A pair of mating blue crabs, known as a "doubler," in a dip net in Kent Island, Md., on Aug. 27, 2010. (Photo by Alicia Pimental/Chesapeake Bay Program)

I.   Introduction

The blue crab (*Callinectes sapidus*) is an icon for the Chesapeake Bay region. The blue crab commercial and recreational fisheries are some of the most economically valuable fishery sectors in the Bay. Blue crab is also an important component of the Chesapeake Bay ecosystem. Sound management is critical to ensure the sustainability of this resource. The Chesapeake Bay blue crab fishery is managed by three jurisdictions: the State of Maryland, the Commonwealth of Virginia, and the Potomac River Fisheries Commission.

Jurisdictions and blue crab fishery stakeholders have recently explored tools, such as electronic harvest reporting protocols, to improve management of the fishery. The Blue Crab Management Outcome promotes continuing these discussions. Further, fishery managers and scientists continue to discuss possible timing and funding for the next benchmark stock assessment, which may present new data analyses and inform any changes to the current management.

II. Goal, Outcome and Baseline

This management strategy identifies approaches for achieving the following goal and outcome:

Sustainable Fisheries Goal

Protect, restore and enhance finfish, shellfish and other living resources, their habitats and ecological relationships to sustain all fisheries and provide for a balanced ecosystem in the watershed and Bay.

Blue Crab Abundance Outcome

Maintain a sustainable blue crab population based on the current 2012 target of 215 million adult females. Refine population targets through 2025 based on best available science.

Blue Crab Management Outcome

Manage for a stable and productive crab fishery including working with the industry, recreational crabbers and other stakeholders to improve commercial and recreational harvest accountability. By 2018, evaluate the establishment of a Bay-wide, allocation-based management framework with annual levels set by the jurisdictions for the purpose of accounting for and adjusting harvest by each jurisdiction.

Baseline and Current Condition

Abundance

The 2011 benchmark blue crab stock assessment recommended female-specific reference points with an abundance target of 215 million spawning-age (1+ years old) females as estimated at the completion of the annual Winter Dredge Survey. This target abundance is associated with a recommended target exploitation rate. The 2011 benchmark assessment also recommended a threshold, or "minimum safe level", of 70 million spawning-age female crabs. These reference points were developed and recommended based on widespread convention in fisheries management. The stock assessment recommended that reference points be specific to adult (age 1+) female crabs as they represent the spawning stock. The jurisdictions have been operating under these female-specific reference points since they were adopted in 2012.

Management: Allocation-Based Framework

The jurisdictions, with stakeholder input, evaluated the application of an allocation-based management framework, which refers to the development of one or more methods to allocate an annual total allowable catch (TAC) of female and male crabs for the Chesapeake Bay blue crab fishery among the three management jurisdictions—Virginia, Maryland and the Potomac River Fisheries Commission. A TAC is the total number/pounds of crabs that can be harvested by recreational and commercial fisheries in the Chesapeake Bay each year. Based on constituent feedback and management agency perspectives, the jurisdictions decided to maintain the current management approach, recommending not to implement an allocation-based framework.

III.   Participating Partners

The following partners have participated in the development of this strategy. A workplan to accompany this management strategy will be completed six months after this document is finalized. It will identify specific partner commitments for implementing the strategy.

Chesapeake Bay Watershed Agreement Signatories
- State of Maryland (management jurisdiction)
- Commonwealth of Virginia (management jurisdiction)
- Potomac River Fisheries Commission (management jurisdiction)
- National Oceanic and Atmospheric Administration (NOAA)
- Chesapeake Bay Commission

Key Participants

The Maryland Department of Natural Resources (MD DNR), Virginia Marine Resources Commission (VMRC), and the Potomac River Fisheries Commission (PRFC) are the management agencies for the Chesapeake Bay blue crab fishery. The management jurisdictions rely on established blue crab stakeholder advisory groups (listed in the next section) for input in the management process. The Chesapeake Bay Stock Assessment Committee (CBSAC) and the NOAA Chesapeake Bay Office provide scientific and coordination support to the management jurisdictions. CBSAC has met each year since 1997 to review the results of annual Chesapeake Bay blue crab surveys and harvest data, and to develop management advice for the Chesapeake Bay jurisdictions. CBSAC combines the expertise of managers and scientists from the Chesapeake Bay management jurisdictions as well as federal fisheries scientists. CBSAC presents their annual findings and recommendations in the form of an annual advisory report to the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team.

In addition to data analysis and management recommendations, CBSAC also provides research recommendations in their annual report. Targeted research is essential to better understand the blue crab population and fisheries.

Stakeholder Engagement

Stakeholders include commercial and recreational harvesters, the general public, and interested non-profit organizations. Each management jurisdiction actively engages commercial and recreational harvesters through established blue crab stakeholder committees and advisory groups, including the:

- Maryland Blue Crab Industry Advisory Committee
- Maryland Blue Crab Industry Design Team
- Maryland Sport Fisheries Advisory Commission
- Maryland Tidal Fisheries Advisory Commission
- Maryland Watermen's Association
- PRFC Crab Advisory Committee
- Virginia Marine Resources Commission Crab Management Advisory Committee
- Virginia Blue Crab Industry Panel
- Virginia Waterman's Association

IV. Factors Influencing Success

The Chesapeake Bay blue crab population and associated fisheries are impacted by a variety of ecosystem factors and natural variability in population dynamics. Many of these factors cannot be controlled or managed by the jurisdictions; instead managers and scientists rely on the best available data to understand the impacts of these factors and make informed management decisions.

The following are natural and human factors that influence the partnership's ability to attain this outcome. Harvest and fishery conditions were identified as high priority factors to consider since harvest and effort controls are regulated by the fishery management agencies. Regarding ecosystem factors that can affect blue crab abundance, habitat loss and predation were identified as high priority.

Harvest Impacts and Fishery Conditions

Blue crabs continue to support a valuable commercial and recreational fishery in the Bay. The blue crab fishery is complex, with multiple commercial and recreational gear types, various season lengths and regulations in three management jurisdictions. Fishing practices and the resulting harvest vary because of the complex ways crabs migrate and disperse throughout the Bay. Harvest regulations may affect fishermen in one area differently than in another area, and regulation changes can alter fishery impacts on the blue crab population. In addition to understanding Baywide fishing effort, knowing how harvest levels change from year-to-year and within each year is important to inform management decisions. Improving commercial and recreational harvest reporting would provide managers with an improved accounting of harvest and more complete information about the economics of the fishery.

Public Engagement/Comprehension

In addition to understanding harvest levels and improving reporting, ensuring the public understands regulations and is invested in a healthy blue crab population is important. Presenting data and uncertainty around exploitation rates in a concise way is something fishery managers consider when drafting the annual advisory report. Additionally, developing management triggers will better explain to stakeholders why certain management actions are taken.

Scientific and Technical Understanding

Resource managers make management decisions based on the best available data, and must make assumptions when data are unavailable. Key data gaps for blue crabs in the Chesapeake Bay include improved accounting of harvest and effort, summer abundance and spawning stock data, and estimates of juvenile abundance, recreational harvest and effort, non-harvest mortality (bycatch, discards, etc.), natural mortality, reproductive limitations and success and other factors. As managers begin to evaluate options for an allocation-based jurisdictional framework, the need to better understand the spatial distribution of exploitable stock and to receive timely and accurate harvest and effort data will become more important. Filling these data gaps would reduce uncertainty associated with management decisions. Availability of funding, coordination, and data analysis resources will affect how and when these data gaps can be addressed.

Government Agency Engagement and Coordination

Planning and implementing the next benchmark stock assessment will require coordination across jurisdictions. While the terms of reference have been selected, a lack of funding has prohibited the

completion of a new benchmark stock assessment since 2011. Coordinating with federal, state, and academic partners will be necessary to fund such an analysis.

Population Dynamics

The blue crab exhibits highly variable population dynamics, in part because of its complex life history during which different life stages occupy different habitats. Blue crabs produce many offspring in multiple broods released over two or more years, but survival of larvae in the ocean is unpredictable. Recruitment of young crabs into the Bay fluctuates widely from year to year, and is influenced by a variety of oceanic and climatic conditions that influence larval survival in the ocean waters and the ability of larvae to be transported back into the Bay via winds and currents. Larval abundance is also dependent on the abundance of spawning females although a high abundance of spawning age females does not guarantee consistently high reproduction. Once young crabs arrive back in the Bay, many factors continue to influence their survival, including:

- Salinity
- Temperature
- Overwintering mortality
- Habitat
- Predator and prey abundance
- Hypoxia
- Disease
- Climate Change

Ecosystem Factors

Environmental Variability

Seasonal variations in the physical oceanography of the system, stochastic environmental processes, and blue crab behavior all play key roles in population dynamics. Blue crabs spend the first month or more of their life as drifting planktonic larvae in the coastal ocean before migrating back into nursery habitats in Chesapeake Bay. Larval retention in coastal waters and post larval settlement in seagrass beds and other structured habitats depend upon seasonal oceanic flow, storm events (especially nor'easters and tropical cyclones) and current patterns. Tides, salinity, and other chemical cues also impact larval settlement. Timing of life history events is regulated by seasonal fluctuations in temperature. Larval settlement in the lower bay occurs in summer and fall, with dispersal of juveniles into nursery areas in fall. Small juveniles remain in shallow nurseries over winter, while larger juveniles and adults move into deeper water in channels and the main stem of the Bay to over-winter. Winter in Chesapeake Bay is a period of dormancy, with movement, feeding, and molting proceeding slowly if at all. Extremely cold winters can cause significant mortality of blue crabs in the Bay, especially in low salinity areas.

Habitat Loss

Juvenile and molting adult blue crabs obtain refuge from predation by use of key habitats that provide structural complexity or are inaccessible to predators. Loss of submerged aquatic vegetation (SAV) limits primary nurseries in the Chesapeake Bay and potentially affects blue crabs by concentrating recruiting individuals in limited nursery habitats. The unvegetated bottom adjoining salt marshes also provides crucial resources for juvenile blue crabs. The loss of shallow water

habitats along natural marshes and forested areas because of shoreline hardening has affected benthic communities and habitats in the nearshore areas. This results in loss of shallow-water refuge and benthic prey provided by marsh edges and other shallow habitats.

Predation and Prey Availability

Predation is a limiting factor on blue crab population size in Chesapeake Bay and affects population dynamics, survival, and reproduction. Predation varies seasonally, spatially, and among habitats and affects the smallest and earliest life history stages most greatly. The highest mortality from predation likely occurs during the larval stage when the blue crab larvae are outside the Bay in the ocean. Juvenile and adult blue crab mortality is contingent upon predation by a variety of finfish, birds and other species in the Bay. Cannibalism is also a major source of mortality, especially for juvenile crabs as their smaller size increases their susceptibility to cannibalism and predation. Limited habitat availability can concentrate blue crabs into smaller areas which also increases competition and cannibalism pressure.

Blue crabs feed on benthic prey that can be limited by environmental conditions such as long periods of severe hypoxia. Eutrophication, habitat alteration and abundance of crab competitor species impact benthic prey abundance and may limit availability to blue crabs.

Hypoxia

Hypoxia responses to low dissolved oxygen (DO) by blue crabs is determined in part by the severity of such events and the crab's tolerance to low oxygen levels. Hypoxic and anoxic zones have been increasing, due in part to nutrient loading from land-based sources, including an increase in impervious surfaces in the Bay watershed. Typically, blue crabs move out of deeper water affected by low DO and into shallow areas during hypoxia or anoxia. In doing so, they become more concentrated in the shallows and are more susceptible to fishing gear, density-dependent predation and agonistic interactions. Low DO may also interfere with the dispersal of juvenile blue crabs into the estuary and with mature females migrating to the mouth of the Bay to spawn.

Disease

Blue crabs are known to harbor a variety of pathogens that can be fatal to the crabs, but are not harmful to humans. *Hematodinium perezi* is commonly found infecting crabs during fall in high salinity areas of the lower Chesapeake Bay. In contrast, reo-like virus can be found Baywide and is often observed infecting crabs that die in crab shedding facilities. The effects of these and other diseases on the Baywide crab population remain poorly understood and potentially could make a large contribution to mortality in the fishery as well as affected ecosystems.

Climate Change

Climate change is predicted to have a wide range of effects on the blue crab in Chesapeake Bay, including blue crab mortality, habitat availability, and weather effects on recruitment dynamics. Temperature changes could affect the mortality rates of blue crabs during the winter and change the species assemblage of blue crab predators and prey in the ecosystem. Sea level rise and changes in temperature and salinity may affect the marsh, benthic and SAV habitats that serve as important blue crab nursery and foraging areas, but these impacts may be complex and difficult to predict as the correlation is highly variable and changes along with interactions between abiotic factors. With warming temperatures and changing precipitation, low DO areas are likely to increase in extent and

duration, which could reduce foraging resources and limit the available suitable habitat for blue crabs.

V. Current Efforts and Gaps

Stock Assessments and Annual Surveys

Currently, blue crabs are managed in a Baywide manner in which the jurisdictions work collectively to ensure that fishing levels stay at or near the established target. Blue crab management in Chesapeake Bay is guided by comprehensive stock assessments that are done approximately every five years. Stock assessments are mathematical analyses that combine the most recent information (catch and effort, survey data) on a given fishery to answer important questions about the health and management of the harvested species. Stock assessments inform managers about levels of fishing pressure that will ensure maintenance of a healthy population and provide guidance on the abundance of spawning-age animals necessary to ensure the population can sustain itself. A stock assessment also provides estimates of fishing pressure and stock abundance relative to the estimated benchmarks for a healthy population. These benchmarks are known as biological reference points. The most recent Chesapeake Bay blue crab stock assessment was conducted by scientists in 2011 from the University of Maryland Center for Environmental Studies, MD DNR, VMRC and the Virginia Institute of Marine Science (VIMS). The assessment was peer reviewed by international fisheries scientists from the Center of Independent Experts (CIE). CBSAC continues to consider the timing for the next benchmark stock assessment. Currently, both stakeholders and fishery managers are satisfied with the current management framework, but the 2018 Advisory Report identified opportunities to adjust management or incorporate new information. The development of male crab reference points is a potential topic that could serve as an impetus for the next benchmark assessment.

The annual Baywide Winter Dredge Survey is the only comprehensive Baywide survey designed specifically to estimate the number of blue crabs present in the Bay by gender and size class. The survey has been conducted since 1990 and takes place in winter when blue crabs are not highly mobile. The survey is the cornerstone of the periodic, comprehensive stock assessments and provides an annual measure of population health. Other efforts are ongoing to gather the best possible data about the blue crab population. Both MD DNR and VIMS conduct trawl surveys during the summer and fall. These surveys have been conducted annually since the 1970s and provide valuable ancillary information about growth and distribution of crabs in the Bay.

Management of the Chesapeake Bay blue crab fishery is informed by annual biological monitoring of population status and the annual exploitation fraction relative to the benchmarks (biological reference points) produced by the periodic stock assessments. An annual review of the blue crab population is conducted by CBSAC, which reviews the Winter Dredge Survey results, summer trawl survey data, and harvest estimates in order to assess the status of the blue crab population and exploitation using reference points, currently the female-specific targets and thresholds. This information is published in an annual Chesapeake Bay Blue Crab Advisory Report and Figures.

Harvest and Effort Data Reporting

High-quality harvest and effort data are essential for crafting effective and equitable management approaches, as well as for making decisions about jurisdictional allocation. As such, all Chesapeake Bay management jurisdictions have ongoing efforts to improve the quality of catch and fishing effort information submitted by commercial and recreational harvesters. Maryland, Virginia, and PRFC all require daily harvest reports to be submitted on a regular basis that include information on the water body fished, the gear type used, the amount of gear, sex and size specific harvest amounts, where catch was landed in and who the harvest was sold to. The three jurisdictions are also pursuing new reporting technologies and analyses:

Maryland

- In the past, the State of Maryland has conducted effort surveys which provide estimates of the number of pots deployed each month in Maryland waters. This survey, combined with data from the Maryland reference fleet (Cooperative Blue Crab Data Collection Program) which provides number of crabs caught per pot has allowed Maryland to quantify the magnitude of bias in harvest reports during the years when both surveys were conducted. The reference fleet provides valuable information about fishing effort, the biological characteristics of the catch, including size, sex, and life stage composition.

- The pilot electronic reporting system initiated by the Maryland Blue Crab Design Team in 2012 is ongoing through MD DNR. This system, called FACTS allows commercial crabbers to enter each day's harvest from their vessel and provides opportunity for roving monitors to meet crabbers as they arrive at the dock and verify the electronically reported harvest. This results in more timely, accurate, and verifiable harvest data that are essential for a robust stock assessment. Maryland has continued to expand the use of this system for the commercial crabbing and finfish fleet. In 2017, 275 (10 percent) active crabbers were reporting harvest in the system. Additional licensed, but non-active crabbers received 2017 permits to use the system. Seven percent of the finfish fleet is currently using FACTS.

Potomac River Fisheries Commission

- PRFC has explored several options for electronic reporting, but encountered fiscal and/or logistical challenges with most methods. Currently, the Commission is experimenting with a basic version of electronic reporting where the crabbers may submit their reports via e-mail. This is a first step that saves time and postage costs, but does not necessarily improve accuracy accountability or reduce potential false reporting.

Virginia

- Electronic reporting began in 2009 as an alternative mandatory harvest reporting option versus paper reporting, but growth has been slow. In recent years, the VMRC has worked with Virginia Sea Grant and various industry groups to promote VMRC online reporting interests, with special focus on the commercial blue crab industry. Through this cooperative work, an informational flyer, a visual guide and online tutorial were produced and the number of commercial crab harvesters participating has increased.

Gaps: Reduce Uncertainty

A key to improving fishery management is reducing the uncertainty in the data upon which management is based. Identifying areas of uncertainty and developing strategies to address them are ongoing priorities of the Chesapeake Bay blue crab management jurisdictions. The annual CBSAC Blue Crab Advisory Reports contain advice to the Chesapeake Bay management jurisdictions on priority areas of uncertainty. Currently, priorities are focused on studies that would reduce uncertainty in estimates of crab abundance generated by the Baywide Winter Dredge Survey. Specifically, the CBSAC has recommended work to acquire a better understanding of the effectiveness of the dredge gear at sampling crabs of various sizes in differing sediment types. The

CBSAC has also recommended that the jurisdictions continue to advance methods to improve the accounting of commercial harvest and to better understand recreational harvest in the jurisdictions. Understanding how harvest levels change from year to year and within each year will better inform management decisions. Reducing uncertainty leads to management improvements on all levels: more robust reference points that establish target levels of fishing and abundance and more accurate estimates of stock abundance.

In addition, blue crab management can be improved by assessments of the economic value generated by the commercial and recreational sectors of the fishery and how these are impacted by regulatory changes and stock fluctuations. In order to predict these impacts, it is necessary to understand how economic incentives interact with regulations and stock fluctuations to influence the supply responses of harvesters. Similarly, managers would need access to economic information in order to fully evaluate allocation in terms of economic efficiency and benefit. In collaboration with the industry, each jurisdiction may find a way to invite the various stakeholders in the fishery to voluntarily provide this economic information. Finally, given that maximizing economic welfare may not be the only consideration behind the management of the resource, understanding the costs associated with trading off economic benefits for alternative objectives will inform adaptive management decisions.

Aside from improving harvest data and understanding the economic value of the blue crab fishery, gaps still exist in our knowledge of the ecology of the species. Studies on seasonal oceanic flow, storm events, and current patterns are useful in determining larval retention in coastal waters and post larval settlement. Understanding how key habitats may change with climate and sea level rise, as well as variations in temperature and salinity, will help managers plan for a robust blue crab population in the coming years.

VI. Management Approaches

The jurisdictions with stakeholder input will work together to carry out the following actions and strategies to achieve the blue crab abundance and management outcomes. These approaches seek to address the factors affecting the ability to meet the outcomes and the gaps identified above.

Planning and Implementing the Benchmark Stock Assessment
Benchmark stock assessments are conducted approximately every five years to assess the blue crab population status and provide scientific advice to managers. Planning for the next benchmark stock assessment began during fall 2014, when the CBSAC discussed current available data sources and

research needs. From the results of the previous 2011 stock assessment model, a female-specific exploitation fraction and female-specific abundance reference points were developed. The next benchmark stock assessment will address specified Terms of Reference (TORs) that include management guidance for both female and male crabs for holistic management of this stock. Male and female reference points are important because of the differences in life history strategies between male and female blue crabs. Females migrate to higher salinity waters to spawn, while males remain in lower salinity waters.

The TORs have been finalized for the next benchmark assessment and they address specific needs of the Bay jurisdictions for future management, including management guidance for both male and female crabs, analyses specific to fishery sectors (recreational, commercial, gear-specific), an evaluation of available fishery independent survey data, and an analysis of the impacts of ecosystem factors on the blue crab population.

Cross-Outcome Collaboration and Multiple Benefits
More information can be found in the "Factors Influencing" section on pages 4-7.

- *Forage:* Understanding the status of the forage base will help determine the extent to which blue crab is prey for key predator species and how this contributes to blue crab mortality rates.
- *Climate change:* Monitoring and quantifying climate change impacts would help managers and scientists better predict the effects on blue crab mortality.
- *Fish Habitat and SAV:* Improving and/or protecting important habitats that blue crabs rely on will promote survival of blue crabs, especially juveniles that rely on habitats such as SAV for refuge from predators.
- *Water quality:* Improvements in water quality and decreased nutrient loading could improve suitable habitat available to blue crabs that are currently uninhabitable because of low dissolved oxygen levels from eutrophication.

VII. Monitoring Progress

The Winter Dredge Survey data result in estimates of blue crab abundance in the Chesapeake Bay each year. This abundance estimate is paired with harvest data from the management jurisdictions to calculate the percentage of the crab population that is removed by harvest each year. See the "Assessing Progress" section below for more detail on how these estimates are used to determine the status of the blue crab population.

VIII. Assessing Progress

Biological monitoring and assessing the progress toward the Blue Crab Abundance Outcome will occur through the CBSAC's annual review of blue crab survey data and through its annual determination of population status relative to biological reference points. In particular, the jurisdictions will closely monitor annual exploitation fraction estimates. It is the maintenance of the annual exploitation fraction at or near target levels that maximizes the probability of achieving and maintaining the target abundance level. The continuation of the annual Baywide Winter Dredge Survey will be essential for the

biological monitoring of the stock and for determining whether management changes are needed to maintain fishing at target levels.

It is anticipated that a new benchmark stock assessment will occur in 2018-19, pending identification of funding. If the new benchmark stock assessment recommends refined estimates of biological reference points (fishing levels and abundance) the jurisdictions will assess fishery performance relative to these new benchmarks.

Lessons Learned

As a result of preparing for the adaptive management process and reviewing our 2016-2017 workplan to assess our progress in achieving our goals, the Fisheries GIT noted that the funding for the five-year stock assessment and a lack of understanding of environmental impacts are current gaps which reduce our ability to achieve our outcomes.

Change to management approach: We solicited and received stakeholder input from the blue crab industry advisory committees on the possibility of instituting an allocation-based management framework. The responses received showed a lack of support for this management framework (concerns included difficult to implement and enforce, lack of necessary harvest data to support practical allocation, confidence in current management framework) and the jurisdictions will maintain the existing framework.

The last benchmark stock assessment was completed in 2011. A stock assessment was planned for 2016-2017 but a source of funding was not identified. In the future, a reliable source of funding will be needed. The stock assessment is important to evaluating the current reference points and refining annual analyses run by the Chesapeake Bay Stock Assessment Committee for the Blue Crab Advisory Report.

A new action was added to the workplan to respond to emerging research and management issues in the blue crab fishery, including:

- Evaluating how to present uncertainty around estimates of exploitation and how to present this information to stakeholders and managers
- Providing a technical review of "Ecological and Economic Effects of Derelict Fishing Gear in the Chesapeake Bay" to GIT Executive Committee
- Discussing options for developing blue crab management triggers

IX. Adaptively Manage

The jurisdictions with stakeholder input will use the following approaches to ensure adaptive management:

- The jurisdictions and CBSAC will continue to estimate the population of blue crabs by using the best available data and incorporating new data when available.
- Scientists who work on the benchmark stock assessments will continue to update stock assessment models and incorporate the best available data to address priority research and management needs.

■ Management jurisdictions with stakeholder input will discuss management response when female population abundance and/or the exploitation fraction do not fall within the boundaries of the established reference points.

X.   Biennial Workplan

Biennial workplans for each management strategy will be developed by March 2019. It will include the following information:

■ Each key action
■ Timeline for the action
■ Expected outcome
■ Partners responsible for each action
■ Estimated resources

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