2020 Chesapeake Bay Blue Crab Advisory Report

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Report Final: June 22, 2020

EXECUTIVE SUMMARY

The Chesapeake Bay Stock Assessment Committee (CBSAC) meets annually to review the results of the Chesapeake Bay blue crab surveys and harvest data, and to develop management advice. CBSAC adopted the Bay-wide Winter Dredge Survey (WDS) as the primary indicator of blue crab population health in 2006 because it is the most comprehensive and statistically robust of the blue crab surveys conducted in the Bay. Based on survey estimates, the total abundance of all crabs (males and females of all ages) was estimated at 405 million crabs in 2020. Recruitment, or the number of age 0 crabs (less than 60 mm or 2.4 inches carapace width), was estimated as 185 million crabs in 2020. Approximately 141 million age 1+ female crabs were estimated to be present in the Bay at the start of the 2020 crabbing season, which is above the abundance threshold of 70 million crabs, but below the target of 215 million crabs. The 2011 benchmark stock assessment recommended a control rule based on biological reference points for the female component of the population. The percentage of female crabs (ages 0+) removed by fishing (exploitation fraction) in 2019 was 17%. This exploitation fraction is below the target of 25.5% and the threshold of 34% for the 12th consecutive year since 2008. Therefore, overfishing is not occurring and the population is not depleted.

Based on analysis of the 2020 winter dredge survey results, CBSAC recommends that substantial changes in management are not necessary. CBSAC further recommends that the jurisdictions implement procedures that provide accurate accountability of all commercial and recreational harvest moving forward, as this is an important component for accurately accessing stock health.

1. INTRODUCTION

1.1 Background: Management and Science

Management of the blue crab stock is coordinated among the jurisdictions by the Chesapeake Bay Stock Assessment Committee, a workgroup of the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (SFGIT). Organized by the Chesapeake Bay Program and chaired by NCBO, the SFGIT is led by an Executive Committee of senior fisheries managers from MD DNR, VMRC, PRFC, the Atlantic States Marine Fisheries Commission, and the DC Department of Energy and Environment.

The Chesapeake Bay Stock Assessment Committee (CBSAC) combines the expertise of state representatives and scientists from the Chesapeake Bay region, as well as federal fisheries scientists from the National Marine Fisheries Service's Northeast and Southeast Fisheries Science Centers. This committee 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 Chesapeake Bay jurisdictions: the State of Maryland, the Commonwealth of Virginia, and the Potomac River Fisheries Commission (PRFC).

Three benchmark stock assessments of the Chesapeake Bay blue crab have been conducted since 1997. The most recent benchmark assessment was completed in 2011[1] with support from the Virginia Marine Resources Commission (VMRC), Maryland Department of Natural Resources (MD DNR), and the NOAA Chesapeake Bay Office (NCBO). The 2011 assessment recommended revision of the former overfishing reference point, which had been based on conserving a fraction of the maximum spawning potential (MSP), to one based on achieving the maximum sustainable yield (MSY; Table 1). The 2011 stock assessment recommended replacing the empirically-estimated overfished age 1+ (both sexes) abundance threshold and target with an MSY-based threshold and target based solely on the abundance of female age 1+ crabs. Female-specific reference points were formally adopted by all three management jurisdictions in December 2011.

CBSAC adopted the Bay-wide Winter Dredge Survey (WDS) as the primary indicator of blue crab population health in 2006 because it is the most comprehensive and statistically robust of the blue crab surveys conducted in the Bay[2]. The WDS measures the density of crabs (number per 1,000 square meters) at approximately 1,500 sites throughout the Bay. The measured densities of crabs are adjusted to account for the efficiency of the sampling gear and expanded based on the area of Chesapeake Bay, providing an annual estimate of the number of overwintering crabs by age and sex[2]. An estimate of the mortality during winter is also obtained from the survey results.

1.2 Stock Status and Current Management Framework

Under the current framework, annual estimates of exploitation fraction are calculated as the annual harvest of female crabs in a given year (not including discards, bycatch, or unreported losses) divided by the total number of female crabs (age 0+) estimated in the population at the start of the season. As part of this calculation, the juvenile component of the total estimated number of crabs is scaled up by a factor of 2.5 so that the empirical estimate of exploitation uses the same assumption about juvenile susceptibility to the survey as the stock assessment that generated the reference points. Thus, the empirical estimates of exploitation rate can be compared with the target and threshold reference points derived from the assessment model.

Crab abundance is estimated from the WDS each year. The current framework recommends monitoring the abundance of spawning-age female crabs (age 1+) in comparison to female-specific abundance reference points. Management seeks to control the fishery such that the number of crabs in the population remains above the minimum set by the overfished (depleted) threshold. Ideally, the fishery should operate to meet target values and should never surpass the exploitation fraction threshold value and never go below the abundance threshold value.

2. POPULATION SIZE (ABUNDANCE)

2.1 All Crabs (both sexes, all ages)

Based on survey estimates, the total abundance of all crabs (males and females of all ages) was 405 million (Figure 1). This was a decrease from last year's estimate of 594 million crabs, below the long-term average (geometric mean[1]), but near the median of observed values (400 million) over the last 30 years.

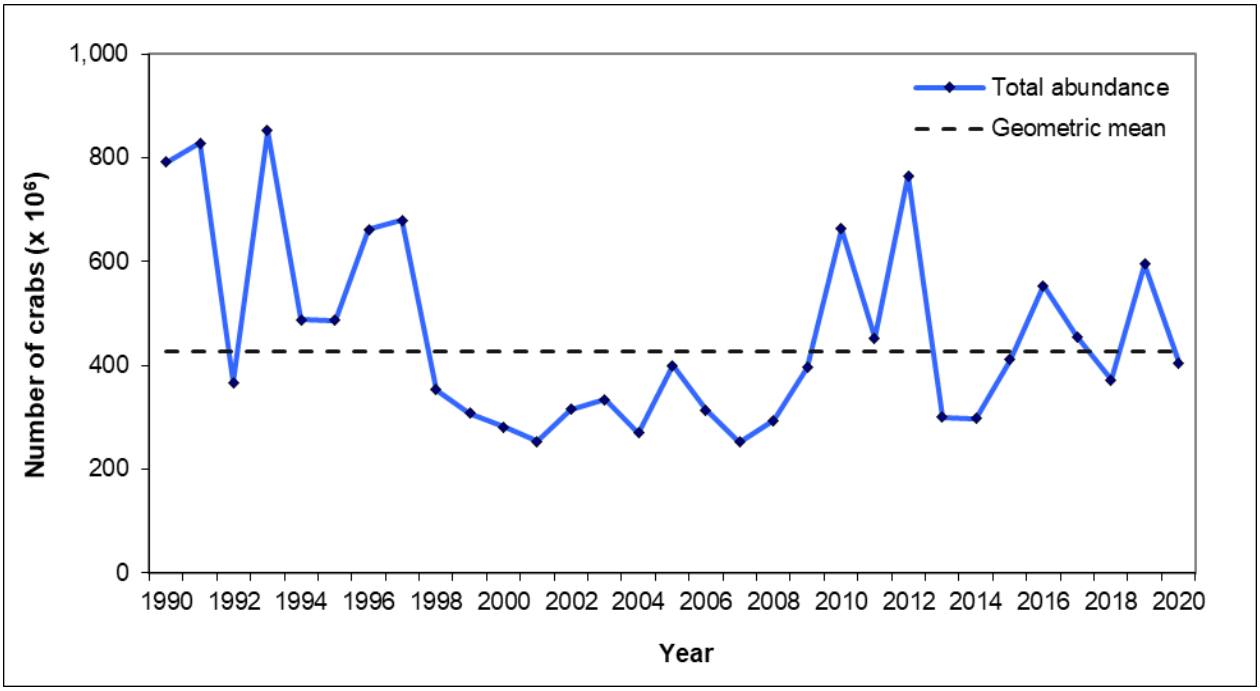

Figure 1. Winter dredge survey estimate of abundance of all crabs (both sexes, all ages) in Chesapeake Bay, 1990-2020.

2.2 Age 0 Crabs

Recruitment is estimated as the number of age 0 crabs (less than 60 mm or 2.4 inches carapace width) in the WDS. Based on survey estimates, the abundance of age 0 crabs in 2020 was 185 million, a decrease from the 2019 abundance of 324 million crabs (Figure 2). This year's estimate was below the time series average of 224 million crabs (geometric mean).

[1] A geometric mean ($GM_{\bar{x}} = \sqrt[n]{\sum x_1, x_2, \ldots x_n}$) was used because it is not as sensitive to fluctuation from a single large value.

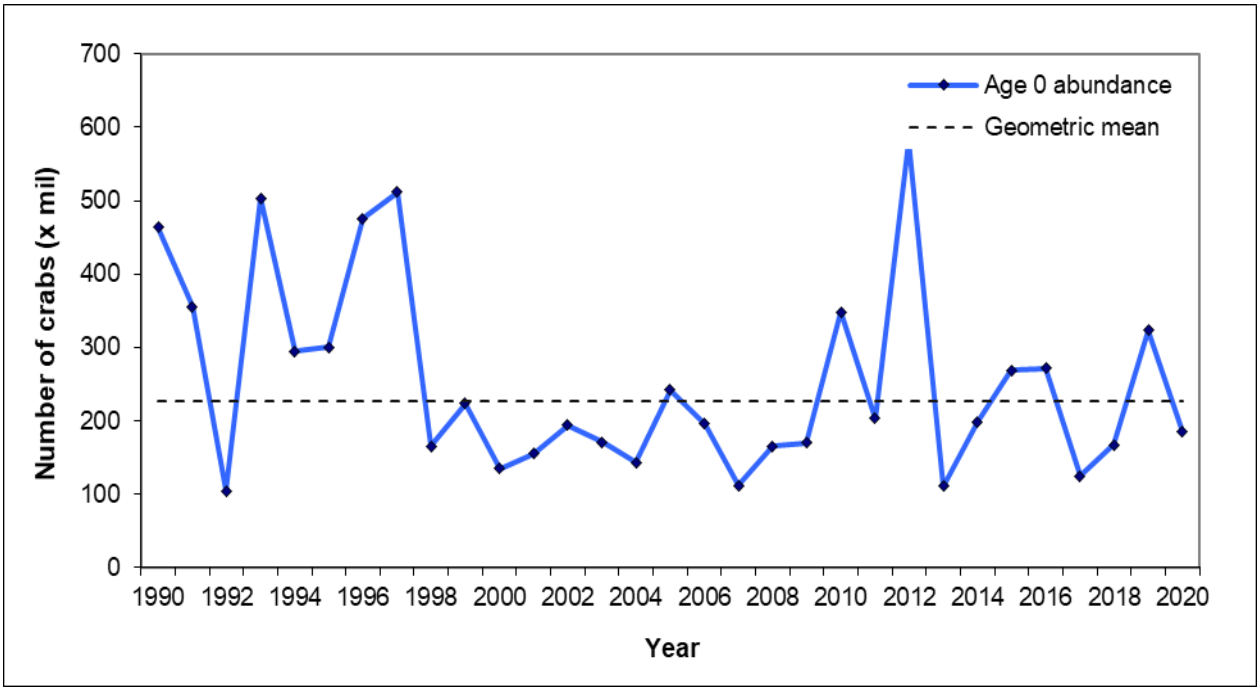

Figure 2. Winter dredge survey estimate of abundance of juvenile blue crabs (age 0), 1990-2020, calculated without the catchability adjustment for juveniles (section 1.2). These are male and female crabs measuring less than 60 mm across the carapace.

2.3 Age 1+ Male

The survey estimate of age 1+ male crabs (greater than 60 mm or 2.4 inches carapace width) in 2020 was 79 million crabs, almost unchanged from the 2019 estimate of 80 million adult male crabs (Figure 3). Age 1+ male abundance was above the time series geometric mean of 66 million, but does not exhibit the same amount of variation that has been observed in female abundance.

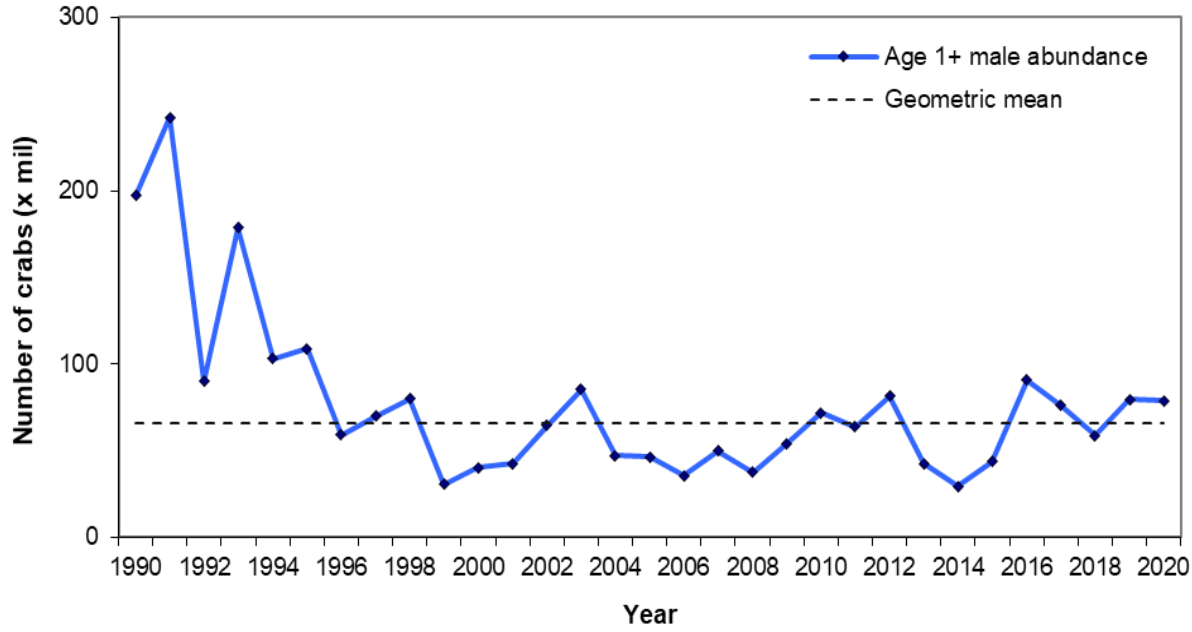

Figure 3. Winter dredge survey estimate of abundance of adult male blue crabs (age 1+), 1990-2020. These are male crabs measuring greater than 60 mm across the carapace and are considered the "exploitable stock" capable of mating within the year.

2.4 Overwintering Mortality

Overwintering mortality estimates in 2020 were the lowest observed in the time series (Table 1).

Table 1. Percent dead crabs found in late winter dredge samples each year from 2015-2020 and the average for 1996-2020.

Bay-wide Age/sex group	1996-2020 average	2015	2016	2017	2018	2019	2020
All crabs	4.53%	15.68%	1.95%	1.15%	6.37%	1.80%	0.36%
Juveniles	1.18%	10.84%	0.50%	0.00%	0.87%	0.15%	0.00%
Adult Females	8.07%	19.25%	2.99%	1.37%	11.06%	1.87%	0.47%
Adult males	9.29%	28.11%	1.06%	2.29%	13.66%	7.83%	0.78%

3. HARVEST

3.1 Commercial and Recreational Harvest

Chesapeake Bay commercial blue crab harvest rose slightly in 2019. The three management jurisdictions loosened harvest measures from those in place during 2018. The 2019 commercial harvest for both males and females from the Bay and its tributaries was reported as 32 million pounds in Maryland, 25.8 million pounds in Virginia, and 3.1 million pounds in the Potomac River. Relative to 2018, annual female harvest increased in all three jurisdictions, while male harvest was stable. The 2019 Bay-wide commercial harvest of approximately 61 million pounds was below the 1990-2018 average (Figures 4-5).

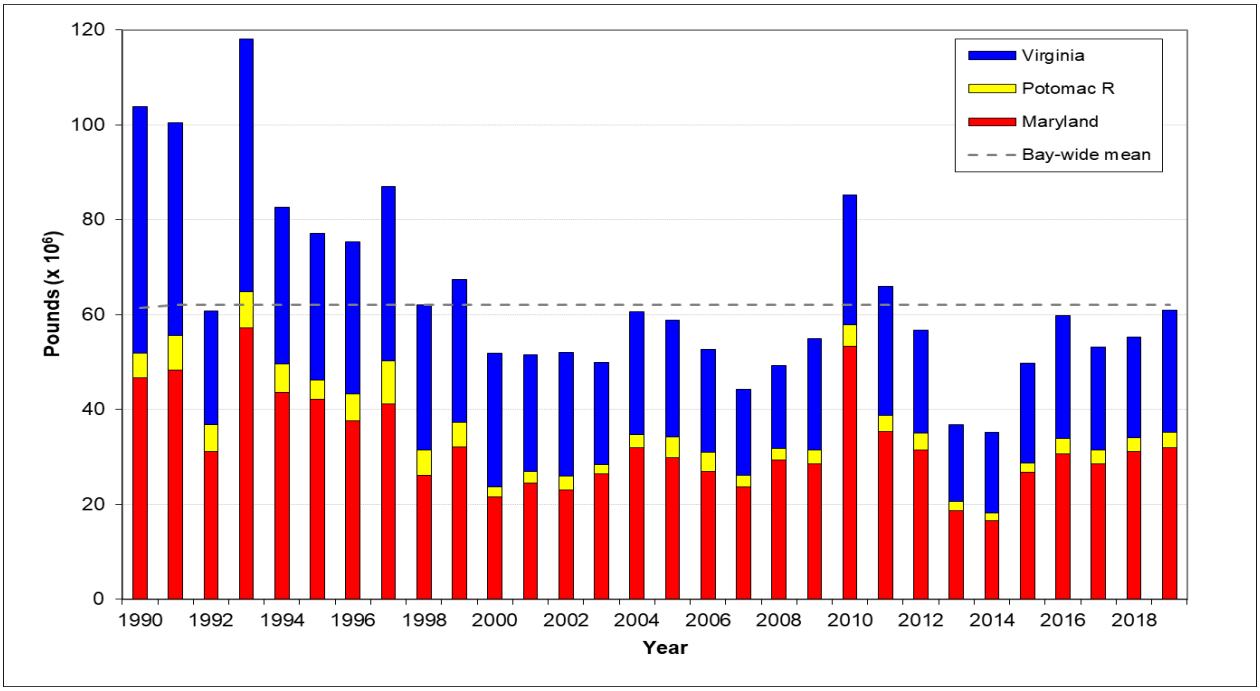

Figure 4. Total commercial blue crab landings (all market categories) in Chesapeake Bay, 1990-2019.

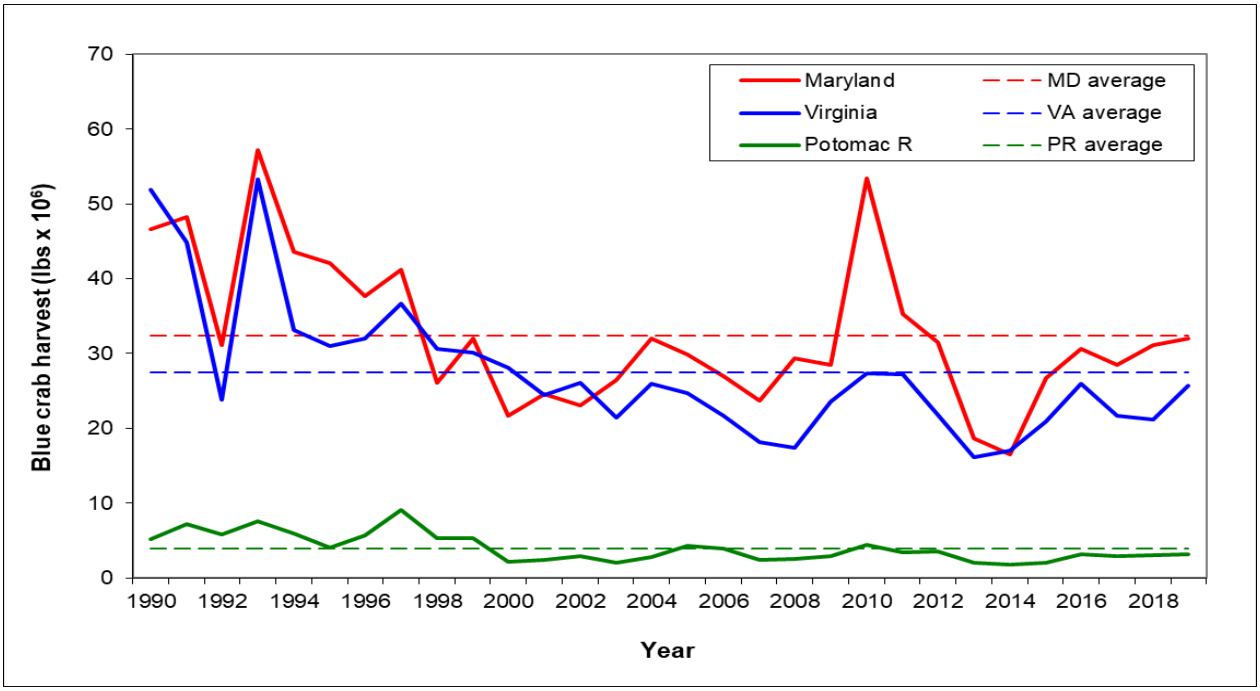

Figure 5. Maryland, Virginia, and Potomac River commercial blue crab harvest in millions of pounds from Chesapeake Bay (all market categories), 1990-2019.

Prior to 2009, recreational harvest had been assumed to be approximately 8% of the total Bay-wide commercial harvest.[4,5,6] Since recreational harvest of female blue crabs is no longer allowed in Maryland or in the Maryland tributaries of the Potomac River, recreational harvest is better described as 8% of commercial male harvest in those jurisdictions. Bay-wide recreational harvest in 2019 was estimated as 3.8 million pounds, similar to the 2018 recreational harvest estimate of 3.4 million pounds. Combining the commercial and recreational harvest, approximately 64.7 million pounds of blue crabs were harvested from Chesapeake Bay and its tributaries during the 2019 crabbing season.

4. STOCK STATUS

4.1 Female Reference Points

The 2011 benchmark stock assessment recommended a control rule based on biological reference points for the female component of the population. The current female-specific targets and thresholds were developed using an MSY approach. U_{MSY} is defined as the level of fishing (expressed as the percentage of the population harvested) that achieves the largest average catch that can be sustained over time without risking stock collapse. Following precedent adopted by the New England and Mid-Atlantic Fishery Management Councils, the 2011 assessment recommended a target exploitation level that was associated with 75% of the value of U_{MSY} and a threshold exploitation level set equal to U_{MSY}. The female-specific age 1+ abundance target and threshold were set accordingly at abundance levels associated with $N_{0.75*UMSY}$ (target) and 50% N_{MSY} (threshold).

4.2 Exploitation Fraction

The percentage of all female crabs (ages 0+) removed by fishing (exploitation fraction) in 2019 was approximately 17%. This exploitation fraction is below the target of 25.5% and the threshold of 34% for the 12th consecutive year since 2008, when female-specific management measures were implemented (Figure 6).

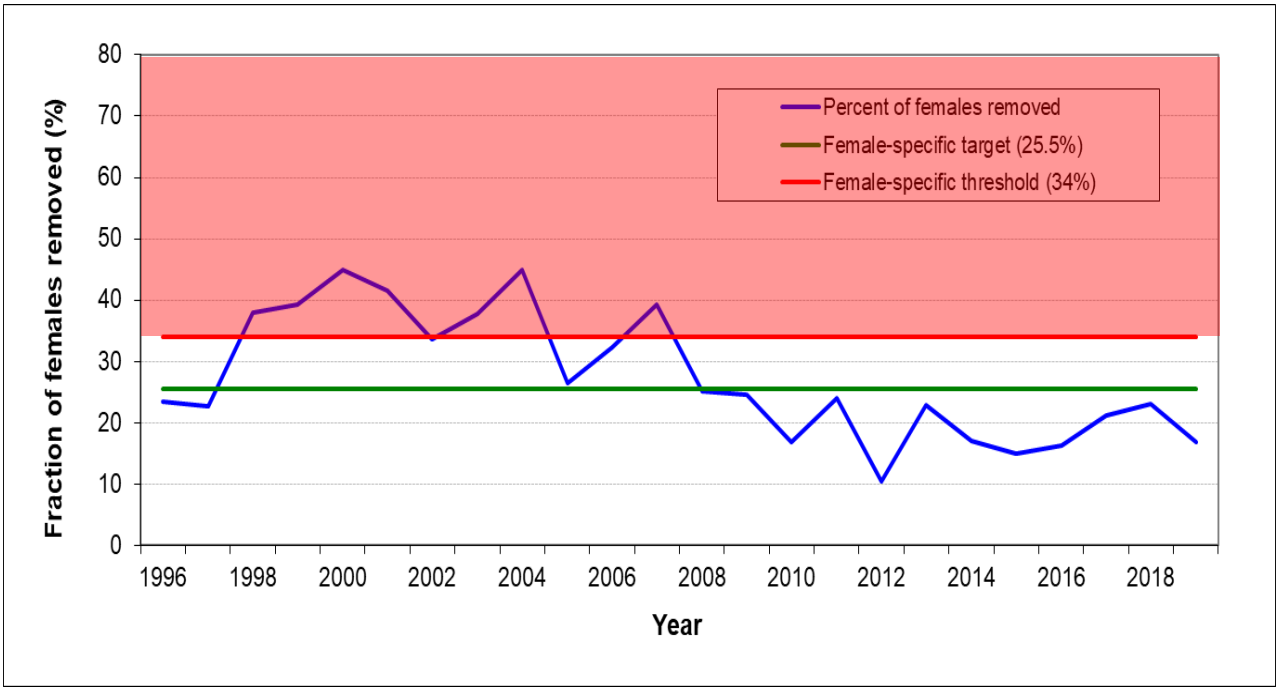

Figure 6. The percentage of all female blue crabs removed from the population each year by fishing relative to the female-specific target (25.5%) and threshold (34%) exploitation rates, 1990-2019. Exploitation rate (proportion removed) is the number of female crabs harvested within a year divided by the female population (age 0+) estimated by the WDS at the beginning of the year.

4.3 Spawning Stock Abundance

The abundance reference point for the spawning stock was set with a threshold abundance of 70 million spawning-age (age 1+) female crabs and a target abundance of 215 million. Approximately 141 million age 1+ female crabs were estimated to be present in the Bay at the start of the 2020 crabbing season. This was slightly below the average abundance since 2009 (after female-specific management measures were enacted), but much higher than the average abundance for the 14-year period preceding those measures (Figure 7). The 2020 abundance of spawning-age female crabs is above the threshold, but below the target.

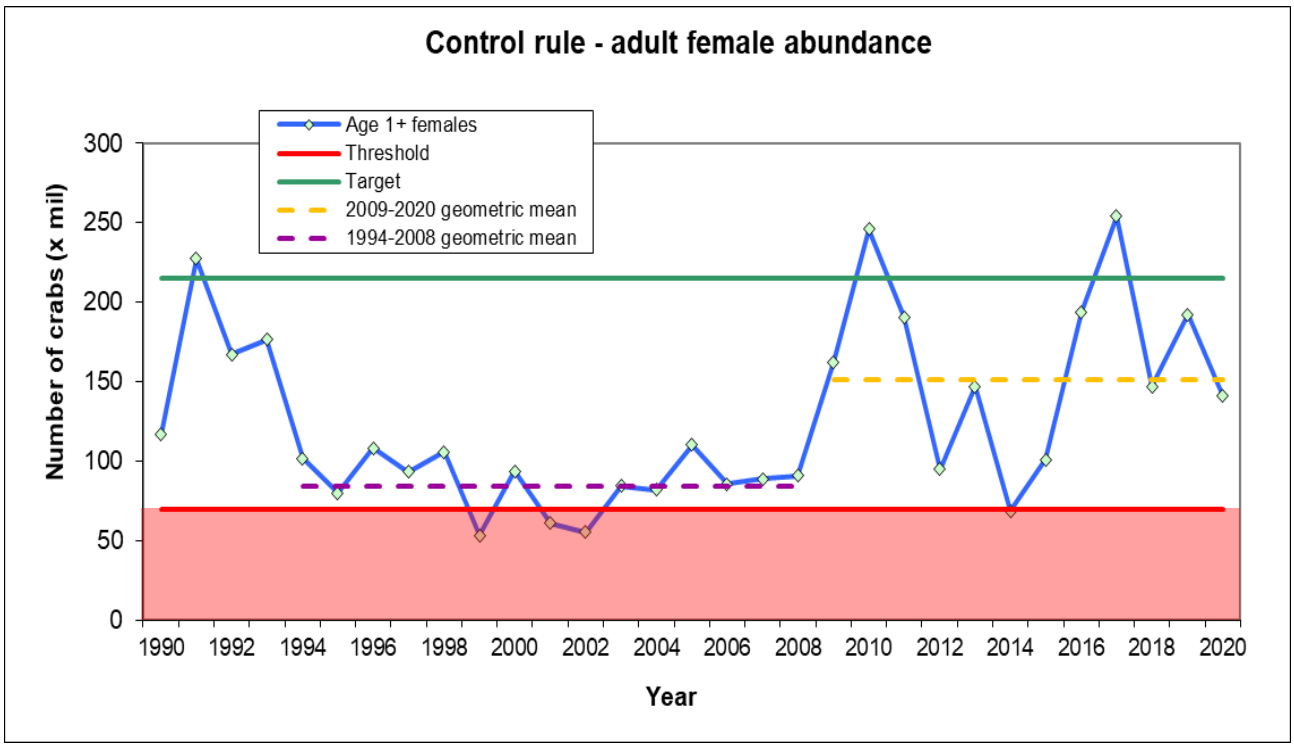

Figure 7. Winter dredge survey estimate of abundance of spawning-age female blue crabs (age 1+), 1990-2020, relative to female-specific reference points. These are female crabs measuring greater than 60 mm across the carapace and are considered the "exploitable stock" capable of spawning within the year. The dashed lines represent the geometric mean of adult female abundance during two time periods: 2009-2020, after the current management framework was enacted; and 1994-2008, the period of low abundance which prompted the management changes.

4.4 Stock Status

Figure 8 shows the status of the blue crab stock each year relative to both the female age 0+ exploitation (μ) reference points and the female age 1+ abundance (N) reference points (sections 4.2 and 4.3). The red areas show where the thresholds for the female exploitation fraction and/or female abundance are exceeded. The intersection of the green lines shows where both the abundance and exploitation fraction targets would be reached. The figure includes data through 2019; 2020 data will be added at the completion of the 2020 fishery.

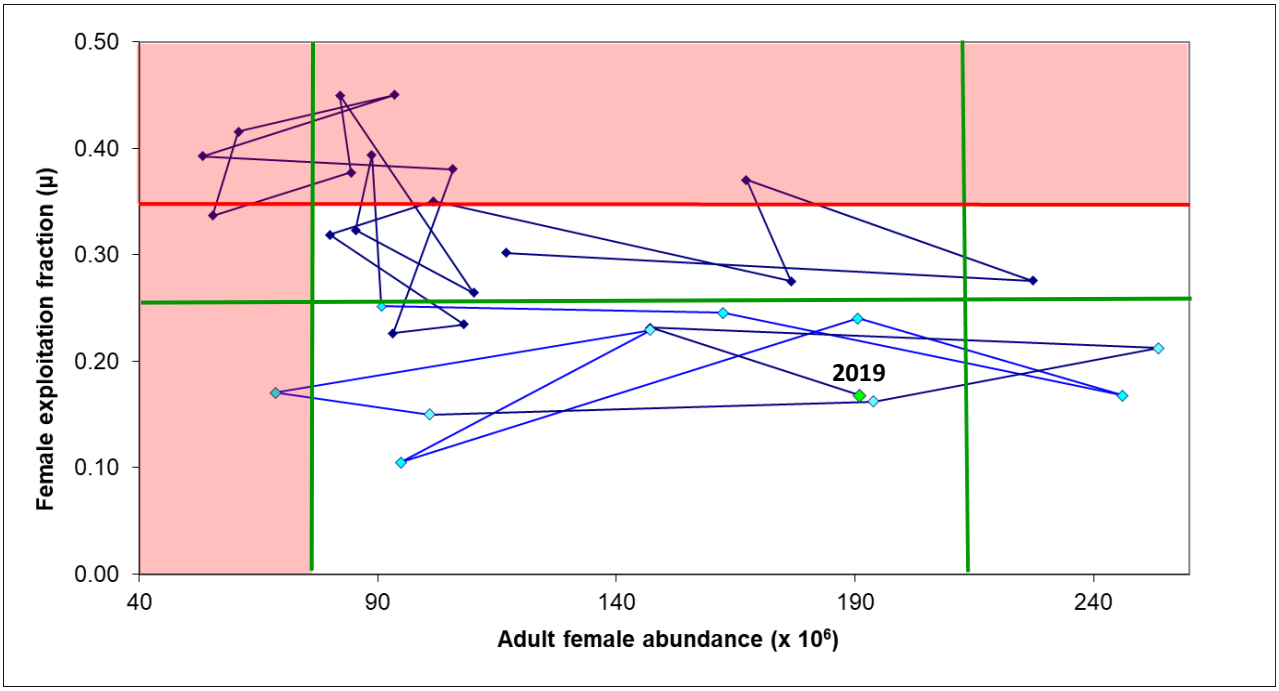

Figure 8. Status of the stock for the Chesapeake Bay blue crab fishery prior to and after implementation of initial female-specific management measures in 2008. The current female-specific management framework was formally adopted in 2011. In 2019, adult female abundance (N) was 191 million, which was below the 215 million target and above the 70 million threshold. The 2019 female exploitation fraction (U) was 17%, which was below the 25.5% target and 34% threshold.

The Chesapeake Bay blue crab stock is currently **not depleted and overfishing is not occurring** (Table 2). The 2020 estimated abundance of the spawning stock is above the threshold of 70 million age 1+ female crabs, but below the target of 215 million adult females, as outlined in the current management framework. The 2019 exploitation fraction of 17% was below the target (25.5%) and threshold (34%). Abundance, harvest, and exploitation of all crabs are summarized in Appendix A and in the preceding sections.

Table 2. Stock status based on reference points for age 0+ (exploitation fraction) and age 1+ (abundance) female crabs. Recent stock status levels that did not exceed threshold values are shown in green, whereas exploitation values or abundance estimates exceeding thresholds are shown in red.

Control Rule	Reference Points			Stock Status						
	Period	Target	Threshold	2014	2015	2016	2017	2018	2019	2020
Exploitation Fraction (age 0+ female crabs)	Current, Female-Specific	25.5%	34% (max)	17%	15%	16%	21%	23%	**17%**	TBD
Abundance (millions of age 1+ female crabs)	Current, Female-Specific	215	70 (min)	68.5	101	194	254	147	191	**141**

4.5 Male Conservation Trigger

In 2013, CBSAC recommended a conservation trigger for male blue crabs based on the history of male exploitation. Under this trigger, conservation measures should be considered for male crabs if the male exploitation rate exceeds 34% (calculated with the juvenile scalar as described in section 1.2), which is the second-highest exploitation fraction observed for male crabs since 1990. Choosing the second-highest value in the time series ensures a buffer from the maximum observed value of exploitation. It should be noted that this value does not represent a fishing threshold or target. Rather, this trigger will ensure that the male component of the stock is not more heavily exploited than has occurred in 24 of the last 26 years. The 2019 male exploitation fraction was estimated at 18%, below the male exploitation rate conservation trigger (Figure 9). No further management action is needed at this time.

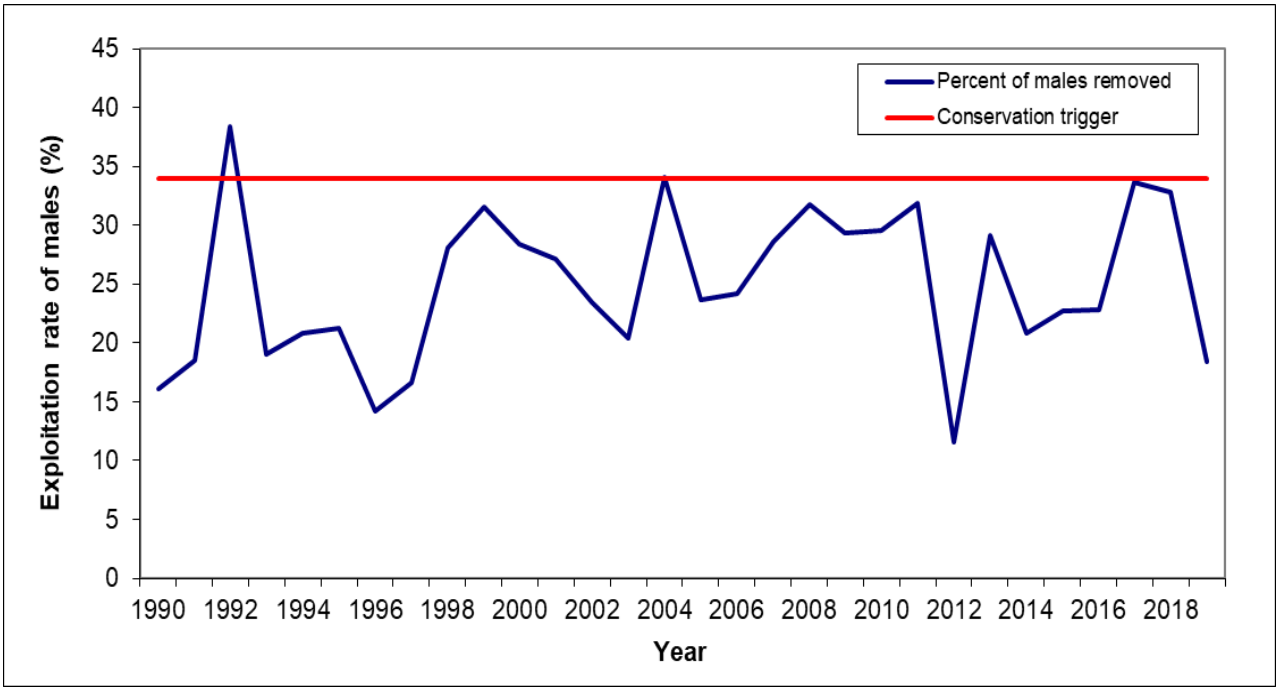

Figure 9. The percentage of male crabs removed from the population each year by fishing, 1990-2019. Exploitation rate (proportion removed) is the number of male crabs harvested within a year divided by the male population estimate (age 0+) at the beginning of the year, calculated with the juvenile scalar.

4.6 Potential Management Impact

Female exploitation fractions from 1990-2007 were much higher than the exploitation fractions from 2008-2019. These lower female exploitation fractions in recent years illustrate the influence of the female-specific management measures implemented by the jurisdictions starting in 2008. Male exploitation fractions have not shown the same pattern (Figure 10). Additionally, the rapid increase in female abundance from 2008-2010, and again from 2014-2016, indicate that the current management framework has allowed the stock to regain some of its natural resilience to environmental changes.

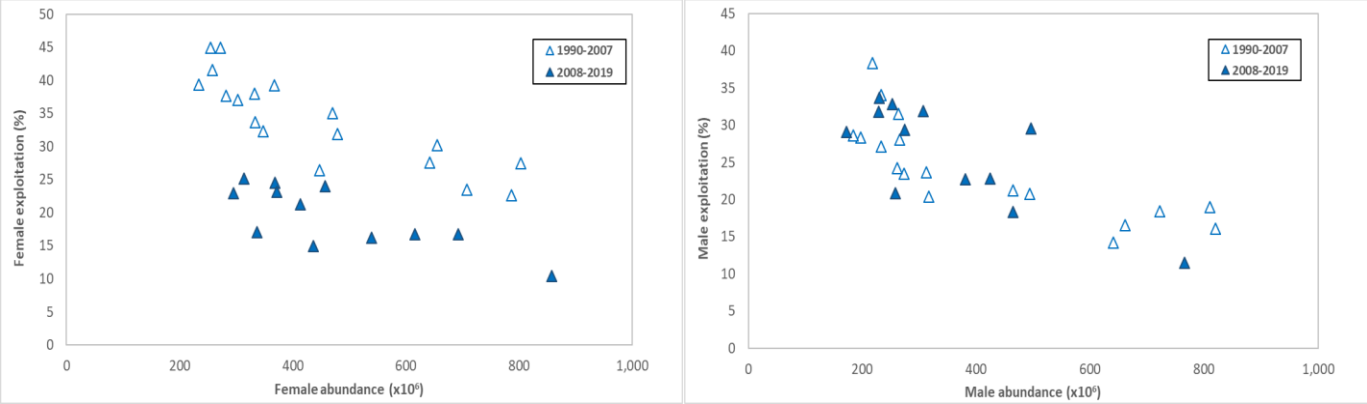

Figure 10. Female (left) and male (right) exploitation rate comparison of the time periods prior to and after the 2008 implementation of female-specific management measures.

5. MODEL UPDATE

After an update to the 2011 benchmark assessment was completed in 2017[x], CBSAC decided that annual model updates should be conducted to determine the status of the stock, monitor model performance, and help guide the decision process for timing of the next benchmark stock assessment.

Input data for the model included each jurisdiction's commercial landing reports, the Bay-wide winter dredge survey, VIMS trawl indices, and MD DNR trawl indices. The model update used the same methodology set forth by the 2011 benchmark stock assessment. The population and fishery parameters incorporated into the model – natural mortality, recruitment sex ratio, fraction of juveniles recruited to the fishery, recreational harvest fraction – were also the same. No changes were made to the sex-specific catch, multiple survey analysis (SSCMSA) model.

Among the model outputs were estimates of female abundance, female exploitation, and harvest and biological reference points. Temporal patterns for all estimates were similar for all three runs of the SSCMA model – the 2011 benchmark assessment, the 2017 update, and the current update.

Both the female abundance and exploitation reference points were slightly lower for the most recent model run than in 2017 (Table 3). Relative to the 2011 benchmark assessment, both the 2017 and 2019 updates produced lower target abundance and higher target and threshold exploitation.

Table 3. Biological reference points from the three runs of the SSCMSA model – the 2011 benchmark assessment, the 2017 update, and the current update. The abundance reference points are for adult female crabs (millions of crabs); the exploitation reference points represent the fraction of female crabs (age 0+) removed from the population by the fishery.

	Abundance		Exploitation fraction	
	Target	Threshold	Target	Threshold
2011 Assessment	215 mil	70 mil	25.5 %	34%
2017 Update	196 mil	72.5 mil	28%	37%
2019 Update	191 mil	70 mil	27%	36%

The updated model-generated estimates of female abundance exhibited the same pattern as previous runs, and has underestimated abundance since 2015 (Figure 11).

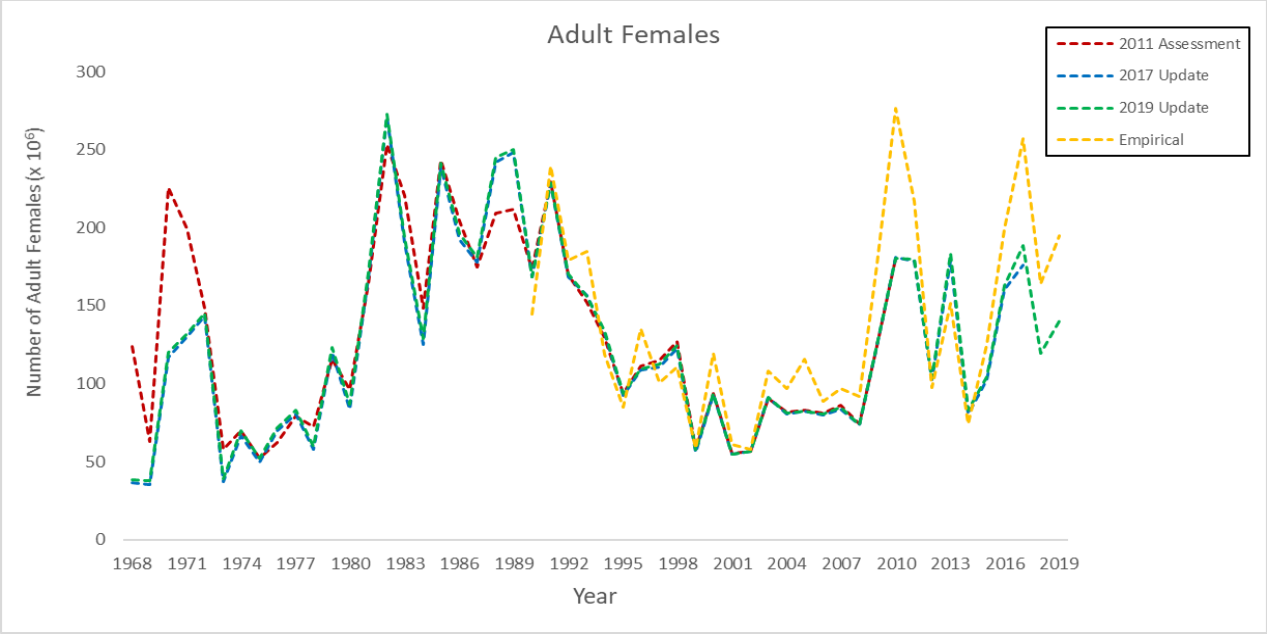

Figure 11. Time series of abundance estimates for adult females (age 1+), as predicted by the base runs of the SSCMSA in 2011, 2017, and 2019.

Model estimates of female exploitation continued to be in agreement and have been nearly identical since 1995. Between 1999 and 2009, there were, sometimes, large differences between model estimates of exploitation and empirically-estimated values (Figure 12). Since 2010, both time series have been in agreement.

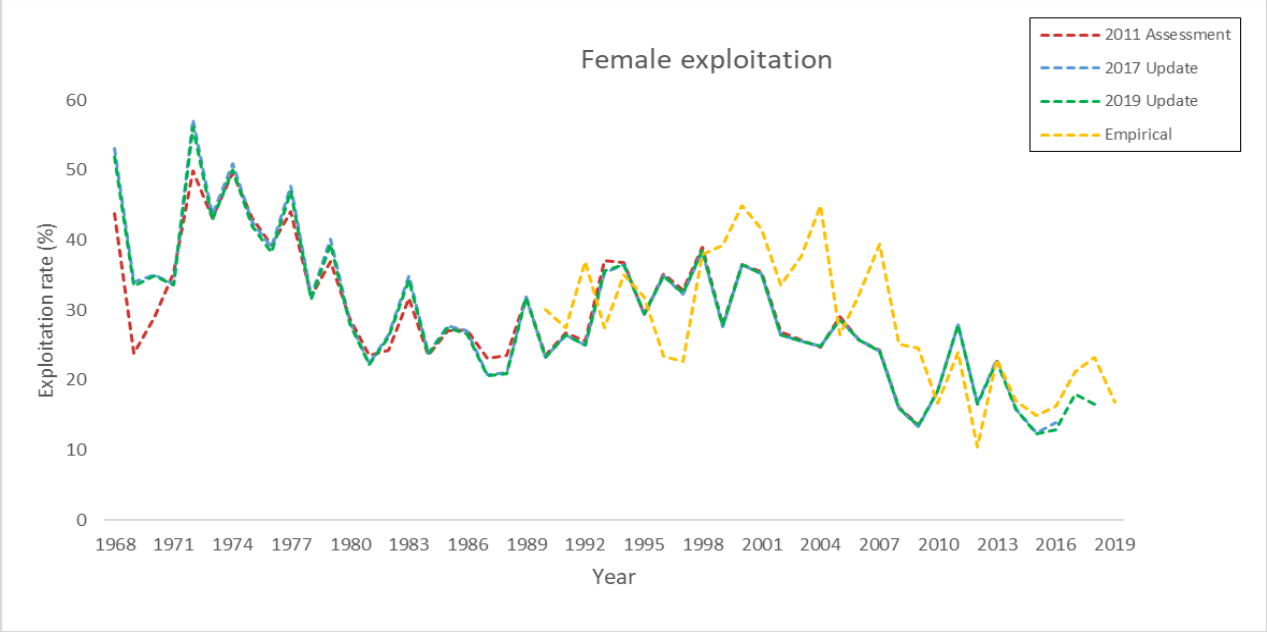

Figure 12. Time series of female exploitation rate estimates, as predicted by the base runs of the SSCMSA in 2011, 2017, and 2019.

Despite the general agreement in the model estimates across all three runs, there is still tension in the model's ability to fit estimates of sex-specific harvest to reported harvest, as the model continues to underestimate female harvest and overestimate male harvest. Therefore, model improvement should continue to be a CBSAC priority.

Given the updated biological reference points, the fishery has been operating under the exploitation target since 2005 and has not exceeded the threshold since 2001. Adult female abundance has not reached the target since 1991 and has not been below the threshold since 2002. Model-estimated adult female abundance in 2018 was 119.5 million, while exploitation was estimated to be 16.6%. Female harvest in 2018 was estimated to be 76 million individuals. The results show that the population was not depleted or being overfished.

6. MANAGEMENT ADVICE

6.1 Monitor Fishery Performance and Stock Status Relative to Reference Points

The female exploitation fraction in 2019 was below the target of 25.5% for the 12th consecutive year. The abundance of adult female crabs decreased in 2020, but remained above the threshold. The abundance of juveniles decreased and was below the long-term average. Based on analysis of the 2020 winter dredge survey results, CBSAC concludes that substantial changes in management are not necessary. Past harvest regulations are summarized in Appendix B.

Large variations in recruitment (age 0 abundance) are a characteristic of blue crab biology and not unexpected. However, it should be the goal of management to maintain a robust spawning stock, thereby increasing the resiliency of the population to downturns in recruitment.

6.2 Catch Reports and Quantifying Effort

CBSAC recommends that the jurisdictions continue implementing procedures that provide accurate accountability of all commercial and recreational harvest. All three Chesapeake Bay management jurisdictions have programs in place to gather more accurate catch and effort information from commercial and recreational harvesters. Most blue crab regulations focus on effort control in the form of limited entry, size limits, daily time limits, pot limits, spatial closures, spatial gear restrictions, and seasonal closures. To determine the efficacy of these management measures, detailed effort data that reveal the spatial and temporal patterns of gear-specific effort should be included in any system used to improve harvest data and reporting. Maryland, Virginia, and PRFC all require daily harvest reports to be submitted on a regular basis, and are collaborating with industry groups to pursue new reporting technologies. Maryland has implemented an electronic reporting program that allows for daily harvest reporting in real time and harvest validation. Virginia continues to promote its online reporting system that began in 2009 and plans to transition all crab harvesters to the online system in 2021. PRFC is exploring the use of electronic reporting to potentially begin in the next few years.

While implementing systems for greater accuracy, efforts should also be made, where possible, to better determine the biological characteristics of the catch, both landed and discarded. Note that when changes in reporting requirements are implemented, it is vital to quantify the impact of these changes on the current harvest estimates. Efforts should also be undertaken to assess the reliability of recreational harvest estimates Bay-wide.

7. CRITICAL DATA AND ANALYSIS NEEDS

CBSAC has identified the following prioritized list of fishery-dependent and fishery-independent data needs as well as the benefits provided to management.

In addition to specific data needs, CBSAC recognizes the importance of future stock assessments in providing in-depth analyses of the Chesapeake Bay blue crab population and scientific guidance to managers. MD DNR conducted a stock assessment update in 2017 using the 2011 stock assessment model, which CBSAC recommends be considered for adoption, providing a new framework for management. CBSAC now conducts annual runs of the stock assessment model to aid in determining stock status. Given new information and issues with fishery performance, improvements to the current model should be pursued.

CBSAC is currently pursuing funding opportunities through the Chesapeake Bay Program's Goal Implementation Team (GIT) Project Initiative, which provides funds to advance Bay Program goals and outcomes stipulated by the 2014 Chesapeake Bay Watershed Agreement, including the Blue Crab Abundance and Management Outcomes. The projects being put forth for FY2020 are summarized in sections 7.1 and 7.2.

7.1 Population Simulation Model for Management Strategy Evaluation

CBSAC is interested in developing a spatially-explicit blue crab population simulation model that can be used to evaluate stock assessment model and management performance under various hypotheses (e.g. differential natural mortality by sex and catchability of the winter dredge survey). This work would provide a better understanding of the current assessment model performance and a foundation for management strategy evaluation by which alternative management approaches for the blue crab population can be compared. The results of this modeling exercise could confirm the robustness of the current stock assessment and management framework or identify the need to adjust the framework through a benchmark stock assessment.

This proposed project will complement current efforts by VIMS researchers to develop a stage-structured population dynamics model, which is being calibrated with WDS and VIMS Trawl Survey data. The VIMS model is being used to examine the effects of depensatory exploitation, changes in reproductive output due to climate change, and habitat effects on the blue crab population and fishery. This year the model is also being made spatially-explicit.

7.2 Quantifying Environmental Factors Related to Recruitment Variability and Productivity

CBSAC recommends continued examination of the environmental factors that may contribute to interannual recruitment variability and changes in productivity over time. Using prior GIT funding, researchers at the Chesapeake Biological Laboratory (UMCES) developed a Bayesian

statistical framework for evaluating the simultaneous impacts of multiple biotic and abiotic factors affecting blue crab recruitment and abundance in Chesapeake Bay. The results of this work were presented at the Fisheries GIT Summer 2019 Meeting in Cambridge, Maryland. This proposed project would use a similar methodology and existing data to conduct additional analyses to examine the impact of environmental factors on recruitment success (i.e. number of recruits per spawner) in the Chesapeake Bay blue crab population. This research would improve understanding of blue crab population dynamics in the Bay, particularly the stock-recruitment relationship. Emphasis should be two-fold: prediction of future recruitment success based on environmental conditions during the year, and documenting environmental changes over time that may have affected productivity.

This proposed project will also complement current work underway at VIMS. Researchers at VIMS have completed an examination of the reliability of the VIMS SAV Aerial Survey to assess habitat effects on blue crab recruitment, and found that it is not a reliable measure of SAV availability due to discrepancies in the timing of the SAV survey (and the seasonality of SAV) and blue crab recruitment. VIMS is now assessing the efficacy of other spatial mapping platforms to examine habitat effects on the blue crab population. VIMS is also continuing analyses of environmental effects on blue crab productivity using WDS and VIMS Trawl Survey data.

7.3 Efficacy of WDS as an Index of Abundance

The winter dredge survey is a key tool used by managers for determining the status of the stock and management decisions. It is also utilized by researchers in stock assessments for setting targets and thresholds. There are several aspects of survey design and interpretation that should be further explored and improved upon. At least three approaches using winter dredge data have been proposed to estimate relative abundance (Sharov et al 1993; Jensen and Miller 2005; and Liang et al 2018). The relative reliability of the means and variances of abundance estimated from these different approaches have never been evaluated. In partnership with CBSAC, researchers at the University of Maryland Center for Environmental Science (UMCES) are currently working with graduate students to conduct this analysis, and expect it to be completed in Fall 2020.

7.4 Increased Accountability and Harvest Reporting for Commercial and Recreational Fisheries

CBSAC recommends jurisdictions continue to develop, explore, and evaluate implementation of real-time electronic reporting systems to increase the accuracy of commercial and recreational landings. Improving commercial and recreational blue crab harvest accountability would provide managers with a more accurate exploitation fraction each year and better support midseason management changes.

The jurisdictions have been working to implement new harvest reporting technologies over the past few years. Since pilot efforts were introduced in 2012, MD DNR has been using an electronic reporting system that allows commercial crabbers to enter each day's harvest from their vessel. The system includes random daily catch verification and a "hail-in, hail-out" protocol. Maryland is continuing to expand the use of this system for the commercial crabbing fleet. Virginia implemented electronic reporting in 2009 as an alternative mandatory harvest reporting option, but growth has been slow. Through cooperative work among VMRC, Virginia Sea Grant, and various industry groups, promotional products were produced and participation of commercial crab harvesters has increased. To increase reporting efficiency, Virginia plans to require all crab harvest be reported through the online system beginning in 2021. There is interest in electronic harvest reporting among PRFC stakeholders, and it is possible that PRFC will consider using an electronic reporting system in the next few years.

CBSAC also recommends conducting a survey of recreational catch and effort to ensure the reliability of estimates of recreational removals. The last available estimate for Maryland waters was that for 2011[5,6,7,8]. The last available estimate for Virginia was 2002[5]. Future surveys should ensure that recreational harvest from the Potomac River is also included. A license for recreational crabbing in all jurisdictions would greatly increase the accuracy of catch and effort estimates.

7.5 Improving Recruitment Estimates Using a Shallow Water Survey

Based on the 2011 stock assessment and field experiments by VIMS and the Smithsonian Environmental Research Center, a large fraction of juvenile blue crabs in shallow water is not sampled by the WDS[9]. VIMS was actively pursuing funding at the state level to conduct a shallow water survey concurrent with the Virginia WDS to assess the potential for interannual bias in the fraction of juveniles not sampled by the WDS; however, this effort has stopped temporarily due to COVID-19 effects on the state budget. CBSAC will discuss applying this effort Bay-wide based on funding and findings if a Virginia survey is conducted in the future. In the meantime, VIMS is evaluating trawl survey and WDS data as a relative measure of age 0 abundance.

7.6 Blue Crab Data Hub

To assist in stock assessments and analyses, CBSAC recommends exploring the creation of a data hub focused on Chesapeake Bay blue crab data. This would provide a consistent data platform for all research and minimize the lengthy QA/QC process undertaken before any analyses can begin. Several steps would be necessary to implement such a data hub:

A) Data policy workgroup to develop policies to ensure all interests are protected
B) Determine best database design and structure
C) Data QA/QC prior to loading into database

7.7 Application of Fishery-Independent Survey Data

CBSAC recommends continued review of existing fishery-independent survey data and potential application to provide additional information on the blue crab population, complementing the population estimates from the WDS. Characterizing the seasonal distribution, spatial patterns in recruitment and production, and sex-specific abundance of blue crabs remains important.

7.8 Investigation of the Influence of Male Abundance on Population and Fishery Productivity

CBSAC recommends continued examination to quantify and better understand the influence of male crabs on reproductive success, the overall population, and fishery productivity. In lieu of biological metrics to determine the stock status of male blue crabs, CBSAC recommends investigating if a set of indicators that would help to determine when management adjustments specific to male crabs would be warranted. Researchers at VIMS are currently examining nemertean presence in the gills of female crabs as an indicator of reproduction after their first spawning season, which would consequently indicate increased susceptibility to sperm limitation.

7.9 Fishery-Dependent Data

A verifiable electronic reporting system would collect much of the fishery-dependent data needed to improve management. In lieu of such a system, improvements in management could be made via a more detailed characterization of the catch. Mandatory harvest reporting is currently the only fishery-dependent data in Virginia and the Potomac River. Understanding catch composition by size, sex, and growth phase, both spatially and temporally, as well as effort characterization (section 6.2), would help improve the effectiveness of regulations and ensure they are compatible at a Bay-wide level. VMRC conducted short-term fishery-dependent sampling in 2016-2017 to provide some characterization of commercial harvest. CBSAC recommends that the jurisdictions consider options for future fishery-dependent sampling programs.

7.10 Other Sources of Mortality

CBSAC also recommends analyzing the magnitude of other sources of incidental mortality, specifically sponge crab discards, unreported losses after harvest from the peeler fishery, disease, and predation. An analysis of non-harvest mortality could improve reliability of exploitation fraction estimates and inform future assessments.

7.11 Biological Parameters

Longevity, age structure, and growth rates, particularly with respect to the timing of recruitment to the fishery within the season, are not fully characterized and remain as sources of uncertainty**.**

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Appendix A. Estimated abundance of blue crabs from the Chesapeake Bay-wide winter dredge survey, annual commercial harvest, and removal rate of female crabs.

Survey Year (Year Survey Ended)	Total Number of Crabs in Millions (All Ages)	Number of Juvenile Crabs in Millions (both sexes)	Number of Spawning-Age Crabs in Millions (both sexes)	Number of spawning age Female crabs in Millions	Bay-wide Commercial Harvest (Millions of Pounds)	Percentage of Female Crabs Harvsted
1990	791	463	276	117	104	43
1991	828	356	457	227	100	40
1992	367	105	251	167	61	63
1993	852	503	347	177	118	28
1994	487	295	190	102	84	36
1995	487	300	183	80	79	36
1996	661	476	146	108	78	25
1997	680	512	165	93	89	24
1998	353	166	187	106	66	43
1999	308	223	86	53	70	42
2000	281	135	146	93	54	49
2001	254	156	101	61	54	42
2002	315	194	121	55	54	37
2003	334	172	171	84	49.5	36
2004	270	143	122	82	60	46
2005	400	243	156	110	58.5	27
2006	313	197	120	85	52	31
2007	251	112	139	89	43	38
2008	293	166	128	91	49	25
2009	396	171	220	162	54	24
2010	663	340	310	246	85	16
2011	452	204	255	191	67	24
2012	765	581	175	95	56	10
2013	300	111	180	147	37	23
2014	297	198	99	68.5	35	17
2015	411	269	143	101	50	15
2016	553	271	284	194	60	16
2017	455	125	330	254	53	21
2018	371	167	206	147	55	23
2019	594	324	271	191	**61**	**17**
2020	**405**	**185**	**220**	**141**	**TBD**	**TBD**

*2019 Bay-wide commercial harvest and exploitation rate are preliminary (TBD = to be determined)

Bay-wide harvest totals and female exploitation rates listed on this page for 2010 and prior were updated in 2016 to reflect final Bay-wide harvest totals. Previous reports listed preliminary harvest data on this page.

Appendix B. Summary of female blue crab harvest regulations in the Chesapeake Bay jurisdictions 2008-2019.

Starting in 2008, the jurisdictions (Maryland, Virginia, Potomac River Fisheries Commission) implemented female-specific management measures for the Chesapeake Bay blue crab fishery. The jurisdictions adopted the current female-specific reference points with targets and thresholds for spawning-age (age 1+) female abundance and female exploitation rate in December 2011. The chart below summarizes changes in spawning-age female management regulations each year from 2008-2019.

Year	All Crabs	Age 0 Juv Crabs	Age 1+ Female Crabs	%Female Crabs Harvested	Maryland Female Harvest Regulations	Virginia Female Harvest Regulations	Potomac River Fisheries Commission Female Harvest Regulations
2008	293	166	91	21%	34% reduction: restricted access to female fishery from Sept 1 to Oct 22 based on harvest history; created tiered bushel limits for females based on harvest history	34% reduction: closed winter dredge fishery; closed the fall season for females early on Oct 27 (five weeks early); eliminated the five-pot recreational crab license; required two additional/larger cull rings; reduced # pots per license by 15% as of May 1 and another 15% next year; reduced # peeler pots per license by 30% on May 1.	34% reduction: closed the mature female hard crab season early on Oct 22; established separate female daily bushel limits Sept 1 to Oct 22 for areas upstream of St. Clements Isl. And areas downstream of St. Clements Isl; reduced peeler & soft shell seasons; established that all hard males, hard females, peelers and soft shell crabs kept separate on catcher's boat.
2009	396	171	162	24%	Open access, with industry input created season-long bushel limits that vary by license type and through the season/ Created a 15-day June (1-15) closure and a 9 day fall (9/26 - 10/4) closure to female harvest	Closed crab sanctuary from May 1-Sept 15 (closed loopholes that prevented a uniform May 1 closure for entire sanctuary). Nov 21 harvest closure; waived proposed 15% reduction of pots per license class; reinstated 5-pot recreational license; continued closure of winter dredge fishery.	Maintained 2008 season dates. Did not continue female daily bushel limits from 2008.

Year	All Crabs	Age 0 Juv Crabs	Age 1+ Female Crabs	%Female Crabs Harvested	Maryland Female Harvest Regulations	Virginia Female Harvest Regulations	Potomac River Fisheries Commission Female Harvest Regulations
2010	663	340	246	16%	Same bushels limits as 2009, but eliminated the 9-day fall closure based on industry input	Continued moratorium on sale of new licenses; relaxed dark sponge crab regulation to allow possession as of July 1 (instead of July 16); continued closure of winter dredge fishery	Established three mature female hard crab closure periods: Sept 22-28 above 301 bridge; Sept 29-Oct 6 from 301 bridge to St. Clements Isl./Hollis Marsh; Oct 7-13 below St. Clements Isl./Hollis Marsh. Closed season Nov 30.
2011	452	204	191	24%	Increased bushel limits	Closed sanctuary May 16 instead of May 1; continued closure of winter dredge fishery.	Refined mature female closed seasons: Sept 20-30 above St. Clements Isl./Hollis Marsh; Oct 4-14 below St. Clements Isl./Hollis Marsh.
2012	765	581	95	10%	Decreased bushel limits to compensate for removal of June closure, which added 15 days (based on industry advice). 6-day emergency extension to offset days lost to Hurricane Sandy.	Extended fall season until Dec 15; 6-day emergency extension to offset days lost to Hurricane Sandy; continued closure of winter dredge fishery.	Maintained 2011 mature female closed seasons.
2013	300	111	147	23%	Decreased bushel limits.	Implemented daily bushel limits to offset 2012 fall extension; extended fall pot season to Dec 15; continue closure of winter dredge fishery.	Refined mature female closed seasons: Sept 18-Oct 2 above St. Clements Isl./Hollis Marsh; Oct 3-17 below St. Clements Isl./Hollis Marsh.

Year	All Crabs	Age 0 Juv Crabs	Age 1+ Female Crabs	%Female Crabs Harvested	Maryland Female Harvest Regulations	Virginia Female Harvest Regulations	Potomac River Fisheries Commission Female Harvest Regulations
2014	297	198	68.5	17%	Daily bushel limits the same as 2013; additional vessel bushel limit reduction of 12%.	10% reduction: reduced pot bushel and vessel limits; continued closure of winter dredge fishery.	10% reduction: Closed mature female hard crab season Nov 20 and extended closure periods: Sept 12-Oct 2 above St. Clements Isl./Hollis Marsh; Oct 3-23 below St. Clements Isl./Hollis Marsh.
2015	411	269	101	15%	Increase in min. peeler size April-July 14 due to low 2014 adult females. Daily bushel limited increased ~20% Sept-Nov 10 based on adult female increased abundance in 2015.	Maintained 2014 daily bushel limits; continued closure of winter dredge fishery. Redefined the blue crab sanctuary into 5 areas with separate closure dates	Set female daily bushel limits from April-June.
2016	553	271	194	16%	Extended season to Nov 30, adding 20 days. Increased bushel limits in Sept and Oct.	Extended season 3 weeks to Dec 20; maintained 2014 bushel limits; continued closure of winter dredge fishery.	Extended fall season through Dec 10. Set female daily bushel limits starting in July for the whole season.
2017	455	125	254	21%	Shortened season to Nov 20. Reduced bushel limits.	Shortened season to Nov 30. Continued closure of dredge fishery. Reduced Nov bushel limits.	Shortened season to Nov 30. Reduced bushel limits.
2018	372	167	147	23	Extended season to Nov 30. Reduced bushel limits.	Continued closure of dredge fishery and Nov bushel limits. Added hard crab allowance for scrapers.	Status quo
2019	594	324	191	17	Increased bushel limits for July - Nov. Season remained open through Nov 30.	Increased November bushel limits to the same limits as April-October.	Status quo

Additional Online Resources

Maryland Department of Natural Resources: http://dnr.maryland.gov/fisheries/Pages/default.aspx
Potomac River Fisheries Commission: http://prfc.us/
Virginia Marine Resources Commission: http://www.mrc.state.va.us/
Chesapeake Bay Program: https://www.chesapeakebay.net/issues/blue_crabs