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Chesapeake Bay - A case study in resiliency and restoration

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CHESAPEAKE BAY
A case study in resiliency and restoration

By Richard R. Arnold, William C. Dennison, Louis A. Etgen, Peter Goodwin, Michael J. Paolisso, Gary Shenk, Ann P. Swanson and Vanessa Vargas-Nguyen

Chesapeake Bay ("mother of waters" or the "great shellfish Bay" in Algonquin), is the largest estuary in the United States and arguably the best studied estuary in the world. Chesapeake Bay is immense, with the main stem stretching 200 nautical miles (315 km) from the mouth of the Susquehanna River to its terminus at the Atlantic Ocean and an overall watershed encompassing 64,000 mi² (165,000 km²). The mainstem, tributaries, and Bay islands form thousands of miles of coastline (Figure 1). Because of its prominence in estuarine science and ecosystem restoration, developing a working knowledge of Chesapeake Bay science and restoration is important. Hopefully, this overview will whet the appetite to learn more from information available both in the scientific literature and on the Chesapeake Bay Program website www.chesapeakebay.net

Figure 1 | Chesapeake Bay as seen from the International Space Station (Photo courtesy of NASA).

Figure 2 | Chesapeake Bay Map. The Chesapeake Watershed includes New York, Pennsylvania, Delaware, Maryland, the District of Columbia, West Virginia, and Virginia.

The Bay is relatively shallow, average depth of 30 feet (8.5 m), with narrow deeper channels formed by drowned river valleys. The Bay was and is still incredibly productive with abundant fish and shellfish, waterfowl, marshes and aquatic grasses. The extensive Chesapeake watershed is connected to the Bay by a myriad of streams and rivers. The Chesapeake watershed extends into New York State, contains half of Pennsylvania, essentially all of Maryland, the majority of Virginia, all of the District of Columbia, and includes portions of Delaware and West Virginia (Figure 2). The rivers, creeks and streams that flow into the tributaries or directly into Chesapeake Bay dissect the watershed, and there's virtually nowhere in the watershed that is more than a few miles or kilometers from a stream that ultimately empties into Chesapeake Bay.

The watershed is dominated by two major rivers, the Susquehanna to the north and the Potomac to the west. The region contains a diverse mix of major urban areas including Norfolk, Richmond, Washington, DC and Baltimore, as well as extensive agriculture on its Eastern Shore, within its Piedmont region, and nestled in the valleys of the Ridge and Valley.

Chesapeake Bay is naturally nutrient-retentive. This creates two important features: its productivity[11] and its vulnerability. Nutrients from predominantly human activities run off into the Bay both from the thousands of point sources and from diffuse non-point sources lying within its watershed. This causes excess algal growth which leads to low levels of oxygen in the water, creating 'dead zones' that negatively impact living resources[12]. Sediments transported from the watershed and from coastal erosion accumulate throughout the estuary, requiring dredging of the deeper regions to maintain shipping channels[7]. Toxins derived from industry, agriculture, neighborhoods, power plants, and automobiles enter local waterways and ultimately Chesapeake Bay. The long residence time within the Bay's waters and sediments diminishes the effect of regular flushing of nutrients, sediments and toxins into the ocean[4].

The Chesapeake region supports unique and diverse human cultures and livelihoods. Approximately 50,000 Native Americans had many villages along its shores and included the Algonquin peoples, the Sioux, and the Iroquois beginning about 10,000 years ago. Europeans first settled in the Chesapeake Bay region in 1607, in Jamestown, Virginia along the James River. Communities of watermen sprung up along its shores to take advantage of the rich harvest of oysters, blue crabs and fish. Many islands in the Bay were inhabited by Chesapeake Watermen, and the isolation of island communities created cultures that still retain traces of an Elizabethan English dialect. The abundant fish and shellfish harvests allowed these communities to be relatively self-sufficient. Farming was also prevalent both on islands and on the mainland. Due to declining fisheries resources and sea level rise, these island communities remain in only a few isolated locations.

Chesapeake Bay has been a strategic region throughout American history, serving as a highway for ships from Europe and other North American ports. Slavery played a prominent part in much of the watershed's economy. The Underground Railroad smuggled escaping slaves from plantations to the South, who took advantage of the myriad Chesapeake Bay waterways in their quest for freedom to the North.

Rigorous academic study of the Bay ecosystem began in earnest with the establishment of the University of Maryland Center for Environmental Science's Chesapeake Biological Laboratory (CBL) in 1925 in Solomons, Md. It was the first laboratory on the Bay and the first of its kind; a state-sponsored facility within the United States. Its founder, the pioneering scientist Reginald Truitt, established the laboratory in a small waterman's shack to better facilitate his work with Chesapeake Watermen on fisheries-related issues. Early research conducted at CBL, and other laboratories that sprang up, established the principle of two-layer water flow in estuaries, where fresher surface water flows seaward while salty and more dense water flows into the estuary from the Atlantic Ocean. Chesapeake scientists defined the biology, chemistry, physics and geology of the estuary, thus establishing the field of estuarine science and setting the standard for global estuarine research. For example, the local scientific organization, the Atlantic Estuarine Research Society, evolved into the international Coastal and Estuarine Research Federation and the local scientific journal *Chesapeake Science* evolved into the international *Estuaries and Coasts* journal.

In 1972, tropical storm Agnes dumped a historic amount of rain into the watershed. This led to flooding and the highest ever recorded runoff into Chesapeake Bay, exacerbating the challenges to an already stressed ecosystem. In response, local research institutions began documenting the declining health of the ecosystem; the U.S. Congress funded a five-year study of the Bay to better understand the loss of fisheries and wildlife; and in 1981, Maryland and Virginia formed the Chesapeake Commission (joined by Pennsylvania in 1985) to advise legislators on how to best manage the Bay's resources. The findings following this weather event highlighted some worrying signs of degradation, including low oxygen bottom waters and the widespread loss of aquatic grasses caused by excess nutrients, thus demonstrating the concept of coastal eutrophication.

A better understanding of the regional nature of these challenges prompted the formation of the Chesapeake Bay Program in 1983, a multi-state partnership with the Federal and local governments, the Administrator of the U.S. Environmental Protection Agency (EPA), and the Chair of the Chesapeake Bay Commission. This was marked by the signing of the first Chesapeake Bay Agreement. Over the past four decades, three additional agreements have been signed, each building on the commitments of the last, in 1987, 2000 and 2014. In the 1987 and 2000 agreements, largely voluntary nutrient reductions were called for by each jurisdiction. A major change was initiated when most of the Chesapeake waterways were declared impaired in the year 2000. During the following 10-year period when voluntary efforts did not achieve the nutrient reduction targets, a legislatively mandated nutrient diet known as the Total Maximum Daily Load or TMDL was initiated in the year 2010.

The current Chesapeake Bay Watershed Agreement, signed in 2014, addresses a diversity of issues including clean water, fisheries and their habitats, abundant conservation areas, rights to water access, a vibrant cultural heritage, and engaged citizens and stakeholders. The agreement has codified an adaptive management approach of setting goals, identifying the factors and gaps, developing a strategy to assess performance and actively managing the restoration. The management of the Bay now includes participatory modeling where stakeholders take part in building and parameterizing the management models. It was expected that this inclusive approach would increase stakeholder buy-in to the Bay models; surprisingly, it also resulted in greater accuracy in identifying where the nutrient loads are coming from. Broader sources of input into Bay models also allows for better accuracy of nutrient and sediment load predictions at a more localized scale[3].

Another advance has been a major effort to upgrade sewage treatment for the cities and towns within the watershed. The sewage treatment upgrades have led to rapid localized ecosystem responses including the resurgence of aquatic grasses known in the Chesapeake Bay as submerged aquatic vegetation or SAV[5]. The largest improvements in SAV health have been documented at the head of the Bay, leading to improvements in both water clarity and increased fish and shellfish production. SAV resurgence is also visible from a sequence of aerial photos adjacent to CBL. This is an indication that the nutrient reductions are beginning to make a difference.

In addition to sewage treatment upgrades, the Clean Air Act of 1972 mandated both catalytic converters for automobiles and smokestack scrubbers for power plants and factories, which have resulted in less nitrous oxide being discharged into the atmosphere. This has led to a reduction in atmospheric nitrogen deposition, which in turn has led to less nitrate in the streams and rivers entering the headwaters of Chesapeake watershed. Another positive sign for Chesapeake restoration is the recent return of bottlenose dolphins to their historic range within the Bay.

While wastewater and atmospheric source reductions have been strong and measurable, sediment runoff and nutrient loads from both urban areas and agricultural fields remain a challenge. Agriculture, which covers twenty-five percent of the watershed, generates runoff that is often high in nutrients from excess fertilizer and animal manure. The practice of planting winter cover crops over successive years has been shown to dramatically reduce ground-water nitrate levels. This has led to a concerted effort to incentivize farmers to use cover crops across the watershed and the state of Maryland has the highest percent adoption of cover crops in the US.

Urban stormwater runoff is exacerbated by the buried streams in towns and cities. Restoration efforts for urban runoff include implementing stormwater retention or treatment, detecting and repairing sewage overflows into the stormwater system, and replacing impervious surfaces with grassy fields and green roofs. In Washington, DC, large water-holding tunnels were constructed to capture stormwater that can be slowly fed into and treated by sewage treatment facilities.

Unfortunately, while there has been a high level of effort to make reductions from both urban and agricultural sources, clear results are generally not yet evident. Possible explanations may include unrealistic expectations, insufficient monitoring, lag times, and competing effects such as population growth and climate change[1].

An important feature of the Chesapeake restoration effort is the plethora of non-governmental organizations (NGOs) that mobilize citizens, river keepers and waterkeepers. In addition, these NGOs coordinate citizen scientists and work with local communities to implement practices that serve to protect and restore

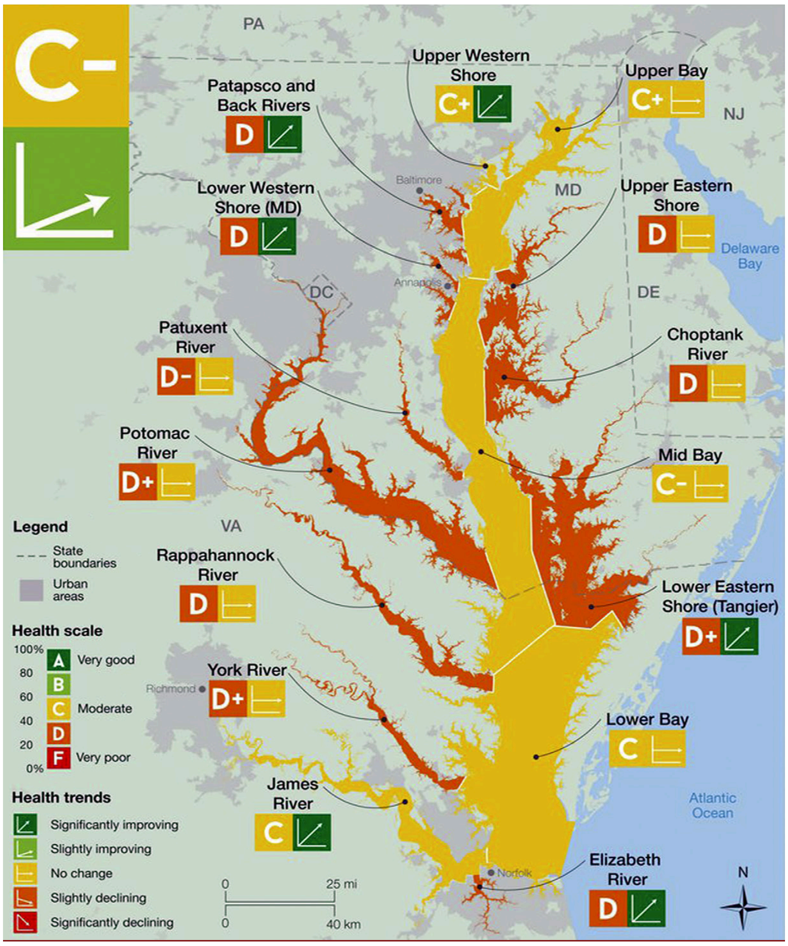


Figure 3 | 2019 Report Card for Chesapeake Bay[13]. Report card releases are high visibility events that effecti-ely shape public opinion and inform decision-makers (based on methods documented by Williams *et al.* 2009[13] photo credit: IAN Press 2020).

the Chesapeake watershed. With a growing population of over eighteen million people, engagement at the landowner level has proven absolutely critical. Further, with active engagement of citizens, it has become obvious that continued improvement in the ecosystem health of the watershed will only occur if it is balanced with the economic and social needs of its inhabitants.

A unique management tool developed by the University of Maryland Center for Environmental Science that has now been replicated on a global scale is the report card for the Chesapeake Bay (Figure 3). Started in 2007, it is the first scientifically rigorous assessment of the Bay using indicators of water quality and biodiversity collated from the Chesapeake Bay Program and its network data providers[14]. An ecosystem health "grade" accompanied by trend analysis is released annually with much fanfare in the media and among local leaders. The report card has proven to be a critical and highly effective tool to communicate the state of the ecosystem to all inhabitants of the region.

With a diversifying population in the watershed and changing needs of the watershed residents, the Chesapeake Bay Program recognizes that more social science research is needed. The Bay program identified these social science research needs to be the following: behavior change, economics, cultural landscape, communication barriers, and institutional change[9]. A coordinated and collaborative restoration effort for Chesapeake Bay is best articulated with a shared vision for what a restored Chesapeake Bay would look like. Recent interviews with Chesapeake Bay leaders resulted to a shared vision that reflect the increasing focus on the people and communities of the Bay and the holistic inclusion of cultural and social issues with the environmental issues providing Bay managers with a path forward[13].

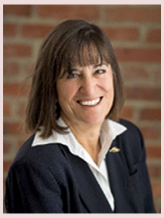
Dr Peter Goodwin is past-president of IAHR and is a professor and president of the University of Maryland Center for Environmental Science, a graduate university that provides independent scientific advice to help inform environmental policy and management state. Goodwin has worked on ecosystem restoration, ecohydraulics, and enhancement of river, wetland and estuarine systems throughout the world.

Dr William Dennison is UMCES' Vice President for Science Application, is a biologist with 40 years of experience in environmental research and science communication. In 2002, he founded the Integration and Application Network, a collection of Science Integrators and Science Communicators who partner with groups around the world to engage with diverse stakeholders to co-produce effective science communication products and environmental report cards.

Richard Arnold is UMCES' Director of STEM Engagement. He received his BS from Frostburg State University and MS from the University of Maryland in Marine and Estuarine Environmental Science. A global educator, he has taught Science and Mathematics in five countries. In 2004, he was selected as a NASA Astronaut in 2004 and has completed two missions to the International Space Station.

Dr Vanessa Vargas-Nguyen is a Science Integrator with UMCES' Integration and Application Network of the University of Maryland Center for Environmental Science. Originally a molecular microbiologist and marine scientist from the Philippines, she is an emerging transdisciplinary scientist and practitioner, specializing in science communication, socio-environmental assessments and synthesis, and stakeholder analysis and engagement through co-production.

Louis Etgen serves as the Executive Director of the Gunpowder Valley Conservancy. He has worked with several Chesapeake Bay environmental organizations including most recently as the Maryland State Director/Interim Executive Director for the Alliance for the Chesapeake Bay. During his career he has worked hard to bring people and organizations together to advance the collective goal of clean water throughout the Chesapeake Bay watershed.



Ann Swanson has served as a leader in the Bay restoration for nearly 35 years, the last 29 as the Executive Director of the Chesapeake Bay Commission, a tri-state legislative authority serving the states of Pennsylvania, Maryland and Virginia. She graduated with honors from the University of Vermont and Yale University; she served as a member of the University of Vermont's Rubenstein School of Environment and Natural Resources for 23 years, as Chairman for 11.

Dr Michael Paolisso is Professor of Anthropology at the University of Maryland, College Park, USA. Since 1997, Paolisso has been engaged in applied anthropology research on human and environmental issues confronting the Chesapeake Bay, including management of fisheries and agriculture, water pollution, restoration, social justice, socio-ecological adaptation and resilience, and climate change.

Gary Shenk is a USGS hydrologist at the EPA's Chesapeake Bay Program Office in Annapolis Maryland. He leads a multi-disciplinary team responsible for the development and operations for the CBP Partnership's watershed modeling effort. His work in Chesapeake modeling and monitoring informed the Chesapeake Bay Total Maximum Daily Load.

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