Lifeblood of the Bay: How Increasing Acidity Threatens the Chesapeake Bay's Shellfish and Economy

TSEM 190

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The Chesapeake Bay, an impressive body of water located on the eastern shore of the United States stretches across six states, with more than 3,600 species of plants and animals depending on the Bay for survival and safety.[1] Because of this rich saturation of plant and animal life in the Chesapeake Bay, more than 18 million people depend on the Bay as a source of food, shelter, and business. The waters of the Bay are fed by the Chesapeake Bay watershed, which is the third-largest estuary in the world. An estuary, which is an enclosed body of water fed by a series of rivers creates a unique mix of freshwater and saltwater in the Chesapeake Bay[2]. Since the Bay is so expansive, and its waters so diverse, several factors contribute to the health and quality of the water including concentrations of toxins, acidity, and more. Shellfish that make their homes in the Chesapeake Bay, including crabs, oysters, and clams provide a substantial source of industry and economic success to the surrounding states, growing by the year[3]. But, ironically, even though these animals are considered cornerstones of American diets and industry, often, the problems facing these animals are completely ignored. In the years since mass industrialization in the United States, the waters of the Chesapeake Bay have been under significant threat from the increasing

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[1] "Geography and Facts," Chesapeake Bay Foundation, Accessed April 26, 2021. https://www.cbf.org/about-the-bay/chesapeake-bay-watershed-geography-and-facts.html#overview

[2] Benjamin E. Cuker, *Diet for a Sustainable Ecosystem: The Science for Recovering the Health of the Chesapeake Bay and Its People* (Switzerland: Springer, 2020), 32.

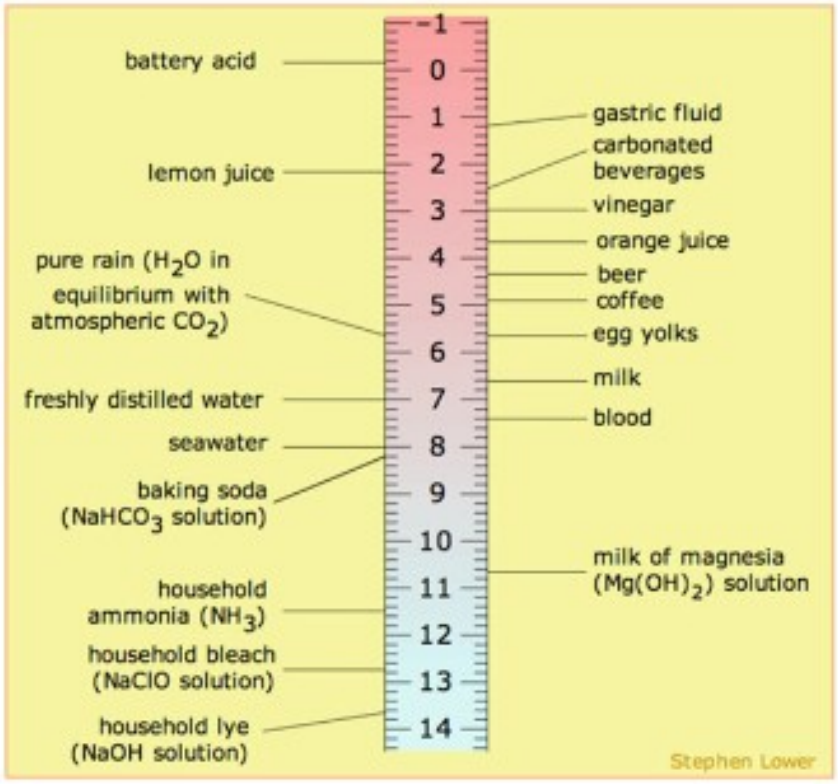
[3] Jonathan van Senten, Carole Engle, Matthew Parker and Donald Webster, "Economic Benefits of the Maryland Shellfish Aquaculture Industry," December 31, 2019. https://www.cbf.org/document-library/non-cbf-documents/analysis-of-the-economic-benefits-of-the-maryland-shellfish-aquaculture-industry-full-report.pdf

acidity of the water. The acidification of the water of the Chesapeake Bay uniquely affects essential, yet often underestimated organisms, such as shellfish. The increasing acidity of water in the Chesapeake Bay is directly responsible for the decline in the health of shellfish in the bay, therefore, to combat this, action needs to be taken toward improving the quality of the water so that shellfish and their associated industries can thrive.

The concept of acidity is an important yet complex issue involving the health of water and the organisms that reside within it. Acidity is the concentration of H^{+}[4] and OH^{-}[5] ions that are a part of fundamental chemical reactions in the body. Acidity is measured by the pH scale, which spans from numbers 1 to 14. The value of 7 on the scale represents a neutral pH, or otherwise when the concentration of H+ and OH- ions are equal. Any substance that measures above the number seven is considered basic, meaning that there is a greater concentration of OH^{-} ions, while any substance with a pH of below 7, has a greater amount of H^{+} ions and is acidic. The pH scale provides a context to the acidity of many solutions and allows scientists to quantify the acidity of water and gauge the threat acidity might pose to the organisms that reside within the water. In its natural state, water is slightly acidic, with a pH of a little less than 7. To maintain the health of the water, it is essential that the pH, or rather the concentration of ions remains close to water's natural pH. It is the shifting concentrations of these ions, and therefore a shift in pH, that poses a threat to the Chesapeake Bay's shellfish. Because the pH scale, and therefore acidity is logarithmic, any change in pH represents a tenfold change in the acidity of water. For example, if the pH of a solution changed from seven to five, then the overall solution becomes 100 times more acidic.[6] For delicate

[4] H^{+} ions, otherwise known as hydrogen ions, are a single atom of the element hydrogen that has become more positive due to the loss of an electron, which is one of the three components of an atom.
[5] OH- ions are the combination of an oxygen atom and a hydrogen atom that have become more negative due to the addition of an electron, an essential component of an atom.
[6] Cuker, *Diet for a Sustainable Ecosystem,* 33-34.

creatures such as shellfish, this kind of change can have a disastrous effect on their health and development.



Pictured above is the pH scale that is marked with common household items, chemicals, and food by their acidity to contextualize the acidity of known solutions. Take note of the pH of distilled water as compared to seawater.[7]

However, there is a method for managing pH changes, in the form of buffers. Buffers are salts, a combination of a metal[8] and a nonmetal ion[9] that absorb other ions in water, and therefore keep the overall pH of the water from changing too drastically. Buffering is a complex and vital process in all areas of life, but perhaps most importantly, managing the pH of water. One of the most important buffers in the Chesapeake Bay is calcium carbonate ($CaCO_3$) that works both as a

[7] Lower, Stephen. n.d. Accessed April 27, 2021. http://chemwiki.ucdavis.edu/@api/deki/files/8232/639px-PH_scale.png?revision=1.
[8] Examples of metal ions include calcium, sodium and magnesium, among others.
[9] Non-metal ions include oxygen, nitrogen, carbon and more.

buffer and a substance that shellfish use to build their shells. As discussed, drastic changes in pH have disastrous effects on the Chesapeake Bay and nearly every organism that depends on it. As the pH of water decreases more and more, a greater amount of buffering must take place to manage the acidity of the water.[10]

Much of the fault for this unfortunate reality can be attributed to human invention and industrialization[11]. The past two hundred years have brought about the burning of fossil fuels, massive deforestation, and increased animal production and breeding for consumption. The prevalence of fertilizer and other nutrient usage has also increased significantly, which ultimately drains into rivers and streams that sustain the Bay's freshwater sources[12]. These processes are some of the primary reasons why, and how the acidification of the Chesapeake Bay has and continues to occur. In both cases, the chemical compound CO_2 is largely responsible for acidifying the water in the Bay and decreasing the amount of available calcium carbonate[13].

Since the early twentieth century, the burning of fossil fuels has become the primary source of energy in our modern world.[14] Fossil fuel formation, though it is a natural process is one that takes millions of years to complete, and because of this, fossil fuels are a very limited energy source. The formation of these fuels depends on the decomposition of dead organic material that is broken down by organisms called decomposers. The process of decomposition leaves behind residue that, with enough time, is buried underneath other sediments and compressed, eventually

[10] Cuker, *Diet for a Sustainable Ecosystem,* 34.
[11] Cuker, *Diet for a Sustainable Ecosystem,* 50.
[12] Aaron L. Strong, Kristy J. Kroeker, Lida T. Teneva, Lindley A. Mease, and Ryan P. Kelly, "Ocean Acidification 2.0: Managing our Changing Coastal Ocean Chemistry," BioScience 64, no.7 (July 2014): 581–592, http://proxy-tu.researchport.umd.edu/login?ins=tu&url=http://search.ebscohost.com.proxy-tu.researchport.umd.edu/login.aspx?direct=true&db=ulh&AN=96950117&site=eds-live&scope=site
[13] Aaron L. Strong, Kristy J. Kroeker, Lida T. Teneva, Lindley A. Mease, and Ryan P. Kelly, "Ocean Acidification 2.0: Managing our Changing Coastal Ocean Chemistry," BioScience 64, no.7 (July 2014): 581–592, http://proxy-tu.researchport.umd.edu/login?ins=tu&url=http://search.ebscohost.com.proxy-tu.researchport.umd.edu/login.aspx?direct=true&db=ulh&AN=96950117&site=eds-live&scope=site
[14]

becoming part of the ground itself. The environment that results from this decomposition is extremely acidic and completely lacks oxygen. This combination of conditions then allows these dead organisms to be chemically transformed into fossil fuel structures, otherwise known as hydrocarbons. As these fossil fuels are then extracted from their underground environment and burned, the hydrocarbon compounds present in the fossil fuels are then transformed into carbon dioxide.[15] The burning of fossil fuels has become a cornerstone of modern life, as fossil fuels power our machinery, transportation, electricity, production, food growth and storage, pumping and delivering water, and more. Yet, this comes at a steep price, the health of our planet.

The threat that fossil fuels pose to the atmosphere, through the addition of CO_2, is immense, causing a cascade of disastrous events, starting with overall global warming which directly contributes to the acidification of the water. Like many other gases and chemicals present in the Earth's atmosphere, CO_2 naturally diffuses into bodies of water like oceans, rivers, lakes, bays, and estuaries across the Earth. As CO_2 enters the water, it interacts with the water molecule and forms the compound carbonic acid.[16]This carbonic acid then splits into H+ ions and bicarbonate ions. Bicarbonate ions then can lose another H+ ion under the right conditions and become carbonate ions. These carbonate ions are an essential part of the buffering compounds used to control the pH, as well as a key component of calcium carbonate. Yet, as more and more CO_2 enters the water from the atmosphere, and the acidity of the water increases, less carbonate is available due to the increased need for buffering and the decline in the amount of bicarbonate that transforms into

[15] Cuker, *Diet for a Sustainable Ecosystem: The Science for Recovering the Health of the Chesapeake Bay and Its People,* 50.
[16] Robert F. Service, "Rising Acidity Brings An Ocean of Trouble," Science 337, no. 6091 (July 2012): 146–148, http://proxy-tu.researchport.umd.edu/login?ins=tu&url=http://search.ebscohost.com.proxy-tu.researchport.umd.edu/login.aspx?direct=true&db=asn&AN=78091629&site=eds-live&scope=site

carbonate. Therefore, this creates a looping cycle of environmental and water quality issues that seemingly, has no end.[17]

Additionally, another process that increases the acidity of water, especially around coastlines is eutrophication[18]. Since the Chesapeake Bay contains nearly 11,684 miles of shore and coastlines that include both island and wetland habitats[19], the impact of eutrophication is devastating to so many of the shellfish species that live in and near coastlines, like crabs, oysters, and clams[20]. Eutrophication is the process in which chemicals are released into water systems resulting in the increased bloom of a type of algal organism called phytoplankton, which ultimately causes a host of problems relating to water quality and acidity. Yet, one of its more devastating effects is on the pH of water near coastlines. Because of the dumping of chemicals like wastewater, fertilizers, and other nutrient runoff, phytoplankton can grow at an increased rate because of the abundant amounts of nutrients to feed on. Yet, it is the end of the phytoplankton's life that poses the greatest threat to water quality. Like processes on land, when these organisms die, their remains are broken down through decomposition. This process causes the release of CO_2 at an increased rate, which directly causes the acidification of the water[21]. Given that the Chesapeake Bay is an extremely productive area for the harvesting of shellfish, the lower the acidity, the more harm that is done to the shellfish.[22]

It is these processes that have become such an ingrained part of our society that have the most dangerous effects on shellfish. Shellfish are very complex creatures and depend chiefly on the

[17] Strong, et al., "Ocean Acidification", 1.
[18] Strong, et al., "Ocean Acidification", 2.
[19] Chesapeake Bay Foundation, "Geography and Facts."
[20] Strong, et al., "Ocean Acidification", 1.
[21] Strong, et al., "Ocean Acidification", 2.
[22] Cuker, *Diet for a Sustainable Ecosystem,* 34.

formation of their shells to act as a protective layer against predators, allowing them to survive[23]. The shell structure, which is made primarily of the chemical compound called calcium carbonate is becoming increasingly short in supply in the Chesapeake Bay, due to the need for buffering the water. Without their shells, shellfish are extremely vulnerable, and it is precisely these shells that are under the greatest threat from water acidification. With dueling purposes at play, with calcium carbonate and other compounds being essential for the survival of shellfish, and to maintain the quality of water, where can a balance be struck? The answer is a rather sad one, where so often, the need to buffer the water is naturally prioritized above the health of shellfish, simply because of the nature of supply and demand. Only so much calcium carbonate is available in the water, and in most situations, the water absorbs and uses the carbonate, leaving very little behind for shellfish to use to build their shells, and ultimately, survive.[24]

While examining the causes and effects associated with the increasing acidity of water and shellfish health, a natural question remains. Why does this matter? Water quality is an issue that plagues nearly every body of water around the world, and the acidification of water is certainly nothing new. Yet, to disregard this issue would simply ignore a fundamental effect of the water crisis in America, and its universal impacts on shellfish life and human industry in the Chesapeake Bay. The value of the shellfish industry cannot be understated, as the combination of fresh and salt waters of the bay creates an extremely successful and unique economy centered around shellfish and other seafood[25]. In Virginia, "shellfish aquaculture, which produces the most eastern oysters on

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[23] Cuker, *Diet for a Sustainable Ecosystem,* 109-110.
[24] Cuker, *Diet for a Sustainable Ecosystem,* 34.
[25] Jennifer L. Wolney, Michelle C. Tomlinson, Stephanie Schollaert Uz, Todd A. Egerton, John R. McKay, Andrew Meredith, Kimberly S. Reese, Gail P. Scott, and Richard P. Stumpf, "Current and Future Remote Sensing of Harmful Algal Blooms in the Chesapeake Bay to Support the Shellfish Industry," Frontiers in Marine Science, May 1, 2020. http://proxy-tu.researchport.umd.edu/login?ins=tu&url=http://search.ebscohost.com.proxy-tu.researchport.umd.edu/login.aspx?direct=true&db=edsdoj&AN=edsdoj.5b4d051cf1494caf879e7821cceb94e8&site=eds-live&scope=site

the United States East Coast… had a… value of $53.3 million in 2018"[26]. In Maryland, the oyster industry "was valued at $10.6 million between 2016 and 2017"[27]. Similarly, blue crab fishing in the Chesapeake Bay accounts for over a third of the supply of blue crab for the entire country, over 55 million pounds of crab being fished over a period of 9 years, which equaled about $78 million in value. Yet, the true impact of the shellfish industry is most aptly quantified by the amount of money that has been lost through the decline of shellfish health, quality, and survival. In fact, over the last three decades, Maryland and Virginia have lost over $4 billion because of the decline of oyster harvesting industries in the Chesapeake Bay.[28] Likewise, between the years 1998 and 2006, about $640 million in revenue have been lost due to the decline of blue crab populations.[29] Furthermore, the impact of the shellfish industry in Maryland extends far beyond the business created by the sale of shellfish and includes additional direct[30], indirect[31] , and induced[32] effects on the industry.[33]A study by the Chesapeake Bay Foundation[34] that examines the economic benefits in the Chesapeake Bay reports on the annual economic impacts of the shellfish industry for the years of 2017 and 2018. Considered to be consistently representative of the economic magnitude of the Chesapeake Bay's shellfish production, the study reports that in both years, the value of the industry averaged over $8 million per year. This value has only grown over the years, as over six years from 2012 to 2018, the average annual growth of shellfish harvest in Maryland increased by 115%. The overall impact of the shellfish industry cannot be understated, as year after year, the

[26] Wolney, et al., "Current and Future Remote Sensing." 2.
[27] Wolney, et al., "Current and Future Remote Sensing." 2.
[28] Chesapeake Bay Foundation. "The Economic Importance of the Bay." Accessed April 2021. https://www.cbf.org/issues/what-we-have-to-lose/economic-importance-of-the-bay/index.html
[29] Chesapeake Bay Foundation, "Economic Importance."
[30] Direct effects are the amount of revenue made from the sale of shellfish from those who fish and harvest it, as well as the economic benefit of direct employment by fisheries and hatcheries.
[31] Related industries like the purchase of fuel, supplies and places of business experience indirect effects of the shellfish industry and its revenue.
[32] Induced effects of the shellfish industry are defined as the amount of money that spent by employees and companies on a more personal income level.
[33] Van Senten, et al., "Economic Benefits." 22.
[34] Van Senten, et al., "Economic Benefits." 22-26.

economic impact of the shellfish industry has consistently been responsible for millions of dollars of business and economic success. [35]

As the need for the shellfish industry continues to increase, supply must also be maintained, making the need for fundamental change even more urgent. Examining the economic impact provided by a small subsection of the Chesapeake Bay contextualizes the need for change regarding water policies. Water, a most essential resource is under significant threat from acidification, and yet, time and time again, nothing is done to work toward correcting or changing the issues that directly harm the environment. And while it may be obvious to say that as a society, we must work to find more renewable energy resources besides fossil fuels and decrease the use of nutrient fertilizers and decrease nutrient runoff, this does not fully capture the scope of the problem. Proposing a solution like this creates a façade that the only change that can be made is a massive societal change that no individual person can truly institute. Instead, work must be done to attack the specifics of these problems and determine the true causation of the acidification water in individual circumstances so that productive solutions and changes can be instituted.

A study[36] that examines the causes of water acidification in oceans, coastal areas, and bays around the US proposes several possible solutions. These solutions create a blueprint for significant productive strides toward improving our water quality to save our shellfish industries. Firstly, though some of the issues surrounding water quality and water acidification have been studied and discussed, a very large proportion of these issues have not. To correct this, initiatives to study the threat of water acidification on ecosystems and human endeavors could provide a detailed overview of the specific threats and their severity, such as CO_2 diffusion and eutrophication. After all, without being fully aware of the scope of the issue, how could we hope to

[35] Van Senten, et al., "Economic Benefits." 22-26.
[36] Strong, et al., "Ocean Acidification", 8-9.

fix it? Secondly, establishing monitoring systems and networks in water systems like the Chesapeake Bay will be a major benefit to local governments and businesses, so that priority can be assigned to areas of the Bay that require the most attention. Satellite monitoring has shown the most promise for treating and predicting algal blooms of phytoplankton in the Chesapeake Bay. With this, action can be taken towards ensuring that areas at risk are treated with extra caution when it comes to agricultural runoff and fossil fuel burning. These directives can then streamline the decision-making processes of local governments and agencies when it comes to preventative measures being levied against the acidification of water.[37]

Additionally, the same study[38] examines the existing laws regarding water quality, which reveal some staggering realities of the power of inaction. For example, the Clean Water Act, a federal law, "affirms the authority of states to address the… runoff associated with coastal… acidification" and more. In the case of places like the Chesapeake Bay's shorelines and coasts, runoff from agricultural pursuits like farming and raising animals has been proven to cause some of the most intense challenges. Ultimately, the power to make changes about certain farming practices that contribute to water acidification lies in the hands of local governments, many of which are in Maryland. Similarly, prioritizing the acidification of water as an issue that requires regulation and action is of utmost importance. Federal action programs like the Interagency Climate Change Adaptation Task Force and the EPA's Climate Change Adaptation Plan include the acidification of water systems and oceans as an effect of human activities that drive climate change. But strangely, this is not featured as a priority item of action, and therefore, on a federal level, no change or policy recommendation can occur to address this issue, even in America's most vital sources of industry, like the Chesapeake Bay. It is this fact that speaks to the importance of

[37] Strong, et al., "Ocean Acidification", 8.
[38] Strong, et al., "Ocean Acidification", 9.

advocacy and education about this issue, given that much of the power to change the practices of companies and farmers is centered within the government.[39]

Education and awareness regarding the water crisis in America that concerns issues such as water availability and water quality are often limited. And yet, the true impact and scope of the water crisis are far from insignificant. Since the issue of water quality is so broad and multi-faceted, it is often difficult to discern how the acidification of the Chesapeake Bay uniquely impacts some of our most essential sources of food, like shellfish. Because of this, the natural reflex for most is to ignore issues such as these that cannot be easily observed. And so, we are left with a dilemma; a worsening situation, and an increasingly disinterested public that scientists and activists are left to inspire into action. Although, through the pursuit of knowledge and discussion of more realistic solutions, a brighter future may be ahead. Yet, we must ask ourselves a vital question; what are we willing to do to protect the resources that sustain us, like our water systems and food sources? The Chesapeake Bay is just one example of a water system that has an urgent need for assistance and visibility. Numerous examples across the US, such as Netarts Bay in Oregon[40], exemplify exactly why eutrophication and the burning of fossil fuels is such a harmful process, and how lack of action causes climate change and associated ocean acidification to continue unimpeded. At the source of this problem is the water, and with so many other factors contributing to the current water crisis in America, there is no time to meditate on the severity of these issues. To correct these problems and achieve change, we must consider what we are willing to do to make real change. With so much at stake, the lives of the animals that sustain us, and the industries we rely on, what choice do we have but to act? Continued inaction and apathy towards

[39] Strong, et al., "Ocean Acidification", 9.
[40] Service, "Rising Acidity", 1.

issues of water quality and water acidification bring the entire Chesapeake system closer to the brink of collapse, unless something is done, and soon.

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