Chesapeake Bay Restoration:
Past, Present, and Where We Are Going

by David E. Smith

Introduction

Even though most people consider the Chesapeake Bay to be a national treasure, this consensus has been insufficient to significantly improve the health of the ecosystem over the last 25 years. The history of management of the Bay’s ecosystem has been replete with halting progress in regard to programs that have had an impact on the Bay’s health.

The watershed or catchment area for the Chesapeake Bay includes significant portions of New York, Pennsylvania, West Virginia, Virginia, and Maryland, the District of Columbia, and parts of Delaware. In total, the Chesapeake Bay watershed is approximately 64,000 square miles. The color-coded areas in Figure 1 represent the major river catchments within the whole Bay watershed.

As this article unfolds, it is important to realize that population, which is now 17.4 million in the Chesapeake region, has more than doubled since

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1 The health of an ecosystem is probably one of these things that is easier to recognize than define. One definition includes “an ecosystem is healthy and free from ‘distress syndrome’ – if it is stable and sustainable – that is if it is active and maintains its organization and autonomy over time and is resilient to stress.” Benjamin D. Haskell, Bryan G. Norton and Robert Constanza, “Introduction: What is Ecosystem Health and Why Should We Worry About It?” in Ecosystem Health: New Goals of Environmental Management edited by Haskell, Norton and Constanza (Washington, D.C.: Island Press 1992).
Why Watershed Management is Difficult
The first disconnect with regard to trying to manage this national resource is that many people in the watershed don’t know what watershed they live within. By my clearly unscientific survey, it appears that the further one moves away from the main stem of the Bay, the less likely that residents in the Bay catchment will know they are living in one of the Bay’s tributary watersheds. There seems to be a rough relationship with their viewscape; in other words, as you move away from the Bay proper and the view outside your home or place of business no longer includes a clear view of the Chesapeake Bay or one of its major river systems, there is a lower probability of recognition that you still live in the Chesapeake Bay’s watershed.

The multistate composition of the Chesapeake Bay watershed creates a challenge for Bay managers and regional environmental administrators because of the myriad geo-political boundaries that fall within any one major river tributary. The six major river systems that empty into the bay are the Susquehanna, the Patuxent, the Potomac, the Rappahannock, the York and the James. There are also many smaller systems that drain the eastern shores of Virginia and Maryland and parts of Delaware. Complicating this picture is the fact that each major watershed includes all or parts of many counties, cities and towns in different states.

Many competing users also make use of this particular national resource. It is central to the local economies that border the Bay’s main stem by providing water-based employment opportunities such as commercial shipping, seafood harvesting, and recreational activities such as privately-owned marinas and recreational boat sales and service that abound on the Bay. The ports of Baltimore and Hampton Roads generate significant revenues for Maryland and Virginia, respectively. Military use of this resource is critical to our national security. The military presence in the Hampton Roads area is one of the nation’s largest in terms of Department of Defense employment and land area. Additionally, the water in the Bay itself is important as a coolant and as a sink for many of the industrial and municipal processes that occur throughout the Bay’s large watershed. And finally, while sometimes difficult to quantify, the ecosystem services that the Bay provides, such as absorbing excess nutrients through the bordering wetlands, providing refuge and nursery habitat for the many fish and shellfish species that we eat, and providing habitat for economically and ecologically important bird species and others, are just as important. Unfortunately, these competing uses are often in conflict, resulting in significantly more difficulty in trying to manage this resource.

Where Do We Start?
Traditionally, management of the Chesapeake Bay is based on two concepts: 1) some level of scientific understanding of the natural processes occurring in the Bay, and 2) some assessment of value that society places on the Bay’s resources. In the scientific corner, scholars have been investigating the scientific processes in operation in the

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2 Ecosystem services are a relatively new group of recognized economic services that are provided by nature at essentially no cost to humankind. Examples are water purification, waste assimilation, nursery habitats for fish, etc.
Bay for a long time. For example, thanks to Don Pritchard and his pioneering work in the 1950s we have a pretty good understanding of the circulation in the Bay.\(^3\)

Chesapeake Bay circulation is primarily driven by the salinity and thermal structure of the water column. Water that is cooler, with a relatively high salinity is denser than water that is warmer and fresher. Consequently, water flowing out of the major tributaries tends to flow along the Bay surface and water entering the Bay at its mouth tends to flow into the Bay at depth. This circulation pattern, which is shown in Figure 3, results in classic two-level, gravitational circulation where a saltwater wedge flows northward in the bay along the bottom with typically fresher water flowing along the top. Denser oceanic water enters the Bay from the right as residual flow and fresher riverine water enters the Bay from the uplands of the watershed on the left. Net flow into the Chesapeake Bay is through the mouth of the Bay and into the ocean to the right.

Wind and other factors can alter this pattern at times, but this simplistic circulation pattern probably dominates about 40 percent of the time.\(^4\) This information alone is powerful because it explains why the Bay and other similar bodies of water tend to trap sediments and other materials as they fall to the bottom. One of the largest, coordinated scientific inquiries about the Bay occurred in the late 1970s and early 1980s. Primarily the U.S. Environmental Protection Agency (EPA) funded it. Former U.S. Senator Charles McC. Mathias Jr. (D-Maryland) pushed money through Congress to undertake the research. The research program focused on three scientific questions: 1) the cause of the apparent die-off of the seagrasses in the shallow areas of the Bay immediately adjacent to the shoreline, 2) the dynamics of the low dissolved oxygen layer that would form in the deeper water of the Bay during the warmer months, and 3) the characterization of the toxics throughout the Bay, primarily in the two toxic “hot-spot” areas of Hampton Roads and Patapsco (Baltimore) Harbor. The Chesapeake Bay Research Conference held at George Mason University in 1983 collated and summarized this information.\(^5\) As a result of this work, additional research was funded in subsequent years by the National Oceanic and Atmospheric Administration (NOAA) and other federal and state agencies in an effort to further refine our understanding of the natural processes that drive the Bay’s ecosystem. Then, as today, one of the biggest concerns and drivers of the ecosystem responses involved the apparent enhanced loads\(^6\) of nitrogen and phosphorous flowing into the Chesapeake Bay.

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4 W.C. Boicourt, “Influences of Circulation Processes on Dissolved Oxygen in the Chesapeake Bay,” in *Oxygen Dynamics in the Chesapeake Bay: A Synthesis of Recent Research*. Edited by David E. Smith, Merrill Leffler and Gail Mackiernan (College Park, MD; Sea Grant Publication, UM-SG-TS-92-01, 1992)


6 Nutrient loads refer to the amount of nutrient (nitrogen or phosphorous) moving into an ecosystem (e.g., Chesapeake Bay) in a given period of time. A nutrient load is not a concentration.
Much of this work has focused on the effect of eutrophication,\footnote{Eutrophication refers to the enrichment of an environment, typically by inorganic nutrients. Often times the enrichment is the result of anthropogenic activities; sometimes referred to as cultural eutrophication} or over-fertilization, of the Chesapeake Bay. In brief summary, nitrogen and phosphorus are primary inorganic nutrients for plants (both terrestrial and aquatic). Just as when you occasionally fertilize your houseplants or your lawn by adding “plant food” or fertilizer that enhances plant or lawn growth, essentially the same thing happens when nutrients are added to aquatic environments; that is, the fertilization enhances the growth of algae and phytoplankton,\footnote{Plankton species that obtain their energy by photosynthesis; they are generally quite small.} among other aquatic plants. While this may not seem a significant problem, if the growth of phytoplankton is extreme, it will undergo a population “boom” (as typically happens in the spring in the Chesapeake Bay). When this abundant plant material dies, sinks and decays, it consumes the oxygen in the bottom waters. (Respiration and decay are the opposite processes of photosynthesis, so instead of producing oxygen, these processes consume oxygen.) This process is exacerbated because as the oxygen is used up, it is often not replaced via diffusion from the atmosphere through the surface layer of the Bay and into the bottom waters because the density difference between the top and bottom water layers created by the gravitational flow stifles the diffusion process. Consequently, at certain times of the year the bottom water can go hypoxic or anoxic\footnote{Hypoxic refers to conditions of low oxygen concentrations (often an abnormal condition), while anoxic refers to conditions of no oxygen; both conditions can be stressful or lethal to aquatic organisms, depending on species.} creating environmental stress for many aquatic organisms, particularly those that reside for some part of their life cycle in the deeper waters of the Bay. So, the level of oxygen in the bottom waters of the Bay is commonly considered a major variable in assessing the Bay’s health.

The way to combat these effects is essentially to reduce the loading of nitrogen and phosphorus to the main stem of the Bay. This solution has been recognized for quite some time and the Bay states have been trying to do this effectively. For example, Table 1 displays the relative success of reducing nitrogen and phosphorus in several of the Bay states since 1985. Unfortunately, this has not been effective enough to significantly enhance the Bay’s health or to reach targets set by the states and the federal government.

Societal values also play an important role in management of the Bay. In other words, what kind of system do we as the general citizenry wish to create and foster in the Bay? For example, do we want an ecosystem dominated by finfish or an ecosystem dominated by bacteria? Unlike the science aspects, these issues are rather subjective and this melding of the scientific understanding (as imperfect as it sometimes is) with the subjective assessment of values is anything but easy. In fact, this melding process is the challenge for the Bay’s management as well as for most questions of environmental sustainability today, including global climate change. Originally, this melding...
resulted in the creation of the first Bay agreement signed by the governors of Maryland, Virginia, and Pennsylvania; the mayor of Washington, DC; and the administrator of EPA. The text of the Chesapeake Bay Program 1983 Chesapeake Bay Agreement is shown in Figure 4.

Short, but certainly not simple, this agreement formed the foundation block for an evolving Chesapeake Bay Management Program, including several different subsequent agreements, a very large institutional organization at the federal and state levels, and a significant amount of funding. For a concise history of the evolution of the agreement and its implementation, see EPA’s Chesapeake Bay Program web site.10

This structure for regional environmental management of the Bay was one of the first in the nation. The process and its resulting implementation structure, the Chesapeake Bay Management Program, were an attempt to create a sophisticated and robust program to significantly improve an important regional environmental resource. As stated earlier, while I could argue that progress has been made through this effort, particularly in the face of an ever-increasing population base within the Bay’s watershed, many argue that the program has not been as successful as promised and that expectations have not been reached. For an example, U.S. Naval Academy Professor Howard Ernst, a well-known environmental policy expert, has stated

“…a functionally dead ecosystem [of which he views the Chesapeake Bay as an example] is one in which necessary policies have been delayed so long and the price of restoration has grown

http://www.epa.gov/region3/chesapeake/

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Figure 4: Chesapeake Bay Program 1983 Chesapeake Bay Agreement

We recognize that the findings of the Chesapeake Bay Program have shown an historical decline in the living resources of the Chesapeake Bay and that a cooperative approach is needed among the Environmental Protection Agency (EPA), the State of Maryland, the Commonwealths of Pennsylvania and Virginia, and the District of Columbia (the States) to fully address the extent, complexity, and sources of pollutants entering the Bay. We further recognize that EPA and the States share the responsibility for management decisions and resources regarding the high priority issues of the Chesapeake Bay.

Accordingly, the States and EPA agree to the following actions:

1. A Chesapeake Executive Council will be established which will meet at least twice yearly to assess and oversee the implementation of coordinated plans to improve and protect the water quality and living resources of the Chesapeake Bay estuarine systems. The Council will consist of the appropriate Cabinet designees of the Governors and the Mayor of the District of Columbia and the Regional Administrator of EPA. The Council will be initially chaired by EPA and will report annually to signatories of this Agreement.

2. The Chesapeake Executive Council will establish an implementation committee of agency representatives who will meet as needed to coordinate technical matters and to coordinate the development and evaluation of management plans. The Council may appoint such ex officio nonvoting members as deemed appropriate.

3. A liaison office for Chesapeake Bay activities will be established at EPA’s Central Regional Laboratory in Annapolis, Maryland, to advise and support the Council and committee.

Date: December 9, 1983

Signers:
For the Commonwealth of Virginia — Charles S. Robb, Governor
For the State of Maryland — Harry Hughes, Governor
For the Commonwealth of Pennsylvania — Richard Thornburgh, Governor
For the District of Columbia — Marion Barry, Mayor
For the United States of America — William Ruckleshaus, Administrator, Environmental Protection Agency
so large that true restorative polices are not taken seriously. It is not that reversing ecological decline is impossible: it is that the polices that could bring about this type of change have become economically and politically impractical...And as population continues to increase and its appetite for material things continues to grow, political realities take hold. Politicians still talk about returning the Bay to the pre-1950s conditions, especially around election time, but their policy initiatives do not reflect a sincere commitment to restoration.”

Given the state of our scientific understanding today, the evidence of nutrient load pollution and the apparent societal interest to significantly improve the Bay, why has the region been unable to muster the political will to undertake the necessary actions to meet the goals of the Chesapeake Bay Program? This disconnect was recognized at the November 2008 meeting of the bay agreement signatories during which the governors of the affected states decided to examine the way Chesapeake Bay restoration goals were set. Consequently, instead of setting very long-term goals that were consistently missed, they decided a more meaningful approach would be to set goals with long-term end points but also to include much shorter term milestones. Governor Tim Kaine of Virginia indicated that this approach was adopted to keep pressure on the states over the short term, thereby enhancing the probability that long-term end-points would also be met. Then in May 2009 President Obama issued Executive Order Number 13508 entitled “Chesapeake Bay Protection and Restoration,” which instructed the federal government to take the lead role in controlling pollution flowing into Chesapeake Bay and protecting regional wildlife habitats. The executive order was recognition by the federal government that the Bay states were unable to meet the challenge of restoring the Chesapeake Bay and signaled the beginning of a more active federal role in the restoration process. The Environmental Protection Agency, in partnership with the states and the District of Columbia, has just finished the process of crafting the Chesapeake Bay Total Maximum Daily Load (TMDL).

The Total Maximum Daily Load Process

As a result of a lawsuit against EPA in the late 1990s and pressure from various citizen groups, the agency initiated the TMDL process for the Chesapeake Bay. A TMDL must be established according to the U.S. Code if certain conditions exist. Essentially, if a body of water continually fails to meet state water quality standards as required by the Clean Water Act, EPA may initiate the TMDL process if the states have not implemented a program to meet these standards. In the Chesapeake Bay region, TMDLs are established and the jurisdictions affected must meet these load limits or they are subject to further action by EPA (for example, the EPA could tighten up concentrated animal feeding operations (CAFO) permit requirements, or storm water management

“...given the generally-agreed-upon position that people that use the Bay would appreciate a dynamic and healthy Chesapeake Bay that includes a dominate metazoan food web, why is it so difficult to obtain the political will to make it happen?”

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11 Howard R. Ernst, Fight for the Bay: Why a Dark Green Environmental Awakening is Needed to Save the Chesapeake Bay (Lanham, MD: Rowman and Littlefield, 2009), p. xiii.
12 The chief executives of the Chesapeake Bay watershed jurisdictions were the signatories of the Chesapeake Bay Agreement and together they were members of the Chesapeake Bay Program Executive Council.
13 At both the 2008 and the 2009 meeting of the Chesapeake Bay Program Executive Council it was recognized that prior goals set earlier in the decade regarding targeted Bay enhancements would be missed.
14 The Chesapeake Bay airshed can be defined as the geographic coverage of the air space that contains the atmosphere that eventually brings airborne materials and particles over the Chesapeake Bay watershed. Obviously, the airshed is much larger than the watershed and reaches over many more states.
15 A metazoan food web is a food web composed primarily of multicellular organisms, such as commercially important fish; that is, not dominated by unicellular organisms like bacteria.
16 In June 1999, the American Canoe Association won a consent decree order against the EPA. The consent decree laid out an 11-year schedule for the establishment of total maximum daily loads for all impaired waters in Virginia.
17 The creation of this Chesapeake Bay TMDL Strategy is the largest TMDL ever developed by EPA and includes 92 smaller TMDLs for individual bay tidal segments that together compose the Bay’s TMDL plan (EPA, “Fact Sheet—Chesapeake Bay Total Maximum Daily Load (TMDL)” (12/29/2010)). http://www.epa.gov/reg3wapd/pdf/chesbay/BayTMDLFactSheet8_6.pdf
19 A TDML is the calculation of the maximum amount (or load) of pollution (in this case, nitrogen, phosphorous, or sediments) that a body of water can receive and still meet state water quality standards designed to ensure waterways meet a national primary goal of being swimmable and fishable. (EPA December 29, 2010 Fact Sheet).
requirements. For the Bay region, this process has been painful. The general goal of the Bay TMDL process is “…to ensure that all pollution control measures to fully restore the Bay and its tidal rivers are in place by 2025, with 60 percent of the actions competed by 2017.” For example, reductions of 20.5 percent for nitrogen and 25.0 percent for phosphorous from 2009 levels will be required for Virginia to meet the TMDL goals (see Table 1). For the Chesapeake Bay region, the steps involved boiled down to having EPA set and justify the loading limits for sediment, nitrogen, and phosphorous entering the entire Bay from jurisdictions and major river systems. Then, the various jurisdictions were responsible for drafting watershed implementation plans (WIPs) designed to achieve EPA load targets. These WIPs were then reviewed by EPA for deficiencies and input from EPA. The draft TMDL Plan, including the WIPs, was then subject to public comment and further revision. The jurisdictionally revised draft TMDL was then submitted again to the EPA, which then released the final TMDL for the Chesapeake Bay. The Environmental Protection Agency went through an iterative review process with the final TMDL for the Bay region as a whole being adopted in December 2010. This brief description does not do this entire process justice because many hours went into the public hearings and the drafting of comments by the many affected geopolitical jurisdictions, various professional groups (e.g., the Virginia Farm Bureau, the National Chicken Council, and various developer groups, to name a few), and concerned citizens on both sides of this issue.

Next Steps

Much of the subsequent discussion surrounding this TMDL Strategy focuses on cost. Table 1 displays the relative reductions in nitrogen and phosphorous loads that will be needed to meet targets. And there will be new costs incurred by states, localities and individuals. Most recently opposition to the TMDL process has been getting the attention of individual members of Congress. Representative Bob Goodlatte (R-Virginia’s 6th District) introduced a budget amendment to remove funding that would support EPA’s activities related to its oversight and involvement with the Chesapeake Bay TMDL process. The American Farm Bureau Federation (AFBF) has also filed suit in January against the EPA. According to the Southeast Farm Press, the AFBF, citing three issues, including inaccurate assumptions and a flawed scientific model, asserting the meaningful public participation in the process was violated, and that the TMDL rules unlawfully “micromanage” state actions and the actions of farmers, is apparently concerned about the process and the precedent being set by this process. The Hampton Roads Planning District Commission has also expressed concern about the TDMl Plan by passing a resolution that petitions the governor and the General Assembly to develop “… state programs to implement the most cost effective methods of reducing nutrient and sediment loads and committing the financial resources necessary to fund the restoration of water quality in the Chesapeake Bay” to achieve the goals of the TMDL program. So things are continuing to heat up. The debate continues, and in most cases the subject of the debate is not the science surrounding the Bay restoration strategy, although there is always that ever-present chorus that the data behind the science that went into the decision (in this case, the use of science experts and modelers that assisted in the creation of the TMDL targets) are flawed and need to be either augmented or re-evaluated. My experience is that scientists take what they know, with all its imperfections, and given their best judgment, objectively respond to requests for input. Yet this archetypal chorus continues to come up time and time again. Like many scientific issues in many different complex arenas, the only way a scientist can state unequivocally what will happen is if the event has already happened. This is why peer-

21 These nitrogen, phosphorous, and sediment targets were crafted by the EPA “using state-of-the-art modeling tools, extensive monitoring data, peer-reviewed science, and close interactions with jurisdictional partners.” (EPA Chesapeake Bay TMDL Executive Summary, Dec. 2010) The purpose of the WIPs was to provide EPA with essentially a “roadmap” for how the jurisdictions plan to actually achieve the TMDL targets and thereby provide EPA with a level of “reasonable assurance” that the TMDLs will be met. (EPA, Chesapeake Bay TMDL Executive Summary, Dec. 2010). http://www.epa.gov/reg3waps/pdf/pdf_chesbay/FinalBayTMDL/BayTMDLExecutiveSummaryFINAL122910_final.pdf
22 EPA’s Final Chesapeake Bay TMDL document can be viewed at http://www.epa.gov/reg3waps/tmdl/ChesapeakeBay/tmdlexec.html
review is used so commonly in the scientific realm as a way to double check and evaluate scientific statements and interpretations.

In most cases, the pushback comes from decision makers responsible for spending on the Bay. And this, too, is entirely understandable. This is where the political will tends to evaporate.

An in-depth economic analysis of the Bay’s value is beyond the scope of this article, but about seven years ago a Blue Ribbon Finance Panel, composed of 15 distinguished leaders\(^27\) from the private sector, government and the environmental community, was appointed by the governors of the six states within the Bay watershed, the mayor of the District of Columbia, the Chair of the Chesapeake Bay Commission and the Administrator of the U.S. EPA. This panel was charged with identifying “funding sources sufficient to implement basin wide clean-up plans so that the Bay and its tidal tributaries would be restored sufficiently by 2010 to remove them from the list of impaired waters under the Clean Water Act."\(^28\) According to their report, when it was published in 2004 the economic value of the Bay was more than $1.0 trillion annually. These sorts of Bay-wide economic analyses are difficult to find. Generally, the economic reports of the value of the Bay focus on a particular business sector, like fishing. What these estimates generally don’t value is the economic benefits to the region of the ecosystem services that nature provides to humankind for free—the services associated with the purification processes that occur naturally as water flows through forests and wetlands, the services provided by wetlands as refuge and nursery habitat for commercially valuable fish and invertebrates, and the services associated with the natural buffers that the shallow, sea grass filled bays provide to coastal homes.

The important point here is that the value of these services is significantly enhanced if the Chesapeake Bay and watershed is healthy; imagine if we had to pay for all these sorts of services that nature provides for us at no charge. As difficult as it is to value these economic/ecosystem services, these sorts of things are worth trying to evaluate. When looking at the true costs of restoring the Chesapeake Bay, the costs of the TMDLs will be significant, which is why a partnership between federal, state and local governments as well as the private sector and individual citizens will be necessary. But the return to the region resulting from a healthy Chesapeake Bay is also quite significant. Sometimes the long view is more important than the short view, and also perhaps less expensive in terms of the true costs.

A New Modus Operandi
The case could be made that up to this time the Bay’s regulators, and in fact the general citizenry, have depended too much on the natural science community to direct policy and have not recognized the complexity of the Chesapeake Bay system itself. Instead of viewing the Bay as solely a system driven by natural science processes, it might be better to recognize the Bay as what it is, that is, a complex socio-ecological system (SES). Complex in this context refers to the behavior of the system and means a system that is not only complicated (i.e., possessing many different parts), but one in which the behavior of the system is difficult to predict and often non-intuitive. The SES refers to a system in which human behavior heavily impacts the intensity and direction of the natural processes dominant in the environment.

Elinor Ostrom has been a vocal proponent of this approach and in fact is a Nobel Prize winner for her articulation and advocacy for this way of thinking.\(^29\) For many environmental managers, the solution to effectively manage the Bay was essentially a divide-and-conquer strategy. Reduce the various processes at work in the Bay (generally viewed as natural processes) down to understandable, manageable and modeled units, and then reassemble them into a whole again. The resulting whole, or in this case the composite model, could be used to relatively easily model and manage the Bay appropriately. At least that is the theory. And quite honestly, this approach has resulted in some much-improved understanding of the first order processes responsible for the natural science occurring in the Bay’s watershed. But some systems are not that easily modeled. And when the social processes of farming, fishing, and/or developing land in the Chesapeake Bay watershed are added to the management mix, emergent behavior begins to appear, sometimes resulting in unintended consequences. This is behavior that is not always seen or obvious when described as a simple process.

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\(^27\) The members of this group included leaders such as Secretary of the Interior, Bruce Babbit, Jim Perdue, Chairman of the Board, Perdue Farms, Inc, and William Baker, President of the Chesapeake Bay Foundation, among others.

\(^28\) Chesapeake Bay Watershed Blue Ribbon Finance Panel, “Saving a National Treasure: Financing the Cleanup of the Chesapeake Bay” (October 2004) http://www.chesapeakebay.net/content/publications/cbp_12881.pdf

After each decision-iteration, the simulation calculates economic status and Bay health, providing the user/agent with a plethora of relevant information about their economic situation and the sub-watershed in which they live in the game, as well as the Bay’s health in terms of anoxic volume in the Bay’s deep waters. The game development team tried to focus on the behavioral fidelity of the game, more so than precisely modeling the scientific processes; testing and further game refinements indicate that the interactions and behavior of the various agents is in fact quite reasonable.

Other Chesapeake Bay models, including EPA’s super-computer model of the hydraulics of the Bay have a very different goal than the UVA Bay Game. Use of the game can enhance classroom learning about complex socio-ecological systems like Chesapeake Bay where good intentions by some “agents” may have unintended consequences for other players, as well as a tool for informing policy and building awareness of the tight coupling of individual decisions.


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The Chesapeake Bay Socio-Ecological System

About 30 months ago, a group of scholars from the University of Virginia (UVA) representing 8 different schools began a discussion of what sustainability meant at UVA. The initial guiding principle was that for any ecosystem to be truly sustainable required that it be both economically and environmentally sustainable. This group then took up the challenge to explore the concept of complex SESs further in the context of the Chesapeake Bay. They developed an innovative computer program called the UVA Bay Game.

Recognizing the need to creatively couple the human and natural science systems within the Bay watershed, the game is a dynamic simulation or, more appropriately, a dynamic agent-based simulation. Participants in the simulation take on the roles of crop farmers, livestock farmers, watermen, land developers or policy-makers (the agents) and make decisions about their livelihood based on their own set of values. For example, which method of planting will farmers use—conventional high-yield crops or low-impact farming that may incorporate various best management practices (BMPs)? This game plays out over a 20-year period, from 2000 to 2020, during which players make 10 sets of decisions. Figure 5 shows UVA students participating in the game during April 2010. Philippe Cousteau (upper-right), grandson of explorer Jacques Cousteau, served as co-host of the event.

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and the enhancement or reversal of the declining trends in the health of the Bay.

**Learning Outcomes**
The game has been used in multiple courses at UVA in engineering, environmental sciences, architecture and commerce as well as by actual stakeholders, such as farmers, watermen and state regulators. From these game plays, we have learned several things about the complex socio-ecological system of the Chesapeake Bay and its management. These include:

- Initially, not all resident game players in the Bay watershed fully understand the extent of the watershed or, perhaps more importantly, the role of nutrients in determining the Bay’s health. This occurs in spite of all the focused publicity on the Bay in the region.
- The game is politically neutral. It is what it is, so players with different perspectives can play it without a great deal of animosity toward each other. Instead they can play with a common goal of understanding the complexity of the Chesapeake Bay system. Some understanding of the trajectory of the Bay is valuable to most people, regardless of prior perspective.
- Some players’ actions influence game play and overall Bay health more than others. In other words, not all agents or roles are created equal.
- Communication and cooperation among the players is critical. For example, communication between the policy makers and the constituent groups that they regulate is important, but so is communication between watermen and farmers, or between farmers in the Susquehanna watershed and the James River watershed, or for that matter, between the different policy makers.
- The kind of information that different roles see is important, as is the desire for transparency of data between the various roles. In other words, the information that the policy makers see is not always available to the roles being regulated. Sometimes this causes problems and emphasizes the desire for full transparency and information sharing.
- Unanticipated consequences are possible and, in fact, likely.

The UVA Bay Game is not perfect, and the developers recognize this; however, it is a robust attempt to change the paradigm of how we, as the joint inhabitants of the Bay’s watersheds look at, perceive and manipulate this environmental resource, recognizing it is, in fact, a complex system involving coupled human and natural science processes. It is this aspect of the approach that is innovative and perhaps novel that will allow Bay watershed residents to ask and answer some very difficult questions about their role and goals concerning the future of the ecosystem.

**Conclusions**
The material covered in this article is far reaching, and both complicated and complex. It has been the author’s goal to not only provide historical context with regard to where the Chesapeake Bay management process is currently, but to also inject an understandable dose of natural science and suggest a new approach for addressing sustainability of complex socio-ecological systems, such as the Chesapeake Bay. These kinds of systems are becoming more important to our species each day.

The history of the Chesapeake Bay restoration effort has not been overly successful. Agreements that set target goals for reductions of nutrients since 1987 have not been achieved; the TMDL process is yet another approach. The resulting TMDL Plan is not bullet-proof either, since the water improvement plans may include commitments by the states to go to their legislatures for additional relief in the form of new money or regulation should the programs that are included in the WIPs not be as effective as anticipated. And even though states have met their commitment to take programs to their governing bodies, there is no assurance that the legislatures will approve these new requests.

For observers who have been tracking Bay issues for some time, it should be obvious that the one factor affecting where we are today and where we are going in the future is population growth in the Chesapeake Bay watershed.
I will conclude with an observation by Gene Odum, one of the fathers of ecosystem-based ecology. In his book entitled *Ecological Vignettes*, he makes the case that instead of growing bigger all the time, society needs to grow better and smarter. He uses the principles of energy flow in ecosystems to make comparisons with all sorts of other systems (business systems, governing systems, etc.) to point out that bigger systems ultimately will require the bulk of the energy within the system to go to maintaining the system and not for growth. And the larger the system, the more energy for maintenance will be required. Consequently, there are limits. For example, the energy processed by an acorn as it grows into a large tree is initially shunted into tissue growth. But eventually, as the tree gets quite large, the energy processed by the tree goes to maintain the tree; otherwise the tree would just keep getting larger and larger. His point is that governing systems, municipal systems, urban systems, suburban systems, agricultural systems, and others are the same way. There is a time when our social systems, including our socio-ecological systems, will need to grow better. The way things were done in the past is no longer relevant and we need to think smarter. The first step in this process is to begin thinking about these complex systems as just that: a complex coupling of the social and natural sciences, where open minds and communication trump partisan bickering, and new ways that are politically neutral are used to better inform and guide our responses.

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