Blue Crab Population Drivers and Stock Assessment in Chesapeake Bay

Chesapeake Bay Stock Assessment Committee
Blue Crab Workshop Report

September 20-21, 2022
Hampton, Virginia

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Executive Summary

The Chesapeake Bay blue crab (*Callinectes sapidus*) population has experienced significant recent declines in abundance and recruitment. The total abundance of blue crabs estimated in the Bay, based on the 2022 Winter Dredge Survey (WDS), was 227 million—the lowest estimate since the survey began in 1990. Although the blue crab population tends to exhibit natural fluctuations from year to year, the recent continued declines have caused concerns about the effects of changing environmental conditions on blue crab population dynamics and the suitability of the current stock assessment model.

The Chesapeake Bay Stock Assessment Committee (CBSAC), the blue crab technical workgroup within the Chesapeake Bay Program, hosted a workshop that brought together blue crab and other scientific experts to discuss Chesapeake Bay blue crab population dynamics and stock assessment to inform an upcoming benchmark stock assessment and analysis of population drivers. The workshop objectives were to:

1) Identify and discuss potential mechanisms, data needs and available sources, and analytical methods to better understand drivers of blue crab population dynamics in the Bay; and

2) Discuss the assumptions for the current blue crab stock assessment model and evaluate other options that could be incorporated into a benchmark stock assessment.

Workshop discussions identified priority research needs and data gaps that are essential for improving our understanding of blue crab population drivers and stock assessment modeling. These include analyses that quantify the relationship between blue crab abundance and various environmental factors (e.g., wind events, coastal freshwater flow, hypoxic volume/duration/distribution), predator abundances (e.g., blue catfish, red drum, striped bass), and habitat availability (e.g., seagrass, marsh). Better information about blue crab habitat use, movement, and juvenile abundance, and Bay-wide indices of predator abundance are needed to conduct such analyses. Effects of environmental factors, such as hypoxia, on key benthic prey (e.g., clams) could also provide a better understanding of blue crab population dynamics. Additional studies and analyses of blue crab brood production (e.g., number of broods per female, number of eggs per brood), sperm quantity and viability, and sperm:egg ratios were also suggested to address questions about population productivity in the Chesapeake Bay. Other research needs that would help inform the blue crab stock assessment model include factors that affect WDS efficiency (e.g., temperature, bottom type, amount of chain deployed) and the magnitude of mortality in the peeler fishery.

Based on the workshop discussions, CBSAC has advised that the focus of the new benchmark stock assessment should be the incorporation of a shorter time-step rather than an annual time-step. This would allow the stock assessment team to evaluate population and fishery parameters that are operating at a shorter temporal scale, including within-season changes in fishing mortality (F), the fraction of F that occurs prior to spawning, natural mortality (M) functions that vary by size or over time (e.g., Lorenzen, exponential), changes in size

distribution due to growth and fishing removals, and the variability in the start of spawning. Another important consideration is the stock-recruitment function. The stock assessment team first needs to work with managers to determine if reference points based on maximum sustainable yield (MSY) are appropriate; if they are, the team can then explore other options for the stock-recruitment function, such as size-structured models weighted by biomass or fecundity, or other functional forms of the relationship.

Other important parameters could also be reevaluated in the benchmark stock assessment using existing data. For example, sex ratios can be calculated from the various surveys around the Bay, and selectivity can be estimated from size composition data from each of the jurisdictions. Sensitivity analyses of M, F, sex ratios, and other key parameters should also be run to help with parameter estimation. The biggest hurdle in the new benchmark assessment will likely be WDS efficiency. To address this issue, the stock assessment team should consider developing a ratio estimator to rescale the WDS data, or treat the WDS as a relative index and allow the model to estimate catchability.

To address potentially important factors that influence blue crab population dynamics, CBSAC is interested in developing a Chesapeake Bay ecosystem status report or ecological risk assessment (ERA) in addition to the benchmark stock assessment. Factors of interest include hypoxia volume and duration, nursery habitat area (e.g., seagrass, marsh), predator abundance (e.g., blue catfish, striped bass, red drum), benthic prey abundance (e.g., soft-shell clams), and the fraction of females harvested in the spring, possibly before spawning. Tracking these factors over time could provide insight into correlations with blue crab population trends and potentially explain significant changes in abundance as seen in recent years.

Introduction

The Chesapeake Bay blue crab stock (*Callinectes sapidus*) is managed by three jurisdictions: the State of Maryland, the Commonwealth of Virginia, and the Potomac River Fisheries Commission. The Chesapeake Bay Stock Assessment Committee (CBSAC) is a technical workgroup within the Chesapeake Bay Program that identifies and prioritizes science needs, and reviews scientific studies and analyses that support blue crab stock assessment and inform management. The role of CBSAC is to provide the management jurisdictions with science-based advice for sustaining the blue crab population in the Chesapeake Bay.

In the last five years, the Chesapeake Bay blue crab population has experienced significant declines in abundance and recruitment. Abundance of juvenile blue crabs in the Winter Dredge Survey (WDS) has been declining since 2019, reaching an all-time low in 2021, and remaining low in 2022. Mature female abundance has also experienced a declining trend since 2017, falling to near-depleted levels in 2022, while the estimated abundance of adult males was the lowest since the WDS began in 1990. The total abundance of blue crabs estimated in the Bay based on the WDS was at an all-time low in 2022 at 227 million crabs. Given concerns about the low abundances in recent years, CBSAC has committed to addressing knowledge gaps related to blue crab population dynamics and identifying alternative modeling approaches to improve the stock assessment model.

To address these needs, CBSAC hosted a workshop with experts in blue crab science and fisheries management in September 2022. The workshop had two objectives:

1) Identify and discuss potential mechanisms, data needs and available sources, and analytical methods to better understand drivers of blue crab population dynamics in the Bay; and

2) Discuss the assumptions for the current blue crab stock assessment model and evaluate other options that could be incorporated into a benchmark stock assessment.

The purpose of these discussions was to identify analytical and other science needs to prioritize, and to inform an upcoming blue crab benchmark stock assessment. This report summarizes the key take-aways from the workshop.

Blue Crab Population Drivers

In addition to harvest, many factors play a role in blue crab population dynamics in the Chesapeake Bay including environmental factors (e.g., physical conditions, water quality), available suitable habitat, predator-prey interactions, and the intrinsic biology of the species (e.g., fecundity, disease). All of these factors can influence blue crab reproduction, distribution, growth, and survival, and consequently determine the abundance and recruitment of the population in a given year. Quantifying the relationship between each of these factors and blue crab abundance is an important data gap to address. This section summarizes the discussions about blue crab population drivers held at the workshop, including current knowledge about the

mechanism by which each factor affects the blue crab population, its relative importance, and if/how each factor could be addressed.

Environmental Factors

<u>Coastal conditions</u>

Coastal conditions such as wind and current patterns are important drivers of blue crab recruitment success in estuaries along the Mid-Atlantic Bight including the Chesapeake Bay. Shelf circulation driven by wind events and tidal flow entrains zoeae in coastal waters adjacent to the mouth of the estuary after spawning, where they undergo eight stages of development in high-salinity waters before being transported back into the estuary as megalopae. Favorable winds that result in upwelling, such as those out of the northeast, typically facilitate the ingress of larvae into the Bay in the fall. For example, in North Carolina, managers have observed strong blue crab recruitment signals in response to hurricanes and northeasterly winds. Particle tracking models have indicated that interannual variability in physical oceanic conditions can result in differences in megalopal recruitment success that vary by as much as an order of magnitude.

In addition to wind and tides, outflow from the Bay is another important factor that determines shelf circulation and, consequently, blue crab recruitment. Strong outflows of fresh water not only affect buoyancy-driven circulation, but can also reduce salinity on the coastal shelf. Blue crabs require a high-salinity environment during larval development, and freshwater intrusion in the coastal waters could negatively affect larval survival. More frequent and intense storms as a result of climate change could therefore significantly affect blue crab recruitment success, either by facilitating onshore transport of megalopae due to strong wind events, or by reducing larval survival and onshore transport due to high-precipitation events that result in a strong outflow.

CBSAC recommends continued investigation of the relationships between blue crab larval recruitment (or juvenile abundance) and coastal conditions such as wind events and freshwater outflow. This will involve identifying the appropriate spatial and temporal domains of survey data and the equivalent scale and magnitude oceanic conditions. Understanding these relationships and quantifying impacts could help managers explain variation in blue crab abundance and potentially inform a management response. These efforts become more important as climate change will likely alter the dominant relationships that drive the timing and magnitude of blue crab recruitment patterns.

<u>Hypoxia</u>

Summer hypoxia indirectly affects mortality rates of adult blue crabs in the Chesapeake Bay, likely by altering the behavior and distribution of individuals. Avoidance of low-oxygen areas in the deeper channels of the Bay can concentrate crabs in shallow waters where they are more susceptible to competition, predation (including cannibalism), and harvest. Crabs may also be more susceptible to disease during hypoxic events, either from increased stress in hypoxic

conditions that impair normal pathogen removal processes or from increased contact with conspecifics.

Studies have shown that blue crabs tend to avoid areas with dissolved oxygen concentrations <3 mg/L, but data gaps remain with respect to the population-level effects of avoidance behaviors and changing distributions. Little is also known about the overlap of hypoxia and critical blue crab habitats such as the spawning sanctuary, which could potentially affect female fecundity and spawning migrations. Given the wealth of oxygen data and models available, CBSAC recommends prioritizing analyses that quantify the relationship between hypoxia (volume and duration, or oxygen concentration) and blue crab abundance, recruitment, and harvest. While it may not be possible to incorporate hypoxia into the blue crab stock assessment at this time, it could be included as a factor in a Chesapeake Bay ecosystem status report or ecological risk assessment (ERA).

<u>Water temperature</u>

Water temperature directly regulates the seasonal life cycle and growth of blue crabs such that warming temperatures due to climate change could have significant effects on blue crab biology and ecology in the Chesapeake Bay. Currently, in the temperate latitudes of the Mid-Atlantic Bight, blue crabs undergo an overwintering period of metabolic torpor (i.e., suspended activity) that is initiated when water temperatures fall to around 10°C. Overwintering mortality significantly increases when temperatures drop below 3.4°C. Preliminary studies indicate that warming water temperatures in the spring dictate the timing of female spawning and migration.

Changes in the Bay's thermal regime would likely have competing consequences on the blue crab population. Increased water temperatures in the summer and fall would increase blue crab growth rates, allowing juveniles to reach size refuge quickly, but crabs would likely start to experience higher mortality rates at temperatures above 30°C. A longer duration of the growing season would also allow crabs to grow to bigger sizes prior to overwintering, but juveniles may be more susceptible to predation and cannibalism if seasonal predators linger in the Bay. Warmer winter temperatures would likely reduce overwintering mortality, but may also affect the efficiency of the WDS, which relies on the immobile state of buried crabs to estimate the population abundance.

Although temperature thresholds have been established in previous studies, additional modeling efforts are needed to better understand the population-level effects of increased temperatures on blue crab growth rates, mortality, fecundity, and timing of spawning. It may be possible to develop temperature-based models in the new benchmark stock assessment.

Habitat Availability

<u>Nursery habitat</u>

Structured habitats such as submerged aquatic vegetation (SAV) and marsh are important nurseries for juvenile blue crabs in the Chesapeake Bay, providing refuge from predators when

they reenter the Bay in the summer and fall. *Zostera marina* is the primary SAV species that is considered when discussing blue crab nursery habitats in the Bay, but other SAV species (e.g., widgeongrass, pondweed), macroalgae, and coarse woody debris can provide similar functions for juvenile crabs, particularly in the mainstem of the upper Bay and upper reaches of smaller tributaries where *Zostera* is absent. In Virginia rivers such as the York, high abundances of juvenile blue crabs have been found along marsh edges in areas of high turbidity, which indicates that marshes are also an important nursery habitat in this region.

Loss of nursery habitats due to climate change, sea level rise, and nutrient loading is a serious concern for the blue crab population. However, quantitative information about the level of blue crab production provided by the various nursery habitats is lacking. CBSAC is interested in understanding the relative importance of each habitat type (i.e., SAVs vs. marsh) for blue crab productivity, and the relationship between blue crab abundance and recruitment and total nursery habitat availability. Long-term data sets for these habitats are available and should be used to evaluate the functional form of the relationship in order to include nursery habitat availability in the stock assessment. While it may not be possible to incorporate habitat into the blue crab stock assessment at this time, it could be included as a factor in a Chesapeake Bay ecosystem status report or ERA.

Shoreline hardening

Shoreline hardening reduces the availability of natural, shallow-water foraging and refuge habitats that are important for mobile benthic species such as the blue crab. A recent study in Virginia identified a negative, monotonic relationship between percent hardened shoreline and juvenile blue crab abundance. Depending on the strength of this relationship Bay-wide, it is possible that increasing shoreline development could negatively affect juvenile abundance in the Bay. Percent hardened shoreline could be tracked and included in a state of the ecosystem report or ERA using the Center for Coastal Resources Management shoreline inventories for Maryland and Virginia. This would potentially allow for an examination of the correlations between shoreline hardening and blue crab abundance over the long term.

Predation and Prey Availability

Predation is an important component of population dynamics and is highly variable in time and space. The impacts of predation often vary by life stage, with smaller individuals (i.e., juveniles) being more susceptible. Many species eat blue crabs in the Chesapeake Bay, but this workshop focused on blue catfish (*Ictalurus furcatus*) and red drum (*Sciaenops ocellatus*), two finfish species that may increasingly affect the blue crab population due to changing environmental conditions. Availability of prey for blue crabs was also discussed as an important aspect of food web and population dynamics. In general, these factors are not likely to be incorporated into the upcoming benchmark stock assessment because Bay-wide abundance data for potential predators and quantitative estimates of predation are currently lacking. However, abundance of key blue crab predators and prey could be tracked over time in an ERA or ecosystem status report to provide some insight into correlations with blue crab population trends.

Blue catfish

Blue catfish are invasive generalist predators in the Chesapeake Bay and have recently become a source of concern for the blue crab population. Juvenile blue crabs in Virginia tributaries are abundant at the estuarine turbidity maximum (ETM) where blue catfish are also likely to occur. A recent study in the James River estimated that about 2.3 million blue crabs were consumed annually in a 199.2-km^2 study area, primarily by intermediate-sized (301-500 mm fork length) blue catfish. These results suggest that blue catfish predation could have a significant effect on the blue crab population, particularly on juvenile stages. However, the spatial limitations of the study and the lack of Bay-wide blue catfish abundance estimates preclude inferences of population-level impacts for blue crabs. CBSAC recommends additional research and analyses to quantify the abundance of blue catfish and juvenile blue crabs by tributary to better understand predation impacts in the Chesapeake Bay.

Red drum

Blue crabs are the primary component of the red drum diet in the northern Gulf of Mexico. Red drum typically forage in shallow-water habitats that juvenile blue crabs use as nurseries, such as marshes and SAV beds. Although red drum are not typically found in the Chesapeake Bay in high abundances, increasing water temperatures due to climate change may result in an increase in red drum presence, particularly in the lower Bay. However, red drum data in the Bay are sparse given that the current fisheries trawl surveys sample areas deeper than ~2 m in the Bay and its tributaries. Additional shallow-water surveys (e.g., gill nets, trammel nets) should be conducted to estimate red drum abundance and quantify predation impacts on the blue crab population.

Other species

Cannibalism is also an important component of blue crab population dynamics and is incorporated in the current stock assessment model via a Ricker stock-recruitment function. Other finfish species that CBSAC may want to consider evaluating for predation impacts on the blue crab population include striped bass (*Morone saxatilis*), speckled trout (*Cynoscion nebulosus*), Atlantic croaker (*Micropogonias undulatus*), and cobia (*Rachycentron canadum*).

Prey

Blue crabs are generalist predators that feed primarily on benthic invertebrates, particularly soft-shell clams (*Mya arenaria*). Although blue crab diet studies have shown food preferences, quantitative estimates of consumption at the population level are lacking. In addition to more comprehensive blue crab diet studies, CBSAC recommends tracking prey abundance indices to identify relationships with blue crab abundance.

Intrinsic Biological Factors

<u>Disease</u>

Several pathogens and parasites infect blue crabs in the Chesapeake Bay, including a highly pathogenic parasitic dinoflagellate (*Hematodinium perezi*), an egg-predatory nemertean (*Carcinonemertes carcinophila*), bacterial infections such as *Vibrio* spp., and several viruses, including *Callinectes sapidus* reovirus 1 (CsRV1). Most of the known parasites and pathogens have only had descriptive work, but a few (e.g., Hematodinium, CsRV1, Paramoeba) are known to occur in outbreaks or are highly endemic in the coastal bays of the Eastern Shore.

Hematodinium perezi has a low prevalence in the lower Bay, at about 5% in female crabs in the WDS. However, prevalence is very high in the coastal bays of the Eastern Shore, approaching 100% in juveniles in the fall. The pathogenicity and transmission of Hematodinium are highly affected by temperature, with temperatures of 4°C and 25°C causing significant mortality.

Carcinonemertes carcinophila is a symbiotic nemertean worm that feeds on the eggs of blue crabs, and ranges from the Gulf of Mexico to the Chesapeake Bay, and possibly farther north. Carcinonemertes can reach modest prevalence levels in the Chesapeake Bay, and at high intensity levels may affect blue crab productivity. Related species of nemerteans have impacted other crab fisheries through their high levels of egg predation.

Vibrio spp. are bacteria that are also highly prevalent in blue crabs and increase stress and mortality of individuals in captivity, such as shedding facilities, or in periods of high temperature. They are normally present at low intensities in crabs, but are opportunistic and can overwhelm crabs stressed by handling or rapid temperature fluctuations.

There are eight viruses reported from blue crabs. The reovirus CsRV1 is also commonly associated with high blue crab mortality rates in shedding operations. High water temperatures and hypoxic conditions tend to increase infection rates and mortality of blue crabs, which may suggest that disease will become a more important component of blue crab population dynamics as the climate continues to change. Although diseases are a known source of blue crab mortality, there are many data gaps that need to be addressed to better understand their role in blue crab population dynamics, particularly those in juvenile blue crabs moving from high-salinity coastal waters as they may disperse pathogens into the Chesapeake Bay.

<u>Sperm limitation and sex ratios</u>

In 2008, female-specific management regulations were implemented in the Chesapeake Bay blue crab fishery in order to improve stock productivity. Now, however, there are concerns that a male-targeted fishery may lead to sperm limitation by reducing the operational sex ratio (i.e., the ratio of mature males available to mate per maturing female that is ready to mate), such that males mate more frequently but transfer fewer sperm per mating event. When females receive fewer sperm per mating event, they must then store sperm for several months to several years before fertilizing broods of eggs. This can reduce the reproductive output of females, particularly

those that live to a second spawning season. In the Bay, sperm limitation has been estimated to reduce the reproductive output of the population by 5-10%. In Louisiana, where the blue crab fishery also targets males, sperm quantities were found to be an order of magnitude lower than those previously observed in other areas, suggesting limitations in brood production. However, the results of earlier studies in the Chesapeake Bay provided conflicting evidence for sperm limitation due to operational sex ratios. Additional studies of multiple brood production, sperm quantity and viability, and sperm:egg ratios are needed to better understand the potential influence of sperm limitation on the Chesapeake Bay blue crab population. CBSAC also recommends exploring the magnitude of the impacts of changing sex ratios in future simulation modeling.

Fecundity and spawning

Understanding fecundity is an important component to understanding blue crab population dynamics. Since females only mate once in their lifetime, overall fecundity is the result of the number of eggs per brood and the number of broods produced. Early research in the Chesapeake Bay has shown the number of eggs per brood to be a highly variable, size-dependent relationship. It is generally acknowledged that smaller females produce fewer eggs per brood. In North Carolina, female blue crabs have been known to produce up to seven broods over one to two spawning seasons, but this information is lacking in the Chesapeake Bay. Preliminary studies in the Bay indicate that female size-at-maturity is decreasing, with ovigerous females occurring at sizes <50 mm carapace width. Information on the number of broods produced per female in the Chesapeake Bay is a significant knowledge gap. Evidence of a decreasing female size-at-maturity in the Chesapeake Bay could suggest that the productivity of the population is decreasing. CBSAC suggests prioritizing research studies that aim to address data gaps related to blue crab fecundity and population productivity to better understand trends in abundance. It may be possible to model fecundity by size within the stock assessment.

Stock Assessment Model Assumptions

Stock assessments require assumptions to be made about the status and behavior of various population and fishery parameters. However, if these assumptions are inappropriate for the population, biased or inaccurate estimates can result, which can skew the perceived stock status. Evaluating alternative assumptions that could potentially improve the stock assessment model is a priority in the upcoming benchmark assessment. This section summarizes the discussions about stock assessment model assumptions held at the workshop, including the current assumptions and how they influence model estimates, alternative model structures or analyses, and if/how alternatives could be incorporated into the benchmark stock assessment.

Spawning Assumptions

Pre-spawning mortality rates

A critical assumption of the blue crab stock assessment model is the fraction of mortality that occurs before females have a chance to spawn and contribute to the population. The current model, which has an annual time-step, specifies that 60% of fishing mortality (F) and 50% of natural mortality (M) occurs between the time of the WDS, which starts in November, and spawning, estimated as July 1. In Virginia, the highest monthly harvest occurs in spring, and in recent years, there has been an increase in effort and harvest earlier in the season in certain areas of the lower Bay. This potential shift in harvest intensity could result in the removal of more females prior to spawning, which could decrease the reproductive potential of the population.

To assess shifts in fishing intensity and impacts on population productivity, CBSAC recommends incorporating sub-annual time-steps into the benchmark stock assessment. A monthly time-step could reflect what fraction of F occurs before spawning, and could model changes in size distribution due to growth and fishing removals. Sensitivity analyses for a range of pre-spawning mortality rates and harvest estimates could also be conducted in simulation models and in the stock assessment to better understand how those factors affect the productivity of the blue crab population and our understanding of the stock status. CBSAC also suggests tracking changes in the fraction of females harvested in the spring.

Timing of spawning

In the current stock assessment model, the abundance of spawning females is calculated as those that survive to July 1 each year. However, there is evidence that females are starting to spawn earlier in the spring as water temperatures warm faster. There are several data gaps that need to be addressed in response to shifts in blue crab phenology, including the potential mismatch in coastal conditions and larval ingress earlier in the year that could result in a recruitment loss, and the potential increase in population fecundity due to increased spawning duration and likelihood. Changes in the size of spawning females is also important to consider as those spawning earlier in the year may be smaller and therefore may produce smaller, less viable broods.

To address questions about population-level effects of shifts in spawning timing, variability in the start of spawning should be examined in models with a monthly time-step. Analyses of spawning timing and water temperature could likely be run in the benchmark stock assessment, but preliminary analyses of the data would be required to ensure that this exercise could be supported.

Stock-recruitment function

The current stock-recruitment model for Chesapeake Bay blue crabs assumes that: (1) the spawning stock is based on egg production and is therefore defined as the number of mature

females (age 1+); (2) spawning occurs July 1 after 60% of F and 50% of M occurs; (3) a Ricker function invokes density dependence using the abundance of all adult crabs (males and females age 1+) to address cannibalism of juveniles; (4) all density dependence occurs prior to the WDS; and (5) the start of the WDS is when age-0 crabs appear.

The Chesapeake Bay blue crab population shows a defined stock-recruitment relationship, and parameters can be estimated using abundance data from the WDS. The current stock assessment model uses stock-recruitment parameters to develop female-specific reference points based on maximum sustainable yield (MSY). The management jurisdictions could possibly adopt other reference points that would not rely on the stock-recruitment relationship if there are concerns about the reliability and appropriateness of the stock-recruitment relationship. Others have suggested that both male and female abundance should be included in the stock-recruitment function if sperm and egg limitations are unknown, as is the case in the Chesapeake Bay currently.

Given the concerns surrounding the stock-recruitment relationship, CBSAC recommends prioritizing the exploration of a range of stock-recruitment functions (as well as the removal of stock-recruitment functions) in the benchmark stock assessment. Another consideration would be to develop a size-structured spawning stock model to evaluate the different trends in spawning stock metrics. Recruitment could also be incorporated into the stock assessment model as a random walk that includes random effects and links to key environmental factors.

Winter Dredge Survey and Catch Estimate Mismatch

The biggest challenge with the current blue crab stock assessment model is tension in the model fits to survey and catch data. The current model cannot reconcile the sex ratio of the WDS and the catch. That is, with an assumed 50:50 sex ratio at recruitment, a higher male catch would suggest that there are fewer males in the Bay and fewer males should be caught in the WDS. However, on average, the model estimates that there are more males and fewer females present in the Bay than indicated by the WDS, even though male catch is higher than female catch. This discrepancy in the catch and abundance patterns is a primary issue that needs to be addressed in the upcoming benchmark stock assessment. Potential causes of this discrepancy include inaccurate estimates of WDS efficiency, sex ratio at recruitment, patterns in natural mortality, fishery selectivity, and catch. Each of these factors is discussed in further detail below.

<u>Winter Dredge Survey efficiency estimates</u>

The WDS is conducted by the Maryland Department of Natural Resources (MD DNR) and the Virginia Institute of Marine Science (VIMS) and is used to estimate an absolute abundance of blue crabs in the Chesapeake Bay. A catchability scalar is applied in the stock assessment to account for gear efficiency in the population estimates, but this catchability estimate could be a source of bias, particularly between the Maryland and Virginia surveys. Previous studies have examined catchability differences between Maryland and Virginia through depletion experiments and paired-tow comparisons. The most recent paired-tow studies suggest that the differences in

catchability are smaller than previously thought, but there are still data gaps about the effects of depth, bottom type (i.e., sand vs. mud), deployed dredge chain length, size- and sex-specific crab distributions, and changing environmental conditions (e.g., water temperature) on WDS estimates.

There are several ways the WDS efficiency estimates used in the blue crab stock assessment model could be addressed. Improving understanding of WDS catchability between Maryland and Virginia in various conditions through paired-tow sampling will continue to be a priority for CBSAC. CBSAC also recommends collecting more detailed information about dredge operations (e.g., amount of chain deployed, location), possibly using high-resolution sonar and/or cameras to track dredge deployments. In terms of stock assessment modeling, the stock assessment team could potentially rescale the WDS data using a ratio estimator, which would require a closer look at the data and the results of previous efficiency studies. A Vector-Autoregressive Spatio-Temporal (VAST) approach could also be used to model the spatial distribution of the blue crab population using the combined Maryland and Virginia WDS data. A final consideration would be to treat the WDS as a relative index of abundance and allow the model to estimate catchability.

Sex ratio at recruitment

In the current stock assessment model, the sex ratio of blue crabs entering the population each year is assumed to be 52:48, females to males. Evidence from the WDS, laboratory studies of blue crab brood production, and a field study in the York River all suggest that the sex ratio of crabs is approximately 50:50. It seems unlikely, therefore, that the sex ratio assumption is a major concern in the blue crab stock assessment model. However, this assumption could easily be addressed in the benchmark stock assessment by conducting the same evaluation as in the 2011 benchmark and calculating an empirical blue crab sex ratio estimate from the various surveys throughout the Chesapeake Bay.

Although there appears to be enough data to address the sex ratio assumption in the stock assessment, CBSAC recommends investigating the uncertainty in the sex data introduced by the visual inspection of crabs to determine the sex. In the Virginia portion of the WDS, a 15-mm size cut-off is used for sexing crabs; crabs <15 mm carapace width (CW) are considered "indeterminate" to avoid assigning the wrong sex to small, immature individuals. The Maryland WDS assumes a 50:50 sex ratio for blue crabs <12 mm CW. Inaccurate sexing and differences in sexing methodologies between Maryland and Virginia could introduce bias in the sex ratio estimates provided by the WDS. CBSAC also recommends examining the possibility that the sex ratio may change over time with changing environmental conditions such as warming water temperatures. Additional information is necessary to address this possibility.

Natural mortality rates

In stock assessment, natural mortality (M) estimates help scale the population size and determine the effect of fishing mortality (F) on a population. In the 2011 blue crab benchmark stock assessment, a constant M was implemented for all ages and sexes based on tagging

estimates of mature female crabs. However, if M actually differs between males and females, the assumption of a constant M could be causing the mismatch between WDS and catch estimates. Differences in distribution and habitat use of males and females across the Bay suggest that M may vary by sex, but more information is needed to determine if the magnitude of this potential difference is sufficient to cause significant bias in the stock assessment model. M also likely varies by age (i.e., size), as juveniles are typically more vulnerable to predation and poor environmental conditions.

To improve estimates of M in the blue crab stock assessment, CBSAC recommends implementing a shorter, monthly time-step and considering functions of M that vary by size and/or over time (e.g., Lorenzen, exponential). Density dependence is an important consideration for time-varying M. In addition to varying over time, M likely also varies in space based on habitat availability and environmental conditions such that incorporating a spatial component to the model would significantly improve population estimates. However, developing a spatial model would be time-consuming and would require movement data that are currently lacking. Therefore, in the upcoming benchmark assessment, CBSAC recommends that the stock assessment team focuses on building a population model with a shorter time-step before considering spatial components.

Prior to the benchmark assessment, sensitivity analyses of M can be run in the UMCES blue crab population simulation model, currently under development. Simulations of the stock assessment model can also be run to test the assumptions. An initial assessment of survey data could provide indications of changes in M over time. Ideally, auxiliary data (e.g., predation, disease) would be used to inform estimates of M. Given the difficulty of incorporating various external factors into the stock assessment that may affect parameters like M, CBSAC recommends tracking key factors in a Chesapeake Bay ecosystem status report or ecological risk assessment (ERA) to better inform management strategies.

Fishery selectivity

Although fishery selectivity does not seem likely to be a significant enough source of bias in the stock assessment model to account for the mismatch in model fits between the WDS and catch estimates, other options should be considered for developing selectivity parameters in the new benchmark stock assessment to improve the model. Potential options include: (1) incorporating length-based selectivity parameters based on management regulations; and (2) estimating selectivity using available size composition data from each of the jurisdictions. Estimating selectivity using jurisdiction data would be a substantial advancement in the blue crab stock assessment.

Catch reporting

Accurate catch reporting is an important component of the blue crab stock assessment model; if the catch data are biased, the model estimates will be biased, usually by a comparable amount. Detailed information about each jurisdiction's commercial harvest reporting procedures and efforts can be found in CBSAC's Blue Crab Harvest Reporting Document. Recreational harvest

is assumed to be 8% of the commercial harvest as estimated by both effort surveys and mark-recapture methods.

To improve the accuracy of the stock assessment, management jurisdictions should continue to collect effort and catch composition data to better understand the size and sex of crabs harvested across the Chesapeake Bay. Another key data gap is the magnitude of mortality in the peeler fishery. Currently, the number of crabs sold is reported, but not the number of crabs that die in the shedding facility, which suggests that removal estimates in the stock assessment may be low. Catch bias can also be evaluated in the benchmark stock assessment by running sensitivity analyses.

Research Needs and Data Gaps

The discussions at the blue crab workshop identified priority research needs and data gaps that need to be addressed to improve understanding of blue crab population drivers and stock assessment modeling. One of the primary research needs is to quantify relationships between blue crab abundance and environmental factors that may drive population dynamics. Specifically, CBSAC is interested in understanding relationships between: (1) larval/juvenile blue crab abundance and wind events and freshwater flow; (2) blue crab abundance and hypoxic volume and duration (or oxygen concentrations); (3) blue crab habitat use and hypoxia distribution; (4) blue crab prey abundance (e.g., clams) and hypoxic volume and duration; and (5) blue crab abundance/production and nursery habitat availability (e.g., SAV, marsh). To conduct these analyses, better information about blue crab habitat use, movement, and juvenile abundance in the Chesapeake Bay would likely be required. Additional shallow-water surveys focused on sampling juvenile blue crabs would be particularly useful as the WDS does not effectively sample smaller individuals.

In addition to environmental drivers, predation impacts are an important research gap that needs to be addressed to better understand blue crab natural mortality rates in the Bay. Workshop discussions suggested that the predation rates of blue catfish, red drum, and striped bass should be quantified, and correlations between population trends of these species and blue crab abundance should be evaluated. However, these analyses may prove difficult at this time given the lack of Bay-wide indices of predator abundance. Shallow-water fisheries surveys (e.g., gill nets, trammel nets) would help fill these data gaps and provide some of the information needed to assess predation impacts on the blue crab population.

There are also a number of unknowns about blue crab fecundity, sperm limitation, and population productivity that should be addressed to inform parameters in the stock assessment model. Studies and analyses of blue crab brood production (e.g., number of broods per female, number of eggs per brood), sperm quantity and viability, and sperm:egg ratios required for fertilization would help address questions about population productivity in the Chesapeake Bay. Other research needs that would help inform the blue crab stock assessment model include factors that affect WDS efficiency (e.g., temperature, bottom type, amount of chain deployed, vessel used), the proportion of spawning stock biomass harvested from November to June, variation in fishing effort, and the magnitude of mortality in the peeler fishery.

Stock Assessment Planning

Roles and Responsibilities

Chesapeake Bay Stock Assessment Committee

The Chesapeake Bay Stock Assessment Committee (CBSAC) is responsible for providing scientific support for management of the blue crab population in the Chesapeake Bay, and is therefore leading the overall coordination of the upcoming benchmark stock assessment. For the stock assessment, CBSAC will:

1) Provide general oversight of the stock assessment team;

2) Provide technical guidance on the terms of reference;

3) Support data compilation and pre-assessment analyses;

4) Collaborate with the stock assessment team to explore ways of including environmental and ecological factors into the assessment; and

5) Ensure that the peer review recommendations are adequately addressed.

Sustainable Fisheries Goal Implementation Team Executive Committee

The Executive Committee of the Sustainable Fisheries Goal Implementation Team (SFGIT) serves as the charging body of CBSAC within the Chesapeake Bay Program, providing general oversight of CBSAC tasks. For the upcoming stock assessment, the Executive Committee will:

1) Manage funding decisions and mechanisms;

2) Provide input and approve the terms of reference;

3) Identify the stock assessment team;

4) Develop and approve the peer review process; and

5) Review and approve the final stock assessment report.

Stock Assessment Team

The stock assessment team will take the lead in the actual stock assessment process and will consist of scientific experts in blue crab biology and fisheries management. The responsibilities of the stock assessment team will include:

1) Development of the stock assessment model;

2) Development of the stock assessment report and all related materials;

3) Presentation of the assessment to the peer review panel;

4) Addressing peer review comments as appropriate; and

5) Presentation of the final assessment results to the SFGIT.

Process and Timeline

Fisheries stock assessments tend to follow a standard process. The first step is to develop the terms of reference (TORs), or specific questions that the stock assessment will address. A TOR subcommittee consisting of CBSAC members and jurisdiction leadership will develop a draft of the TORs. The draft TORs will then undergo a technical review by all CBSAC members. The management jurisdictions will conduct a final review to approve the TORs. Once the final TORs are in place, the stock assessment team will be identified and CBSAC will hold a data workshop to compile and organize all necessary and auxiliary information that will/can be used in the benchmark assessment. This may also be an opportunity to review preliminary analyses. Once all the data are gathered and in the correct format, the stock assessment team will work on developing the stock assessment model, obtaining input from experts on CBSAC as necessary. The completed stock assessment will undergo a formal external peer review process conducted by NOAA's Center of Independent Experts (CIE). The stock assessment will be complete once all peer review comments are adequately addressed. Below is a general timeline for the blue crab benchmark stock assessment.

Blue Crab Benchmark Stock Assessment Timeline	
Subcommittee develops draft TORs	Feb. 15, 2023
CBSAC technical review of TORs	Feb. 22, 2023
Final TOR review/approval by jurisdictions	Mar. 1, 2023
Data workshop	June 2023
Stock assessment model development	Sep. 2023 - 2025
CIE peer review	Tentatively late 2025
Final stock assessment report complete	Tentatively 2025

Appendix I: Workshop Participants

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Commission

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Mike Wilberg
UMCES, Chesapeake Biological
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Rich Wong
DE Division of Fish and Wildlife

Dan Zapf
NC Division of Marine Fisheries

Appendix II: Workshop Agenda

Chesapeake Bay Stock Assessment Committee
Fall 2022 Blue Crab Workshop

September 20-21, 2022

Virginia Marine Resources Commission
380 Fenwick Road
Hampton, VA 23651

Webinar: https://meet.goto.com/503430373
Phone: 224-501-3412
PIN: 503-430-373

Purpose:
The purpose of this workshop is to bring together blue crab and other scientific experts to discuss Chesapeake Bay blue crab population dynamics and stock assessment to inform future work for CBSAC, including preparations for an upcoming benchmark stock assessment and analyses of population drivers.

Objectives:
1. Identify and discuss potential mechanisms, data needs, and analytical methods to better understand drivers of blue crab recruitment and abundance in the Chesapeake Bay.
2. Discuss the current model assumptions for blue crab stock assessment and evaluate other options that could be incorporated into a benchmark stock assessment.

Important Information:
- The format of this workshop is discussion-driven so please come prepared to participate and provide feedback on the topics listed in this agenda.
- We will be using online tools (Google Jamboard, Mentimeter) to obtain input and feedback so please bring a laptop or other internet-capable mobile device.
- This workshop will be recorded for internal purposes only.

Agenda

Day 1 - Tuesday, September 20

9:00am   **Welcome and Introductions**
               Pat Geer, CBSAC Chair (VMRC)
               Kristin Saunders, Workshop Facilitator (UMCES)

               Pat will introduce the Chesapeake Bay Stock Assessment Committee (CBSAC), provide the context for the workshop, and give an overview of the workshop purpose and objectives. Kristin will provide a brief overview of workshop logistics. Each participant will then have an opportunity to briefly introduce themselves.

9:30am   **Intro to the Blue Crab Population Drivers Session**
Mandy Bromilow, CBSAC Coordinator (ERT/NOAA)

For the remainder of the day, the group will discuss various drivers of blue crab population dynamics in the Bay with the goal of informing CBSAC's future analyses and potential incorporation into the upcoming benchmark stock assessment. These discussions will address the following topics for each factor:

- How the factor affects blue crab abundance and/or recruitment
- Potential mechanisms underlying this effect
- The temporal and spatial scales at which the factor affects the population
- Data required to evaluate the effects of the factor and potential data sources
- What inferences can be drawn from the available data
- How can management respond, if at all
- Feasibility of including the factor in the upcoming benchmark stock assessment

9:35am   **Environmental Factors Discussion**
Introduction by Alexa Galvan (VMRC)
Jamboard #1: https://tinyurl.com/362bjzx9

- Coastal currents and conditions
- Hypoxia
- Water temperature
- Other environmental factors

10:50am   **Break**

11:00am   **Habitat Availability Discussion**
Introduction by Rom Lipcius (VIMS)
Jamboard #2: https://tinyurl.com/yxpsa6mz

- SAV abundance
- Shoreline hardening
- Other habitat factors (e.g., marsh)

12:15pm   **Lunch** (provided)

1:15pm   **Predation and Prey Availability Discussion**
Introduction by Genine McClair (MDNR)
Jamboard #3: https://tinyurl.com/4rvuxjf3

- Blue catfish
- Red drum
- Other species to consider (e.g., striped bass)
- Prey availability

2:45pm   **Break**

3:00pm   **Intrinsic Biological Factors Discussion**
Introduction by Tom Miller (UMCES)
Jamboard #4: https://tinyurl.com/5n7r79nz

- Disease
- Sperm limitation and sex ratios
- Fecundity and spawning

• Any other factors to consider

4:30pm   **Wrap Up**
Pat Geer (VMRC), Bruce Vogt (NOAA)

The day will wrap up with a recap of the key discussion points about population drivers, and further feedback will be obtained from the group with several Mentimeter questions.

5:00pm   **Adjourn**

Day 2 - Wednesday, September 21

9:00am   **Day 2 Introduction**
Pat Geer, CBSAC Chair (VMRC)
Kristin Saunders, Workshop Facilitator (UMCES)

Kristin will provide a brief recap of key points from Day 1. Pat will review the context and purpose of the workshop and introduce the discussion topic for Day 2.

9:15am   **Intro to the Stock Assessment Model Assumptions Session**
Bruce Vogt (NOAA)

For the remainder of the day, the group will discuss various assumptions that are currently being made in the blue crab stock assessment model that could be causing issues in the model estimates. These discussions will address the following topics for each assumption/issue:

 • Mechanism by which the assumption influences model estimates
 • Links to factors discussed on Day 1
 • Alternative model structures and/or analyses
 • Data required to evaluate other model options and potential data sources

9:20am   **Spawning Assumptions Discussion**
Introduction by Glenn Davis (MDNR)
Jamboard #5: https://tinyurl.com/4znvu574

 • Pre-spawning mortality rates
 • Timing of first spawning
 • Stock-recruitment function

10:30am   **Break**

10:45am   *Continue discussions about spawning assumptions*

12:00pm   **Lunch** (provided)

1:00pm   **Mismatch Between Winter Dredge Survey and Catch Estimates Discussion**
Introduction by Mike Wilberg (UMCES)
Jamboard #6: https://tinyurl.com/yhdurna5

 • Winter Dredge Survey efficiency estimates
 • Sex ratio at recruitment
 • Natural mortality rates
 • Fishery selectivity
 • Catch reporting

2:30pm   **Break**

2:45pm   *Continue discussions about model estimate mismatches*

4:00pm   **Wrap Up**
Pat Geer (VMRC), Bruce Vogt (NOAA), Sean Corson (NOAA)

The workshop will wrap up with a recap of the major take-aways and a discussion about next steps for planning the benchmark stock assessment and additional analyses of population drivers, and the potential for a follow-up meeting.

4:30pm   **Adjourn**

Appendix III: Datasets and Resources

Dataset / Resource	Owner / Contact	Parameters	Spatial and Temporal Coverage
Abundance Data			
Abbe Blue Crab Pot Survey	MSU-PEARL Contact: Tom Ihde	- Blue crab catch, including juveniles - Sex and size - Survey allows estimates of relative abundance (CPUE), size frequencies, sex ratios, sponge crab frequency, and recruitment indices *Note: The following additional data exist, but are not yet available in a form to support analyses:* - Carapace length-weight subsamples (1980s-present) - Depth, water temperature, salinity, bottom DO	1969-present Biweekly sampling June-November 3 stations in the mainstem of Chesapeake Bay in southern Maryland; 10 pots (2'x2', 1" wire mesh) at each station *Not yet available to support analyses:* 2 additional stations in the Patuxent River (selected years between 1980s-2019)
Blue Crab Winter Dredge Survey (WDS)	MD DNR, VIMS Contact(s): Rom Lipcius (VIMS) Glenn Davis (MD DNR)	- Blue crab density (# crabs/1000 m^2) - Sex and size (age) - Survey allows estimates of abundance, overwintering mortality, etc. - Depth, water temperature, salinity, tow area for each station	1990-present ~1,500 randomly selected sites in waters >6 ft deep across Chesapeake Bay
Juvenile Fish and Blue Crab Trawl Survey	VIMS Contact: Mary Fabrizio	- Fish species identification, length, and count at each tow site - Habitat type (until 2012) - Invertebrates species identification, size, and count (horseshoe crabs, blue crabs, and	1960s-present 22 stations in the James, York (1956-present), and Rappahannock rivers are sampled each month year-round 39-45 stations in the

Dataset / Resource	Owner / Contact	Parameters	Spatial and Temporal Coverage
		penaid shrimp) - Hydrographic and station data including location, depth, tide, air/water temperature, weather conditions, salinity, and DO	Bay mainstem are sampled each month year-round except for Jan and March (1988-present) 17 stations in Mobjack Bay are sampled each month
Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP)	VIMS Contact: Rob Latour	Trawl: - Aggregate weights, counts, and individual length for each fish/invertebrate species size class - Species subsample includes length, weight, sex, maturity stage, ageing analysis, and stomach content analysis - Water quality - Atmospheric conditions - Hydrographic conditions - Habitat	2002-present March-November sampling Chesapeake Bay mainstem: 5 regions with 80 sites each
Maryland Blue Crab Summer Trawl Survey	MD DNR Contact(s): Glenn Davis Genine McClair	Otter trawl: - Crab count - Carapace width - Weight - Sex, maturity, molt stage - Catch per unit effort (CPUE) calculated for each size category as an index of abundance	1977-present Monthly sampling May-October 37 total sites in 6 rivers: Chester River, Patuxent River, Choptank River, Eastern Bay, Tangier Sound and Pocomoke Sound Auxiliary sites in Little Choptank River, Fishing Bay, and Nanticoke River added in 2002

Dataset / Resource	Owner / Contact	Parameters	Spatial and Temporal Coverage
Delaware Bay Trawl Survey	DE DFW Contact: Rich Wong	Trawl: - Species ID, count, and size	1978-present Monthly sampling April-October 40 stations in and around the Delaware Bay
Chesapeake Bay Long-Term Benthic Monitoring Program	Versar	- Species ID, biomass, and abundance of benthic species - Sediment analysis - Water quality - Benthic index of biotic integrity (B-IBI)	1984-present Chesapeake Bay and tidal tributaries
Northeast Area Monitoring and Assessment Program (NEAMAP)	VIMS Contact: Rob Latour	Trawl: - Aggregate weights, counts, and individual length for each fish/invertebrate species size class - Species subsample includes length, weight, size, maturity, aging analysis, and stomach content analysis - Water quality - Atmospheric conditions - Hydrographic conditions - Habitat	2008-present Spring and fall surveys Atlantic coast from Cape Cod, MA to Cape Hatteras, NC
Virginia Blue Catfish Electrofishing Survey	VDWR Contact: Margaret Whitmore	- Both high and low frequency surveys sample catfish - Length and weight (subset of age available for low frequency) - Temperature, conductivity, DO, salinity, turbidity, tidal stage, coordinates	Late 1990s-present Low frequency: James, Chickahominy, York, and Rappahannock rivers sampled periodically (all rivers every other year as of 2021) High frequency: James, Chickahominy, York, and Rappahannock rivers sampled periodically (every year as of 2021)

Dataset / Resource	Owner / Contact	Parameters	Spatial and Temporal Coverage
Maryland Blue Catfish Study	MD DNR, USGS Contact: Mary Groves (MD DNR)	Electrofishing: - Density estimates - Size - Diet info Acoustic telemetry: - Habitat use - Movement	2019-2021 Patuxent River
Maryland Adult Striped Bass Spawning Stock Survey	MD DNR Contact: Genine McClair	Gill nets: - Catch per unit effort (CPUE) - Age and length - Estimates size-at-age and sex ratio-at-age	1985-present Potomac River, Upper Bay
Virginia Game Fish Tagging Program	VIMS, VMRC Contact(s): Alexa Galvan (VMRC) Susanna Musick (VIMS)	- Size, date, and location of initial capture and any subsequent recapture - Some records note additional info such as if fish were caught in crab pots or regurgitated prey	72,000+ red drum tagged since 1995 Mostly tagged in VA, some tagging in NC prior to 2011
Maryland Charter Boat Logbook Survey	MD DNR Contact: Genine McClair	- Catch and release info for species of interest (e.g., red drum)	
Atlantic States Marine Fisheries Commission Species Stock Assessments	ASMFC Contact: Bob Beal	- Abundance and/or biomass estimates - Natural and fishing mortality estimates - Commercial and recreational harvest levels	Time span varies by species Atlantic coast including Chesapeake Bay
Structured Habitat Data			
SAV Survey for Chesapeake Bay and Delmarva Coastal Bays	VIMS Contact: Chris Patrick	Aerial photography: - SAV distribution and density class (%)	1978-present Chesapeake Bay mainstem and tributaries 93 segments grouped into four salinity zones

Dataset / Resource	Owner / Contact	Parameters	Spatial and Temporal Coverage
[Chesapeake Bay Shoreline Inventories for Maryland and Virginia](#)	VIMS	- Presence and condition of shoreline structures for shore protection and recreational purposes	Major tributary areas of Maryland and Virginia
[Virginia Shoreline Permit Data](#)	VMRC, VIMS	- Historical records for all tidal wetland Joint Permit Applications (JPA) in VA	VIMS: Prior to 2015 VMRC: 2010-present
Environmental Data, Models, and Tools			
[Chesapeake Bay Program Water Quality Database](#)	CBP	- Hydrographic profile - Water quality parameters (e.g., chlorophyll, N, DO, etc.)	1984-present Chesapeake Bay mainstem and tributaries
High Frequency Radar Data	Rutgers University Contact: Hugh Roarty	- Surface currents - Wave parameters	
[NOAA Climate Indices](#)	NOAA	- NAO	1948-present
[Chesapeake Bay Interpretive Buoy System (CBIBS)](#)	NCBO Contact(s): Jay Lazar CJ Pellerin	- Water/air temperature - Salinity - DO - Current speed/direction - Turbidity - Wind speed/direction - Chlorophyll A - Wave height/period - Barometric pressure	Currently 8 locations are active: Annapolis, Gooses Reef, Potomac, Stingray Point, York Spit, Jamestown, and First Landing Time series length varies by location
[National Water Information System](#)	USGS	- Streamflow - Water temperature - DO - pH - Conductivity - Turbidity	Parameters measured and time series length vary by site
[Eyes on the Bay](#)	MD DNR	- DO - Temperature - Turbidity	

Dataset / Resource	Owner / Contact	Parameters	Spatial and Temporal Coverage
		- Salinity - pH - Algal blooms	
[Virginia Estuarine and Coastal Observing System (VECOS)](#)	CBNERR, VIMS	- Water temperature - Salinity - pH - Chlorophyll - Turbidity - DO - Depth - Conductivity	Dataflow monitoring: Monthly cruises in each region of interest in the Bay Continuous monitoring: Shallow water, long-term, deployment duration depends on fouling Profiler monitoring: Deployed June-Sep in deeper regions of the Rappahannock and York rivers
[Chesapeake Bay Environmental Forecasting System (CBEFS)](#)	VIMS Contact: Marjorie Friedrichs	Nowcasts and short-term model forecasts: - Surface and bottom temperature, salinity, DO, alkalinity, pH, vibrio, and HABS	
ChesROMS Estuarine Carbon Biogeochemical Model	Contact: Marjorie Friedrichs	Hindcasts: - Temperature, salinity, velocity, water height, tides, Bay outflow, etc. - Oxygen, nitrogen, and carbon components, including inorganic carbonate chemistry variables)	1985-present Daily environmental info on a 600m grid throughout the Bay High resolution (120m) output available for VA tributaries
NOAA Chesapeake Bay Office Hypoxia Arrays	NCBO Contact(s): Jay Lazar Bruce Vogt	- High temporal resolution temperature, salinity, and DO vertical profiles	2 profilers deployed in the mid-Bay in spring 2022 More profilers to be added in the near future (up to 10)

Dataset / Resource	Owner / Contact	Parameters	Spatial and Temporal Coverage
[NOAA CoastWatch Data Portal](#)	NOAA Contact: Ron Vogel	Satellite imagery: - Surface temperature - Chlorophyll - Surface salinity - Ocean color - Altimetry	
[Environmental Research Division's Data Access Program (ERDDAP)](#)	NOAA	- Data server from which environmental data can be downloaded and graphs/map can be generated	
[MARACOOS OceansMap and Data Portal](#)	MARACOOS	- OceansMap: Data visualization tool using real-time observations and model forecasting - Wave/current data, wind speed/direction, water/air temperature, DO, pH, salinity, chlorophyll, animal locations and abundance	
Fishery Data (in addition to standard harvest report info)			
[MD DNR Cooperative Data Collection Program](#)	MD DNR Contact: Genine McClair	- Sex, size, and life stage of commercially harvested blue crabs	2002-present Weekly catch sampling by commercial crabbers throughout the harvest season Monthly catch sampling by MD DNR fishery biologists
PRFC Harvest Reports	PRFC Contact: Martin Gary	- Crab pot mortality info	
VMRC Fishery Sampling Program	VMRC Contact(s): Alexa Galvan Adam Kenyon	- Size composition of blue crab harvest	2016-2017

Dataset / Resource	Owner / Contact	Parameters	Spatial and Temporal Coverage
Peeler Fishery Mortality	UMCES-IMET Contact: Eric Schott	- May have info that would provide insight on blue crab mortality in the peeler fishery	