Blue Crabs: Bad water, bad living conditions, and bad regulations are giving them the blues

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Blue crabs (*Callinectus sapidus*) are the most lucrative fishery of the Chesapeake Bay. Due to their economic prominence, blue crabs are an integral part of the culture of the mid-Atlantic region. The health of the Chesapeake Bay has declined due to lower dissolved oxygen levels in the estuary, which have been attributed to excessive nutrient inputs from human practices. In conjunction with reduced dissolved oxygen levels, the blue crab population has declined. The individuals who harvest these crustaceans face regulation changes aimed to prevent the population decline. These regulations were scrutinized by these individuals whose families rely on their catch for a livelihood. Funding has declined for the institutions which seek to protect the health of the Chesapeake Bay and the organisms inside of it. In order to combat the issue of declining blue crabs, consumers must consider how their habits are contributing to the increased nutrients that cause dead zones. More thought towards how individuals are impacting blue crabs will not only improve the Chesapeake's help, but it will also improve the overall environment's health.

The Chesapeake Bay is the largest estuary in the United States of America. Estuaries are a unique body of water where the mouth of a river, or a system of rivers, connects to an ocean or sea. This connection creates brackish water of varying salinity. The organisms in this unique body of water are accustomed to using the varying conditions throughout the estuary to develop during their different life stages. "For years, people tried to clean it up. States and the federal government spent millions of dollars…And each time, the cleanup efforts failed. The bay's health wasn't getting much better," (Shapiro, 2017). The years which Shapiro is referencing started with the 1983 when, during his State of the Union address, president Ronald Reagan placed an emphasis on Chesapeake Bay cleanup effort and the Environmental Protection Agency (*EPA*) passed the Chesapeake Bay Agreement (Muscatine & Sugawara, 1984). Unfortunately, anthropogenic factors are still disrupting the water conditions throughout the Chesapeake Bay, and the organisms within it either must adapt or perish (Long, Grow, Majoris, & Hines, 2011).

Blue crab *(Callinectus sapidus)* is the crustacean which is a part of the most lucrative fishery in the Chesapeake Bay (Fogarty & Miller, 2004). Because of this position of prominence blue crabs, "are also a powerful icon of the whole mid-Atlantic region—a symbol of our cultural roots in the Chesapeake. And they are an essential strand in the web of life that forms the nation's largest estuary" (Chesapeake Bay Foundation, 2008). Crabbing season is between late spring and early fall, and in the summer of 2018 the blue crab population shrank by one fifth for the second year in a row (Miller, 2018). The decline in blue crabs within the Chesapeake Bay is attributed to a variety of environmental factors, ranging from poor water quality to extreme weather events like hurricanes (Hines et al., 2011). After the Chesapeake Bay Foundation sued EPA in 2009 because of the foundation's belief that that EPA did not perform enough actions to protect and restore the estuary that they agreed to undertake under the Chesapeake Bay Agreement, EPA pledged to adhere to a strict policy that would improve the conditions of the Chesapeake Bay and its various tributaries (Ryan, 2010). As recently as 2016, the decline of blue crabs due to low dissolved oxygen in the water seemed to be solved, but due to changing views and beliefs on environmental policy under the Trump administration, these

programs that started this great progress might be reversed (Shapiro, 2017). Recently, White House Secretary of the Interior David Bernhardt was informed that carbon dioxide in the atmosphere has reached its highest levels in the past 800,000 years, and he noted "I haven't lost any sleep over it" (Smith-Schoenwalder, 2019). With proposed large budget cuts for EPA programs which protect the Chesapeake Bay, such as a 91% funding reduction for the Chesapeake Bay Agreement previously mentioned, the lives of the organisms in the bay will be greatly affected (Lang, 2020). The local seafood industry could potentially suffer losing its most valuable and culturally significant species if these programs are removed.

Environmental Stressors

Blue crabs, like other organisms that live in the brackish waters of estuaries, rely on the variety of conditions in the bay throughout their various stages of development. They shift their habitat throughout their life cycles and reside between deep inside the estuarine system all the way to the coast. Specifically, blue crab larvae hatch and move from the offshore to the continental shelf. After the larvae stage these organisms move from the continental shelf through the tides and re-enter the estuary. These post-larvae grow within the grass until are about 20 millimeters long, where afterwards they move into the lower salinity shallower sections of the estuary in order to develop more and mate (Hines et al., 2011). The development of blue crabs is heavily dependent on specific temperature conditions. When there is a serious change within the seasonal temperature patterns of the Chesapeake Bay, the life of these crabs can either be lengthened or shortened. For example, a severe winter can cause up to a 70% mortality rate of blue crabs, while warm winters typically allow for greater blue crab abundance (Hines et al., 2011). The conditions of warming specifically will shorten the life cycle of crabs, but reproduction output rates should increase (Hines et al., 2011). These assumptions are based on warmer temperatures, but it is important to acknowledge that greater blue crab abundance might not appear if other events of climate change such as the collapse of essential infrastructure from more frequent sporadic natural disasters. More than just the blue crab life cycle is directly affected by climate change. Much of the seagrass that the blue crabs rely on for living

in and raising their young die due to environmental stressors such as extreme heat in the summer (Hines et al., 2011). Without a suitable replacement, the decline of this vegetation will lead to an even quicker decline in the blue crab population.

"Dead zones" are created in bodies of water when there is a reduction of dissolved oxygen (Diaz & Rosenberg, 2008). The reduction in dissolved oxygen is caused by a process known as "eutrophication." Eutrophication is when an abundance of nutrients in a body of water makes algae and other organic organisms grow excessively, and when this abundance dies the decomposition depletes the oxygen and disperses carbon-dioxide making the water uninhabitable for crustaceans like blue crab which require oxygen. These nutrients come as fertilizer runoff from agricultural fields (Diaz & Rosenberg, 2008). Studies have found that climate change, in particular the gradual warming of the earth, will change dynamics of dead zones in estuaries leading to an even more rapid expansion of dead zones (Altieri & Gedan, 2015).

A study by Schall and colleagues in 2018 was conducted with the goal of understanding perspectives of rural farmers on how their practices affect the changing water conditions of the Chesapeake Bay. This study "takes up these broad issues of environmental polarization, values, and identity in order to understand how a diverse group of actors view the importance of agricultural best management practices." (Schall et al., 2018). These Best Management Practices are established by the EPA through its Chesapeake Bay Program and are deigned in order to reduce nutrient runoff from commercial farming (Schall et al., 2018). The study was centered in the Coptank watershed on the Eastern Shore of Maryland, which drains directly into the Chesapeake Bay. This location was of interest because of its historical use for both chicken and grain farming, as well as pressure that local farmers have received to adopt Best Management Practices in order to reduce pollution into the Chesapeake Bay (Schall et al., 2018). The farmers were asked to respond to 34 statements that pertain to the role that agriculture plays on the declining state of the Chesapeake Bay water. In this study the statement which garnered the most polarized response was "There is very strong evidence that agriculture is the single largest source of nitrogen, phosphorous and sediment going into the Chesapeake Bay," (Schall et al., 2018). This is a statement

which would not have much disagreement in scientific circles, but amongst these Maryland farmers, it was the most disagreed upon statement of the 34 they were presented. When examining poultry barns, it was found that the manure these barns produce was a large nitrogen input into streams within the Delmarva Peninsula of the Chesapeake Bay (Amato et al., 2020). Although farmers contribute a significant amount of nutrient inputs into the Chesapeake Bay, they are doing this to make a living growing crops and raising livestock. Additionally, managing the nutrients has done a great deal towards eliminating dead zones in the Hudson and East Rivers in New York, but unfortunately these same management tactics were attempted on the Chesapeake Bay and did not result in improvement of dissolved oxygen levels (Diaz & Rosenberg, 2008). Some key differences for the Chesapeake Bay are the strong seasonality for its lack of dissolved oxygen in the water (Diaz & Rosenberg, 2008), this seasonality leads to increases in populations when new plants bloom in the fall or spring (Graf, 1992). Further investigation should be placed on management tactics which work with the unique seasonality of the Chesapeake Bay, and why the ones that improved the dead zones of New York did not have the same positive effects on the bay.

Although the Chesapeake Bay watershed has a large amount of freshwater, the areas where there is the most freshwater are not its most densely populated (Bilkovic, Mitchell, Havens, & Hershner, 2019). This has led to over usage of groundwater which requires desalinization and some areas of the watershed have sea levels increasing at a rate that is the highest on the United States' Atlantic coast because of the over-drafting of groundwater (Bilkovic et al., 2019). Consumers must be conscious of conservation of water, as well as those who need freshwater for commercial usage. Addressing this issue before it becomes a severe and more complex one is an example of the importance of thinking about the ways that all organisms within the Chesapeake Bay watershed rely on its resources.

Government Policy

Prior to suing the EPA in 2009 for not restoring the health of the Chesapeake Bay as promised during the Regan Administration, the Chesapeake Bay Foundation released a report on the effect of unsuitable water conditions on blue crabs. One of the primary

suggestions for the government to enact in order to improve the water health of the Chesapeake Bay was a reprioritization of program investments. The foundation released a report in 2008, at the height of an economic recession. They suggested,

> The stimulus package can bring new life to the economy as well as the Bay and its rivers by providing money for sewage treatment plant upgrades through the federal Clean Water State Revolving Fund, and by making sure all highway projects include runoff pollution control systems. Smart targeting of federal investments such as these—as well as funds designed to reduce agricultural pollution—is good government and good resource protection (Chesapeake Bay Foundation, 2008).

The reprioritization of investments from unsustainable infrastructure plans and consumer practices to those with sustainable designs would increase jobs, as well as keep the bay clean. This emphasis on sustainable investment will consequently keep fishermen counting on the ecosystem employed. One of the other primary suggestions was to create an enforceable and accountable pollution cap for the bay. In the same 2008 Chesapeake Bay Foundation report, they emphasized the importance of finalizing a pollution cap program that they have been working on with the EPA. The report stated that a "maximum amount of nitrogen, phosphorous, and sediment pollution" would be established in order to indicate health conditions for the bay (Chesapeake Bay Foundation, 2008). This is called a Total Maximum Daily Load (TDML), and the foundation emphasized that it will only work to maintain health conditions of the estuary if it takes into account pollution from all possible sources, as well as aggressively holding all individuals in the system accountable (Chesapeake Bay Foundation, 2008). Without clarity on the execution and consequences for failing to comply with the TDML, the foundation believed that it will be extremely difficult to maintain the health of the bay. Not only did the foundation think it was necessary to create a cap that would keep the water healthier for organisms inside, but they also wanted appropriate consequences (e.g. fines or suspension of license) for violating the cap.

The EPA was subsequently sued after this report by the Chesapeake Bay Foundation in 2009, and the two parties reached a settlement in 2010. In this settlement, the EPA agreed to track regulatory actions that they pledged to implement under the

Obama Administration's Clean Water Act that would restore Chesapeake Bay water quality. Some of these actions were developing the most strict TDML possible, implementing it in a manner which yield positive results, and reviewing the permits and regulations on animal feeding which lead to nutrient rich water as well as the quality of urban and suburban storm water (Ryan, 2010). The report released by the Chesapeake Bay Foundation seemed to have been appropriate guidance for the EPA. In the press release where the EPA announced their settlement with the Chesapeake Bay Foundation, they claimed that by the end of 2010 the most intricate and massive TDML in the nation will be developed and implemented (Ryan, 2010). The EPA appeared to dedicate itself to serious change in the Chesapeake Bay, as requested by the Chesapeake Bay Foundation. This was beneficial for blue crabs and fishermen but placed scrutiny on other groups such as farmers and lawncare services who use fertilizers which are harmful to the health of the bay.

Fishery Regulations

Fishery regulations have changed over the years based on population trends. It is important to have accurate census data on fishery populations in order to understand the population of a group of crustaceans, and any potential detrimental effects on a population. Additionally, gathering a stable timeline on the losses within a fishery population is necessary when developing management interventions (National Research Council, 1998).

A study in 2004 examined the impact that changes on fishery reporting regulations for Maryland blue crabs in 1981 had on the population. This study examined data through 1994 when trip ticket reporting was required for all commercial fishers. Reports of crustacean landings doubled after implementation of a new system in 1981 where instead of forced self-reporting via mail, there was a randomized selection process where reporting was based on interviews (Fogarty & Miller, 2004). This change in reporting drastically impacted the understanding of the volume of fishing within the blue crab industry. This was the beginning of series of gradual regulatory changes based on newly discovered information about the blue crab population being on the brink of overcaught. In order to refine the system for monitoring the abundance of blue crab in the Chesapeake Bay, watermen, officials from the

Department of Natural Resources, and organizational stakeholder have worked on making self-reporting more efficient (Aiosa, 2013). Ideally with more advanced reporting systems which efficiently aggregate data across all watermen without consuming too much of their time, government officials will have a better understanding of the abundance of blue crabs.

Commercial fishers in the Chesapeake Bay region are known as "watermen," and these individuals through generations have depended on the United States' largest estuary to provide for their families and service their community (Paolisso, 2002). Watermen recognize the declining state of blue crabs, and although they believe science has a role in solving this issue, they do not believe that commercial fishing is the main problem. Through multiple public forums, these watermen have argued that the state should focus their efforts on issues of larger fish predation of young blue crabs and the declining water quality of the Chesapeake Bay, rather than insisting that these commercial fishers collect fewer crabs (Paolisso, 2002). With decreased profits, the watermen would not be able to support their families, and many do not have other technical training for a job. The same watermen have also questioned legitimacy of the scientific findings displaying a low population of crabs who can give birth, suggesting that the blue crab population has always been cyclical and there always have been variance through time.

Michael Paolisso, an anthropologist at the University of Maryland College Park conducted a study in which he applied cultural modeling to the blue crab controversy. Paolisso conducted ethnographic studies in order to illuminate how local knowledge of watermen can be used in conjunction with scientific methods in order to solve the issue of the declining population of blue crabs. Between the 2001 and 2002 crabbing season, the Maryland Department of Natural Resources tightened the restrictions for harvesting crabs. During this time period, watermen were required to take one day off weekly and could work a maximum of 8 hours per day. Additionally, the Department of Natural Resources raised the minimum size limit of peeler crabs, soft crabs, and male hard crabs. The amount of undersized crabs that were allowed to be collected in a basket of crabs was also drastically reduced from 20 crabs to five (Paolisso, 2002). The regulation changes in work time might be practical for someone working in an office who is

concerned about being overworked, but watermen were upset about the hour maximum. In their experiences, tides and mechanical difficulties made it challenging for them to harvest consistently for only an 8-hour period. Minimum catch size increases in smaller crabs were also met with frustration from watermen, who collected smaller soft-shell crabs because consumers have expressed that these types of crab taste better than their larger counterparts. These watermen rely on consumer demand, and a catch size increase hampers their ability to catch and sell smaller soft-shell crabs which these watermen feel consumers desire. The change in minimum hard shell crab was increased from 5 inches to 5.25 inches, and watermen argued that attempting to distinguish this difference would slow down the productivity of their operations (Paolisso, 2002).

In his ethnographic work, Paolisso found that the three communities where watermen lived were similar culturally, socially, and economically (Paolisso, 2002). Because the families did not move much and had generations fixed in this same community over time, they were able to observe any changes going on in the area. Paolisso also found that across all three communities, these local families expressed that watermen are the most important local profession (Paolisso, 2002). Watermen do not believe that they are the largest party to blame in the declining numbers of blue crabs. Instead, watermen expressed that the "real enemy" of the Chesapeake Bay are "corporations, who do not adequately treat their waste water discharges, as well as government officials, who have not addressed the urban sprawl and development of overwhelming the capacity of local sewage treatment plants" (Paolisso, 2002).

Future of the Bay

A team of scholars utilized control theory in order to construct precautionary reference points for the management of Chesapeake Bay blue crab fisheries. The metrics that this analysis surrounded were the maximum sustainable yield and the expected fishing mortality rate with the goal of quantifying the limit to the total allowable catch for watermen. These scholars suggested that policymakers who wish to reduce the likelihood of a poor outcome for the blue crab fishery, that they use a higher level of precaution

than the level they employed in their analysis (95% v. 90%) (Wilberg, Woodward, Huang, & Tomberlin, 2019).

In the 2008 report on the effect water condition detrimental to life have on the decline of blue crabs in the Chesapeake Bay, the Chesapeake Bay Foundation outlined the steps to improving water quality as: "Create an Enforceable, Accountable Pollution Cap," "Enforce and Toughen Regulations," "Reprioritize Investments," and "Provide Incentives and Foster Innovation," (Chesapeake Bay Foundation, 2008). These steps were later adopted by the EPA after the 2009 lawsuit. In the summer of 2016 there were no recorded dead zones in the Chesapeake Bay (Shapiro, 2017). Current President Donald Trump's budget calls for large cuts on Environmental Protection Agency programs that assisted in the efforts to counteract these growing dead zones. The president of the Chesapeake Bay Foundation expressed his concern with this budget cut, stating, "I think if we saw the federal government withdraw, you would see the Chesapeake Bay revert to a national disgrace right as it's becoming a great national source of pride," (Shapiro, 2017). Cutting programs, such as the proposed cut to the Chesapeake Bay Agreement which have been essential to helping the health of the bay, will be detrimental to blue crabs. Instead more resources should be allocated into developing technology and hiring personal to monitor and manage the health of the Chesapeake Bay as well as the species which reside in it.

Consumers of these crabs in cities and suburban areas both need farmers and fishermen to produce food for them, but often have poor waste management and emissions practices. Perhaps the often-low income individuals who are trying to make ends meet by crabbing and farming should not be the population most scrutinized. Consumers in cities and suburbs should question their diets, use of fertilizers in their home gardens, and how they dispose of waste. Considering these factors should also prompt them to think about how these practices impact the blue crab, which is representative of the Chesapeake Bay region, and a major part of the local economy and culture. Consumer habits such as the consumption of livestock products which are associated with large phosphorus and nitrogen outputs also indirectly affect the Chesapeake Bay. If consumer habits indicate a large demand for certain product that are detrimental to the environment, companies and farmers will create those products because they will produce

enough product to meet consumer demands. If residents within the Chesapeake Bay watershed want to see their local economy thrive, they must choose to make choices which will not negatively affect the crustacean which represent far more than a summer meal. The Chesapeake Bay and its iconic blue crab fishery can be seen as an example of the importance of ongoing and active intervention in environmental efforts. Decades of time and countless governmental resources have been put into restoring and maintaining the health of the environment which blue crabs live in. A short term feeling of security is only possible when neglecting the previous conditions that led to the conditions of the present. Before making any decision involving environmental conservation, it is critical that policymakers are detailed on possible negative ramification to a system.

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