, and conceptual diagrams to improve communication of results. These can be presented through press releases, public forums, local interest groups, etc.

Figure 7. The five steps to producing a report card. These steps should be followed for the Baltimore Harbor report cards that will be produced in the future, and which will be based on the present report.

The report evaluates a series of water quality and biotic indicators to assess ecological health and bacteria and trash to assess human health of the Harbor and its watershed. Evaluation of each indicator is based on methodologies validated through peer-reviewed scientific articles and years-long development of health indicators of Chesapeake Bay via the Chesapeake Bay Program (U.S. EPA 2003, Williams et al. 2009). Additionally, the authors of this report have developed standardized sampling and data analysis methods for a set of core indicators through the Mid-Atlantic Tributary Assessment Coalition (MTAC). The protocol document describing these standardized methods is available at *www.eco-check.org*.

The current document evaluates eight ecological health indicators *in the Inner Harbor:*

- dissolved oxygen
- chlorophyll *a*
- water clarity
- total nitrogen
- total phosphorus
- benthic community
- aquatic grass and
- toxicants (in the sediment).

It also evaluates two human health and aesthetic indicators: bacteria and trash.

Furthermore, because watershed activities directly impact the water quality and human health status of the Inner Harbor, this current assessment evaluates eight ecological health indicators *in the watershed*:

- dissolved oxygen
- total suspended solids (TSS)
- conductivity
- total nitrogen
- total phosphorus
- water temperature
- pH and
- benthic community.

Two human health and aesthetic indicators are also evaluated in the watershed: bacteria and trash.

Finally, recommendations for future water quality monitoring and data analysis for annual report cards is presented.

The overarching goal of this document is to provide a picture of the current health of Baltimore's Inner Harbor and to suggest future directions for monitoring and assessment.

Literature cited

EcoCheck (20110) Total Maximum Daily Loads: A citizen's guide to the Chesapeake Bay TMDL [newsletter]. www.eco-check.org/communication/

Jin Z (2004) Modeling hydrodynamics and sediment transport in Baltimore Harbor: Time-varying boundary conditions. University of Maryland Masters thesis.

Maryland Department of the Environment (2006) Total Maximum Daily Loads of nitrogen and phosphorus for the Baltimore Harbor in Anne Arundel, Baltimore, Carroll and Howard Counties and Baltimore City, Maryland. Submitted to U.S. EPA in December 2006.

Schubel JR, Pritchard DW (1986) Responses of upper Chesapeake Bay to variations in discharge of the Susquehanna River. Estuaries 9(4A):236-249

Schueler TR, Fraley-McNeal L, Cappiella K (2009) Is impervious cover still important? Review of recent research. Journal of Hydrologic Engineering 14(4):309-315

U.S. Environmental Protection Agency (2003) Ambient water quality criteria for dissolved oxygen, water clarity, and chlorophyll *a* for Chesapeake Bay and tidal tributaries. U.S. Environmental Protection Agency Office of Water EPA-903-R-03-002. Washington, District of Columbia

Williams M, Longstaff B, Llanso R, Buchanan C, Dennison W (2009) Development and evaluation of a spatially-explicit index of Chesapeake Bay health. Marine Pollution Bulletin 59:14-25

Ecological and human health issues

This baseline conditions assessment addresses both ecological and human health status of the Inner Harbor and its watershed. To evaluate the current health of the entire system, an understanding of the pressures (e.g., development, industry, population growth) on the Inner Harbor and its watershed is needed.

A workshop was convened in November 2010 to bring together data providers and experts in the field from local (city and county), state, and federal agencies. Workshop participants described the major pressures and land use impacts (e.g., increased nutrient and sediment run off) on the Inner Harbor (Figure 8). These include nutrient and bacteria coming from broken sewer pipes; stormwater runoff from parking lots, buildings, and roads; trash; and toxicants from industry. Impervious surfaces, such as urban residential areas (neighborhoods), commercial and retail areas, and parking lots, contribute to these pressures on the system. Based on the expertise and experience of the workshop participants, specific water quality and biotic health indicators should be included in an assessment of Baltimore's Inner Harbor. These indicators are dissolved oxygen, chlorophyll *a,* water clarity, toxicants (e.g., PCBs, PAHs, and heavy metals), and fish and benthic communities. Additionally, bacteria and trash should be included as indicators of human health risk and aesthetics.

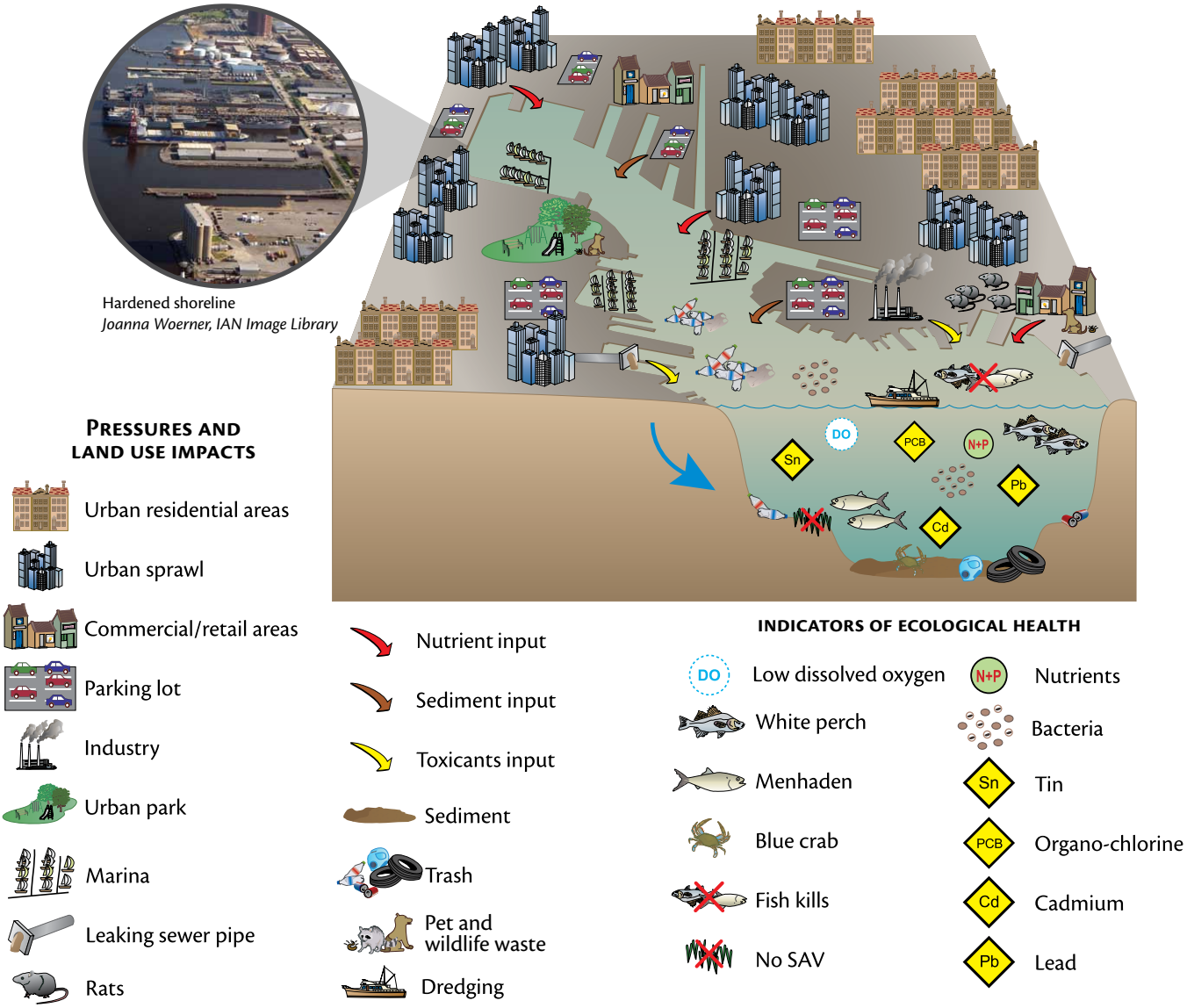


Figure 8. This conceptual diagram illustrates some of the pressures and land use impacts on Baltimore Harbor, as well as some indicators of ecological and human health. The Harbor is highly urbanized.

Specific indicators for Baltimore Harbor

Most of the ecological indicators that were evaluated for this report that describe the quality of the water directly are physical and chemical indicators. For the Inner Harbor, the water quality indicators are dissolved oxygen, water clarity, chlorophyll *a*, total nitrogen, and total phosphorus.

Water quality data were very limited in the Inner Harbor because there was only one station appropriate for use. The spatial resolution of Maryland Department of Natural Resources (MD DNR) tidal ecosystem assessment sampling regime is appropriate when comparing all tributary data. However, because the Inner Harbor is such a small area (approximately 3.3 km^2 or 1.3 mi^2) compared to the entire Patapsco River, only one MD DNR station was available and relevant for water quality assessment in the Harbor. This station is located equidistant from the Fells Point shoreline on the north side and the Locust Point shoreline along the south (see Figure 13).

Indicators of ecological health

The ecological health indicators for Baltimore Harbor are based on the Mid-Atlantic Tributary Assessment Coalition's core indicators for *tidal* waters: dissolved oxygen, chlorophyll *a*, water clarity, total nitrogen, total phosphorus, and aquatic grasses (EcoCheck 2011; Figure 9). These indicators are easily measured, cost effective, and most importantly, illustrate the overall ecological health of a waterbody (Longstaff et al. 2010). Toxicants and benthic macroinvertebrates (e.g., the clams, worms, and other organisms living in the bottom sediment) were also assessed to provide a wider picture of the overall health of the Inner Harbor. The methods for evaluating each indicator, including sampling period and frequency, thresholds, and calculations, will be discussed in detail in the following chapters.

Indicators of human health

Human health is an important component of the Waterfront Partnership's Healthy Harbor Initiative. To that end, this assessment includes three indicators of human health and aesthetics: bacteria, fish toxicity, and trash (Figure 9). The methods for evaluating each indicator, including sampling period and frequency, thresholds, and calculations, will be discussed in detail in the following chapters.

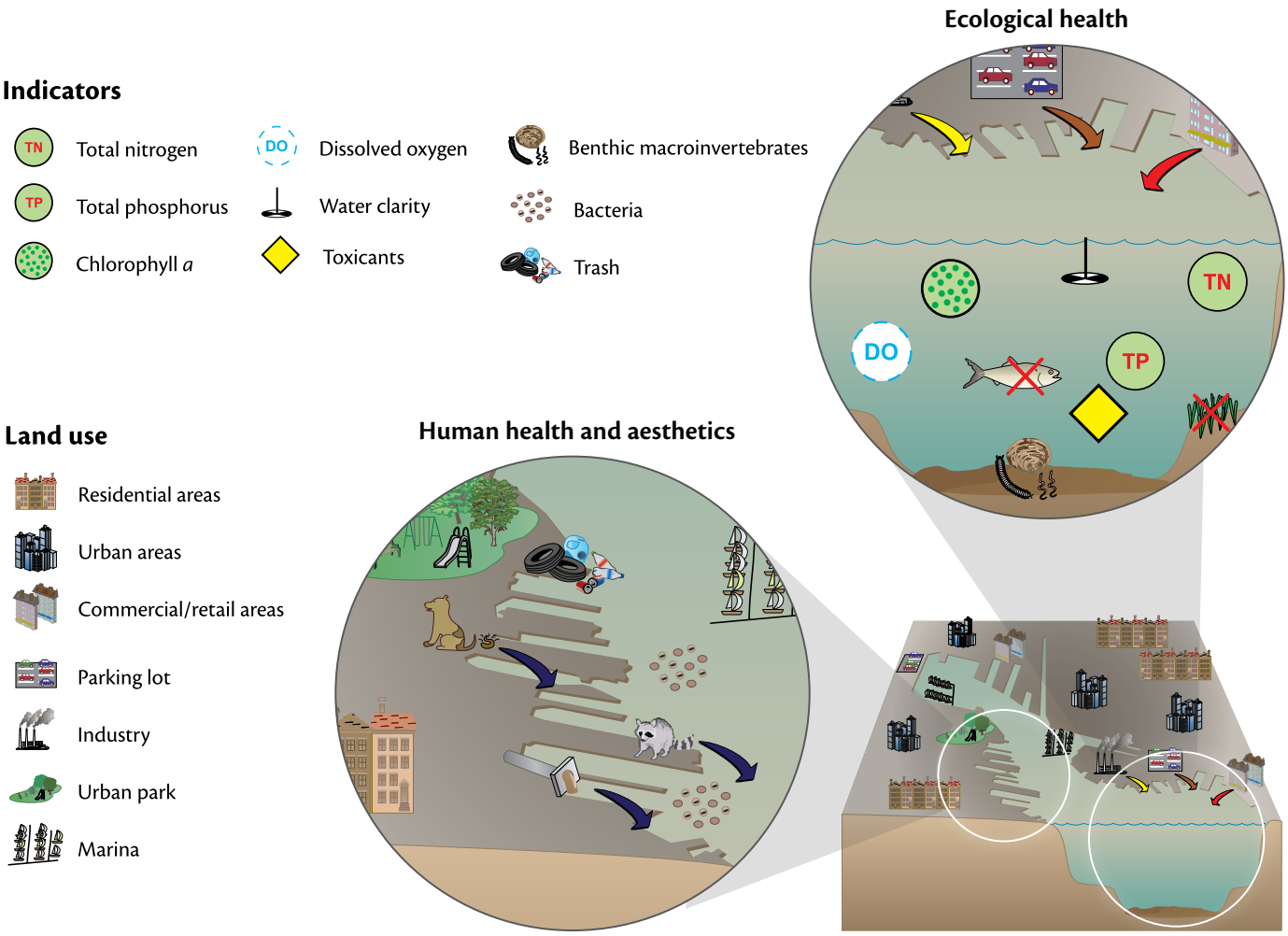


Figure 9. This conceptual diagram shows the ecological and human health indicators that will be used in this baseline conditions assessment. These indicators illustrate the current health of the Inner Harbor and incorporate the impacts of current land use practices.

Reporting regions for Baltimore Harbor

The two tidal reporting regions for Baltimore Harbor were determined by expert opinion at the November 2010 workshop, and correspond to the areas directly impacted by the Jones Falls Creek, Gwynns Falls Creek, and Direct Harbor watersheds (Figure 10). These areas directly influence the ecological and human health of Baltimore Harbor and Middle Branch. Since activities in the watershed ultimately affect water quality downstream, the health scores should reflect these impacts. The mainstem Patapsco River is influenced by areas outside the scope of this study and is not addressed in this report.

The Inner Harbor reporting region (area = 3.27 km^2 or 1.3 mi^2, shoreline length = 32.9 km or 20.4 mi), which stretches from the waterfront promenade area near the Aquarium to Fort McHenry, is commonly known as the Northwest Branch. The Middle Branch reporting region (area = 1.48 km^2 or 0.57 mi^2, shoreline length = 10.2 km or 6.3 mi) is the area west of the Hanover Street bridge (Figure 2). The bridge is a natural cutoff point because everything southeast of the bridge is predominantly influenced by the tidal Patapsco and the Patapsco River tributary (Figure 10).

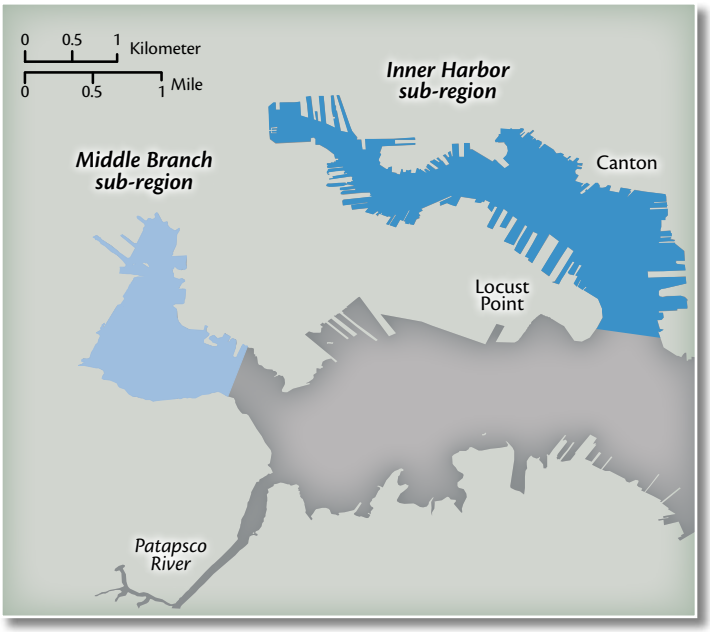


Figure 10. The two tidal reporting regions for this assessment: the Inner Harbor, which includes the area from the waterfront promenade to Fort McHenry, and the Middle Branch, which includes the area above the Hanover St bridge. Note the Patapsco River coming into the mainstem Patapsco south of the Hanover Street bridge.

Specific indicators for Baltimore Harbor's watershed

Indicators of ecological health

Water quality indicators for watershed health are slightly different than water quality indicators in the Inner Harbor. Indicators were chosen that reflect the health conditions in streams. These indicators assess whether there is acceptable habitat for benthic communities and fish directly in the streams.

Indicators of human health

Human health is an important component of the Waterfront Partnership's Healthy Harbor Initiative. To that end, this assessment includes two indicators of human health and aesthetics in the watershed: bacteria and trash. The methods for evaluating each indicator, including sampling period and frequency, thresholds, and calculations, will be discussed in detail in the following chapters.

Reporting regions for Baltimore Harbor's watershed

Three reporting regions for Baltimore Harbor's watershed were determined by the three major watersheds that flow into the Inner Harbor and Middle Branch. They are the Jones Falls watershed, the Gwynns Falls watershed, and the Direct Harbor watershed (i.e., those areas that may not have streams, but drain directly into the Harbor; Figure 11).

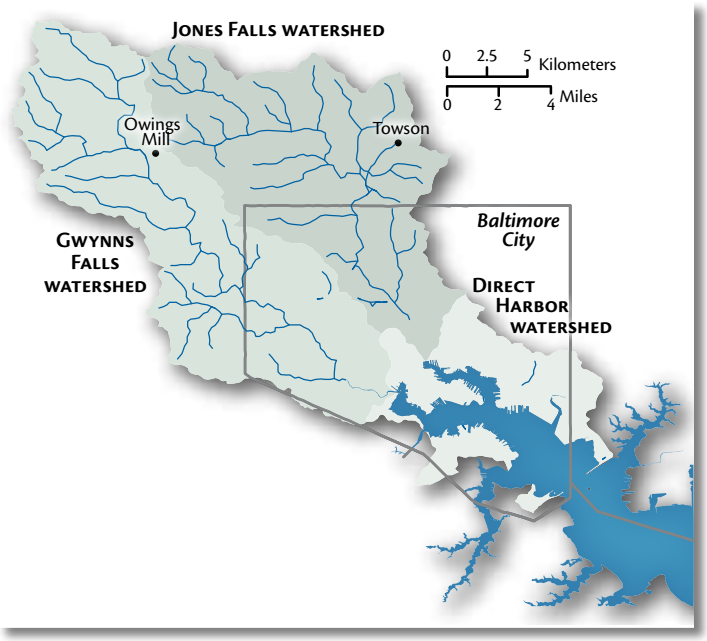


Figure 11. Baltimore Harbor watershed reporting regions: the Jones Falls watershed, the Gwynns Falls watershed, and the Direct Harbor watershed.

The Jones Falls watershed (area = 104 km² or 40 mi²) drains into the Inner Harbor at Pier Six. The watershed stretches north-northwest out of Baltimore City into Baltimore County. Towson and Lutherville-Timonium are cities in the Jones Falls watershed. The Gwynns Falls watershed (area = 171 km² or 66 mi²) is to the west of Jones Falls and drains into the Middle Branch where I-95 crosses the water. Woodlawn, Owings Mill, and Reistertown are cities in the Gwynns Falls watershed. The Direct Harbor watershed (area = 54 km² or 21 mi²) drains directly into the Inner Harbor and Middle Branch. It is mostly within Baltimore City, with a few areas located in Baltimore and Anne Arundel Counties.

An abundance of data is collected by various agencies

From the workshop in November 2010, it was determined that a large amount of data are being collected by Baltimore County, Baltimore City, the Maryland Department of Natural Resources, the Maryland Department of the Environment, the National Aquarium, Maryland Sea Grant, the Maryland Port Administration, the Baltimore WATERKEEPER®, and the Baltimore Ecosystem Study. These data providers were very helpful in describing what and where data are being collected and by providing their data for this analysis. One of the outcomes of the November 2010 workshop was connecting agencies with each other for future collaborative work, which will allow leveraging their funding and effort for a more coordinated monitoring effort.

Spatial and temporal resolution of data is lacking

Mapping of sampling locations identified in the November 2010 workshop (Figure 12) revealed that water quality data for most indicators are not well distributed throughout the Inner Harbor reporting regions.

The Maryland Department of Natural Resources (MD DNR) conducts water quality monitoring in Maryland tidal waters (*eyesonthebay.net*). While MD DNR coverage of the entire Chesapeake Bay is well distributed, there is only one fixed station in the Patapsco River that records water quality data. This station is well outside the boundaries that are being evaluated in this report. However, MD DNR is currently conducting a three-year Dataflow cruise, in which monthly (April to October) monitoring is conducted within the Baltimore Harbor boundaries. The Dataflow cruise data were collected from 2009 to 2011 and include all the water quality indicators that are being assessed in this analysis. Data from the Dataflow station XIE6747 (Figure 13) from 2009 and 2010 was used in this analysis for dissolved oxygen, chlorophyll *a*, and water clarity. This station provided 13 to 14 samples over two years, which were incorporated into this assessment. Total nitrogen and total phosphorus data are available from 2009 only—funding for nutrient analysis was cut from the federal agency's budget that covers this monitoring after 2009. Accordingly, there are a very low number of samples with which to assess nutrients. Furthermore, after 2011, there is no water quality monitoring at all planned for the Inner Harbor. This assessment benefited from the recent Dataflow cruise data, but a lack of data in the future may affect the ability to produce annual assessments.

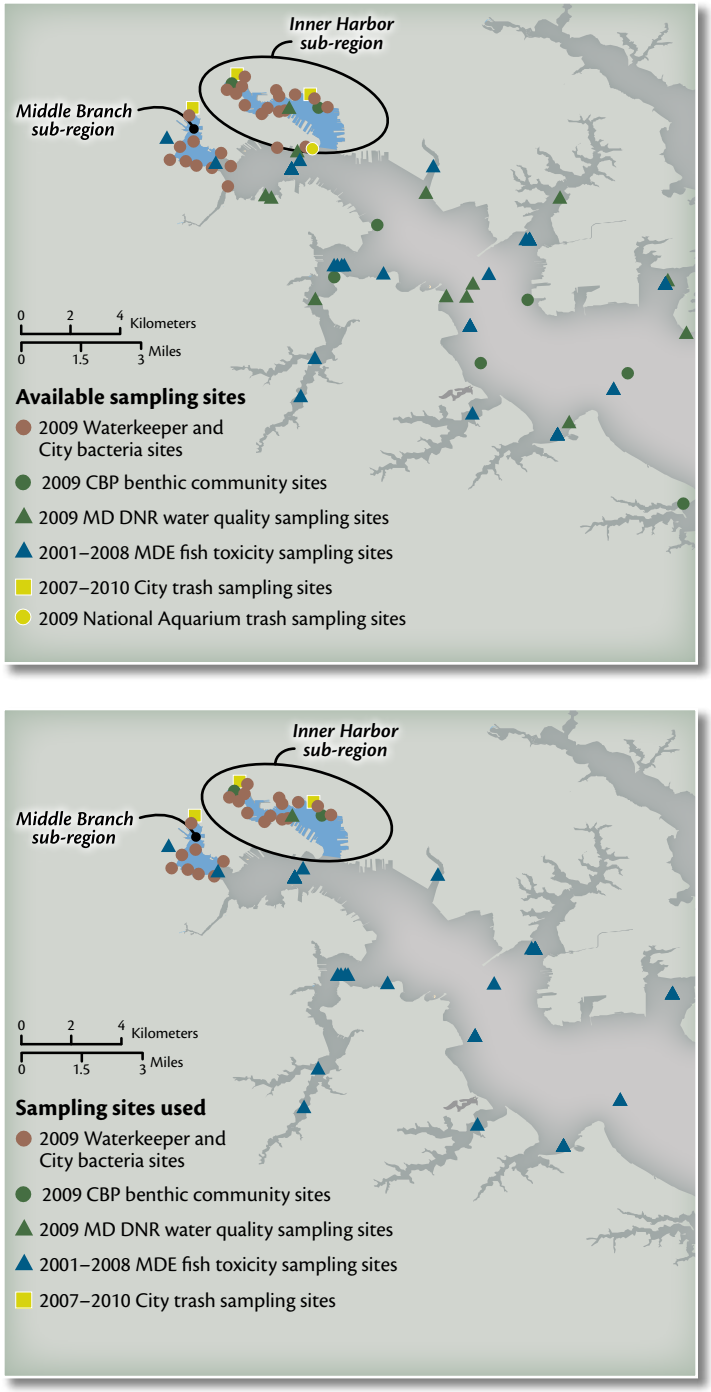


Figure 12. Available sampling sites for all indicators from all agencies in the Harbor and tidal portions of the Patapsco River (top). All sampling sites used in this assessment (bottom). Sediment sampling sites not shown.

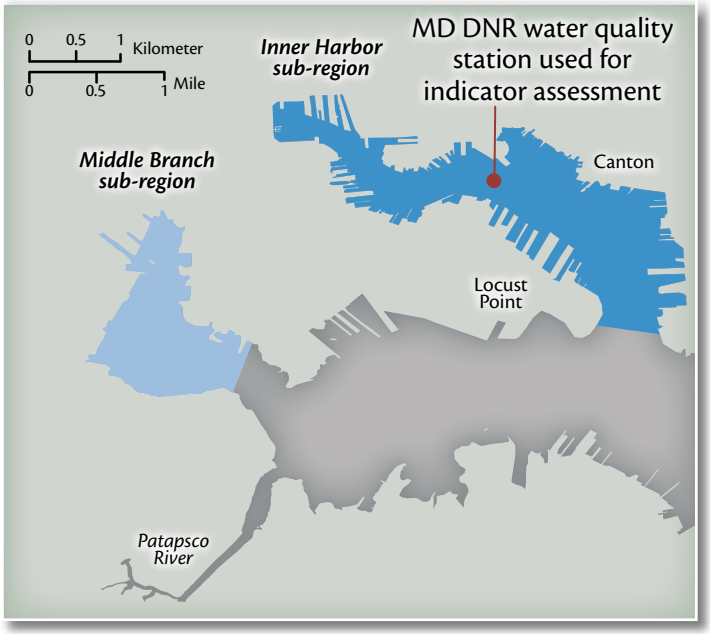


Figure 13. There is only one water quality monitoring station (Station XIE6747) located within one of the reporting regions. There are no water quality monitoring stations in the Middle Branch reporting region.

Bacteria and trash data are collected at a much finer scale than water quality data. The Baltimore WATERKEEPER® program partnered with Baltimore City's Department of Public Works to collect twice monthly bacteria samples at nineteen sites around the Inner Harbor and Middle Branch regions in 2009 (Figure 14). A subset of these data were used in this assessment because four of the sampling sites were outside the reporting region boundaries. No bacteria

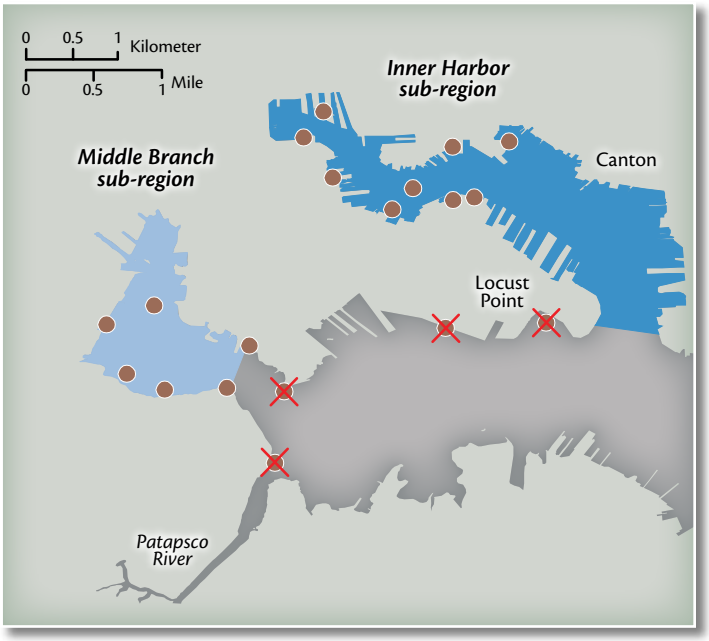


Figure 14. Bacteria sampling sites in 2009. Four samples were outside the reporting region of this assessment, and therefore not used in the analysis.

samples were collected by the Waterkeeper in 2010, but sampling is expected to resume in 2011. The spatial and temporal distribution of these bacteria data are very good and should be maintained in the future.

Trash data are collected by many different groups, using several different methods. For this assessment, trash net and waterwheel data from the Harris Creek, Jones Falls Creek, and Alluvion Creek outfalls were used (Figure 15). Trash nets are strung across the opening of a storm drain, below the surface of the water. The nets hang vertically, held up by floats at the surface. The nets are manually cleared of trash biweekly and need to be replaced after major rain events. A waterwheel is a wheel that powers a conveyor belt that lifts trash from the water and deposits it into a receptacle. The waterwheel is placed at a storm drain outlet, just like the trash nets, but is a more automated system than a net. The amount of trash that is not captured by the nets and the waterwheel is unknown, so the efficiency of the equipment and the accuracy of the trash data (i.e., tonnage and types collected) is also unknown.

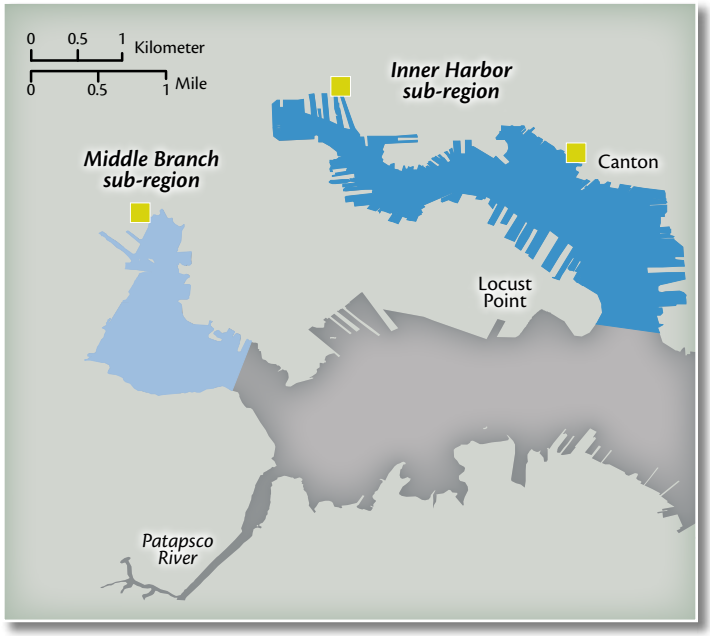


Figure 15. Trash net and waterwheel locations for results presented in this report. Other trash data include boat skimmers, public trash clean-ups, and street sweepers.

Spatial and temporal resolution issues similar to those in the tidal regions were found for the watershed indicators (Figure 16). There is a lot of available data, but not all are appropriate for inclusion in this assessment. For example, several county studies were comprised of targeted sites, which means they were specifically evaluating problem areas. This can bias final assessment results toward lower scores. Additionally, the county water quality program did not measure dissolved oxygen, which is a key water quality indicator. Furthermore, the county only measured

nutrients in the Jones Falls in 2009 and therefore, the upper Gwynns Falls watershed can not be assessed. The city benthic community data are confined to areas where the streams are still aboveground. This presents problems when trying to assess the entire watershed.

The city has two programs that contributed a significant amount of data for assessing the health of the three watersheds. However, there are 11 sites that ring the tidal portion of the Patapsco and therefore are tidally influenced. While presented in the watershed portion of this report, they represent the transition between the watershed and the Harbor and should be viewed as less than ideal data for watershed assessment. With the exception of two or three sites, these 11 sites are all located within the Direct Harbor watershed. Therefore, the Direct Harbor watershed scores are, in many cases, dissimilar from the Gwynns Falls and Jones Falls watershed (see Results section). Whether this difference is due to impacts on this watershed or influence from the tidal portion of the Harbor needs to be examined further.

Temporal resolution was also a problem. For example, the MD DNR stream sites and the county benthic community sites are only measured once a year, which means that seasonal variability or episodic events are not incorporated into the assessment. For each indicator's spatial and temporal resolution, please refer to the individual indicator pages in the following sections.

Despite these restrictions, there is still a wealth of information about the three watersheds that provides an assessment of overall watershed health. One study whose data were not able to incorporated into this report is the Baltimore Ecosystem Study, a long-term study of physical, ecological, and sociological parameters in metropolitan Baltimore. See *www.beslter.org* for more information.

This report is the first time these data have all been combined to give an overview of health of Baltimore Harbor and its watershed.

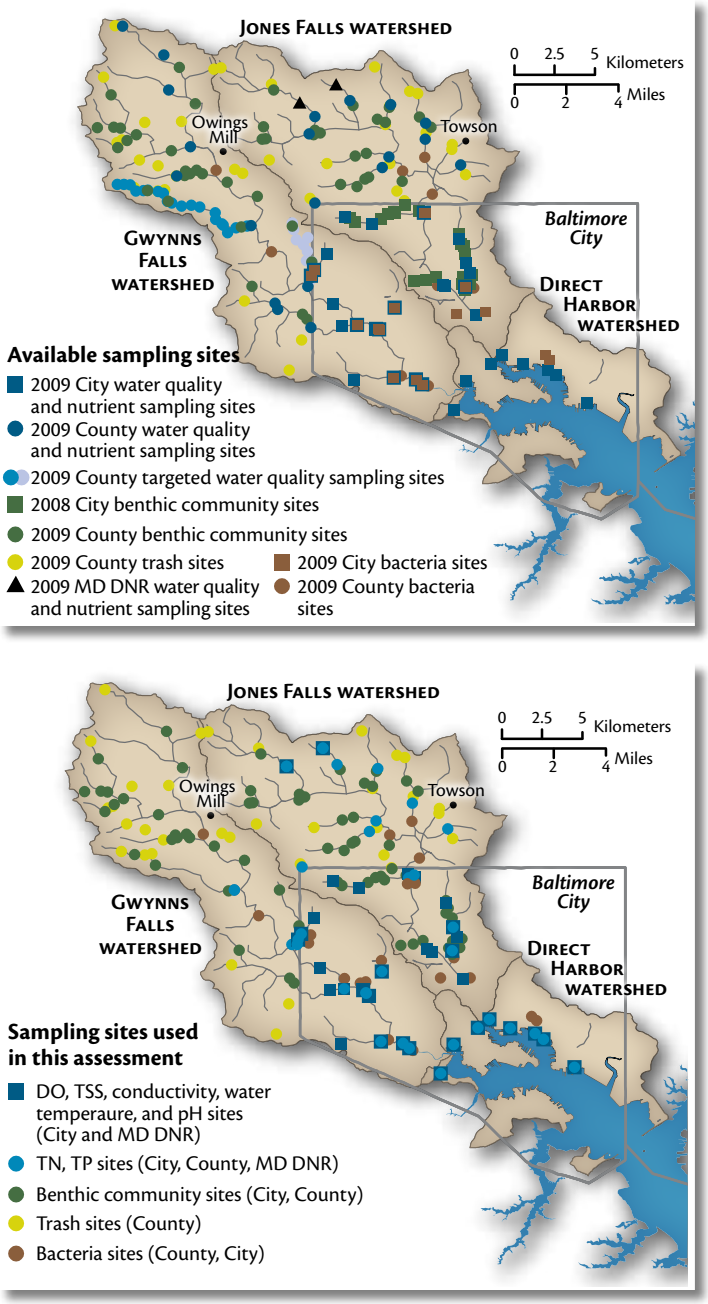


Figure 16. Available sampling sites for all indicators from all agencies in the Baltimore Harbor watersheds (top). All sampling sites used in this assessment (bottom).

Literature cited

EcoCheck (2011) Sampling and data analysis protocols for Mid-Atlantic tidal tributary indicators. Wicks EC, Andreychek ML, Kelsey RH, Powell SL (eds). IAN Press, Cambridge, Maryland, USA.

Longstaff BJ, TJB Carruthers, WC Dennison, TR Lookingbill, JM Hawkey, JE Thomas, EC Wicks, and J Woerner (eds) (2010) Integrating and applying science: A handbook for effective coastal ecosystem assessment. IAN Press, Cambridge, Maryland

Comparing data to reference conditions

Thresholds for scoring data

Assessment thresholds were determined using information from reports and local expertise

The reporting framework used in this project is similar to other assessments done by EcoCheck, and requires that data values be assessed in relation to specific thresholds of ecological significance (Tables 1–3). The thresholds are considered significant because they represent the point where prolonged exposure to unhealthy conditions leads to a negative response (Longstaff et al. 2010). Thresholds for this project were derived from peer-reviewed scientific articles and years-long development of health indicators for Chesapeake Bay via the Chesapeake Bay Program (US EPA 2003, Williams et al. 2009). Additionally, the authors of this report have developed standardized sampling and data analysis methods for a set of core indicators through the Mid-Atlantic Tributary Assessment Coalition (MTAC). The protocol document is available at *www.eco-check.org*.

Table 1. Ecologically relevant thresholds for Harbor dissolved oxygen, total nitrogen, total phosphorus, and water clarity.

Indicator	Threshold	Score
DO—Open Water	5.0 $mg \cdot l^{-1}$	pass if above/ fail if below
DO—Deep Water	3.0 $mg \cdot l^{-1}$	pass if above/ fail if below
DO—Deep Channel	1.0 $mg \cdot l^{-1}$	pass if above/ fail if below
Total nitrogen	≤0.5 $mg \cdot l^{-1}$	5
	>0.5–≤0.6 $mg \cdot l^{-1}$	4
	>0.6–≤0.8 $mg \cdot l^{-1}$	3
	>0.8–≤1.0 $mg \cdot l^{-1}$	2
	>1.0–≤1.5 $mg \cdot l^{-1}$	1
	>1.5 $mg \cdot l^{-1}$	0
Total phosphorus	≤0.02 $mg \cdot l^{-1}$	5
	>0.02–≤0.04 $mg \cdot l^{-1}$	4
	>0.04–≤0.06 $mg \cdot l^{-1}$	3
	>0.06–≤0.08 $mg \cdot l^{-1}$	2
	>0.08–≤0.15 $mg \cdot l^{-1}$	1
	>0.15 $mg \cdot l^{-1}$	0
Water clarity	≥1.8 m	5
	≥1.6–<1.8 m	4
	≥1.0–<1.6 m	3
	≥0.6–<1.0 m	2
	≥0.3–<0.6 m	1
	<0.3 m	0

Table 2. Ecologically relevant thresholds for Harbor chlorophyll *a* for spring and summer.

Score	Spring (Mar–May) thresholds ($\mu g \cdot l^{-1}$)	Summer (Jul–Sept) thresholds ($\mu g \cdot l^{-1}$)
5	≤2.09	≤1.7
4	>2.09–≤6.2	>1.7–≤7.7
3	>6.2–≤11.1	>7.7–≤11.0
2	>11.1–≤19.1	>11.0–≤15.8
1	>19.1–≤49.8	>15.8–≤35.8
0	>49.8	>35.8

Table 3. Ecologically relevant thresholds for watershed indicators.

Indicator	Ecoregion/ Designated use	Threshold	Score
Dissolved oxygen	- -	5.0 $mg \cdot l^{-1}$	pass if above/ fail if below
TSS	- -		pass if below/ fail if above
Conductivity	- -	500 µmhos cm^{-1}	pass if below/ fail if above
Total nitrogen	Mid-Atlantic Coastal Plain	0.87 $mg \cdot l^{-1}$	pass if below/ fail if above
	Southeast Plain	0.618 $mg \cdot l^{-1}$	pass if below/ fail if above
	Northern Piedmont	2.225 $mg \cdot l^{-1}$	pass if below/ fail if above
Total phosphorus	Mid-Atlantic Coastal Plain	0.0525 $mg \cdot l^{-1}$	pass if below/ fail if above
	Southeast Plain	0.0225 $mg \cdot l^{-1}$	pass if below/ fail if above
	Northern Piedmont	0.040 $mg \cdot l^{-1}$	pass if below/ fail if above
Water temperature	I	32° C	pass if below/ fail if above
	II	32° C	pass if below/ fail if above
	III	20° C	pass if below/ fail if above
	IV	23.9° C	pass if below/ fail if above
pH	- -	6.5 ≤ x ≥ 8.5	pass/fail
Benthic community	- -	1–1.9	Very poor
		2–2.9	Poor
		3–3.9	Fair
		4–5	Good

Scoring of data

In addition to data threshold values, appropriate temporal periods over which to assess the data must also be established. It is not informative to include data from periods when data values are consistently below threshold values, for example, because including these data may skew results toward unrealistically high scores. It is more informative to evaluate data when there is the potential for exceedances of thresholds, or during periods when the exceedances would have significant ecological consequences. To determine the appropriate temporal periods for data assessment, evaluation of time series data in relation to specific thresholds can be useful (Figure 17).

Once thresholds and relevant assessment time periods have been identified, data are scored using either a pass/fail or multiple threshold method. Ideally, multiple thresholds are used to provide some gradation of results from poor to excellent, rather than just pass or fail, but this may not be appropriate for all indicators.

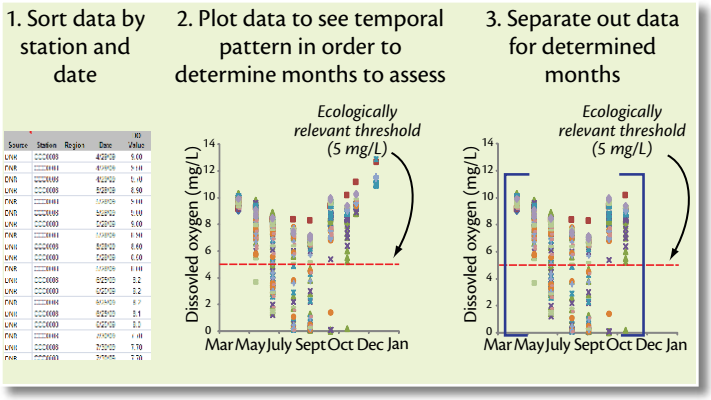


Figure 17. Examining data over time in relation to relevant thresholds helps determine the appropriate temporal period for evaluation.

Pass/Fail scoring method

A pass/fail scoring method is used to calculate the scores for dissolved oxygen, for example. The process is outlined in Figure 18 below, and results in a score on a scale of 0 to 100%, where the higher percentage values represent more healthy conditions (Williams et al 2009).

One disadvantage of using a pass/fail method is that there is no way to know how close a failing value is to passing. In other words, if a dissolved oxygen measurement is 4.9 $mg \cdot l^{-1}$, it fails because the threshold is 5.0 $mg \cdot l^{-1}$. However, it is much closer to passing than a value of 1.0 $mg \cdot l^{-1}$. Therefore, using a pass/fail method does not allow for any knowledge of how close or far values are from the threshold criteria.

Multiple thresholds

Multiple thresholds are used to score indicators based on a gradient of healthy to unhealthy conditions. For example, total phosphorus is an indicator of the amount of phosphorus in a water system. However, the amount of phosphorus, from low, acceptable levels, to just a little bit too much, to a truly excessive amount, can have different effects on the ecosystem. Therefore, when the measured value of total phosphorus is compared to multiple thresholds, it can score low, medium, or high. This is similar to a grading scale, in which an A is excellent, a B is good, and a C is average. In this way, indicators can be assessed with greater precision than using a pass/fail method (Figure 19). Using multiple thresholds is a

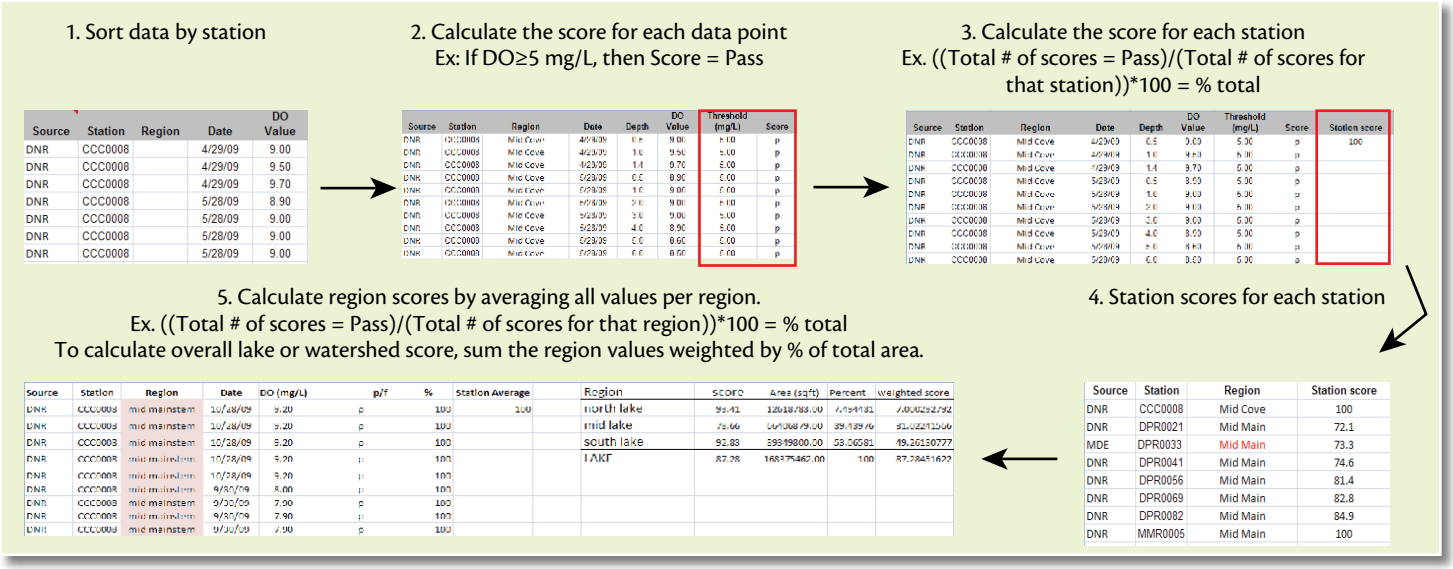


Figure 18. A pass/fail scoring method is a simple way to score some indicators.

	Multiple Thresholds		Scoring		%
Measured indicator value	5	Pristine	A	A+ A A-	80–100
	4		B	B+ B B-	60–80
	3		C	C+ C C-	40–20
	2		D	D+ D D-	20–0
	1	Impaired	F	F	<20
	0		5 categories 13 sub categories		

Figure 19. Multiple thresholds provide a more detailed picture of health than a pass/fail threshold.

relatively new technique for assessing coastal indicators. Where pass/fail thresholds were available through scientifically validated analysis, we continued to use them for this protocol. This allows for comparison of past and current data with future analysis of that particular indicator. However, thresholds for several indicators (e.g., total nitrogen, total phosphorus) needed to be developed and therefore the multiple threshold technique was applied.

Applications of multiple thresholds work well if divided into several categories, corresponding to specific percentiles in the frequency distribution of the data (Figure 20). This creates a scoring scheme based on intervals within the frequency distribution such that the lowest and highest 5% of measurements represent the very worst and best scores.

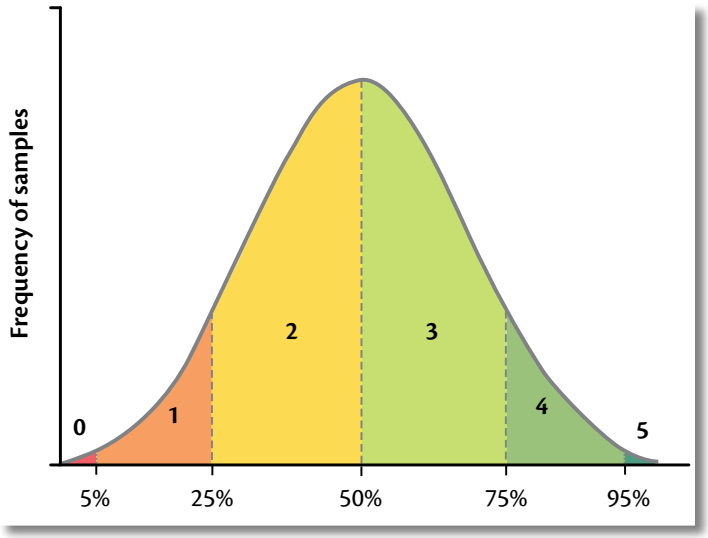


Figure 20. Example frequency distribution—scores are divided equally among percentiles.

Scores between the highest and lowest 5% are divided into regular intervals. If a particular value is identified as standard or ecologically significant criterion, this value can be used to "anchor" the distribution of scores (Figure 21). Previous applications of these types of thresholds have used the preferred or goal value as the next-to-highest score so that this value scores very highly, but values that fall within the top 5% of the distribution receive the best scores (EcoCheck 2011).

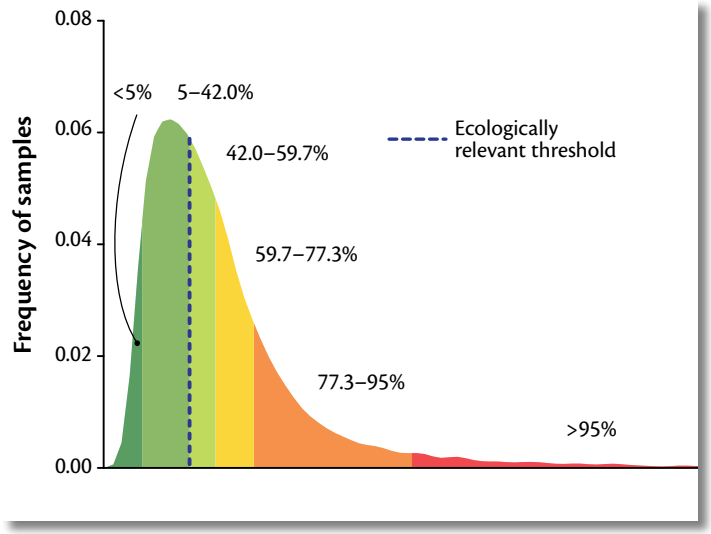


Figure 21. Example frequency distribution—scores are anchored by an ecologically relevant threshold, then divided equally among percentiles.

Scores are standardized to 0-100% scale

A score is calculated for each indicator (Table 4), and a description that relates that score to health is also provided (Figure 22). Reporting regions also receive a score, which is the average of all the individual station scores. The scoring process is based on the Chesapeake Bay report card and reflects an equal interval scoring process. Equal intervals were chosen because they distinguish equally between very poor, poor, moderate, good, and very good health conditions, without skewing the data toward one of the ends.

Confidence in assessment

As noted previously, some of the data used in this assessment were limited spatially and temporally. In these cases, it is difficult to have complete confidence in results when analyzing an entire reporting region. Therefore, qualitative judgments were included regarding uncertainty when interpreting results. Judgments were based on data resolution, appropriateness of data collection methods, and other factors. In each case, a description of these factors was included.

Table 4. A grade and description are assigned based on the score that the indicator or sub-region achieves.

Score (%)	Description
≥0 to <20	Very poor
≥20 to <25	Poor
≥25 to <35	Poor
≥35 to <40	Poor
≥40 to <45	Moderately Poor
≥45 to <55	Moderate
≥55 to <60	Moderate
≥60 to <65	Moderately Good
≥65 to <75	Moderately Good
≥75 to <80	Moderately Good
≥80 to <85	Good
≥85 to <95	Good
≥95 to <100	Good
=100	Very Good

Very Good All water quality and biological health indicators meet desired levels. Water quality in these locations tends to be very good, most often leading to very good habitat conditions for aquatic organisms.

Good Most water quality and biological health indicators meet desired levels. Water quality in these locations tends to be good, often leading to good habitat conditions for aquatic organisms.

Moderate There is a mix of good and poor levels of water quality and biological health indicators. Water quality in these locations tends to be fair, often leading to fair habitat conditions for aquatic organisms.

Poor Some or few water quality and biological health indicators meet desired levels. Water quality in these locations tends to be poor, often leading to poor habitat conditions for aquatic organisms.

Very Poor Very few or no water quality and biological health indicators meet desired levels. Water quality in these locations tends to be very poor, most often leading to very poor habitat conditions for aquatic organisms.

Figure 22. Descriptions of ecological health that correspond with each grade.

Literature cited

EcoCheck (2011) Sampling and data analysis protocols for Mid-Atlantic tidal tributary indicators. Wicks EC, Andreychek ML, Kelsey RH, Powell SL (eds). IAN Press, Cambridge, Maryland, USA.

Longstaff BJ, TJB Carruthers, WC Dennison, TR Lookingbill, JM Hawkey, JE Thomas, EC Wicks, and J Woerner (eds) (2010) Integrating and applying science: A handbook for effective coastal ecosystem assessment. IAN Press, Cambridge, Maryland

U.S. Environmental Protection Agency. (2003). Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll *a* for the Chesapeake Bay and its Tributaries. (EPA Publication No. 903-R-03-002). Washington, DC: U.S. Government Printing Office.

Williams, M., Longstaff, B., Buchanan, C., Llanso, R., Dennison, W. (2009). Development and evaluation of a spatially-explicit index of Chesapeake Bay health. Marine Pollution Bulletin, 59, 14–25.

Ecosystem health conditions—Baltimore Harbor

Water quality

Dissolved oxygen

Relevance and context

Dissolved oxygen is a common water quality indicator because it is important for all organisms living in the water column. Most fish and other aquatic organisms become stressed with dissolved oxygen concentrations below 5.0 $mg \cdot l^{-1}$, severely stressed at concentrations below 2.0 $mg \cdot l^{-1}$ (hypoxic conditions), and cannot survive at concentrations below 1.0 $mg \cdot l^{-1}$ (Moore 1942). Estuarine waters can experience salinity stratification, which is the separation of fresh, less dense water from salty, more dense water. This stratification creates a barrier to dissolved oxygen diffusion from the well-mixed surface layer to deeper layers, and results in low dissolved oxygen concentrations in deep waters during warmer months (Ratasuk 1972). Stratification, and resulting low dissolved oxygen levels, in deep waters are natural phenomena, but can be exacerbated by human activities.

Methods

Data are collected by Maryland's Department of Natural Resources. Data can be obtained from the Chesapeake Bay Program's Information Management System (CIMS, *www.chesapeakebay.net/data/index.htm*). Samples were collected once a month in 2009 and 2010, using depth profiles (one meter intervals), and are measured in $mg \cdot l^{-1}$. Thresholds were based on pycnocline (i.e., density gradient) calculations (EcoCheck 2011a). Each dissolved oxygen measurement was compared against the threshold and an average score for the entire period (2 years) was calculated.

Reference condition

The threshold values for dissolved oxygen are based on the U.S. Environmental Protection Agency's designated use of tidal waters. The designated use is determined by calculating if a pycnocline is present (EcoCheck 2011b). For Baltimore Harbor, the designated uses have been determined as Open Water, Deep Water, and Deep Channel. The threshold value for Open Water is 5.0 $mg \cdot l^{-1}$, the value for Deep Water is 3.0 $mg \cdot l^{-1}$, and the value for Deep Channel is 1.0·mg l^{-1} (see page 17; EcoCheck 2011a).

Current condition

Dissolved oxygen scored a 32.8% (Figure 23). This means there frequently was not enough dissolved oxygen in the water column for fishes and other organisms to survive. A 32.8% is considered a poor score.

Data gaps and confidence in assessment

Data were spatially limited to just one sampling station in the Inner Harbor. Furthermore, data were temporally limited so data from 2009 and 2010 were used. Confidence in the assessment is moderate. While the current data are limited, a poor score is consistent with other health assessments of the Patapsco River (Chesapeake Bay Program 2010, EcoCheck 2011b).

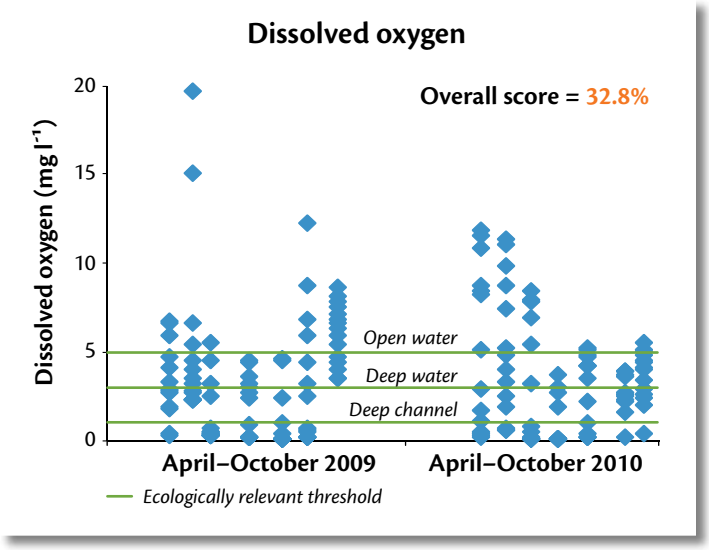


Figure 23. Dissolved oxygen data for 2009 and 2010 in the Inner Harbor. It scored a 32.8% overall.

Literature cited

Chesapeake Bay Program (2010). 2009 Bay Barometer. http://www.chesapeakebay.net/indicatorshome.aspx?menuitem=14871

EcoCheck (2011a) Sampling and data analysis protocols for Mid-Atlantic tidal tributary indicators. Wicks EC, Andreychek ML, Kelsey RH, Powell SL (eds). IAN Press, Cambridge, Maryland, USA.

EcoCheck (2011b). 2010 Chesapeake Bay report card. www.eco-check.org/reportcard/chesapeake/2010/

Moore WG (1942) Field studies on the oxygen requirements of certain freshwater fishes. Ecology 23(3):319-329

Ratasuk S (1972) A simplified method of predicting dissolved oxygen distribution in partially-stratified estuaries. Water Research 6(12):1525-1532

Chlorophyll a

Relevance and context

Chlorophyll is the green pigment that allows plants to convert sunlight into organic compounds via photosynthesis. Chlorophyll *a* is one specific type of chlorophyll and is a measure of the amount of phytoplankton biomass in the water column. Phytoplankton are essential components of the ecology of a waterbody; however, too much is an indication of nutrient pollution in the water. Phytoplankton biomass is controlled by factors such as water temperature and the availability of light and nutrients. Elevated phytoplankton levels can lead to algal blooms and reduced water clarity, which can have negative impacts on aquatic organisms. Additionally, when an algal bloom dies, the algae cells sink to deeper water, where they decay and the process of decomposition depletes the water of dissolved oxygen. Low chlorophyll *a* levels are generally associated with cleaner, clearer water.

Methods

Data are collected by Maryland's Department of Natural Resources. Data can be obtained from the Chesapeake Bay Program's Information Management System (CIMS, *www.chesapeakebay.net/data/index.htm*). Samples were collected once a month in 2009 and 2010, analyzed in the laboratory, and measured in $ug \cdot l^{-1}$. Data were compared against multiple thresholds and scored from 0 to 5, then converted to a 0–100% scale.

Reference condition

The reference conditions for chlorophyll *a* are based on ecologically relevant thresholds (Buchanan et al. 2005). Multiple thresholds were used and are different for spring and summer. They exclude the month of June due to high data variability (see page 17; EcoCheck 2011a).

Current condition

Chlorophyll *a* scored a 41.8% (Figure 24). This is a moderately poor score, which means that chlorophyll *a* levels are too high more than half of the time. Chlorophyll *a* scored better than dissolved oxygen.

Data gaps and confidence in assessment

Data were spatially limited to just one sampling station in the Inner Harbor. Furthermore, data were limited temporally so data from 2009 and 2010 were used. Confidence in the assessment is moderate. While the current data are limited, a moderately poor score is consistent with other health assessments of the Patapsco River (Chesapeake Bay Program 2010, EcoCheck 2011b).

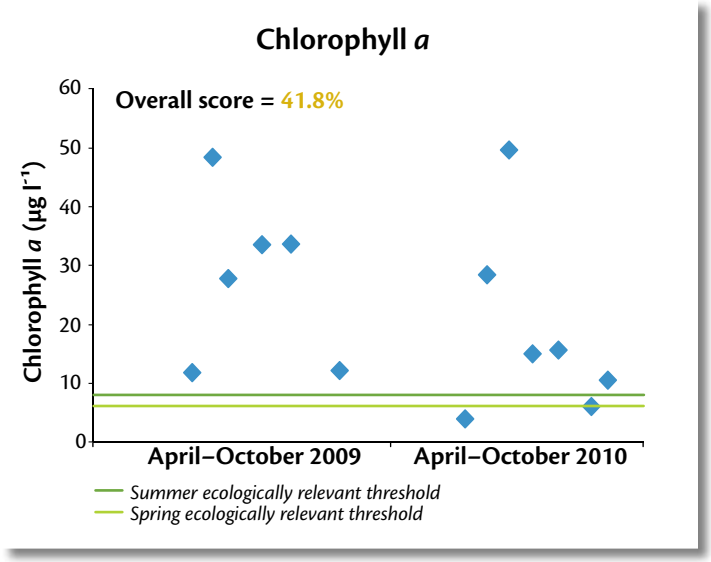


Figure 24. Chlorophyll *a* data for 2009 and 2010 in the Inner Harbor. It scored a 41.8% overall.

Literature cited

Buchanan C, Lacouture RV, Marshall HC, Olson M, Johnson JM (2005) Phytoplankton reference communities for Chesapeake Bay and its tidal tributaries. Estuaries 28(1):138-159

Chesapeake Bay Program (2010). 2009 Bay Barometer. http://www.chesapeakebay.net/indicatorshome.aspx?menuitem=14871

EcoCheck (2011a) Sampling and data analysis protocols for Mid-Atlantic tidal tributary indicators. Wicks EC, Andreychek ML, Kelsey RH, Powell SL (eds). IAN Press, Cambridge, Maryland, USA.

EcoCheck (2011b). 2010 Chesapeake Bay report card. www.eco-check.org/reportcard/chesapeake/2010/

Water clarity

Relevance and context

Water clarity is a measure of how much light penetrates though the water column. Water clarity is dependent upon the amount of particulates (e.g., suspended sediments, plankton) and colored organic matter present. Water clarity plays an important role in determining aquatic grass and phytoplankton distribution and abundance. Poor water clarity is usually caused by a combination of excess suspended sediments and nutrients that fuel the growth of phytoplankton. The color of the water—influenced by organic materials—and upstream vegetation can also affect water clarity.

Methods

Data are collected by Maryland's Department of Natural Resources. Data can be obtained from the Chesapeake Bay Program's Information Management System (CIMS, *www.chesapeakebay.net/data/index.htm*). Samples were collected once a month in 2009 and 2010 by dipping a Secchi disk in the water, and recording the depth where the Secchi disk disappears. Water clarity is measured in meters. Data were compared against multiple thresholds and scored from 0 to 5 and converted to a 0–100% scale.

Reference condition

The reference conditions for water clarity are based on ecologically relevant thresholds for phytoplankton communities (Buchanan et al. 2005). Multiple thresholds were used (see page 17, EcoCheck 2011a). The salinity regime for the study area is mesohaline (>5-18 ppt).

Current condition

Water clarity scored a 41.4% (Figure 25). This is a moderately poor score, which means the water is not clear enough for healthy phytoplankton and aquatic grasses populations.

Data gaps and confidence in assessment

Data were spatially limited to just one sampling station in the Inner Harbor. Furthermore, data were limited temporally so data from 2009 and 2010 were used. Confidence in the assessment is moderate. While the current data are limited, a moderately poor score is consistent with other health assessments of the Patapsco River (Chesapeake Bay Program 2010, EcoCheck 2011b).

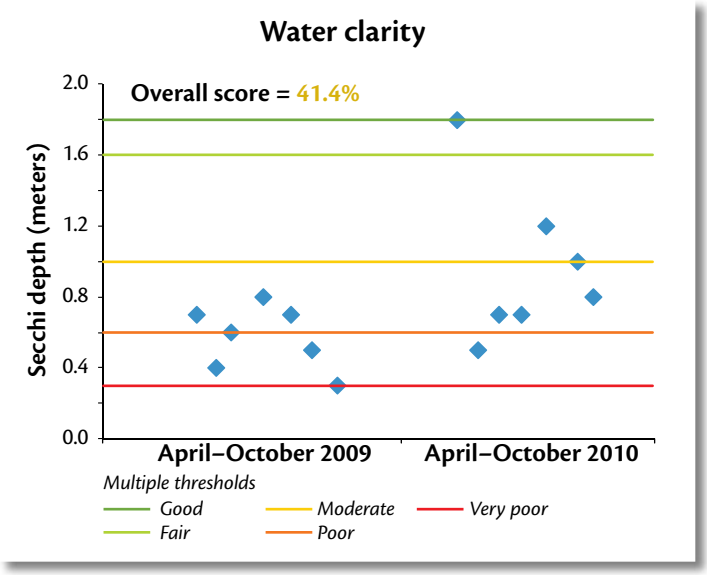


Figure 25. Water clarity data for 2009 and 2010 in the Inner Harbor. It scored a 41.8% overall.

Literature cited

Buchanan C, Lacouture RV, Marshall HC, Olson M, Johnson JM (2005) Phytoplankton reference communities for Chesapeake Bay and its tidal tributaries. Estuaries 28(1):138-159

Chesapeake Bay Program (2010). 2009 Bay Barometer. http://www.chesapeakebay.net/indicatorshome.aspx?menuitem=14871

EcoCheck (2011a) Sampling and data analysis protocols for Mid-Atlantic tidal tributary indicators. Wicks EC, Andreychek ML, Kelsey RH, Powell SL (eds). IAN Press, Cambridge, Maryland, USA.

EcoCheck (2011b). 2010 Chesapeake Bay report card. www.eco-check.org/reportcard/chesapeake/2010/

Total nitrogen and total phosphorus

Relevance and context

Total nitrogen and total phosphorus are measures of the amount of all forms of nitrogen and phosphorus, respectively, in the water. Nitrogen may enter water systems from sources such as power plants (through atmospheric deposition), agricultural practices, septic systems, sewer overflows, and stormwater runoff. Phytoplankton and macroalgae take up nitrogen and use it during photosynthesis for growth. Bacteria also use nitrogen for growth. Phosphorus is an important nutrient found naturally in soil, and is a common constituent of fertilizers, manure, and organic wastes in sewage and industrial effluent. Soil erosion is a major contributor of phosphorus to streams. Phosphorus can also enter surface waters from ground water. Elevated nutrient inputs lead to phytoplankton overgrowth, low dissolved oxygen, and reduced water clarity. Lower nutrient levels promote cleaner, clearer water, more available habitat, and fewer algal blooms.

Methods

Data are collected by Maryland's Department of Natural Resources. Data can be obtained from the Department of Natural Resources. Samples were collected once a month in 2009, analyzed in the laboratory, and are measured in $mg \cdot l^{-1}$. Data were compared against multiple thresholds and scored from 0 to 5 and converted to a 0–100% scale.

Reference condition

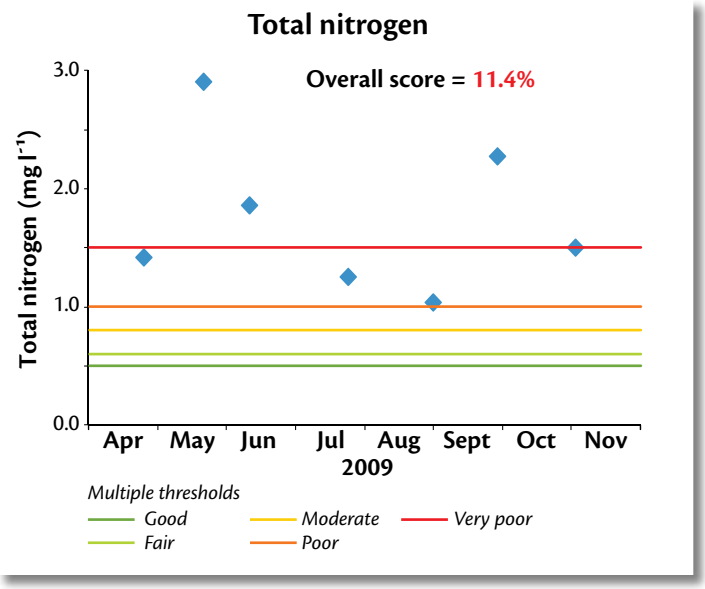
Reference conditions for total nitrogen and total phosphorus are not readily available. Through a rigorous data analysis and scientific consensus process, multiple thresholds for total nitrogen and total phosphorus were determined (see page 17, EcoCheck 2011). The salinity regime for Baltimore Harbor is mesohaline (>5-18 ppt).

Current condition

The overall score for total nitrogen is 11.4%, and the overall score for total phosphorus is 22.9% (Figure 26). The total nitrogen score is very poor, and the lowest water quality score of all the indicators. Total phosphorus scored better than total nitrogen, but is still poor. This means that there are too many nutrients in the water and are creating poor health conditions for phytoplankton, benthic organisms, and fish.

Data gaps and confidence in assessment

Nutrient data were spatially limited due to just one sampling station in the Inner Harbor. Furthermore, only seven data points were available to compare to the thresholds. Confidence in the assessment is low.



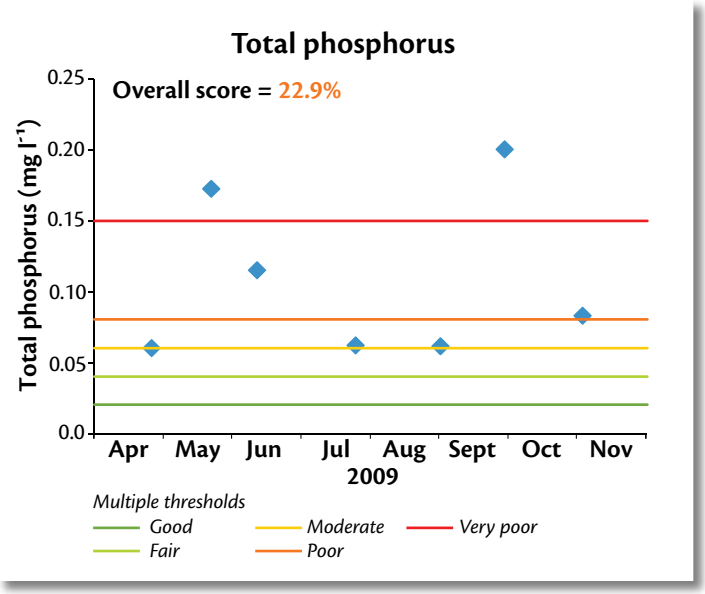


Figure 26. Total nitrogen and total phosphorus data from 2009 in the Inner Harbor. The overall total nitrogen score is 11.4%. The overall total phosphorus score is 22.9%.

Literature cited

EcoCheck (2011) Sampling and data analysis protocols for Mid-Atlantic tidal tributary indicators. Wicks EC, Andreychek ML, Kelsey RH, Powell SL (eds). IAN Press, Cambridge, Maryland, USA.

Benthic community

Relevance and context

Benthic macroinvertebrates are the organisms, such as clams and worms, that live within bottom sediments. Benthic communities are a good indicator of bottom health because different species have different responses to pollution (Chesapeake Bay Program 2011). Additionally, they integrate physical (e.g., temperature), chemical (e.g., dissolved oxygen), and biological (e.g., food they eat) conditions.

Methods

Benthic macroinvertebrate samples are collected and analyzed by Versar, Inc. An Index of Biological Integrity (IBI) has been developed for benthic macroinvertebrates for the entire Chesapeake Bay (Llanso 2002). The data provided here are sampled randomly, although there is also a fixed stations program. The fixed stations are not in the tidal reporting regions, however. Two random samples were taken in the Inner Harbor in 2009. The samples are analyzed in the lab and are unitless.

Reference condition

The Benthic IBI classifies samples from 1 to 5. Values between 1 and 3 are considered to be degraded relative to reference communities, while values between 3 and 5 are considered to be close to reference community condition. Scores of 3 or higher are considered to be passing scores.

Current condition

In 2009, there were two sites located within the Inner Harbor. Both sites scored a 1.0 (Figure 27). Since neither of these scores are 3 or higher, the Inner Harbor scored a 0%, which is a very poor score.

Data gaps and confidence in assessment

Data are spatially limited. Baltimore Harbor does not have its own benthic macroinvertebrate program, so data are from the Baywide assessment. Because the sample sites are randomly assigned, the Inner Harbor may or may not be sampled in a given year. For the 2009 data, the confidence in the assessment is moderate. While the confidence in the collection is high, there are only two data points from which to determine the health of the benthic community.

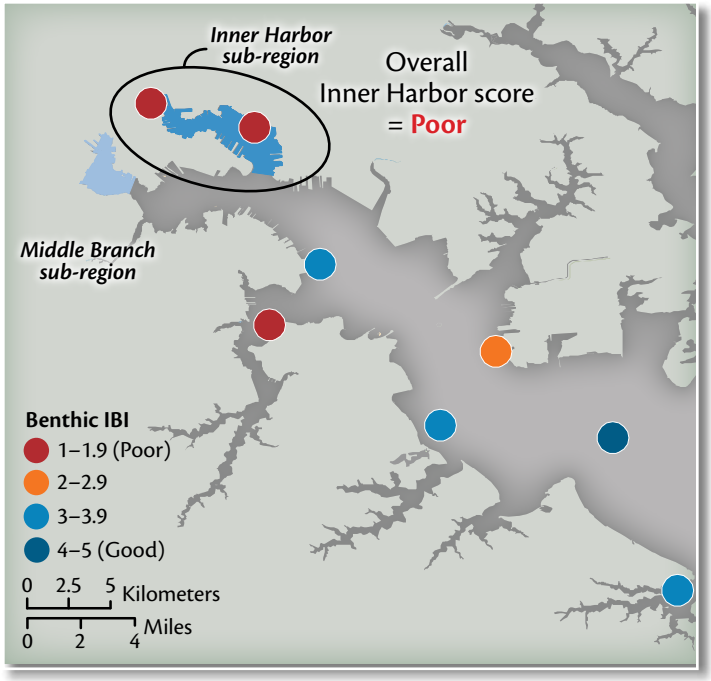


Figure 27. In 2009, benthic communities in the Inner Harbor scored a 1.0, which is a Poor. Notice that other sites within the Patapsco River scored higher than the Inner Harbor. There is the potential for better scores in the future.

Literature cited

Chesapeake Bay Program (2011) Benthos-About. http://www.chesapeakebay.net/benthos.aspx?menuitem=19390

Llanso R (2002) Methods for calculating the Chesapeake Bay Benthic Index of Biotic Integrity. Versar, Inc.

Aquatic grasses

Relevance and context

The Chesapeake Bay Program has designated Baltimore Harbor and Middle Branch as No Grow Zones for aquatic grasses because historically no aquatic grasses have grown there (Moore et al. 2004). Baltimore Harbor's shoreline has been hardened for decades and the water is too deep for light to penetrate to the bottom, where aquatic grasses grow. The habitat conditions (e.g., light, sediment) are unsuitable for aquatic grasses growth. Due to these physical and structural limitations to aquatic grasses growing in the Inner Harbor, there is no goal against which current aquatic grasses acres (zero) can be compared. Perhaps after the many implementation actions (e.g., restoration of natural shorelines) that will occur over the next decade are in place, the Harbor's underwater habitat will be suitable for aquatic grasses growth.

Methods

Aquatic grasses in the tidal Chesapeake Bay are measured by the Virginia Institute of Marine Science's Submerged Aquatic Vegetation Program. Detailed methods are available at *www.vims.edu/bio/sav*.

Reference condition

There is currently no way to score a No Grow Zone.

Current condition

There are currently no aquatic grasses growing in the Inner Harbor, the Northwest Branch out to Fort McHenry, or in the Middle Branch of the Patapsco River. However, this is expected due to the No Grow Zone classification.

Data gaps and confidence in assessment

While the Inner Harbor has been assigned as a No Grow Zone, there is still the possibility of aquatic grasses growth in these areas. However, a large restoration and cleanup effort, as well as habitat availability, would have to occur first.

Literature cited

Moore KA, Wilcox DJ, Anderson B, Parham TA, Naylor MD (2004) Historical analysis of submerged aquatic vegetation (SAV) in the Potomac River and analysis of baywide SAV data to establish a new acreage goal. Chesapeake Bay Program report, CB983627-01

Toxicants

Relevance and context

Toxicants, such as heavy metals and organic contaminants, are found in the sediments of the Inner Harbor. The occurrence of toxicants in the sediments has both ecological and environmental management implications. These contaminants move up the food chain, from benthic macroinvertebrates to the fish that eat them to the humans that catch and eat the fish in a process called bioaccumulation. Cleaning and disposing of contaminated sediments is a difficult process (Independent Technical Review Team 2009). While many of these toxicants are a legacy from past industries, there are still toxicants entering the Harbor sediments through current industrial activities.

Methods

In 2009, Maryland Sea Grant performed a comprehensive study of both historical and recent data regarding levels of toxicants in the shipping channels of Baltimore Harbor. While the goal of the study was to explore ways to re-use dredged materials from the Harbor shipping channels in different projects (Independent Technical Review Team 2009), the initial sediment data provide a general picture of sediment health in the Harbor.

Reference condition

The threshold used in this baseline conditions report is the most conservative threshold used in the Maryland Sea Grant study and is related to the designated use of the dredged sediment. Aquatic restoration use means the dredged sediment would be used to restore marshes and other habitats. The threshold for human exposure levels for aquatic restoration use is less than the Threshold Effect Level (<TEL). TEL values vary by contaminant, and are listed in the Sea Grant Report (Independent Technical Review Team 2009).

Current condition

Sediment health is considered very poor—all of the sample sites exceeded human exposure levels for metals or for organic compounds in the aquatic restoration use category (Figure 28). While the shipping channel is not a likely location for humans to come into contact with Harbor sediments (such as might happen when wading or swimming in shallower areas), the sediment in the shipping channels is generally considered cleaner than other sediments because the channels are regularly dredged. Therefore, it is possible that the sediment in the Harbor that is located outside in the shipping channels (e.g., along the shoreline) may be even more degraded than the sediments evaluated in this study (i.e., shipping channel sediments).

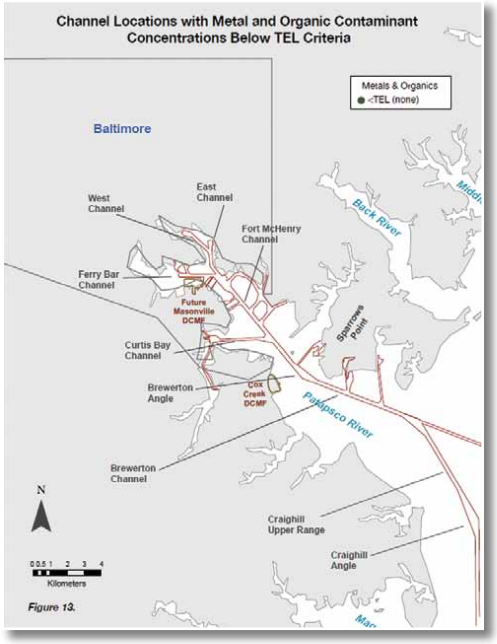


Figure 28. In a sediment study by Maryland SeaGrant, all samples were above the Threshold Effect Level for both metals and organic contaminants, meaning that the sediment did not pass the criteria for human contact.

Data gaps and confidence in assessment

Confidence in the assessment is moderate. While the Sea Grant study is not appropriate for a short-term, annual evaluation of Harbor health because sediment processes occur over multiple years, it is the best available data to use at this time. The study was not a comprehensive spatially explicit look at Harbor sediments based on new samples. Rather, it evaluated historical data for a separate purpose. For future evaluation of sediment health, new monitoring samples should be taken. But the new sediment samples should be evaluated on a long-term basis, not on an annual basis. Additionally, the sediment in the channels most likely is not the same sediment that humans would come into contact with when wading or swimming in the Harbor. New thresholds for human contact need to be established that are more understandable to the general public and which convey a more detailed assessment of toxicants in sediments.

Literature cited

Independent Technical Review Team (2009). Sediment in Baltimore Harbor: Quality and Suitability for Innovative Reuse. An Independent Technical Review. JG Kramer, J Smits, and KG Sellner (eds). Maryland Sea Grant Publication UM-SG-TS-2009-04. CRC Publ No 09-169.

Bacteria

Relevance and context

One objective of the Waterfront Partnership of Baltimore's Healthy Harbor Initiative is to restore the ability to swim in the Inner Harbor and Middle Branch. Suitability for swimming is measured using indicator bacteria, such as *E. coli* and *Enterococci*. The presence of indicator bacteria indicates that harmful pathogens may also be present. Indicator bacteria and pathogens can come from the feces of animals, including wildlife, pets, or humans, through leaking sewer systems and broken sewage lines.

Methods

Enterococci is generally accepted as an indicator of waterborne pathogens in brackish and salt water. *Enterococci* bacteria samples were collected in the Inner Harbor and Middle Branch by the Harbor WATERKEEPER® organization in 2009 in coordination with Baltimore City's Stream Impact Sampling program (City of Baltimore 2010). The samples are analyzed by the Martel Labs, Inc. and are reported as Most Probable Number (MPN) of bacteria per 100 milliliters of water.

Reference condition

The EPA threshold for *Enterococci* in swimming and contact recreation areas is 104 MPN 100 ml^{-1} (USEPA 1986). If a sample exceeds this threshold, EPA has determined that there is unacceptable risk of humans becoming sick when they come into contact with the water.

Current condition

Station averages (Figure 29, top) show that the Inner Harbor has many more days (and locations) during which there is a risk of getting sick compared to the Middle Branch. The station averages were aggregated into sub-region scores of 27% and 71% for the Inner Harbor and Middle Branch, respectively (Figure 29, bottom). Bacteria concentrations were below the swimming threshold 73% of the time in Middle Branch, but only 29% of the time in the Inner Harbor.

Data gaps and confidence in assessment

Confidence in the assessment is high. The data were spatially and temporally robust, however, improvements to the sampling program would be the inclusion two or more sampling sites in the middle of the sub-regions and inclusion of sampling at locations where swimming activities may occur in the future. Most of the sites are currently located along the shoreline, but they may be in areas where swimming is not expected to occur.

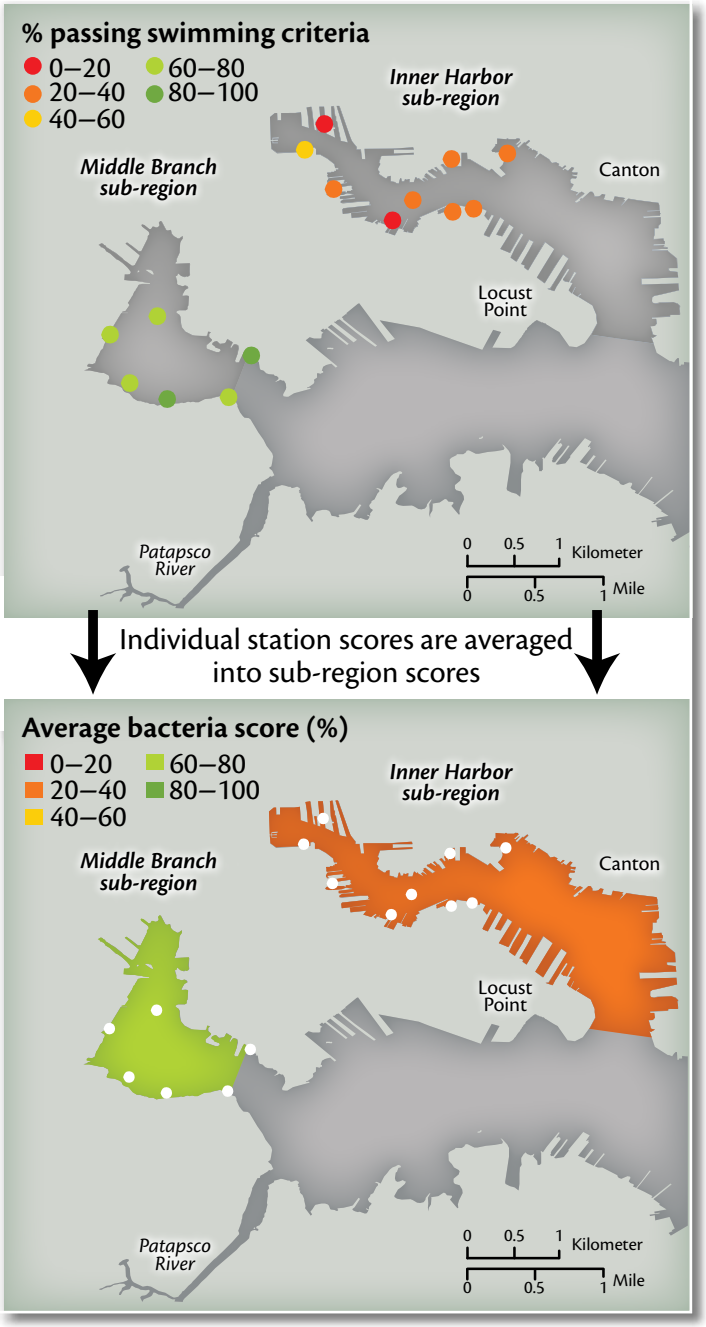


Figure 29 Top: Average station scores (% time samples passed criteria for frequent full body (swimming)), Bottom: Average sub-region scores.

Literature cited

City of Baltimore (2010) National Pollution Discharge Elimination System Annual Report, 2009. City of Baltimore, Department of Public Works, Bureau of Water and Wastewater, Surface Water Management Division.

USEPA (1986). Ambient Water Quality Criteria for Bacteria–1986. U.S. Environmental Protection Agency, Washington, DC. EPA–440/5-84-002.

Fish indicators

Relevance and context

Fish indicators could include aquatic resource, recreational use, and fish consumption indicators. Aquatic resources include habitat parameters, contaminants, sediment type, and food availability. Recreational use indicators measure fishing effort or fish landing information, while fish consumption indicators measure the quality of fish consumed (i.e., is it safe to eat). An example of a harmful substance found in fish tissue is polychlorinated biphenyls (PCBs), which were used in coolant fluids until the late 1970's. PCBs are toxic to animals, causing a variety of organ issues as well as systemic toxicity.

Methods

A fish consumption indicator was chosen for this baseline conditions assessment. The Maryland Department of the Environment (MDE) collects fish tissue samples throughout the waters of Maryland to test for contaminants that may be harmful to humans if consumed. A list of MDE's fish consumption advisories is provided at *www.mde.state.md.us/programs/Marylander/CitizensInfoCenterHome/Pages/citizensinfocenter/fishandshellfish/index.aspx*. White perch were collected throughout the Patapsco River by MDE from 2001 to 2008 at designated sites in the river. Tissue samples from the white perch were analyzed for PCBs in a laboratory, and the results are reported as nanograms of PCBs per gram of fish tissue.

Reference condition

There is no reference condition for levels of PCBs in white perch that directly affect humans. Rather, MDE advises to limit consumption of white perch from the Patapsco River/Baltimore Harbor to 1 meal every other month (Maryland Department of the Environment 2011). This means that levels of PCBs in white perch tissue is high enough, on average, to require significantly restrictive recommendations for human consumption, based on the past decade of sampling.

Current condition

PCBs levels in white perch in Baltimore Harbor are high (Figure 30), which means that human consumption of white perch could include contaminants that are incorporated into the human body. This indicator is measured on a decadal basis—levels of PCBs in white perch tissue are not expected to significantly change from one year to the next.

Data gaps and confidence in assessment

Confidence in the assessment is high. The data is spatially and temporally robust at the tributary (Patapsco River) level. Fish tissue contaminants cannot be assessed at a smaller scale in this case because fish are mobile organisms. A fish that is caught in Baltimore Harbor could also be found at the mouth of the Patapsco River.

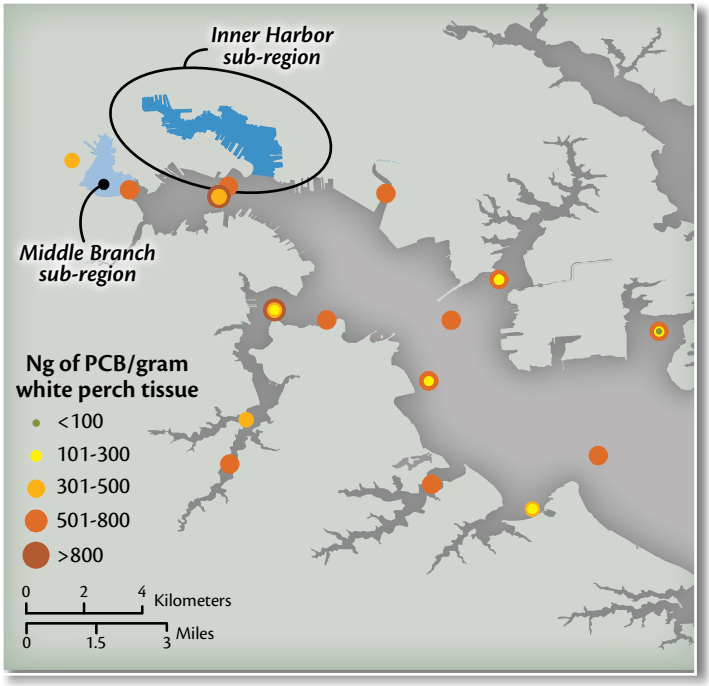


Figure 30. Locations of fish samples and amount of PCBs in fish tissue samples. No samples were taken within the Inner Harbor sub-region. However, fish contaminants are assessed on a tributary wide basis.

Literature cited

Maryland Department of the Environment (2011) Fish and Shellfish. www.mde.state.md.us/programs/Marylander/CitizensInfoCenterHome/Pages/citizensinfocenter/fishandshellfish/index.aspx

Trash

Relevance and context

Trash is an important indicator for measuring progress in relation to restoration goals. Once trash is on the ground in neighborhoods, along roads, and in parking lots, it washes into the storm drain system and local waterways. Each time it rains, trash washes into storm drains and ultimately arrives in the Inner Harbor and Middle Branch. Trash is bad for the environment because it leaches chemicals into the ecosystem and is a breeding ground for harmful bacteria and other pathogens. Trash is also aesthetically unpleasant, which influences quality of life.

Methods

Trash has been collected in a variety of ways in the Harbor, including nets, skimmers, and volunteer trash clean-ups. Trash nets have been placed in a few storm drain outfalls. These nets collect trash while still allowing water to flow freely. Another trash collection mechanism is a water wheel, which powers a conveyor belt that lifts trash out of the water and puts it into a receptacle. Finally, boats, called skimmers, travel around the Harbor, picking up floating trash. For this assessment, the Alluvion net, the Harris Creek net, the Harris Creek waterwheel, and the Jones Falls Waterwheel data were used.

Reference condition

None of these trash collection methods are directly comparable to each other, due to different collection techniques, reporting differences, and technical difficulties with the equipment (e.g., clogging of trash nets). Therefore, an analysis and assessment of the trash collected in these various ways is not possible. Additionally, there is no threshold against which trash amounts can be compared. However, future assessment should be possible due to Baltimore Harbor and Middle Branch regions being listed as impaired for trash under the federal Clean Waters Act 303(d) list. This requires creation of a Total Maximum Daily Load (TMDL) for trash, which will allocate a certain amount of trash that will have to be stopped (by collecting and disposing of it) from entering Baltimore Harbor. The TMDL will be ready for submission for approval by the U.S. EPA by September 2012.

Current condition

Trash in the Inner Harbor could not be assessed on a Very Poor to Good scale, but evidence suggests that trash in the Harbor remains a major problem (Figures 31 and 32).

Data gaps and confidence in assessment

There are a lot of data about trash collection in the Harbor, but few ways to assess them. Also, the confidence in the net and water wheel data is poor because there is no evaluation of effectiveness of the equipment (i.e., how much trash is passing through or around the net and getting into the Harbor?).

Problems exist with each of the trash collection methods: The nets and waterwheel that collect trash tend to become full after rain, creating uncertainty about the trash results. Similarly, skimmer boats are out every day picking up trash, but the total level of effort spent collecting trash each day is not currently available.

In order to use this indicator in future annual report cards, these methods will have to be standardized.

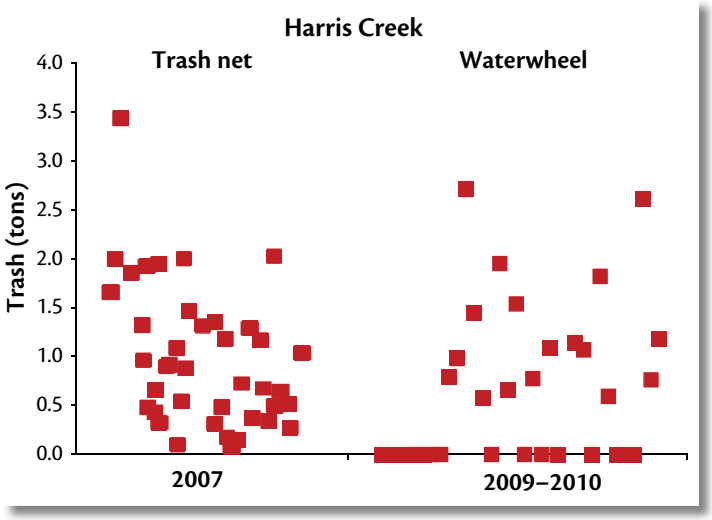


Figure 31. A trash net was set up in front of the Harris Creek outfall in 2007, then replaced with a waterwheel starting in 2009. The total amount of trash that is collected is similar from year to year.

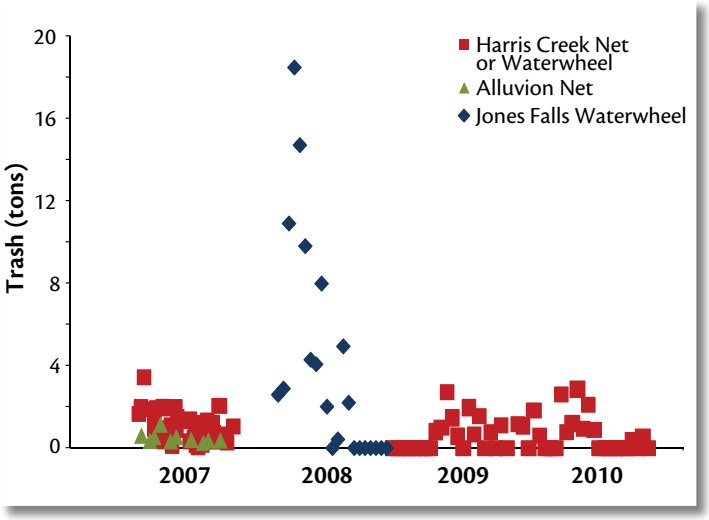


Figure 32 Trash collected at three locations using different methods. While the Harris Creek waterwheel and the Harris Creek and Alluvion trash nets data are comparable, the Jones Falls waterwheel data is not. Additionally, the amount of trash coming out of the outfall overwhelmed the Jones Falls waterwheel, so the data is less reliable.

Literature cited

Moffatt and Nichol (2006) Baltimore Harbor Trash Report, April 2006. Prepared for Baltimore Development Corportion.

Water quality

Dissolved oxygen

Relevance and context

Dissolved oxygen is a common water quality indicator because it is important for all organisms living in the water column. Most fish and other organisms become stressed with dissolved oxygen concentrations below 5.0 $mg \cdot l^{-1}$, severely stressed at concentrations below 2.0 $mg \cdot l^{-1}$ (hypoxic conditions), and cannot survive at concentrations below 1.0 $mg \cdot l^{-1}$ (Moore 1942).

Methods

Dissolved oxygen data is collected by Baltimore City and the Maryland Department of Natural Resources (MD DNR). Baltimore City collected data once a month throughout 2009. MD DNR collected one sample at two sites one time only in 2009. Samples are measured using a dissolved oxygen probe and are reported in $mg \cdot l^{-1}$. Each dissolved oxygen measurement was compared against the threshold and scored as passing or failing. Scores were averaged for each sampling site. Sampling site scores were then averaged into subwatershed scores.

Reference condition

Thresholds for dissolved oxygen were determined by the designated uses of streams in Maryland (COMAR 26.08.02.03-3). The dissolved oxygen threshold for all designated uses is 5 $mg \cdot l^{-1}$.

Current condition

Dissolved oxygen scores were very good throughout the three subwatersheds (Figure 33). Both the Gwynns Falls and Jones Falls watersheds scored close to 100%, while the Direct Harbor averaged approximately 90% (Figure 34). Dissolved oxygen levels in non-tidal streams in Baltimore Harbor's watershed are healthy.

Data gaps and confidence in assessment

Confidence in the assessment is moderate. Data for the upper Gwynns Falls watershed were not available for 2009 leading to an average score for the entire watershed that is based on data in the lower watershed. Additionally, the two MD DNR sites in Jones Falls (see page 16) were only measured once during 2009, which is not representative of the entire year, and therefore weights these measurements less than the other sites. Conversely, there is a wealth of dissolved oxygen data through the city's two monitoring programs (Ammonia Screening and Stream Impact Sampling).

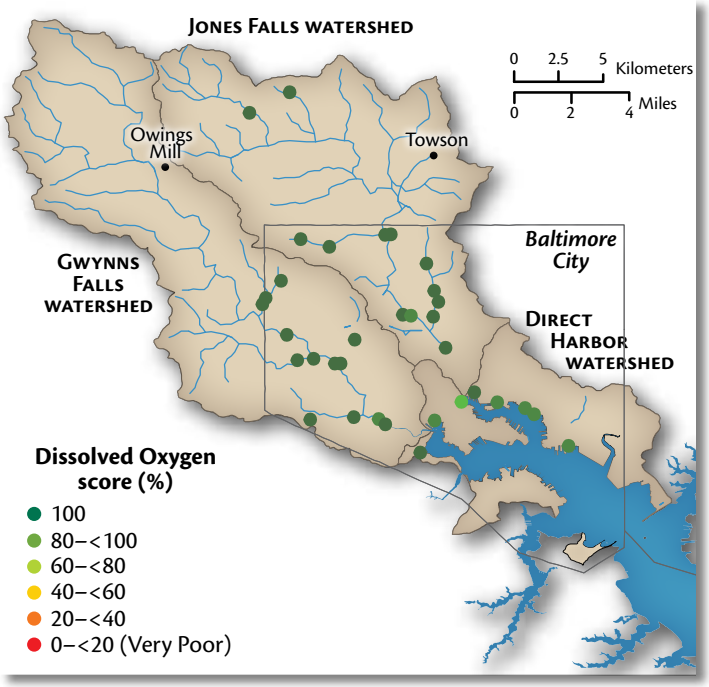


Figure 33. Average dissolved oxygen site scores in 2009.

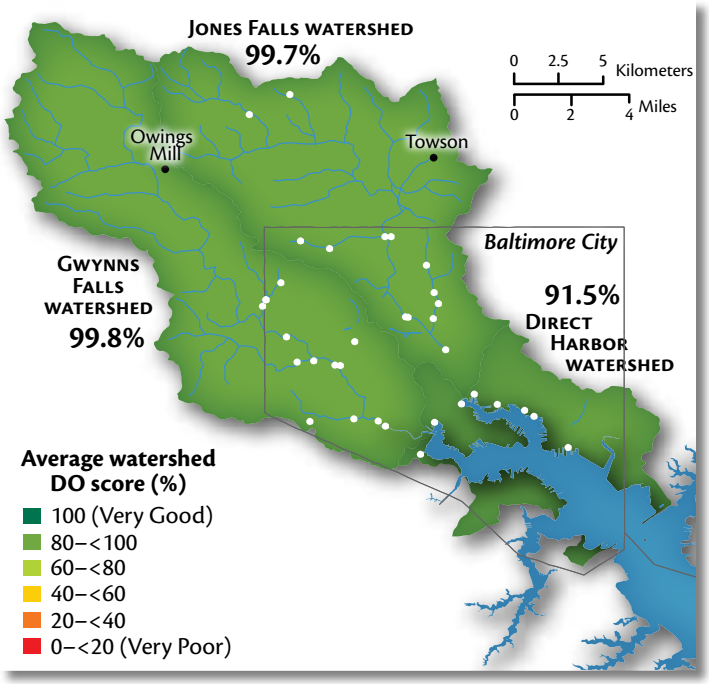


Figure 34. Average dissolved oxygen scores for each subwatershed for 2009.

Literature cited

Moore WG (1942) Field studies on the oxygen requirements of certain freshwater fishes. Ecology 23(3):319-329

Code of Maryland Regulations (2011) Title 26 Department of the Environment, Subtitle 08 Water pollution, Chapter 02 Water Quality. COMAR 26.08.02.0-3. http://www.dsd.state.md.us/comar/searchall.aspx

Conductivity

Relevance and context

Conductivity is a measure of the amount of electrical current that water can conduct. It is important in fresh water streams because ions, such as sodium, nitrate, and phosphate (i.e., nutrients), can affect the conductivity. Additionally, toxic contaminants, including metals and other urban and industrial by-products, can affect the conductivity of a stream. If the conductivity is too high (i.e., if electrical current is easily conducted) it has a direct effect on the health of aquatic organisms.

Methods

Data are collected by Baltimore City and Maryland Department of Natural Resources (MD DNR). Baltimore City collected samples once a month throughout 2009, while MD DNR collected one sample from each site one time only in 2009. Conductivity is measured in microohms per centimeter (μohms cm^{-1}) or microsiemens per centimeter (μs cm^{-1}). A handheld meter is used to record the data. Data from 2009 were used in this analysis. Data were compared against the threshold and scored as passing or failing. Scores were averaged for each sampling site. Sampling site scores were then averaged into subwatershed scores.

Reference condition

The conductivity threshold was obtained from U.S. EPA's Water Monitoring and Assessment webpage (U.S. EPA 2011). The threshold value used is 500 μs cm^{-1} and any site over 500 μs cm^{-1} failed. This value is also used in determining freshwater benthic community health by the Chesapeake Bay Program (Buchanan et al. 2011).

Current condition

Conductivity scores were mixed, with both very low and very high scores. There was a gradient from good to very poor scores from the upper watersheds to the Direct Harbor watershed (Figure 35). The Jones Falls watershed scored the best overall, but is considered only moderate. The Direct Harbor watershed scored the lowest, with only 2.6% of the samples passing the threshold (Figure 36).

Data gaps and confidence in assessment

Confidence in the assessment is moderate. Data for the upper Gwynns Falls watershed were not available for 2009 leading to an average score for the entire watershed that is based on data in the lower watershed. Additionally, the two MD DNR sites in Jones Falls (see page 16) were only measured once during 2009, which is not representative of the entire year, and therefore weights these measurements less than the other sites. Conversely, there is a wealth of dissolved oxygen data through the city's two monitoring programs (Ammonia Screening and Stream Impact Sampling).

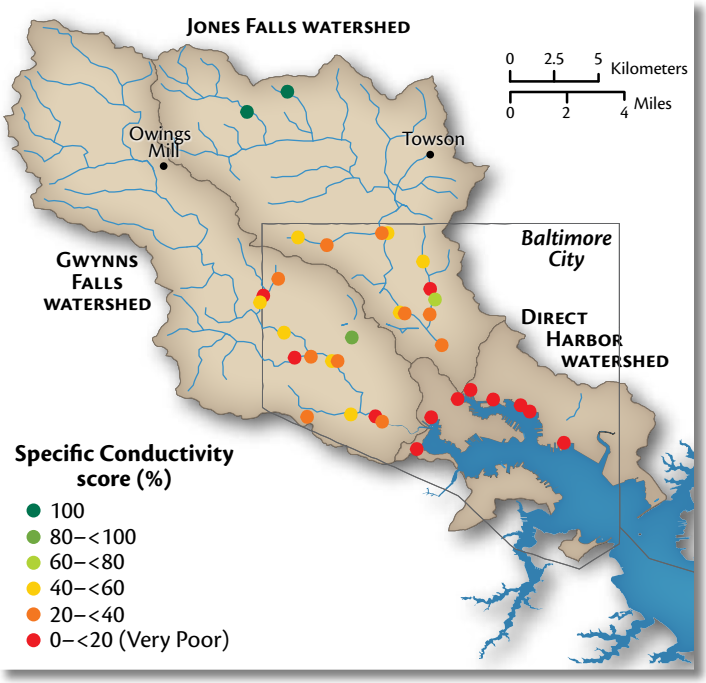


Figure 35. Average conductivity site scores in 2009.

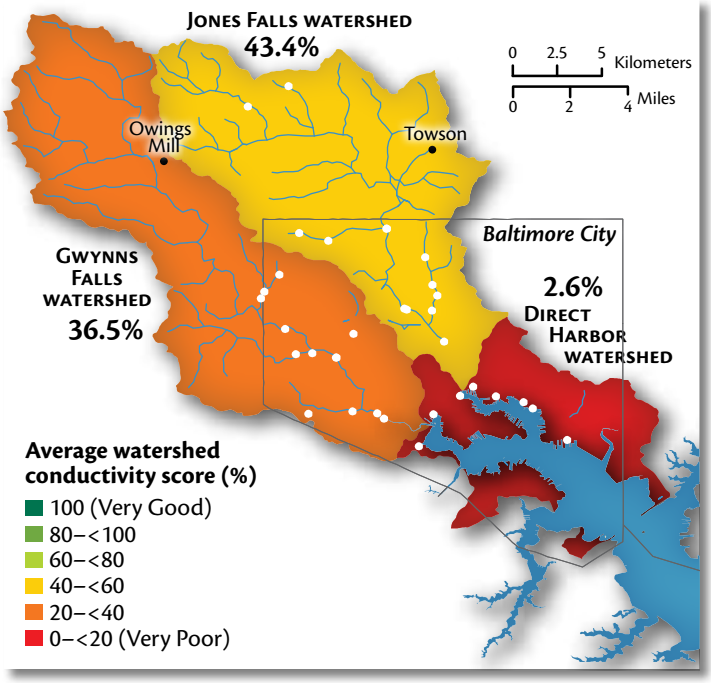


Figure 36. Average conductivity scores for subwatersheds for 2009.

Literature cited

U.S. Environmental Protection Agency (2011) 5.9 Conductivity, Monitoring and Assessment. http://water.epa.gov/type/rsl/monitoring/vms59.cfm.

Buchanan C, K Foreman, J Johnson, A Griggs (2011) Development of a Basin-wide Benthic Index of Biotic Integrity for Non-Tidal Streams and Wadeable Rivers in the Chesapeake Bay Watershed. ICPRB Report 11-1. Report prepared for the US EPA's ChesapeakeBay Program. http://www.potomacriver.org/cms/publicationspdf/ICPRB11-01.pdf

Total nitrogen and total phosphorus

Relevance and context

Total nitrogen and total phosphorus are measures of the amount of all forms of nitrogen and phosphorus, respectively, in the water. Nitrogen may enter water systems from sources such as power plants (through atmospheric deposition), agricultural practices, septic systems, sewer overflows, through runoff from rain events, and from groundwater inputs. Phosphorus is an important nutrient found naturally in soil, and is a common constituent of fertilizers, manure, and organic wastes in sewage and industrial effluent. Excess phosphorus generally enters the stream as runoff during storm events. Elevated nutrient inputs lead to algae overgrowth, low dissolved oxygen, and reduced water clarity.

Methods

Nutrients were measured by Baltimore County, Baltimore City, and the Maryland Department of Natural Resources (MD DNR) at a total of 32 sites throughout 2009. These data represent baseline monitoring and do not address storm events. This is especially important for total phosphorus, which is largely delivered (via sediments) during storm events. Detailed information about sampling methods can be obtained through the NPDES programs (City of Baltimore 2010, County of Baltimore 2010) and from the Maryland Biological Stream Survey Program (MD DNR 2011). Nutrient measurements are reported as $mg \cdot l^{-1}$. Measurements were compared against the threshold and scored as passing or failing. Scores were averaged for each sampling site. Sampling site scores were then averaged into subwatershed scores.

Reference condition

Total nitrogen and total phosphorus thresholds were obtained from the U.S. Environmental Protection Agency (U.S. EPA). These values are based on ecoregions and, therefore, each station was categorized by ecoregion before the thresholds were applied (see page 17 for each threshold value). Ecoregions are available from the U.S. EPA.

Current condition

Overall, total nitrogen scored better than total phosphorus (Figures 37–40). Site scores varied widely, but there was a gradient of good to poor scores from the upper watershed to the Harbor. The Jones Falls and Gwynns Falls watersheds scored good and very good while the Direct Harbor watershed scored very poor for total nitrogen. The Jones Falls scored good, while the Gwynns Falls scored poor and the Direct Harbor scored very poor for total phosphorus.

Data gaps and confidence in assessment

Confidence in the assessment is moderate. Data for the upper Gwynns Falls watershed were not available for 2009 leading to an average score for the entire watershed that is based on data in the lower watershed. Additionally, the two MD DNR sites in Jones Falls (see page 16) were only measured once during 2009, which is not representative of the entire year, and therefore weights these measurements less than the other sites. Conversely, there is a wealth of dissolved oxygen data through the city's two monitoring programs (Ammonia Screening and Stream Impact Sampling).

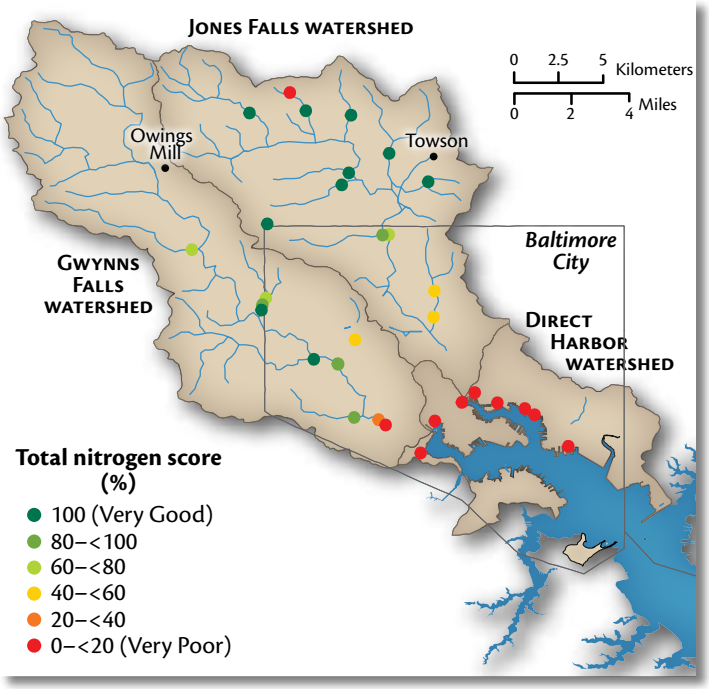


Figure 37. Total nitrogen site scores for 2009.

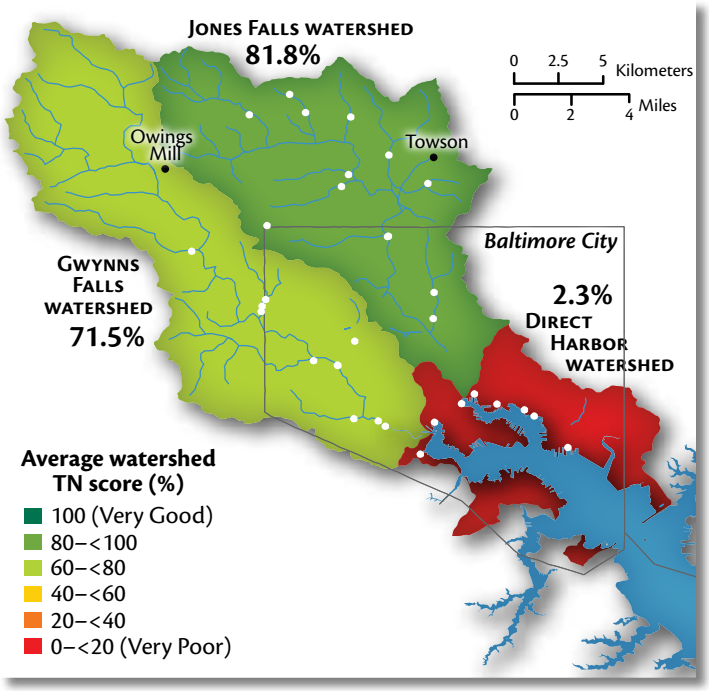


Figure 38. Average watershed scores for total nitrogen for 2009.

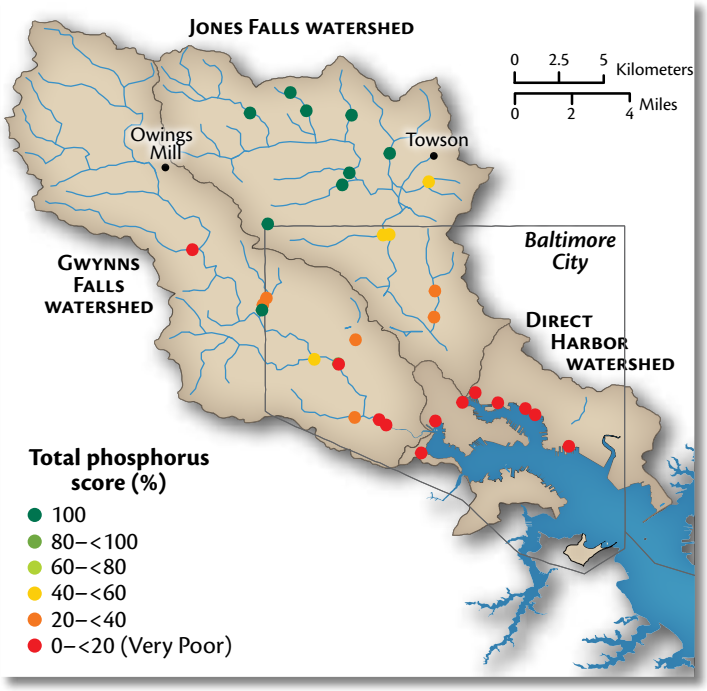


Figure 39. Total phosphorus site scores for 2009.

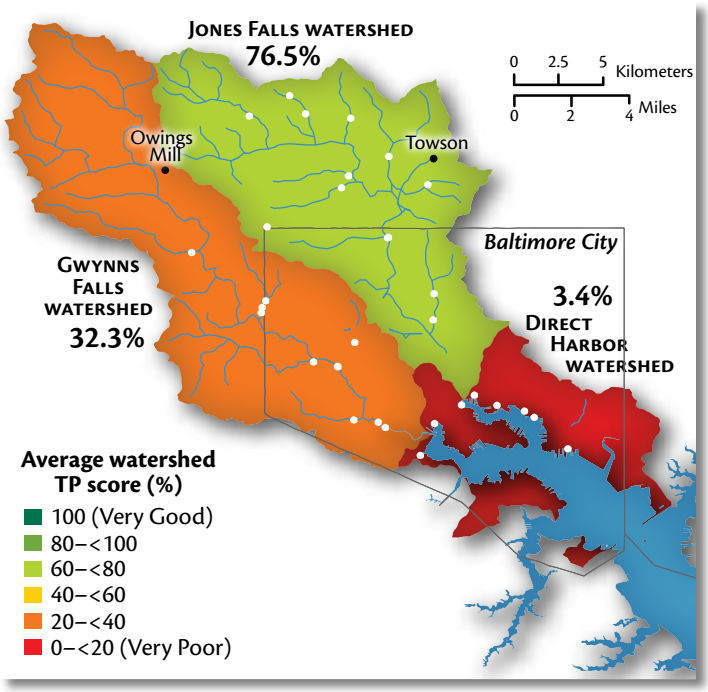


Figure 40. Average watershed scores for total phosphorus for 2009.

Literature cited

City of Baltimore (2010) National Pollution Discharge Elimination System Annual Report, 2009. City of Baltimore, Department of Public Works, Bureau of Water and Wastewater, Surface Water Management Division.

County of Baltimore (2010) NPDES-Municipal stormwater discharge permit, 2010 annual report. County of Baltimore, Department of Environmental Protection and Environmental Management.

Maryland Department of Natural Resources (2011) Maryland Biological Stream Survey. http://www.dnr.state.md.us/streams/MBSS.asp

Water temperature

Relevance and context

Water temperature is an important indicator in streams because it can decrease dissolved oxygen and increase algal blooms. It also affects the health of benthic communities and fish. If the water temperature becomes too high, animals become stressed and may leave the area.

Methods

Water temperature was measured by Baltimore County, Baltimore City, and the Maryland Department of Natural Resources (MD DNR) in 2009. Baltimore County and Baltimore City measure water temperature once a month, while MD DNR collected one sample at two sites one time only in 2009. Methodologies for the county and city can be obtained through their NPDES programs (City of Baltimore 2010, County of Baltimore 2010). Water temperature is measured in degrees Celsius. Data was compared against the threshold and scored as passing or failing. Scores were then averaged for each sampling site. Sampling site scores were then averaged into subwatershed scores.

Reference condition

Thresholds for water temperature were determined by designated use of streams in Maryland (COMAR 26.08.02.03-3). All four designated uses were represented in this study (see page 17).

Current condition

Water temperature scores were very good throughout the three subwatersheds (Figure 41). Every site except one scored above 80%. The Direct Harbor watershed scored a perfect 100% for water temperature (Figure 42). Water temperature appears to be acceptable in these watersheds; however, this indicator does not measure *change* in temperature, which may stress aquatic organisms right after rain events or industrial discharge.

Data gaps and confidence in assessment

Confidence in the assessment is moderate. Data for the upper Gwynns Falls watershed were not available for 2009 leading to an average score for the entire watershed that is based on data in the lower watershed. Additionally, the two MD DNR sites in Jones Falls (see page 16) were only measured once during 2009, which is not representative of the entire year, and therefore weights these measurements less than the other sites. Conversely, there is a wealth of dissolved oxygen data through the city's two monitoring programs (Ammonia Screening and Stream Impact Sampling).

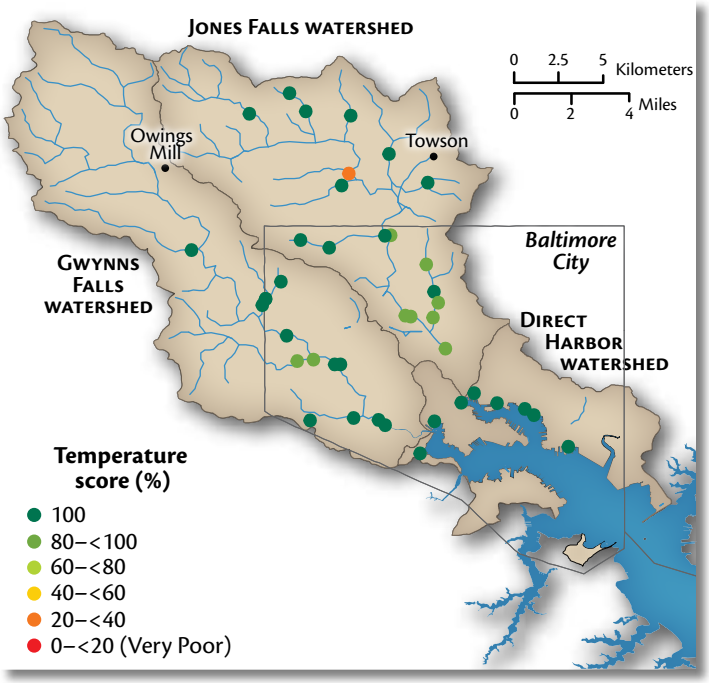


Figure 41. Water temperature site scores for 2009.

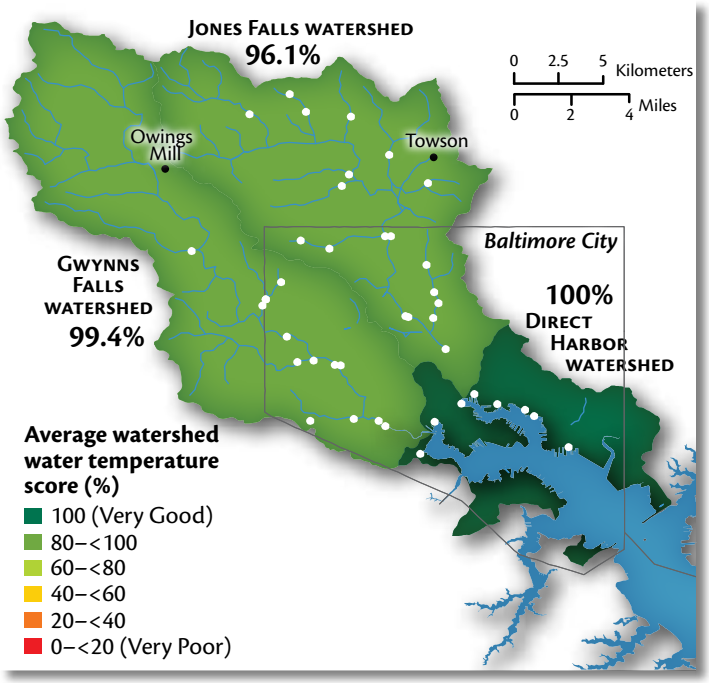


Figure 42. Average watershed scores for water temperature in the three subwatersheds were all very high. The Direct Harbor watershed scored a perfect 100%.

Literature cited

City of Baltimore (2010) National Pollution Discharge Elimination System Annual Report, 2009. City of Baltimore, Department of Public Works, Bureau of Water and Wastewater, Surface Water Management Division.

Code of Maryland Regulations (2011) Title 26 Department of the Environment, Subtitle 08 Water pollution, Chapter 02 Water Quality. COMAR 26.08.02.0-3. http://www.dsd.state.md.us/comar/searchall.aspx

County of Baltimore (2010) NPDES-Municipal stormwater discharge permit, 2010 annual report. County of Baltimore, Department of Environmental Protection and Environmental Management.

pH

Relevance and context

pH is a measure of acidity in streams. Low pH values are acidic, while high values are basic. Streams need to be near a neutral pH (7) to support healthy benthic and fish communities. Elevated or decreased pH can indicate pollution from metals, nutrients, and other toxics from sources such as agriculture, industry, and development.

Methods

pH was measured by Baltimore County, Baltimore City, and the Maryland Department of Natural Resources (MD DNR) in 2009. Baltimore County and Baltimore City measure pH once a month, while MD DNR collected one sample at two sites one time only in 2009. Methodologies for the county and city can be obtained through their NPDES programs (City of Baltimore 2010, County of Baltimore 2010). pH is reported in unitless measurements. Data were scored against a pass/fail threshold, then averaged to sampling site level. Sampling site scores were then averaged into subwatershed scores.

Reference condition

Thresholds for pH were determined by the designated uses of streams in Maryland (COMAR 26.08.02.03-3). All four designated uses were represented in this study. pH for all designated uses must be between 6.5 and 8.5.

Current condition

pH scores were good (Figure 43). One site, in upper Jones Falls, scored very poorly, but this site was only measured once for the entire year. The average subwatershed scores were good (Figure 44). pH in non-tidal streams in these watersheds is healthy.

Data gaps and confidence in assessment

Confidence in the assessment is moderate. Data for the upper Gwynns Falls watershed were not available for 2009 leading to an average score for the entire watershed that is based on data in the lower watershed. Additionally, the two MD DNR sites in Jones Falls (see page 16) were only measured once during 2009, which is not representative of the entire year, and therefore weights these measurements less than the other sites. Conversely, there is a wealth of dissolved oxygen data through the city's two monitoring programs (Ammonia Screening and Stream Impact Sampling).

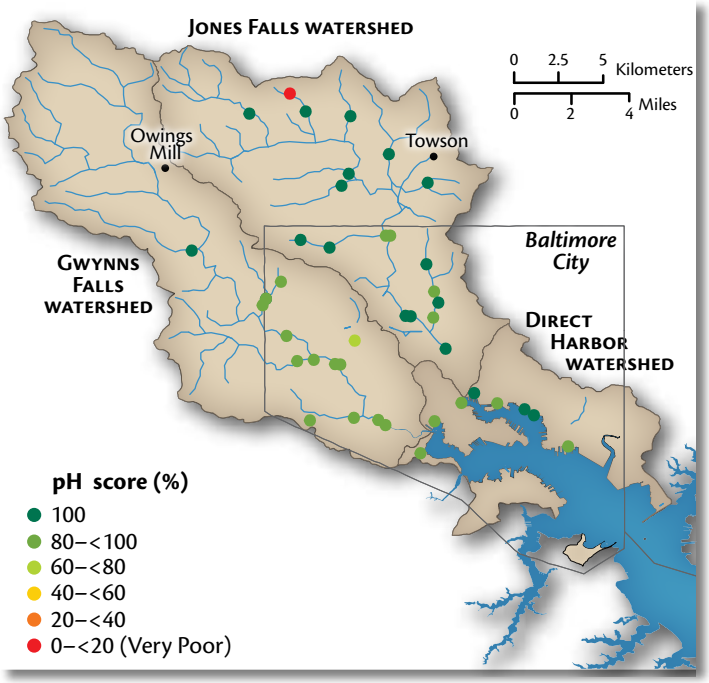


Figure 43. pH site scores for 2009.

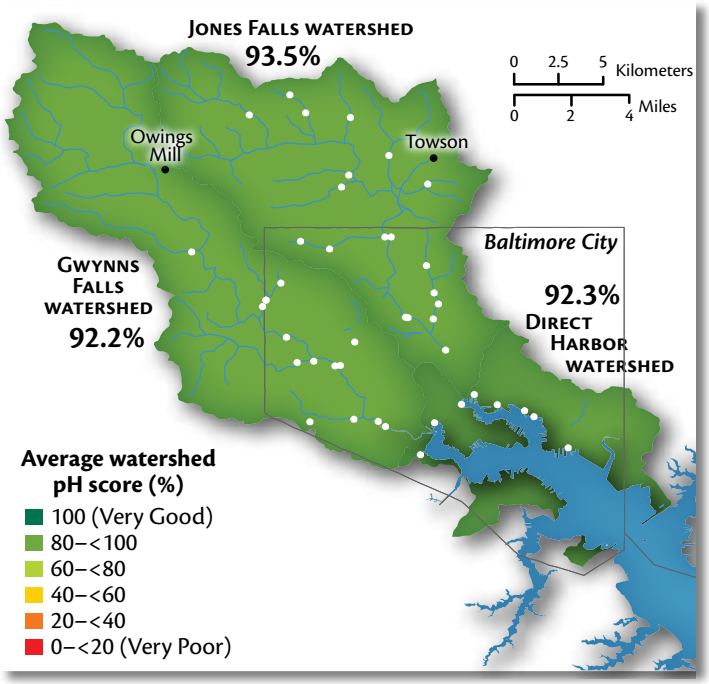


Figure 44. Average watershed scores for pH for 2009.

Literature cited

City of Baltimore (2010) National Pollution Discharge Elimination System Annual Report, 2009. City of Baltimore, Department of Public Works, Bureau of Water and Wastewater, Surface Water Management Division.

Code of Maryland Regulations (2011) Title 26 Department of the Environment, Subtitle 08 Water pollution, Chapter 02 Water Quality. COMAR 26.08.02.0-3. http://www.dsd.state.md.us/comar/searchall.aspx

County of Baltimore (2010) NPDES-Municipal stormwater discharge permit, 2010 annual report. County of Baltimore, Department of Environmental Protection and Environmental Management.

Total suspended solids

Relevance and context

Total suspended solids (TSS) is a measure of how many particles are present in the water column, indicating how dirty the water is. TSS measures the amount of solid particles that are in the water column (MI DEQ 2008). TSS affects other water quality parameters, such as water temperature and dissolved oxygen, which in turn affect fish and shellfish. Suspended solids come from sources such as wastewater treatment plants, agricultural fields, and stormwater runoff.

Methods

Data are collected by Baltimore City, Baltimore County, and Maryland Department of Natural Resources (MD DNR). Baltimore City TSS collects data once a month throughout the year. Baltimore County collects TSS data once every two months. MD DNR collected one sample at two sites one time only in 2009. Water samples are collected and taken to a lab for analysis, and TSS is reported in $mg \cdot l^{-1}$. TSS data was not compared to a threshold and is presented here as raw data (Figure 45).

Reference condition

Currently there is no threshold for TSS. Turbidity is more often used as a measure of the amount of particles in streams, but was not available for this assessment. A TSS threshold needs to be developed before this indicator can be assessed.

Current condition

While TSS can not be assessed against an ecologically relevant threshold at this time, Figure 45 presents a time series graph of all the available TSS data in 2009. TSS is affected by rainfall events, which can be seen in the spikes of data during certain dates. High levels of TSS after rainfall events can negatively impact aquatic organisms.

Data gaps and confidence in assessment

Confidence in data collection is high, however, without a threshold to compare the data against, there is no way to tell if TSS is healthy or unhealthy in the Baltimore Harbor subwatersheds. Therefore, confidence in the assessment is low. A threshold for TSS will hopefully be developed in the near future.

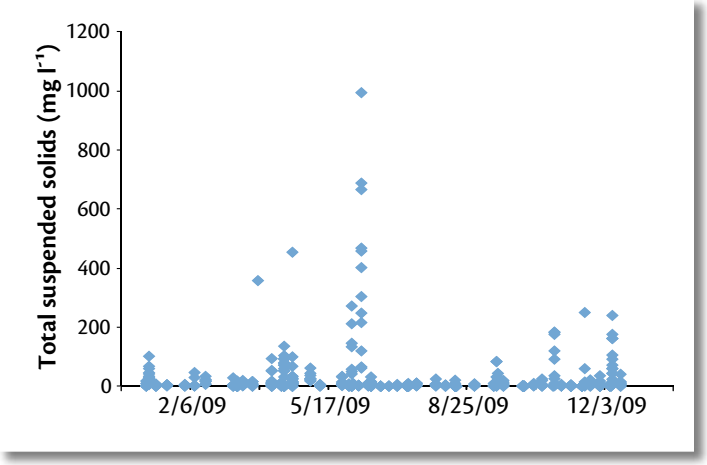


Figure 45. Total suspended solids from all sites over the entire 2009 period. Spikes in TSS indicate a rain event.

Literature cited

Michigan Department of Environmental Quality (2008) Total Suspended Solids. http://www.michigan.gov/documents/deq/wb-npdes-TotalSuspendedSolids_247238_7.pdf

Benthic community

Relevance and context

Benthic macroinvertebrates are organisms, such as mussels and worms, that live on and within the stream bottom sediments. The benthic community is a good indicator of stream health because different species have different responses to pollution. Additionally, they integrate physical (e.g., temperature), chemical (e.g., dissolved oxygen), and biological (e.g., habitat) health conditions of a stream (EcoCheck 2009).

Methods

A Benthic Index of Biological Integrity (IBI) has been developed for assessing the health of benthic macroinvertebrate communities on a scale of very poor to good. Benthic macroinvertebrate samples are collected and analyzed by Baltimore County and Baltimore City, following Maryland Biological Stream Survey Standard Operating Procedures (Klauda et al. 1998, MD DNR 2011). County data is sampled randomly. There is one sampling date for the entire county sampling program. However, this indicator integrates stream conditions over time and single annual measurements are seen as a robust indicator of overall stream health. A few samples were measured in the Gwynns Falls watershed in 2009 by the city. 2008 city data were also used to assess the Jones Falls watershed. Some of these samples are targeted sites and some are random. The samples are analyzed in the lab, reported results are unitless, and are converted to a scale ranging from very poor to good.

Reference condition

The Benthic IBI classifies samples in scores from 1 to 5. Values between 1 and 3 are considered to be degraded, while values between 3 and 5 are considered to be ecologically healthy.

Current condition

In 2008 and 2009, benthic communities in streams in Gwynns Falls and Jones Falls were mostly degraded (Figure 46), although there are some healthy sites in the upper reaches of each watershed. There is no data in the Direct Harbor watershed, most likely due to the lack of free-flowing streams. Sampling sites cannot be averaged into a subwatershed score because some of the sites are targeted. Targeted studies generally focus on problem sites, and these targeted sites would bias an average toward degraded scores.

Data gaps and confidence in assessment

Data is spatially limited in the lower Gwynns Falls watershed and especially in the Direct Harbor watershed. However, this is expected due to lack of free flowing streams. This indicator is useful for integrating environmental conditions over time, so it is temporally robust. While the confidence in the collection methods is high, the overall confidence is only moderate due to lack of data in the lower watershed areas.

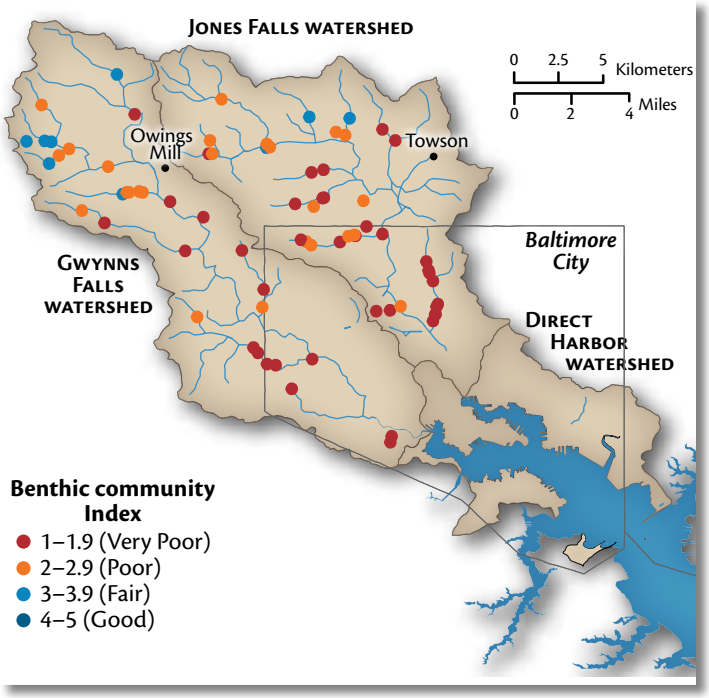


Figure 46. Benthic communities in streams is measured using an Index of Biotic Integrity. Benthic communities in the Gwynns Falls and Jones Falls are degraded. There are some healthy sites in the upper reaches of each watershed. There is no data from the Direct Harbor, most likely due to the lack of aboveground, free flowing streams.

Literature cited

EcoCheck (2009) New Stream Health Indicator being developed. IAN Press, Cambridge, Maryland

Klauda, R, Kazyak P, Stranko S, Southerland M, Roth N, Challoc J (1998) Maryland Biological Stream Survey: A state agency program to assess the impact of anthropogenic stresses on stream habitat quality and biota. Environmental Monitoring and Assessment 51:299-316

Maryland Department of Natural Resources (2011) Maryland Biological Stream Survey. http://www.dnr.state.md.us/streams/MBSS.asp

Bacteria

Relevance and context

Indicator bacteria, such as *E. coli* or *Enterococcus*, are used to evaluate potential human health risks associated with swimming and other recreational activities due to harmful pathogens in the water. The presence of indicator bacteria indicates that harmful pathogens may also be present. Bacteria and pathogens can come from the feces of animals, from human waste that leaks from sewer systems and broken sewage lines, and from nonpoint sources, such as stormwater runoff from parks, sidewalks, and parking lots. The more bacteria in the water, the more likely it is that a person can become sick.

Methods

E. coli is generally accepted as an indicator of waterborne pathogens in fresh water (US EPA 1986). *E. coli* bacteria samples were collected by Baltimore County and Baltimore City in 2010 and 2009, respectively. Samples are reported as Most Probable Number (MPN) per 100 milliliters of water (City of Baltimore 2010, County of Baltimore 2010).

Reference condition

The EPA threshold for *E. coli* for contact recreation is 235 MPN $100 \cdot ml^{-1}$ (USEPA 1986). If a sample exceeds this threshold, EPA has determined that there is unacceptable risk of humans becoming sick when they come into contact with the water.

Current condition

Station averages (Figure 47) show that the streams in Gwynns Falls and Jones Falls have many days and locations where there is a lot of bacteria in the water. The Direct Harbor only has two sampling sites, which scored better than some of the sites in the other watersheds. Jones Falls and Gwynns Falls scored poorly. The Direct Harbor was not scored due to lack of data (Figure 48).

Data gaps and confidence in assessment

Confidence in the assessment is moderate. Data is temporally lacking. For example, the county data starts in June 2010, while the city data covers the whole year (2009). However, the sites were sampled frequently in both cases. There are no sampling sites in the upper reaches of either the Jones Falls or Gwynns Falls watersheds. While more sampling in the Direct Harbor would provide a better picture of the health of streams, there are no free flowing streams in the Direct Harbor watershed.

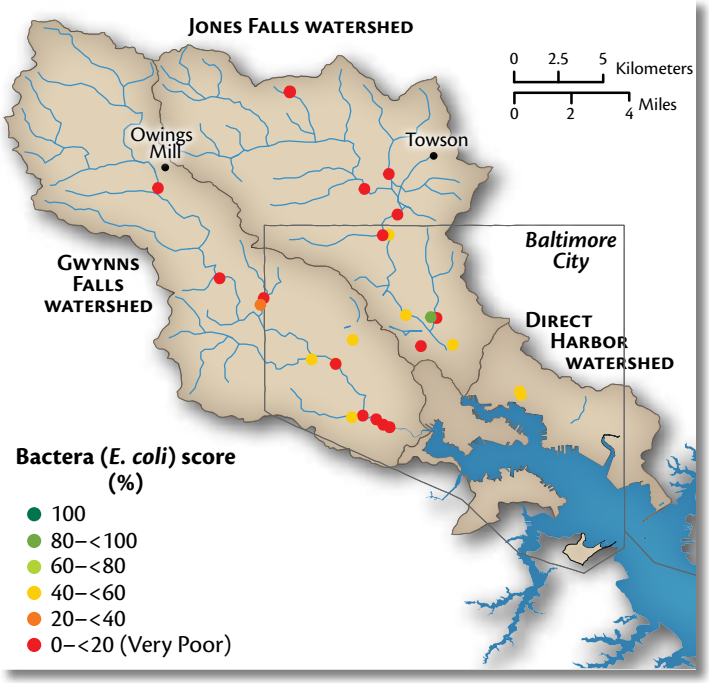


Figure 47. Bacteria site scores in 2009 and 2010.

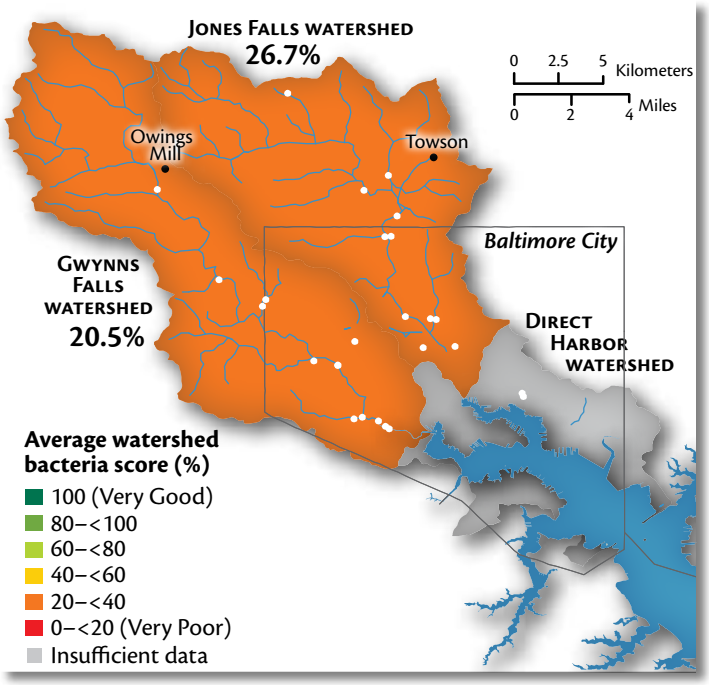


Figure 48. Average bacteria scores for the watersheds. The Direct Harbor only had two sample sites, which is not enough to calculate an average watershed score.

Literature cited

City of Baltimore (2010) National Pollution Discharge Elimination System Annual Report, 2009. City of Baltimore, Department of Public Works, Bureau of Water and Wastewater, Surface Water Management Division.

County of Baltimore (2010) NPDES-Municipal stormwater discharge permit, 2010 annual report. County of Baltimore, Department of Environmental Protection and Environmental Management.

US EPA (1986). Ambient Water Quality Criteria for Bacteria–1986. U.S. Environmental Protection Agency, Washington, DC. EPA–440/5-84-002.

Trash

Relevance and context

Trash is an important indicator for measuring progress in relation to stream restoration goals. Trash is a common problem in urban environments, but it is rarely thought of as a water pollutant. Once trash is on the ground in neighborhoods, along roads, and in parking lots, it washes into the storm drain system and into local waterways. Each time it rains, trash washes into streams. Trash is harmful to the environment because it leaches chemicals into the ecosystem, is a breeding ground for harmful bacteria and other pathogens, and can entangle aquatic organisms. Trash is also aesthetically unpleasant, which influences quality of life.

Methods

Trash data assessed in this study were collected by Baltimore County in 2010 and 2011, in preparation for a trash Total Maximum Daily Load (TMDL) for the Harbor. Baltimore County uses a random sampling method and measures both weight and type of trash accumulated. These data are the best available for assessing trash in the watersheds.

Reference condition

Threshold values for trash have not been established for Baltimore Harbor's subwatersheds. However, a trash Total Maximum Daily Load (TMDL) is being established for Baltimore Harbor, which will determine the trash load allowed in the Harbor. The TMDL should be finalized by 2013. For this assessment, a pounds per acre per year (lbs $\cdot acre^{-1} \cdot yr^{-1}$) metric was calculated to determine the amount of trash within local areas (Figure 49).

Current condition

Currently, the Gwynns Falls watershed trash average was 3.93 lbs $\cdot acre^{-1} \cdot yr^{-1}$, and Jones Falls was 1.25 lbs $\cdot acre^{-1} \cdot yr^{-1}$. At the sites sampled, a variety of trash types (e.g., glass, aluminum, plastic) were found. Some locations are classified as dumping sites and, therefore, skew the data to higher amounts of trash than non-dumping sites. In general, trash is considered a problem throughout the watersheds, although it appears Gwynns Falls watershed has a larger amount of trash than Jones Falls watershed.

Data gaps and confidence in assessment

Currently, only the county is measuring trash in the watersheds for purposes of the Harbor trash TMDL. Therefore, there is a lack of data within the lower reaches of Gwynns Falls and Jones Falls, which are within the city limits, and there are no data in the Direct Harbor watershed. While confidence is high in the collection method and analysis of the available data, the confidence in the overall assessment is only moderate.

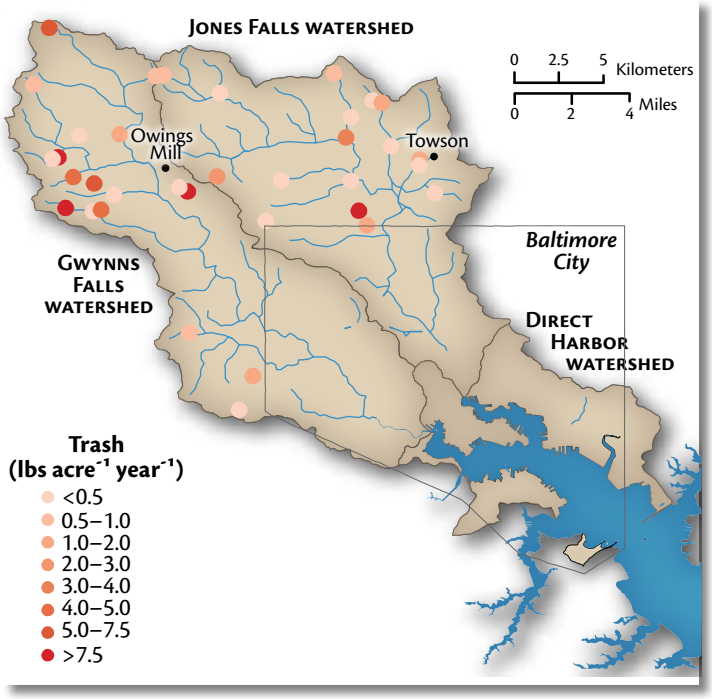


Figure 49. The average amount of trash in the upper watersheds.

Literature cited

County of Baltimore (2011) Trash Monitoring Program. County of Baltimore, Department of Environmental Protection and Management.

Discussion: Harbor health is degraded

This section synthesizes the results for each indicator and sub-region described in previous sections. This synthesis provides an overall assessment of ecological and human health for both the two tidal and three watershed portions of Baltimore's Inner Harbor.

Synthesis process

Water Quality Index calculations

Water quality indicator scores were averaged into a Water Quality Index (WQI) for each tidal sub-region. The WQI for the Inner Harbor and Middle Branch sub-regions included five indicators: dissolved oxygen, chlorophyll *a*, water clarity, total nitrogen, and total phosphorus. Area-weighting is used to balance the area of one region with other regions, so that the final score is representative of the entire region as a whole. For example, scores in a large region (i.e., large relative to the size of the other regions) should have more weight than scores in a smaller region. These methods follow the Chesapeake Bay report card and the Mid-Atlantic Tributary Assessment Coalition's (MTAC) indicator protocol document (Williams et al 2009, EcoCheck 2011).

Although indicators were available to assess the health Baltimore Harbor watershed, there are currently no protocols for wrapping up the indicators into an overall watershed water quality index. The main obstacle for developing a water quality index is that water quality indicator scores can not be easily averaged into a WQI for each watershed region because the high variability in the indicator scores will lead to an average score that does not accurately reflect the health of the watershed. For example, dissolved oxygen, water temperature, and pH consistently score high even as the scores for conductivity and nitrogen and phosphorus can be low. Including parameters in the index that are not pollution sensitive can lead to "averaging out" stream degradation that can result from even just one parameter (such as conductivity) being low. An alternative way to present the data that accurately reflects the health of the region is to calculate a pollution index. A pollution index uses only those indicators that reflect the pollution that is affecting the streams. These indicators would include total nitrogen, total phosphorus, and conductivity. Another option is to include all the water quality indicators, but weight the pollution indicators heavier than the other water quality indicators. This would balance out the high scoring indicators that tend to skew the water quality score higher than it is in reality. However, this kind of complicated averaging is difficult to communicate to the public.

Due to the limitations of using a WQI, this assessment presents the watershed health on an indicator-by-indicator basis, not an overarching index basis. Each indicator is presented for each subwatershed and general patterns are discussed.

In the future, an index of watershed health will be developed through the Mid-Atlantic Tributary Assessment Coalition (MTAC). Scientifically robust protocols for developing non-tidal indices (e.g., pollution index, human health index) should be developed in 2011 and 2012 and will be used to assess the health of the Baltimore Harbor watershed.

Ecological Health Index

Ideally, water quality and other ecological indicators, such as benthic communities and aquatic grasses, are aggregated into an overall ecological health score. However, in both the tidal and watershed areas, some indicators (e.g., benthic communities, aquatic grasses, and toxicants) could not be scored and therefore can not be included in an overall ecological health score. Instead, a narrative approach is used to determine the overall ecological health for each sub-region and subwatershed. These results were aggregated to provide an assessment for the entire tidal and watershed area. In future annual report cards, perhaps ecologically relevant thresholds will have been established, and those indicators that could not be scored in this assessment will be able to be used to provide grades for ecological health.

Human Health Index

The same issues apply with the human health indicators. Bacteria and other indicators should ideally be aggregated into an overall human health score. However, bacteria is the only human health indicator that was scored. Additionally, trash is more of an aesthetic indicator than a human health issue and therefore, may need to be excluded from an overall human health score.

Overall results

Tidal region

Despite the incomplete assessment for the watershed section, the tidal portion of Baltimore Harbor can be assessed. Overall, the ecological and human health of the tidal reporting regions is poor. Decreasing the amount of nutrients, sediments, and trash entering the harbor should help to decrease the bacteria and chlorophyll *a* concentrations in the water, and should also help increase dissolved oxygen levels. Healthier water quality, bacteria levels, and benthic communities will help improve habitat for fish and shellfish.

Overall scores for ecological and human health were qualitatively aggregated to present a summary of conditions in the tidal portion (Table 5). Condition assessments ranged from poor to moderate, with low confidence in the overall assessment results. As noted previously, some of the data used in this assessment were limited spatially and temporally. In these cases, it is difficult to have complete confidence in results when applying analysis results to an entire reporting region. Qualitative judgments were included regarding uncertainty when interpreting results. Judgments were based on data resolution, appropriateness of data collection methods, and other factors.

Watershed region

Due to the indicator-only assessment of the watershed section, the ecological and overall health could not be ascertained. However, the human health (e.g., bacteria and trash) of the watershed was determined to be poor. The bacteria score and the amount of trash collected throughout the watershed indicates poor health. Confidence in the overall assessment is low due to the aforementioned lack of spatial and temporal resolution of the data and the incomplete assessment of water quality health.

Literature cited

Buchanan, C., K. Foreman, J. Johnson, and A. Griggs. 2011. Development of a Basin-wide Benthic Index of Biotic Integrity for Non-Tidal Streams and Wadeable Rivers in the Chesapeake Bay Watershed: Final Report to the Chesapeake Bay Program Non- Tidal Water Quality Workgroup. ICPRB Report 11-1. Report prepared for the US Environmental Protection Agency, Chesapeake Bay Program.

EcoCheck (2011) Sampling and data analysis protocols for Mid-Atlantic tidal tributary indicators. Wicks EC, Andreychek ML, Kelsey RH, Powell SL (eds). IAN Press, Cambridge, Maryland, USA.

Williams M, Longstaff B, Llanso R, Buchanan C, Dennison W (2009) Development and evaluation of a spatially-explicit index of Chesapeake Bay health. Marine Pollution Bulletin 59:14-25

Table 5. Results for all regions of Baltimore's Harbor and watershed. The Inner Harbor and Middle Branch sub-regions results were combined into an average tidal health assessment. The Jones Falls, Gwynns Falls, and Direct Harbor subwatershed results were combined into an average Watershed assessment. Confidence refers to the confidence in the overall assessment (ecological plus human).

Region	Overall	Ecological	Human	Confidence
Tidal	**n/a**	**Poor**	**Poor**	**Low**
Inner Harbor	Poor	Poor	Poor	Low
Middle Branch	n/a	n/a	Moderate	Low
Watershed	**n/a**	**n/a**	**Poor**	**Low**
Jones Falls	n/a	n/a	Poor	Low
Gwynns Falls	n/a	n/a	Poor	Low
Direct Harbor	n/a	n/a	Poor	Low

Tidal region conditions

Ecological health

The ecological health of the entire tidal region is poor, although it is difficult to confidently assess the sub-regions because of low and inconsistent spatial and temporal coverage of water quality, benthic, and other ecological data (Table 6). A Water Quality Index (WQI) was calculated for the Inner Harbor; however, the Middle Branch did not have any water quality data and, therefore, a WQI could not be calculated for the entire tidal region (Figure 50).

Human health

The human health of the entire tidal region is moderately poor. This is based solely on the bacteria indicator scores, which were area-weighted by sub-region and averaged to determine the final score for the region, 41%. This means that 59% of the time, the water in the tidal region has a high risk of bacteria-related illness.

While trash could not be scored, it is intuitive that any trash in the Harbor is too much. Trash continues to be a problem in the Inner Harbor, and new methods for trash data collection and data evaluation need to be developed in order for this indicator to be useful in future annual assessments. Fish tissue toxicity is measured throughout the Patapsco River and assessed on a tributary-wide basis. PCBs levels in white perch tissue are higher than safe human consumption levels and it is not recommended to eat white perch from the Patapsco River. Although fish are mobile, the white perch results do indicate that PCBs remain a concern for the Patapsco River and Baltimore Harbor (MDE 2011).

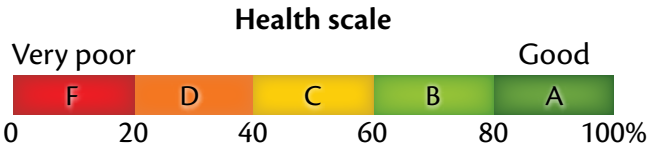


Figure 50. A 0-100% scale is used to score and grade each indicator and overall health.

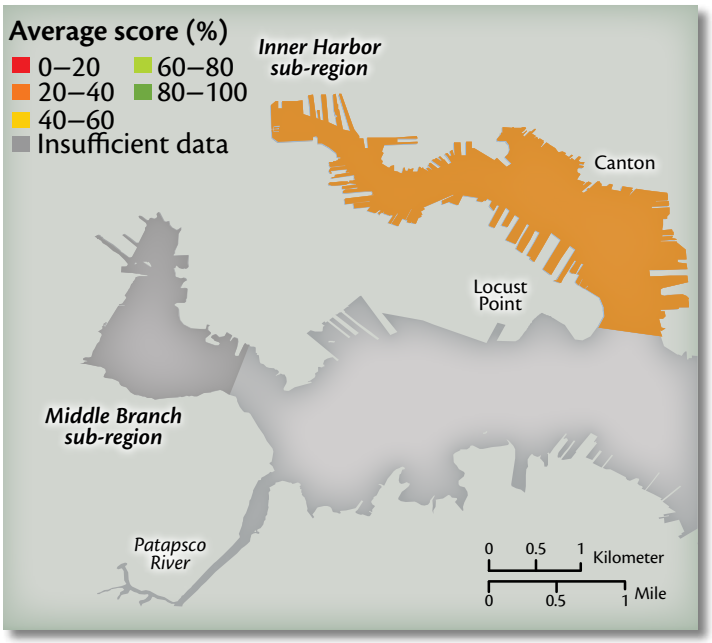


Figure 50. Water Quality Index for tidal regions. There was insufficient data in the Middle Branch sub-region to generate a WQI.

Literature cited

Maryland Department of the Environment (2011) Fish and Shellfish. www.mde.state.md.us/programs/Marylander/CitizensInfoCenterHome/Pages/citizensinfocenter/fishandshellfish/index.aspx

Table 6. Average indicator scores, grades, and narrative value for the tidal region overall. Due to the lack of data in the Middle Branch region, a Water Quality Index and average indicator scores could not be calculated.

Indicator	Score (%)	Grade	Narrative	Confidence
Ecological health				
Water Quality Index	**n/a**	**n/a**	**n/a**	---
Dissolved oxygen	n/a	n/a	n/a	---
Chlorophyll *a*	n/a	n/a	n/a	---
Water clarity	n/a	n/a	n/a	---
Total nitrogen	n/a	n/a	n/a	---
Total phosphorus	n/a	n/a	n/a	---
Benthic community	n/a	n/a	n/a	---
Aquatic grasses	n/a	n/a	Very poor	High
Toxicants (sediment)	n/a	n/a	n/a	---
Human health				
Bacteria	41	B	Moderately poor	High
Fish toxicity	n/a	n/a	Poor	High
Trash	n/a	n/a	Poor	Low to Moderate

Inner Harbor Conditions

Ecological health

Overall, the ecological health of the Inner Harbor reporting region was assessed as poor, but the confidence in this assessment was low, as a result of limited data availability for all indicators (Table 7). All water quality indicator data were from one monitoring station located in the Inner Harbor region. Dissolved oxygen and nutrients scored moderately poor to very poor. Chlorophyll *a* and water clarity had the best water quality scores, but are still only moderately poor.

A Water Quality Index (WQI) was calculated as the average of dissolved oxygen, chlorophyll *a*, water clarity, total nitrogen, and total phosphorus scores. The WQI for the Inner Harbor was 30.1%, a D (Figure 51). This means that on average the water quality in the Inner Harbor is poor and leads to poor habitat conditions for fish and shellfish. Benthic communities and sediments scored Very Poor. Sediments in Baltimore Harbor will continue to be an environmental management issue because the continuing industry surrounding the Harbor, and the nature of sediment contaminants, which are often persistent (Independent Technical Review Team 2009).

Human health

Bacteria in the Inner Harbor scored a poor overall, with much improvement needed (Table 7). Fish toxicity cannot be scored within just the Inner Harbor, but rather must be assessed on a tributary-wide scale because fish are mobile. Fish toxicity is poor in the entire Pataspco River. Trash continues to be a problem in the Inner Harbor. While not assessed with a grade, the total amount of trash being collected from outfalls and through clean ups indicates a large amount of trash is entering the Inner Harbor.

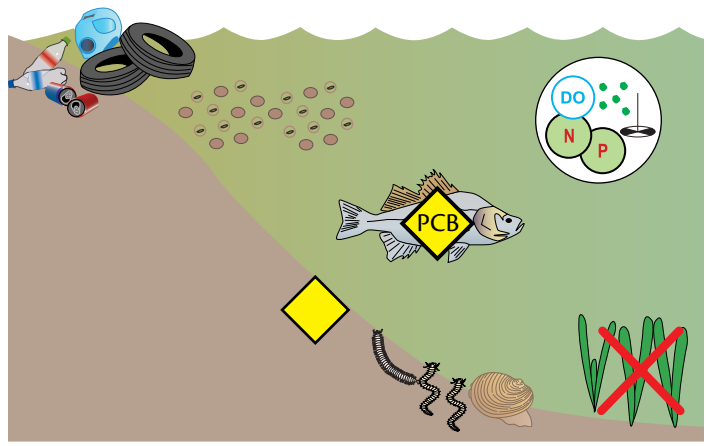
Confidence

Confidence in the assessment of water quality, biotic, and human health indicators in Inner Harbor is low. While the data that are currently collected are reliable, the lack of spatially and temporally resolved data needs to be addressed.

Literature cited

Independent Technical Review Team (2009). Sediment in Baltimore Harbor: Quality and Suitability for Innovative Reuse. An Independent Technical Review. JG Kramer, J Smits, and KG Sellner (eds). Maryland Sea Grant Publication UM-SG-TS-2009-04. CRC Publ No 09-169.

Inner Harbor ecological and human health



The assessed Inner Harbor sub-region had poor water quality, and very poor benthic communities, toxicants, and aquatic grasses. Bacteria, trash, and fish toxicity were all poor.

Table 7. Indicator scores, grades, and narrative values for the Inner Harbor reporting region.

Indicator	Score (%)	Grade	Narrative	Confidence
Ecological health				
Water Quality Index	**30.1**	**D**	**Poor**	**Low**
Dissolved oxygen	32.8	D	Poor	Moderate
Chlorophyll *a*	41.8	C-	Moderately poor	Moderate
Water clarity	41.4	C-	Moderately poor	Moderate
Total nitrogen	11.4	F	Very Poor	Low
Total phosphorus	22.9	D-	Poor	Low
Benthic community	n/a	n/a	Very poor	Moderate
Aquatic grasses	n/a	n/a	Very poor	---
Toxicants (sediment)	n/a	n/a	Very poor	Moderate
Human health				
Bacteria	27	D	Poor	High
Fish toxicity	n/a	n/a	Poor	High
Trash	n/a	n/a	Poor	Low to Moderate

Middle Branch Conditions

Ecological health

Ecological health—water quality, benthic communities, and toxicants—cannot be assessed for the Middle Branch reporting region because there are no water quality data available (Table 8). Furthermore, a Water Quality Index for the Middle Branch cannot be calculated.

Aquatic grasses were not scored because there is no threshold to compare against. Currently, no aquatic grasses are expected in Middle Branch due to the lack of aquatic grass growth there historically. However, restoration is a future possibility.

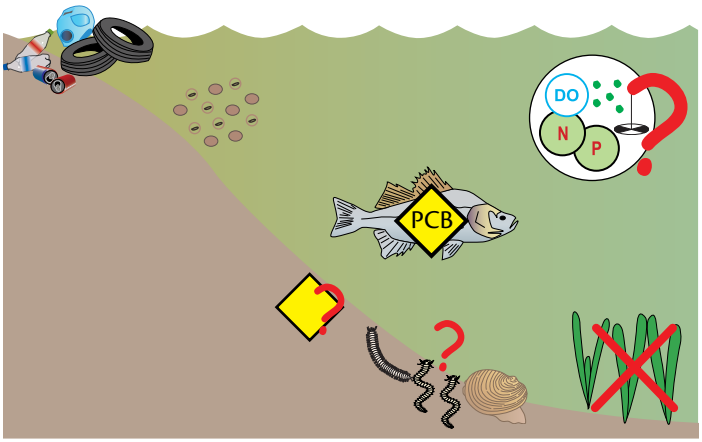
Human health

Overall, the human health of the Middle Branch region was assessed as moderate. Bacteria scored a fair overall in the Middle Branch reporting region (Table 8). This is healthier than the Inner Harbor reporting region and is close to a good score. While not assessed with a grade, the total amount of trash being collected from outfalls and through clean ups indicates that trash continues to be a problem in the Middle Branch.

Confidence

Confidence in the assessment of ecological health is low. While the data that are currently collected are reliable, the lack of data is an issue that needs to be addressed. Confidence in the assessment of human health is moderate. The bacteria, fish toxicity, and trash data are more robust than the ecological health data.

Middle Branch ecological and human health



The Middle Branch sub-region was lacking in water quality data, benthic communities, and toxicants. It had very poor aquatic grasses. Bacteria was fair, while trash and fish toxicity were poor.

Table 8. Indicator scores, grades, and narrative value for the Middle Branch reporting region.

Indicator	Score (%)	Grade	Narrative	Confidence
Ecological health				
Water Quality Index	**n/a**	**n/a**	**n/a**	---
Dissolved oxygen	n/a	n/a	n/a	---
Chlorophyll *a*	n/a	n/a	n/a	---
Water clarity	n/a	n/a	n/a	---
Total nitrogen	n/a	n/a	n/a	---
Total phosphorus	n/a	n/a	n/a	---
Benthic community	n/a	n/a	n/a	---
Aquatic grasses	n/a	n/a	Very poor	---
Toxicants (sediment)	n/a	n/a	n/a	---
Human health				
Bacteria	71	B	Fair	High
Fish toxicity	n/a	n/a	Poor	High
Trash	n/a	n/a	Poor	Low to Moderate

Watershed region conditions

Ecological health

Average water quality indicator scores ranged from Good to Poor (Table 9; Figure 51). These scores are calculated by area-weighting average indicator scores for the Jones Falls, Gwynns Falls, and Direct Harbor subwatersheds, then summing the area-weighted score for an overall average indicator score. Three indicators-total nitrogen, total phosphorus, and conductivity-scored poor to moderately good. These indicators are good indicators for assessing the pollution entering these streams. Any one of these indicators scoring poorly can indicate a degraded stream. Three indicators-dissolved oxygen, water temperature, and pH-scored good, which is not surprising because these indicators are less variable than the other indicators and thresholds for scoring usually only indicate a stream that is severely degraded. These indicators and their thresholds need to be further evaluated to determine their applicability for use in urban environments.

Despite these variable indicator scores, patterns can be seen. The Jones Falls watershed scores are the highest, followed by the Gwynns Falls (Figure 52). The Direct Harbor scores are the lowest and are significantly lower than the Jones or the Gwynns Falls watersheds. This means that the Jones Falls is, in general, the healthiest subwatershed, followed by the Gwynns Falls watershed. Both are much healthier than the Direct Harbor watershed. This is not surprising, considering Jones Falls watershed has the least amount of impervious surface, while the Direct Harbor has the most. As the amount of impervious surface in a watershed increases, water quality of streams decreases. Additionally, the sites used for the Direct Harbor are storm drain outfall areas, which are influenced by the tidal portion of the Harbor due to mixing. The water temperature and pH scores are very similar for all three subwatersheds. Another pattern is the gradient in indicator scores from the upper watersheds to lower watersheds. Conductivity, total nitrogen, and total phosphorus score better in the upper Jones and Gwynns Falls watershed compared to downstream. The Direct Harbor scores the worst. Furthermore, the benthic community score better in the upper Jones and Gwynns Falls watershed compared to downstream as well. Conversely, water temperature and pH, while scoring moderately good and good throughout the watersheds, have lower scores downstream.

Confidence in the assessment is low because the data used to assess ecological health were spatially and temporally limited and an overall Water Quality Index could not be calculated. Benthic community data was limited and an average score for each subwatershed was not able to be calculated.

The indicators chosen for this assessment are common non-tidal indicators, however a review and refinement of these indicators is needed. The thresholds used to calculate the scores (see page 17), may also need to be refined. Currently, the thresholds are pass/fail, which may be masking a gradient from good to very poor within the same location or watershed. Multiple thresholds should be developed for these indicators. EcoCheck, in partnership with the Mid-Atlantic Tributary Assessment Coalition (MTAC), plans on developing multiple thresholds for many of these indicators over the next year (2011–2012), as well as developing non-tidal indices, such as a pollution index.

Table 9. Average indicator scores, grades, and value for the watershed overall. Expand explanation of indicators and confidence

Indicator	Score (%)	Grade	Narrative	Confidence
Ecological health				
Dissolved oxygen	98.4	A+	Good	Moderate
Conductivity	33.1	D	Poor	Moderate
Total nitrogen	63.4	B-	Moderately good	Moderate
Total phosphorus	41.6	C-	Moderately poor	Moderate
Water temperature	98.5	A+	Good	Moderate
pH	92.6	A	Good	Moderate
TSS	n/a	n/a	n/a	Low
Benthic community	n/a	n/a	Poor	Moderate
Human health				
Bacteria	n/a	n/a	n/a	Low
Trash	n/a	n/a	Poor	Moderate

Human health

Overall, the human health of Baltimore's watershed is degraded, and is similar to the tidal regions. It is clear that a significant decrease in bacteria in the watershed is needed. While not scored, the total amount of trash being collected from outfalls and through clean ups indicates a large amount of trash is entering local waterways and making its way into the tidal region.

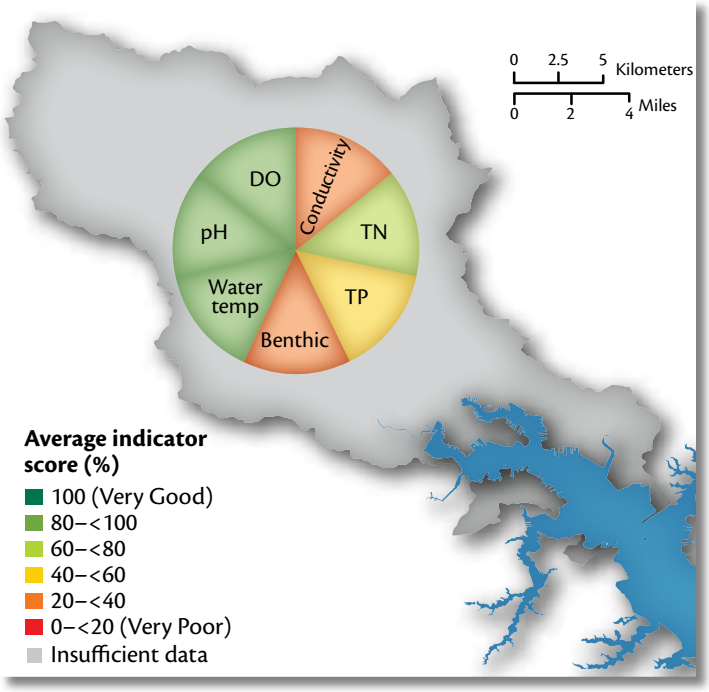


Figure 51. Average indicator scores for entire watershed overall.

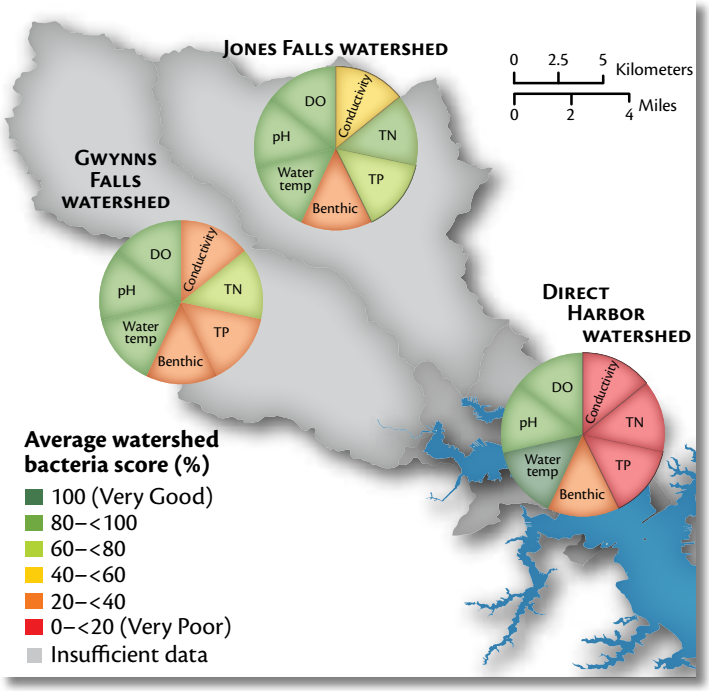


Figure 52. Average indicator scores for each subwatershed.

Jones Falls Conditions

Ecological health

Overall, the ecological health of the Jones Falls watershed is moderate, but the confidence in this assessment is only moderate because data are both spatially and temporally limited (Table 10). A Water Quality Index for the Jones Falls watershed was calculated from the available data and scored an 81.3%, which is a good score, and suggests that habitat conditions for fish and shellfish are good (Figure 52).

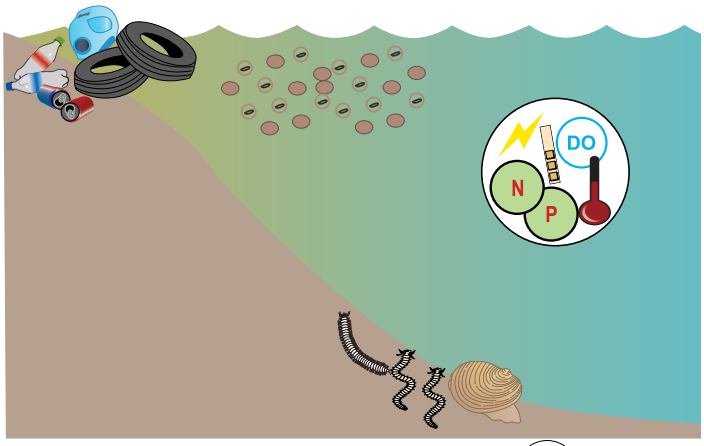
Human health

Overall, the human health of the Jones Falls watershed is poor but the confidence in this assessment is moderate. Bacteria in the watershed scored a Poor, although there are no data for the upper watershed. Bacteria in the watershed needs significant improvement. While not assessed with a grade, the total amount of trash being collected through clean ups indicates a large amount of trash is entering the streams and eventually the Inner Harbor.

Confidence

Confidence in the assessment of water quality, biotic, and human health indicators in Jones Falls is moderate to low. While the data that are currently collected are reliable, the lack of data in some parts of the watershed and the missing time component of some of the data is an issue that needs to be addressed. The variability in the indicator scores may indicate a need to review and refine the water quality indicators and thresholds used to assess watershed health.

Jones Falls ecological and human health



The Jones Falls watershed had good water quality, but poor benthic communities. Bacteria and trash were poor.

Table 10. Indicator scores, grades, and value for the Jones Falls subwatershed reporting region.

Indicator	Score (%)	Grade	Narrative	Confidence
Ecological health				
Dissolved oxygen	99.7	A+	Good	Moderate
Conductivity	43.4	C-	Moderately poor	Moderate
Total nitrogen	81.8	A-	Good	Moderate
Total phosphorus	76.5	B+	Moderately good	Moderate
Water temperature	96.1	A+	Good	Moderate
pH	93.5	A	Good	Moderate
TSS	n/a	n/a	n/a	Low
Benthic community	n/a	n/a	Poor	Moderate
Human health				
Bacteria	26.7	D	Poor	Moderate
Trash	n/a	n/a	Poor	Moderate

Gwynns Falls Conditions

Ecological health

Overall, the ecological health of the Gwynns Falls watershed is moderate, but the confidence in this assessment is only moderate (Table 11). Gwynns Falls health is slightly less healthy than the Jones Falls watershed. Data are both spatially and temporally limited (see individual indicator pages for more details). A Water Quality Index for the Gwynns Falls watershed was calculated and scored a 72.0%, which is a moderately good (Figure 52). The Gwynns Falls watershed is healthy, which means the habitat conditions for fish and shellfish are moderately good.

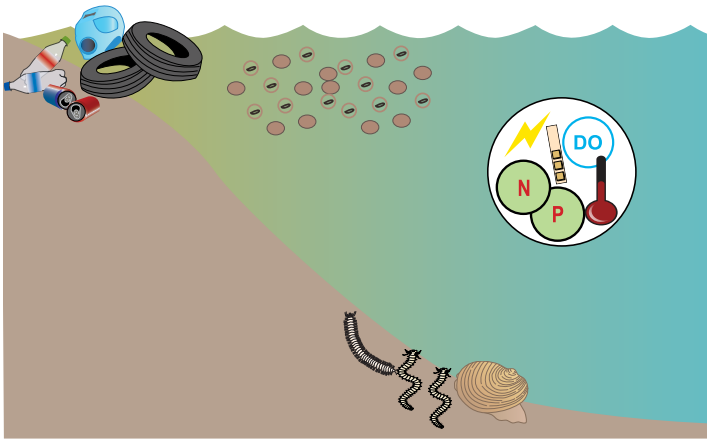
Human health

Overall, the human health of the Gwynns Falls watershed is poor but the confidence in this assessment is only moderate. Bacteria in the watershed scored a poor, although there are no data for the upper watershed. Bacteria in the watershed needs significant improvement. While not assessed with a grade, the total amount of trash being collected through clean ups indicates a large amount of trash is entering the streams and eventually the Middle Branch.

Confidence

Confidence in the assessment of water quality, biotic, and human health indicators in Gwynns Falls is moderate to low. While the data that is currently collected is reliable data, the lack of data in some parts of the watershed and the missing time component of some of the data is an issue that needs to be addressed. The variability in the indicator scores may indicate a need to review and refine the water quality indicators and thresholds used to assess watershed health.

Gwynns Falls ecological and human health



The Gwynns Falls watershed had moderately good water quality, but poor benthic communities. Bacteria and trash were poor.

Table 11. Indicator scores, grades, and value for the Gwynns Falls subwatershed reporting region.

Indicator	Score (%)	Grade	Narrative	Confidence
Ecological health				
Dissolved oxygen	99.8	A+	Good	Moderate
Conductivity	36.5	D+	Poor	Moderate
Total nitrogen	71.5	B	Moderately good	Moderate
Total phosphorus	32.3	D	Poor	Moderate
Water temperature	99.4	A+	Good	Moderate
pH	92.2	A	Good	Moderate
TSS	n/a	n/a	n/a	Low
Benthic community	n/a	n/a	Poor	Moderate
Human health				
Bacteria	20.5	D-	Poor	Moderate
Trash	n/a	n/a	Poor	Moderate

Direct Harbor Conditions

Ecological health

Overall, the ecological health of the Direct Harbor watershed is moderately poor, but the confidence in this assessment is only moderate (Table 12). Direct Harbor watershed health is less healthy than the Jones Falls and Gwynns Falls watersheds, which is not surprising given the high impervious surface coverage. There is a lack of benthic and human health data, both spatially and temporally (see individual indicator pages for more details). However, water quality data is available through the City's Stream Impact Sampling program, which measures water quality at outfall locations around the Harbor. A Water Quality Index for the Direct Harbor watershed was calculated and scored a 48.7%, which is moderate (Figure 52). While this is lower than the other two subwatersheds, it is not surprising, considering this watershed is highly developed and directly adjacent to the Inner Harbor reporting region, which scored poorly (Table 7). Additionally, the monitoring sites used for these data are directly adjacent to the Inner Harbor sub-region, so it is hard to determine the influence of the Inner Harbor on these data and the influence of the Direct Harbor watershed on the Inner Harbor's health.

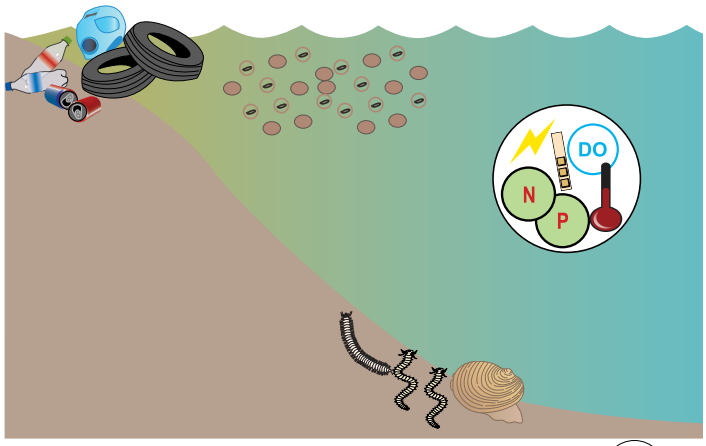
Human health

Human health data were not available for the Direct Harbor watershed. However, considering the high impervious surface cover, the anecdotal evidence of trash on the streets of Baltimore, and the fact that the Direct Harbor watershed is surrounded by other regions with Poor human health assessments, it suggests that the Direct Harbor watershed also has Poor human health.

Confidence

Confidence in the assessment of water quality, biotic, and human health indicators in the Direct Harbor watershed is moderate to low. There are no bacteria sites and no trash measured in the Direct Harbor watershed, which should be addressed, in order to facilitate future annual report card analyses. These human health indicators can not be scored and incorporated into an overall health score for the Direct Harbor until monitoring sites are available. While the water quality data that are currently collected are reliable, the lack of data in some parts of the watershed and the missing time component of some of the data are issues that needs to be addressed. Additionally, the variability in the indicator scores may indicate a need to review and refine the water quality indicators and thresholds used to assess watershed health.

Direct Harbor ecological and human health



The Direct Harbor watershed had moderate water quality , but poor benthic communities . Bacteria and trash were poor.

Table 12. Indicator scores, grades, and value for the Direct Harbor subwatershed reporting region.

Indicator	Score (%)	Grade	Narrative	Confidence
Ecological health				
Dissolved oxygen	91.5	A	Good	Moderate
Conductivity	2.6	F	Very poor	Moderate
Total nitrogen	2.3	F	Very poor	Moderate
Total phosphorus	3.4	F	Very poor	Moderate
Water temperature	100	A+	Very good	Moderate
pH	92.3	A	Good	Moderate
TSS	n/a	n/a	n/a	Low
Benthic community	n/a	n/a	Poor	Moderate
Human health				
Bacteria	n/a	n/a	Poor	Moderate
Trash	n/a	n/a	Poor	Moderate

Increased monitoring and analysis are needed

To advance the process of producing a report card for Baltimore's Inner Harbor in 2012, there are several issues that should be addressed, including:

- Adjust sampling efforts to fill data gaps identified in this current assessment,
- Increase capacity to analyze data and produce the report card annually, and
- Begin the design for a dedicated, Baltimore Harbor report card website.

Improving monitoring resolution

EcoCheck was tasked with providing recommendations for a comprehensive tidal monitoring program that will support the production of an annual report card of Baltimore Inner Harbor health. The following recommendations are based on EcoCheck's collaboration with the Mid-Atlantic Tributary Assessment Coalition (MTAC). MTAC was formed to better organize and coordinate mid-Atlantic citizen monitoring programs that are already producing, or are interested in producing, report cards.

With MTAC, EcoCheck facilitated the production of standard operating procedures for collection of monitoring data to be used for annual report cards. The document, *Sampling and data analysis protocols for mid-Atlantic tidal tributary indicators*, is available on the EcoCheck website, *www.eco-check.org/communication/*.

EcoCheck's recommendations for sampling requirements in Baltimore's Inner Harbor are based primarily on this protocol document. Specifically, it provides clear and consistent protocols for the identification, collection, and analysis of indicators to be used by report card-producing organizations in the mid-Atlantic region. These protocols were developed through data analysis and consensus of MTAC members from 2009 through 2011.

Goals and objectives

The goals and objectives of the monitoring program should adhere closely to the Waterfront Partnership of Baltimore's Healthy Harbor Initiative (HHI) and the Center for Watershed Protection's Implementation Plan. Generally, the HHI's goals are to make the Harbor swimmable and fishable by 2020. Specifically, the plan calls for no fish kills, low bacteria levels, and no trash by 2020. Reducing water pollution and oxygenating the water are two objectives aimed at achieving the goals of the HHI.

Summary of recommendations

Recommendations are based on indicators that would be necessary to achieve HHI goals.

Generally, for assessment of fishability related goals, EcoCheck recommends an ecosystem health approach. Achieving a healthy ecosystem will create the habitat necessary to preserve and promote healthy fish populations. The indicators chosen to assess ecosystem health are total nitrogen, total phosphorus, chlorophyll *a*, dissolved oxygen, and water clarity. To assess progress toward swimmability goals, bacteria and trash indicators will be used.

General conclusions and recommendations for indicator sampling and analysis include:

- Two main sub-regions: Baltimore Harbor and Middle Branch. The Baltimore Harbor sub-region can be further broken down into the Inner and Outer Harbor regions.
- Five core ecosystem health indicators: dissolved oxygen, chlorophyll *a*, water clarity, total nitrogen, and total phosphorus. These indicators are relatively easy to measure, have reasonable lab costs, and are pertinent to the Patapsco River tidal water system.
- Two core human health indicators relevant to HHI goals: bacteria and trash.
- Minimum twice monthly sampling for a minimum total of 14 samples per year during the relevant sampling period.
- Data analysis for core ecological health indicators will be as described in the MTAC protocol document.

Recommendations—Sub-regions

EcoCheck recommends two sub-regions for the annual Baltimore Harbor report card. These are the Baltimore Harbor and Middle Branch sub-regions (Figure 53).

The Baltimore Harbor sub-region extends from the Inner Harbor at Pratt Street in downtown Baltimore south to Fort McHenry at the mouth of the Northwest Branch of the Patapsco River. Drawing a line directly east from Fort McHenry to the opposite shore (LeHigh Cement on Merstens Avenue) delineates the Baltimore Harbor sub-region from the mainstem Patapsco River. This delineating line is slightly north of the I-95 Fort McHenry Tunnel. This sub-region could be divided into two smaller regions, the Inner and the Outer Harbor, if sampling density allows. If

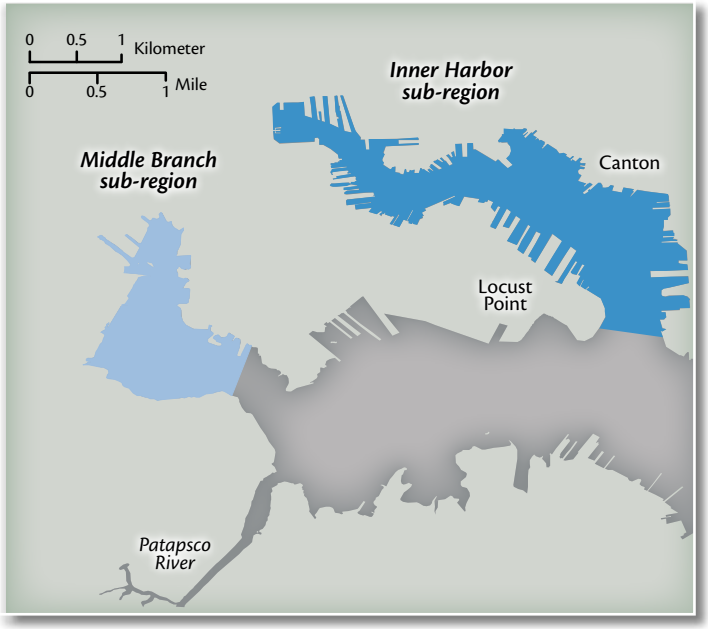


Figure 53. Sub-regions for future report cards.

sampling is concentrated more in the Inner Harbor than in the Outer Harbor, the Baltimore Harbor sub-region boundaries may need to be re-drawn to only encompass those areas that include sampling.

The Middle Branch sub-region is the area located west and north of the South Hanover Street Bridge. This sub-region is important to include because the impacts of pollution from the Gwynns Falls watershed empty into this sub-region. The population in Gwynns Falls is also an integral part of a healthy Baltimore Harbor. This region has a small total area, so further sub-dividing it is not recommended.

The number of sampling stations should be based on geophysical parameters (salinity, depth) of each sub-region. For the Baltimore Harbor sub-region, there should be at least 3 sampling stations in shallow (<2 meters) areas and three stations in deep (>2 meters) water. Sampling sites should be randomly located, but outside of the immediate areas near stormwater outfalls, which would bias the results toward land-based pollutants, rather than well-mixed areas.

The Middle Branch sub-region is smaller than Baltimore Harbor. EcoCheck recommends two shallow water sampling stations and three deep water sampling stations. The shape of Middle Branch also means that the waters will be better mixed than the Baltimore Harbor sub-region and therefore there will not be as much spatial variability to account for in the sampling regime.

Both regions are considered mesohaline in salinity regime, which are seasonally affected by pulsed episodes of freshwater inputs from stormwater.

Recommendations—Indicators (prioritized)

EcoCheck recommends that the Waterfront Partnership fund a spatially and temporally dense water quality monitoring program. The minimum amount of sampling would be 2 times per month but preferred sampling would be weekly. The minimum time period of sample collection would be based on individual indicators, but the preferred season for all indicators would be year-round, with the exception of inclement weather (e.g., ice). Detailed protocols for each indicator are supplied in the MTAC protocol document, and a summary (Table 13) is provided below.

- **Water quality indicators**—Dissolved oxygen, chlorophyll *a*, total nitrogen, total phosphorus, and water clarity are the core parameters needed to evaluate the ecosystem health of Baltimore's Harbor and can all be measured at the same location at the same sampling time. Currently, the Maryland Department of Natural Resources collects water quality data at monitoring sites around Maryland's tidal waters, but there is one Dataflow grab sampling site in the Baltimore Harbor sub-region. It was established in 2009 and will be discontinued in 2011. Nutrient data is available for 2009 only.
- **Trash**—Current trash monitoring is sparse and sampling methods at different locations are not comparable to each other, nor are data conducive to condition assessment. Furthermore, there is only one form of monitoring directly in the Harbor waters. A boat, manned by city employees, skims the Harbor

Table 13. Summary of preferred and minimum sampling recommendations for the five core water quality indicators for Baltimore Harbor.

Indicator	Preferred sampling period	Preferred sampling resolution	Minimum sampling period (needed for data analysis)	Minimum sampling resolution	Salinity regime (needed for data analysis)
Dissolved oxygen	April–October	Weekly	June–September	Twice monthly	No
Chlorophyll *a*	March–October	Weekly	March–May; July–September	Twice monthly	Yes
Water clarity	March–November	Weekly	April–October	Twice monthly	Yes
Total nitrogen	March–October	Weekly	April–October	Twice monthly	Yes
Total phosphorus	March–October	Weekly	April–October	Twice monthly	Yes

and collects floating trash. EcoCheck was unable to retrieve this data from the city to evaluate its usability for this report.

EcoCheck recommends the creation of a new trash monitoring program that assesses the amount of trash in the Baltimore Harbor and Middle Branch sub-regions directly. While trash originates on land and there are ongoing efforts to prevent trash from reaching the Harbor, a direct measurement of the amount of trash in the water is needed. EcoCheck recommends that the Waterfront Partnership work with additional partners to develop an acceptable monitoring program for trash.

A common trash sampling methodology is currently being followed by Baltimore County and City to determine the future Trash Total Maximum Daily Load (TMDL). If trash monitored in the Harbor uses the same methodology as the watershed, the results will be directly comparable. This method involves identifying sampling sites, collecting all the trash within a 500 foot-long stretch of waterfront at that site, then counting and weighing the trash at a laboratory. This methodology is based on the Anacostia River's Trash TMDL monitoring program.

Another way to monitor trash is to take photos of the same location over a set time period, create a grid over the photo, and determine percent cover of trash in the photo. This methodology incorporates trends over time, which would help evaluate if trash is increasing or decreasing in the Harbor.

- **Bacteria**—*Enterococci* in the Harbor is already being measured by Baltimore's WATERKEEPER® group. The sampling scheme and protocol are well thought-out and have been validated through the local health department.

EcoCheck recommends that the Waterfront Partnership supplement the WATERKEEPER's bacteria monitoring with the addition of at least two mid-channel sampling sites would help randomize the sampling protocol and would provide more coverage in the southeast portion of the Baltimore Harbor sub-region (Figure 54).

Ultimately, measuring the core indicators suggested here will require the expansion of current monitoring and data management by one or more potential project partners.

Conclusions—tidal monitoring

There are many ways in which the monitoring of ecological and human health indicators for Baltimore Harbor's annual report card can be established. The recommendations here provide options for the development of a comprehensive monitoring program, and rely heavily on the MTAC protocol document, which should be referenced for sampling regime, sampling station locations, and indicator sampling protocols.

Preferred options include:

1) Establishing new water quality monitoring stations for core indicators in each reporting region, in collaboration with MD DNR.
2) Establishing new protocols for trash data collection within the reporting regions.
3) Establishing at least two new bacteria sampling stations within the Baltimore Harbor reporting region mid-channel area.
4) Maintain field data by the data originators and supplied to the report card producers following strong initial quality assurance procedures.

It should be noted that improvements to monitoring programs should not be expected on an immediate basis, and that improvements can be made as additional capacity is identified. The MTAC protocols referenced here provide recommendations for both preferred and minimum data requirements for report card assessments. It is not envisioned that improvements to achieve preferred data collection and analysis methods can be achieved in a single year, but that efforts to achieve steady improvements toward the preferred goal should be undertaken.

Nontidal indicators

In addition to improvements in tidal indicator monitoring, there are several modifications to non-tidal sampling efforts that could provide data in a way that would ease the production of report card scores for the watershed reporting regions. Similar to tidal regions, watershed data are currently collected by different groups, using different

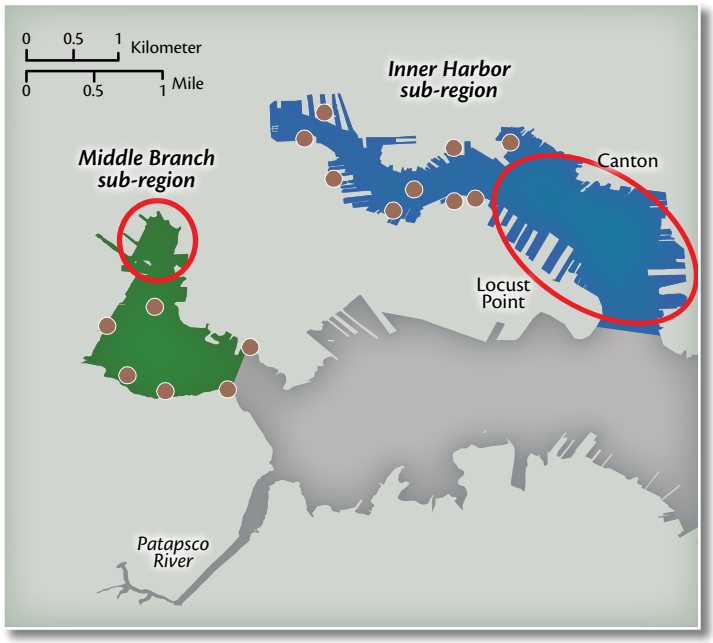


Figure 54. 2011 WATERKEEPER bacteria sampling stations and areas that need mid-channel sampling (red circles).

sampling program goals and objectives, and different data formatting and data management preferences. The result is a data set that is both non-uniform in the indicators collected and the methodology for analysis. Simple adjustments to include a core set of indicators would be helpful in developing scores for the watershed reporting regions.

The MTAC partners will be addressing these core watershed indicator questions beginning in 2011. It is envisioned that a protocol document similar to the tidal monitoring protocols will be produced for non-tidal data. These protocols should be helpful in coordinating non-tidal monitoring efforts.

Capacity building for improved data resolution and information content

During the preparation of this report, significant progress has been made to improve coordination among monitoring partners. This improved coordination will ensure that core indicator data are collected at informative locations, and at a frequency which will increase the confidence in the assessment results. Potential partners for provision of improved data collection in Baltimore's Inner Harbor and its watershed include Blue Water Baltimore, Living Classrooms, and Baltimore City and County.

To coordinate data collection and analysis methods, a workshop has been planned for September 2011. This workshop will engage all potential data providers, with the purpose of identifying modifications necessary to provide data at increased spatial and temporal resolution, improve comparison of data sets, limit unnecessary overlap of data collection by different entities, and identify entities responsible and capable of providing additional monitoring capacity.

Web development is part of the solution

In addition to producing a printed report card, a strong web presence for the communication of the detailed report card results is necessary for success. This capacity is a key element of any communication strategy, and should be considered an important component of future years' efforts. The web presence serves to support and validate the report card products. Design of the web site should include highly interactive pathways to explore report card results, investigate methods used to achieve these results, evaluate the larger context and meaning of the analysis, and explore underlying data. Without this readily accessible supporting information, understanding of, and confidence in, the overall results may be diminished.

The Chesapeake Bay and the Coastal Bays Report Card websites (*www.eco-check.org/reportcard/chesapeake/*; *www.eco-check.org/reportcard/mcb*) may serve as examples of interactive web-sites designed to communicate the results and analysis details of the report card process.

Conclusion

This report provides an assessment of ecological and human health indicators in Baltimore's Harbor and its watershed. Overall, the ecological and human health of Baltimore's Harbor and its watershed is degraded and substantial restoration will be required to improved conditions. Most tidal indicators scored Poor or Very Poor, while the watershed indicators scored from Good to Very Poor. This report has also provided a road map for future monitoring efforts in the area, which is based on the spatial and temporal resolution of existing data.

This baseline conditions report can be used as the benchmark against which progress can be compared. Tracking and reporting on ecological and human health indicators via an annual report card will allow for comparison with this baseline report. As the Healthy Harbor Initiative and specifically the implementation plan for a swimmable, fishable Harbor are put into place, progress in ecological and human health will be tracked in the annual report card. The parallel tracks of implementation and health reporting provide the public, managers, and decision-makers with an adaptive management strategy for cleaning up the Harbor. As restoration efforts continue, specific management and restoration activities can be adapted in response to progress (or lack of progress) toward ecological and human health goals.