2021 Chesapeake Bay Blue Crab Advisory Report

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EXECUTIVE SUMMARY

The Chesapeake Bay Stock Assessment Committee (CBSAC) meets annually to review the results of the Chesapeake Bay blue crab survey and harvest data, and to develop management advice for the jurisdictions based on those results. CBSAC adopted the annual 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. From 2012 to 2020, the survey and harvest data were assessed relative to female-specific biological reference points that were established during the 2011 benchmark stock assessment. In November 2020, the three jurisdictions formally adopted revised female-specific reference points generated by a 2017 blue crab stock assessment update, which included more recent survey and harvest information. CBSAC determined that these new reference points constitute the best available science by which the stock should be assessed and managed.

The Winter Dredge Survey indicated that the total abundance of all crabs (males and females of all ages) was approximately 282 million individuals in 2021. Recruitment, or the number of age 0 crabs (less than 60 mm or 2.4 inches carapace width), was estimated at 86 million. Approximately 158 million age 1+ female crabs were estimated to be present in the Bay at the start of the 2021 crabbing season, which is above the new abundance threshold of 72.5 million adult females, but below the new target of 196 million. The percentage of female crabs (age 0+) removed by fishing (exploitation rate) in 2020 was 19%. This exploitation rate is below the target (now 28%) and the threshold (now 37%) for the 13th consecutive year since 2008. Therefore, overfishing is not occurring and the population is not depleted.

Based on analysis of the 2021 Winter Dredge Survey results, CBSAC does not recommend substantial changes in management at this time. Further, CBSAC recommends that the jurisdictions implement procedures that improve accountability of all commercial and recreational harvest moving forward, as this is an important component for accurately assessing stock health.

1. INTRODUCTION

1.1 Background

Management of the blue crab stock is coordinated among the jurisdictions by the Chesapeake Bay Stock Assessment Committee (CBSAC), a workgroup of the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (SFGIT). Organized by the Chesapeake Bay Program and chaired by the NOAA Chesapeake Bay Office (NCBO), the SFGIT is led by an Executive Committee of senior fisheries managers from the Maryland Department of Natural Resources (MDNR), the Virginia Marine Resources Commission (VMRC), the Potomac River Fisheries Commission (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 resource managers 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 survey and harvest data, and to develop management advice for the Chesapeake Bay jurisdictions: the State of Maryland (MDNR), the Commonwealth of Virginia (VMRC), and the Potomac River Fisheries Commission (PRFC).

1.2 Management Framework

Three benchmark stock assessments of the Chesapeake Bay blue crab have been conducted since 1997. The most recent benchmark assessment was completed by scientists at the University of Maryland Center for Environmental Science (UMCES) in 2011 with support from MDNR, VMRC, and NCBO (Miller et al. 2011). The 2011 assessment recommended reference points based on maximum sustainable yield (MSY) for female blue crabs only. Female-specific abundance and exploitation reference points were formally adopted by all three management jurisdictions in December 2011.

Under the female-specific management framework, estimates of annual exploitation rate are calculated as the 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. For 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, empirical estimates of exploitation rate can be compared with the target and threshold reference points derived from the assessment model. Abundance of mature female crabs (age 1+) is estimated from the Winter Dredge Survey and assessed relative to female-specific abundance reference points. Management seeks to control the fishery such that the number of adult females in the population remains above the

minimum abundance defined by the overfished (depleted) threshold. Ideally, the fishery should operate to meet target values and should never surpass the exploitation rate threshold and never fall below the abundance threshold.

1.3 Data Sources

Blue crab abundance is estimated from the annual Bay-wide Winter Dredge Survey (WDS) conducted by MDNR and the Virginia Institute of Marine Science (VIMS). CBSAC adopted the 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 (Sharov et al. 2003). The WDS measures the density of crabs (number/1,000 m^2) at approximately 1,500 sites throughout the Bay each year. The measured densities of crabs are adjusted to account for the efficiency of the sampling gear and expanded to the area of Chesapeake Bay (m^2). This provides an annual estimate of the total number of crabs overwintering in the Bay by age and sex. The survey also provides an estimate of overwintering mortality. Blue crab data from trawl surveys conducted by MDNR and VIMS also inform the stock assessment model. Commercial and recreational harvest information are collected annually by the three jurisdictions (MDNR, VMRC, PRFC) to determine Bay-wide exploitation rates.

1.4 Stock Assessment Updates

In 2017, fisheries experts at MDNR initiated a stock assessment update to evaluate the performance of the stock assessment model with new model inputs. The same sex-specific catch, multiple survey model used in 2011 was run with abundance data through 2017 and harvest data through 2016. The final report of the stock assessment model update was completed and distributed in 2018. The results of the update showed similar scale and trends in estimated abundance compared to the 2011 benchmark assessment, indicating appropriate model structure and stability, but the estimated reference points were slightly different (Table 1). In November 2020, the three jurisdictions formally adopted the new reference points from the 2017 stock assessment update as these estimates constitute the best available science by which the stock should be assessed and managed.

In 2020, CBSAC recommended that annual model runs be conducted to monitor model performance and help guide the decision process for timing of the next benchmark stock assessment. These model runs use the same data sources and methodologies set forth by the 2011 benchmark 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 – are also the same. CBSAC is currently discussing a standard operating procedure (i.e. methods, timeline, etc.) for updating the reference points in the future. CBSAC aims to have these guidelines finalized and approved by the SFGIT by the end of 2021.

Table 1. Biological reference points generated by the 2011 benchmark stock assessment and the 2017 stock assessment update. The jurisdictions formally adopted the 2017 reference points in November 2020.

Stock Assessment	Female Abundance (Age 1+) (millions)		Female Exploitation Rate (Age 0+) (per year)	
	Target	Threshold	Target	Threshold
2011	215	70	25.5%	34%
2017	196	72.5	28%	37%

2. POPULATION SIZE (ABUNDANCE)

2.1 All Crabs

The WDS estimate of total abundance of all crabs (males and females of all ages) was 282 million in 2021 (Figure 1). This was a decrease from last year's estimate of 405 million crabs, and was below the long-term average (geometric mean*) and the median of observed values over the last 30 years (400 million).

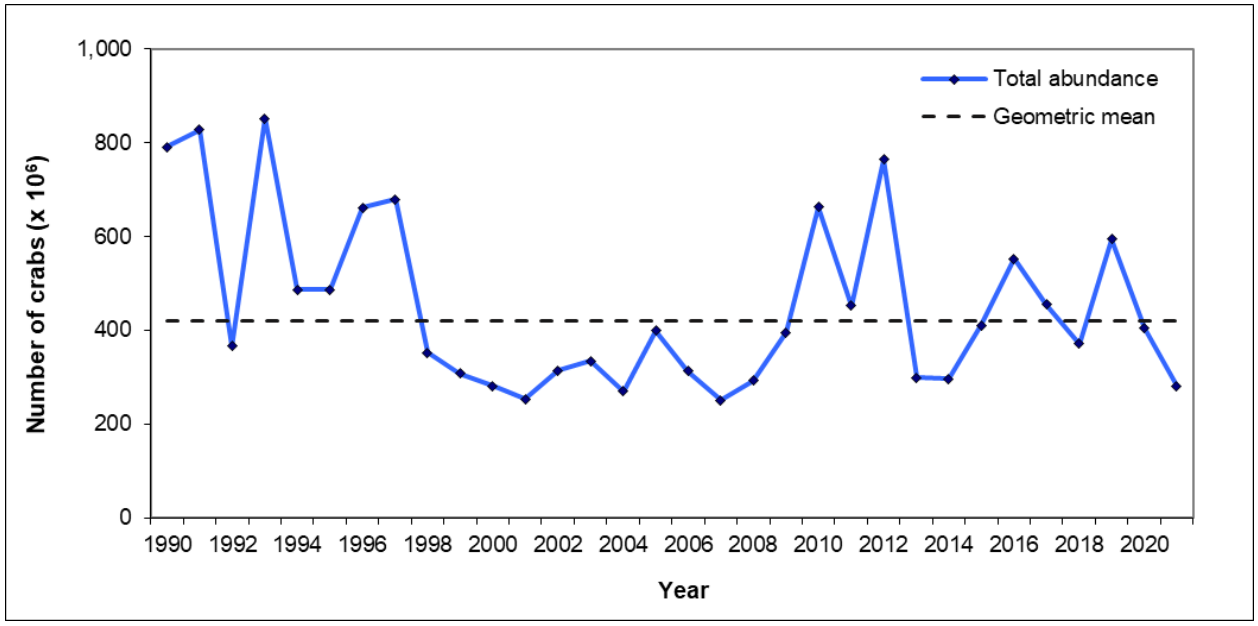

Figure 1. Winter Dredge Survey estimate of abundance of all crabs (both sexes, all ages) in Chesapeake Bay, 1990-2021.

2.2 Juvenile Crabs (Age 0)

Recruitment is estimated as the number of age 0 crabs (less than 60 mm or 2.4 inches carapace width) in the WDS. The abundance of juvenile crabs in 2021 was 86 million, a decrease from the 2020 abundance of 185 million (Figure 2). This year's recruitment estimate was the lowest of the time series, falling well below the average of 219 million juveniles (geometric mean).

* 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.

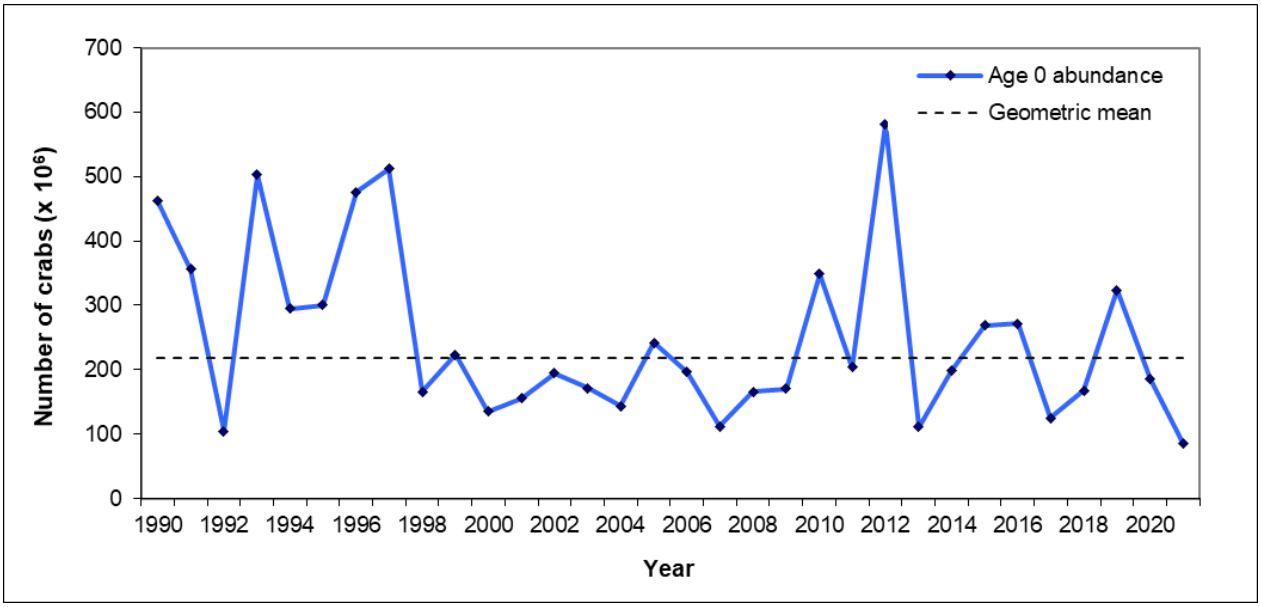

Figure 2. Winter Dredge Survey estimate of abundance of juvenile blue crabs (age 0), 1990-2021, calculated without the catchability adjustment for juveniles (section 1.2). These are male and female crabs measuring less than 60 mm (2.4 in) across the carapace.

2.3 Adult Males (Age 1+)

The WDS estimate of age 1+ male crabs (greater than 60 mm or 2.4 inches carapace width) in 2021 was 39 million, a decrease from the 2020 estimate of 79 million adult males (Figure 3). This was also below the time series average of 65 million (geometric mean).

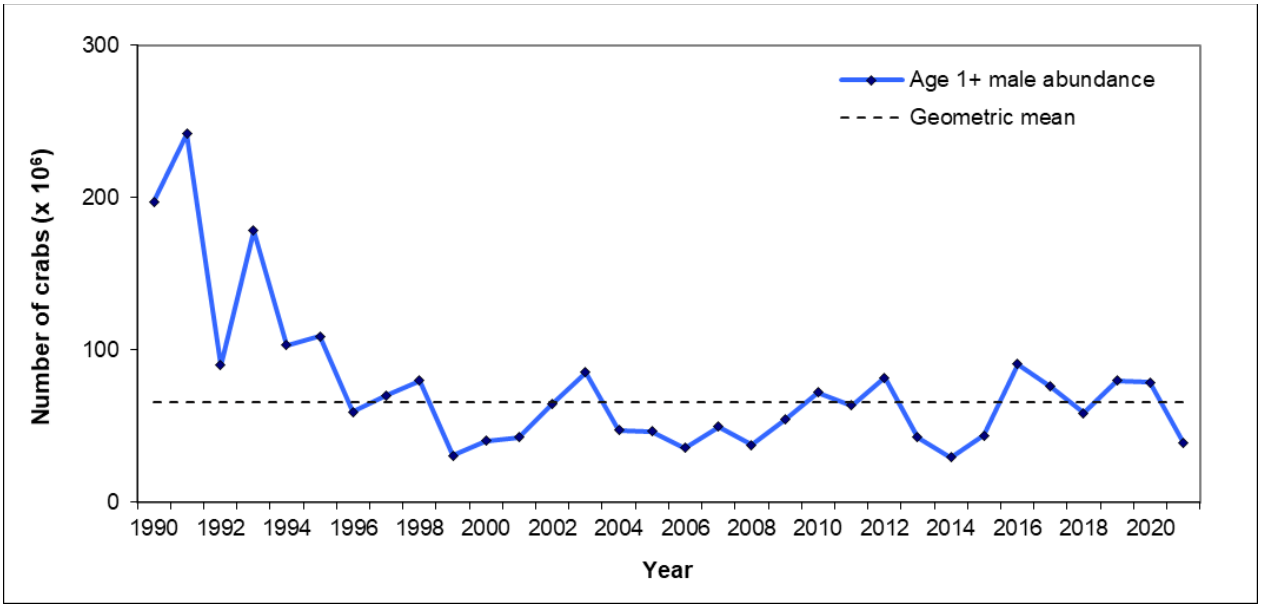

Figure 3. Winter Dredge Survey estimate of abundance of adult male blue crabs (age 1+), 1990-2021. These are male crabs measuring greater than 60 mm (2.4 in) across the carapace and are considered the "exploitable stock" capable of mating within the year.

2.4 Overwintering Mortality

Overwintering mortality is the percentage of dead crabs found in the WDS each year. Blue crab abundance estimates from the WDS are adjusted for loss due to overwintering mortality. In 2021, overwintering mortality estimates were the near median of observed values within the time series (Table 2).

Table 2. Percentage of dead crabs found Bay-wide in dredge samples each year from 2016 to 2021 and the average for 1996-2021.

Age/Sex Grouping	1996-2021 Average	2016	2017	2018	2019	2020	2021
All Crabs	4.46%	1.95%	1.15%	6.37%	1.80%	0.36%	2.80%
Juveniles	1.14%	0.50%	0.00%	0.87%	0.15%	0.00%	0.11%
Adult Females	7.83%	2.99%	1.37%	11.06%	1.87%	0.47%	2.12%
Adult Males	9.25%	1.06%	2.29%	13.66%	7.83%	0.78%	8.39%

3. HARVEST

3.1 Commercial Harvest

Total commercial blue crab harvest decreased throughout Chesapeake Bay in 2020. Commercial harvest for both males and females from the Bay and its tributaries was reported as 19.4 million pounds in Maryland, 19.4 million pounds in Virginia, and 2.8 million pounds in the Potomac River (Figure 4). Commercial harvest decreased for both males and females in Maryland and Virginia. There was a slight increase in female harvest in the Potomac River in 2020. The 2020 Bay-wide commercial harvest of 41.6 million pounds was below the 1990-2019 average of approximately 61 million pounds (Figure 5).

The decline in commercial blue crab harvest may be due to the COVID-19 pandemic. Pandemic restrictions limited patronage of restaurants, which significantly reduced the market for blue crab. In an effort to make up for losses due to COVID-19, MDNR increased female bushel limits for one week in November 2020, and VMRC extended the hard crab pot season through December 19, 2020. PRFC maintained the status quo for their blue crab regulations throughout the 2020 harvest season.

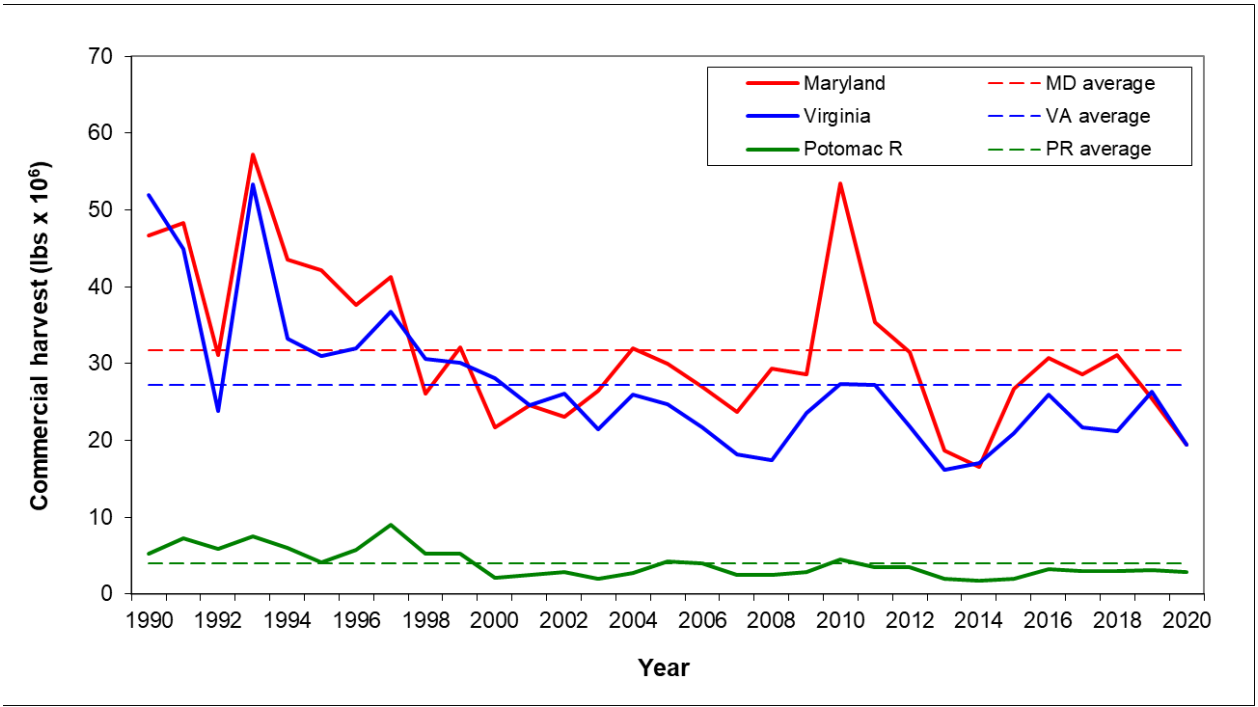

Figure 4. Maryland, Virginia, and Potomac River commercial blue crab harvest in millions of pounds (all market categories), 1990-2020.

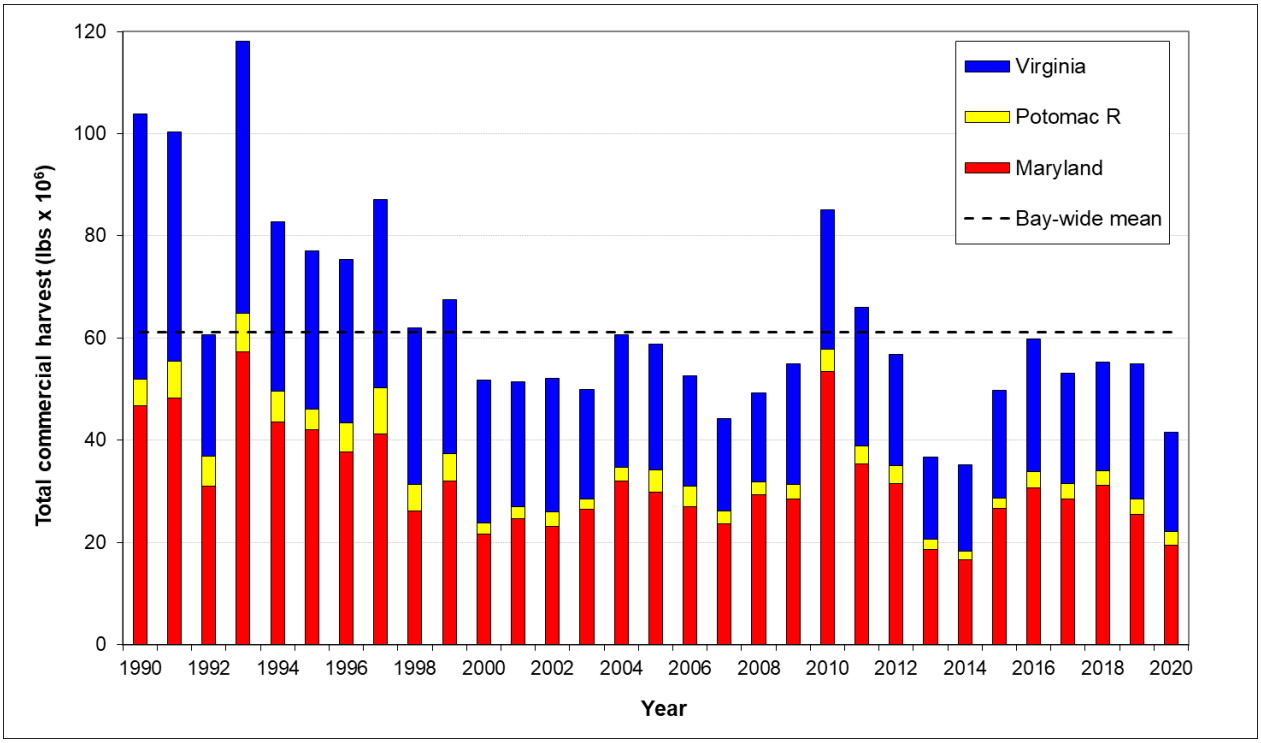

Figure 5. Total commercial blue crab harvest (all market categories) in Chesapeake Bay, 1990-2020.

3.2 Recreational Harvest

Prior to 2009, recreational blue crab harvest had been assumed to be approximately 8% of the total Bay-wide commercial harvest (Ashford & Jones 2011). Since recreational harvest of female blue crabs is no longer allowed in Maryland waters, recreational harvest is better described as 8% of male commercial harvest in this jurisdiction. Bay-wide recreational harvest in 2020 was estimated at 2.4 million pounds, a decrease from the 2019 estimate of 3.8 million pounds. The COVID-19 pandemic may also have impacted recreational crabbing opportunities in the Bay in 2020. Combining commercial and recreational harvest, approximately 44.1 million pounds of blue crabs were harvested from Chesapeake Bay and its tributaries during the 2020 crabbing season.

4. STOCK STATUS

4.1 Female-Specific Reference Points

The current management framework employs MSY-based female-specific targets and thresholds to assess the stock. U_{MSY} is defined as the level of fishing (expressed as the percentage of the population harvested each year) 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 rate that was associated with 75% of the value of U_{MSY} and a threshold exploitation rate equivalent to U_{MSY}. The adult female (age 1+) abundance reference points were set at levels associated with $N_{0.75*UMSY}$ (target) and 50% N_{MSY} (threshold). The 2017 stock assessment update, which generated the new biological reference points, used the same approach to determine appropriate stock and exploitation levels for a sustainable blue crab fishery.

4.2 Exploitation Rate

The percentage of all female crabs (age 0+) removed by fishing (exploitation rate) in 2020 was approximately 19%. This exploitation rate is below the revised target of 28% and threshold of 37%. This is the 13th consecutive year since 2008, when female-specific management measures were implemented, that the female exploitation rate is below both the target and threshold (Figure 6).

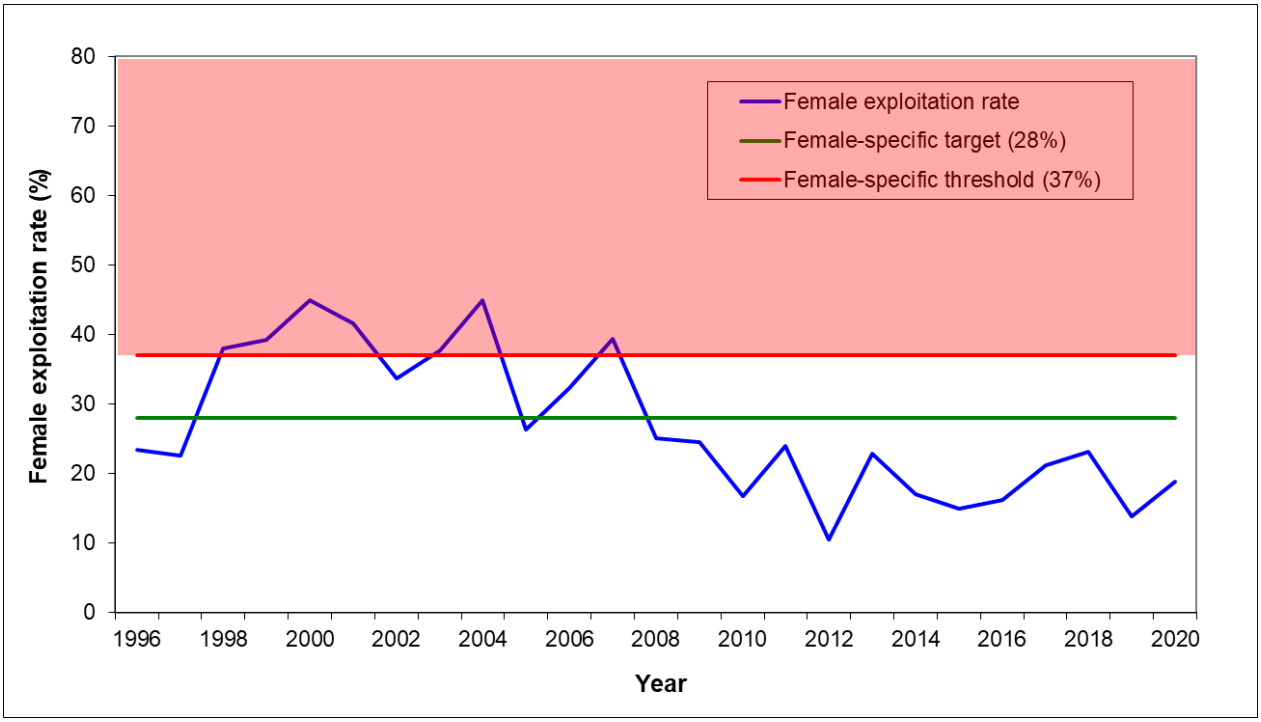

Figure 6. Estimated female exploitation rate relative to the revised female-specific target (28%) and threshold (37%), 1990-2020. The female exploitation rate is the number of female crabs harvested in a given year divided by the female abundance estimate (age 0+) at the beginning of the year.

4.3 Spawning Stock Abundance

Approximately 158 million age 1+ female crabs were estimated to be present in the Bay at the start of the 2021 crabbing season, which is above the new threshold of 72.5 million, but below the new target of 196 million. This abundance estimate of mature females is also slightly above the average abundance since 2008 (after female-specific management measures were enacted), and much higher than the average abundance for the 14-year period preceding those measures (Figure 7).

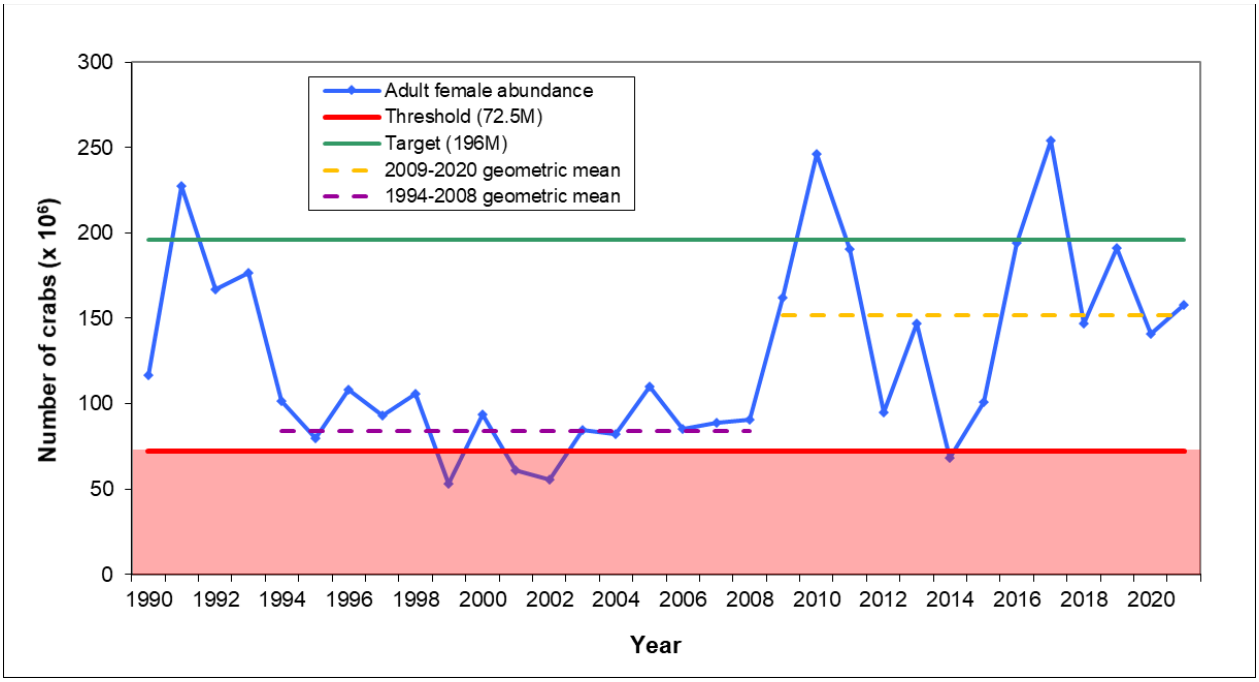

Figure 7. Winter Dredge Survey estimate of abundance of mature female blue crabs (age 1+), 1990-2021, relative to the revised female-specific reference points. These are female crabs measuring greater than 60 mm (2.4 in) across the carapace and are considered the "exploitable stock" capable of spawning within the year. The dashed lines represent the geometric mean of adult female abundance during two time periods: 2009-2021, after the current management framework was implemented (yellow dashes); and 1994-2008, the period of low abundance which prompted the management changes (purple dashes).

4.4 Control Rules

Figure 8 shows the status of the blue crab stock each year relative to both the female exploitation rate (U) and adult female abundance (N) reference points (sections 4.1-4.3). The shaded red areas show where the thresholds for the exploitation rate and/or abundance are exceeded. The intersection of the green lines shows both the abundance and exploitation targets. The figure includes data through 2020; the 2021 data point will be added at the completion of the 2021 fishery.

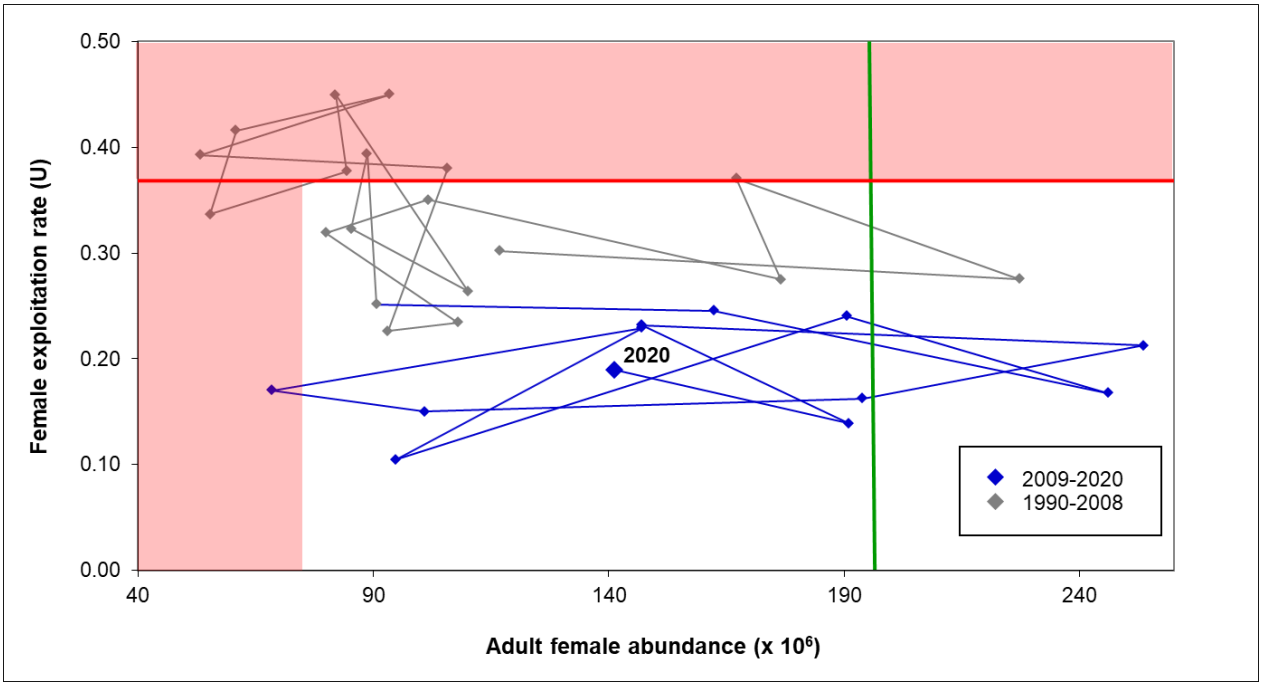

Figure 8. Stock status of the Chesapeake Bay blue crab prior to and after implementation of female-specific management measures in 2008. The female-specific management framework was formally adopted in December 2011, and revised biological reference points were adopted in November 2020. In 2020, adult female abundance (N) was 141 million, which was below the new 196 million target and above the new 72.5 million threshold. The 2020 female exploitation rate (U) was 19%, which was below the new 28% target and 37% threshold.

The Chesapeake Bay blue crab stock is currently **not depleted and overfishing is not occurring** (Table 3). The 2021 estimated abundance of the spawning stock is above the new threshold of 72.5 million adult female crabs, but below the target of 196 million, as outlined in the current management framework. The 2020 exploitation rate of 19% was below the revised target (28%) and threshold (37%). Abundance, harvest, and exploitation of all crabs are summarized in Appendix A and in the preceding sections.

Table 3. Blue crab stock status over the last five years, based on the updated exploitation and abundance reference points for female crabs. Green shading indicates that the threshold was not exceeded.

Control Rule	Reference Points		Stock Status					
	Target	Threshold	2016	2017	2018	2019	2020	2021
Exploitation Rate (percentage of age 0+ females removed)	28%	37% (max)	16%	21%	23%	17%	**19%**	TBD
Abundance (millions of age 1+ females)	196	72.5 (min)	194	254	147	191	141	**158**

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 rate observed for male crabs since 1990. Choosing the second-highest value in the time series is a precautionary measure that provides a buffer from the maximum observed exploitation rate. 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 29 of the last 31 years. The 2020 male exploitation rate was estimated at 19%, below the conservation trigger (Figure 9). No further action is needed at this time.

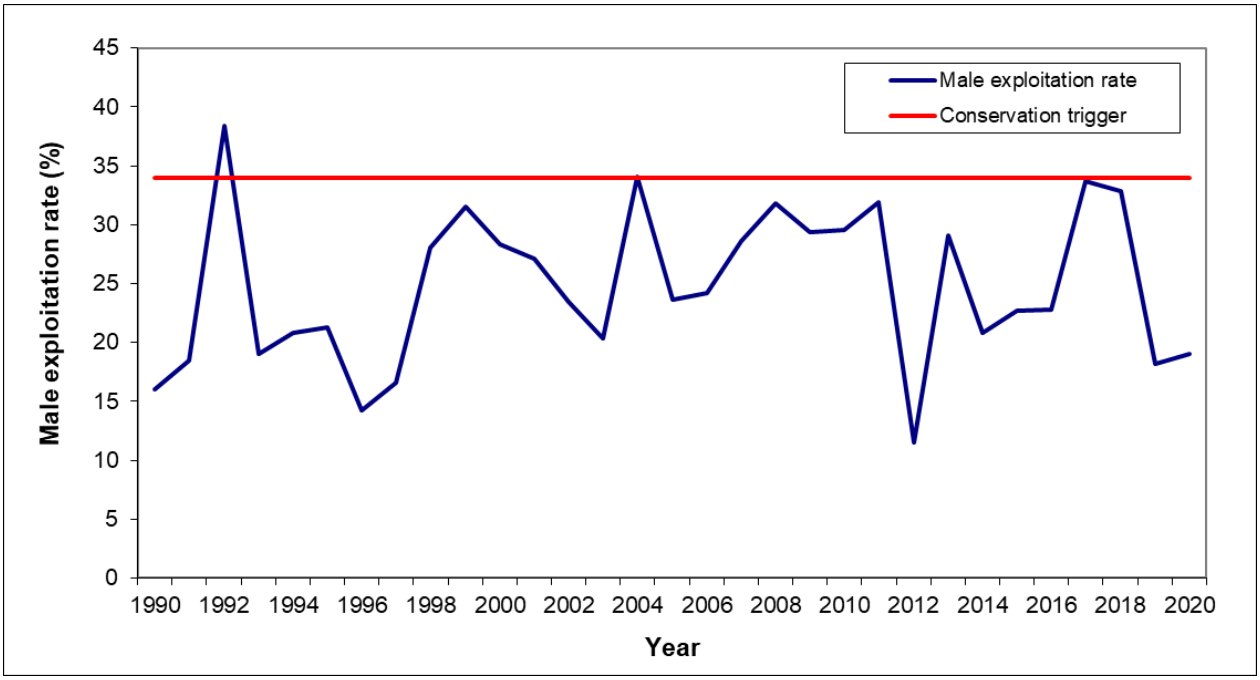

Figure 9. Estimated male exploitation rate relative to the male conservation trigger, 1990-2020. The male exploitation rate is the number of male crabs harvested in a given year divided by the male abundance estimate (age 0+) at the beginning of the year, calculated with the juvenile scalar (section 1.2).

4.6 Potential Management Impact

Female exploitation rates from 1990 to 2008 were much higher than the exploitation rates from 2009 to 2020 (Figure 10a). The lower female exploitation rates in recent years illustrate the influence of the female-specific management measures implemented by the jurisdictions in 2008. Male exploitation rates have not shown the same pattern (Figure 10b). Additionally, the rapid increase in female abundance in 2009-2010, and again in 2014-2016, suggests that the female-specific management framework may have allowed the stock to regain some of its natural resilience to environmental changes.

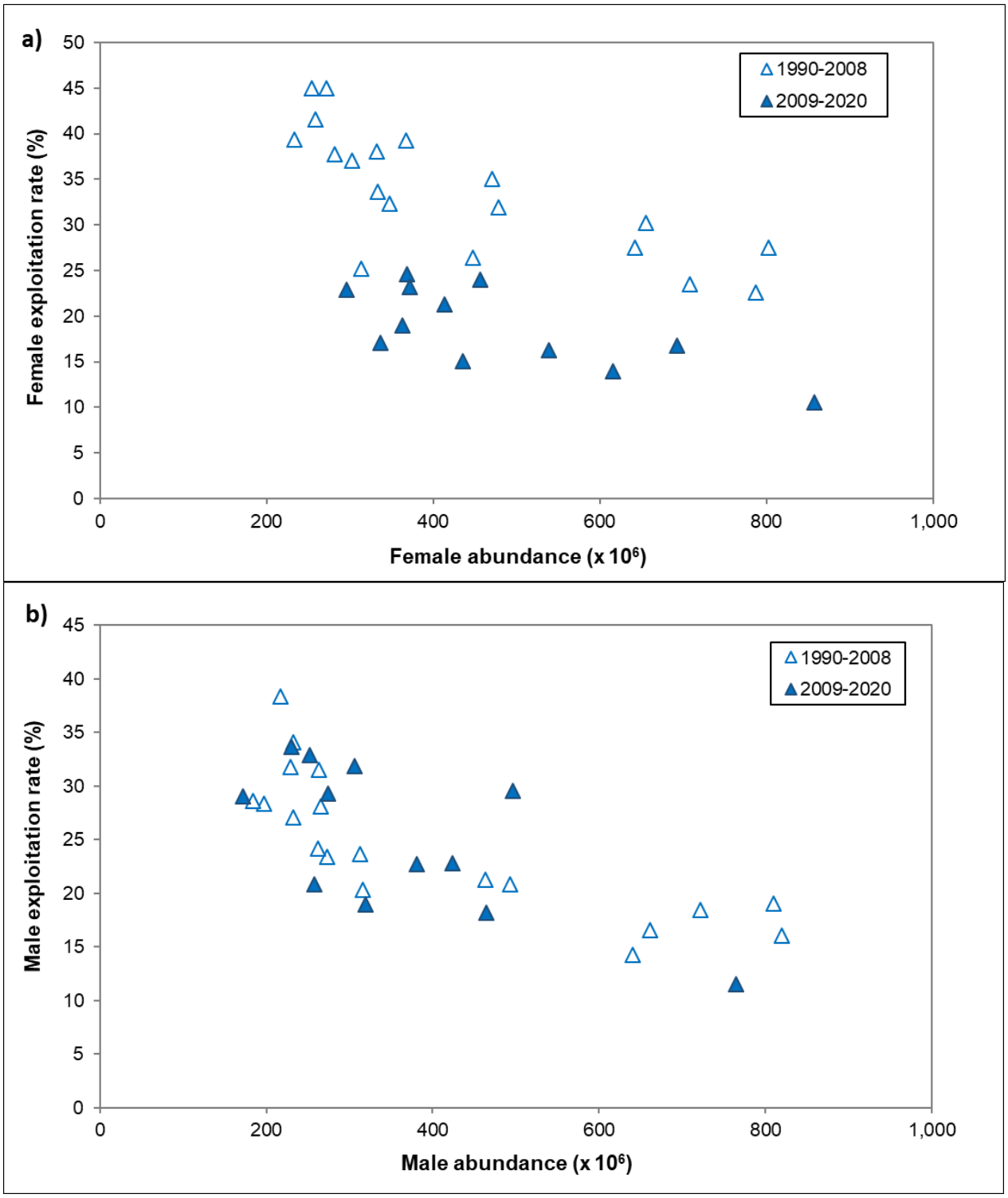

Figure 10. Comparison of female (a) and male (b) exploitation rates during the time periods prior to and after the 2008 implementation of female-specific management measures.

5. MANAGEMENT ADVICE

5.1 Monitor Fishery Performance and Stock Status Relative to Reference Points

The female exploitation rate in 2020 was below the target (28%) for the 13th consecutive year since female-specific management was implemented. The abundance of adult female crabs (age 1+) increased in 2021 and remained well above the threshold (now 72.5 million). Therefore, CBSAC concludes that substantial changes in management are not necessary at this time. For additional information about previous changes in harvest regulations each year, see Appendix B.

However, juvenile abundance in 2021 was the lowest in the time series, but, given the natural variability of recruitment in the blue crab population, this is not cause for concern unless low recruitment is sustained over a period of time. To increase resiliency of the population to downturns in recruitment, management aims to maintain a robust spawning stock as seen in 2021. As a precaution, the jurisdictions will continue to monitor the new recruits throughout 2021 by examining blue crab data from the MDNR and VIMS trawl surveys.

5.2 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. MDNR, VMRC, 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. MDNR has implemented an electronic reporting program that allows for daily harvest reporting in real time and harvest validation. VMRC continues to promote its online reporting system that began in 2009 and plans to transition all crab harvesters to the online system in 2022. 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.

6. SCIENCE AND DATA NEEDS

CBSAC has identified the following prioritized list of science and data needs that will improve management of the Chesapeake Bay blue crab population. To address some of these needs, CBSAC is 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.

6.1 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 performance of the stock assessment model and fishery management under various hypotheses (e.g. differential natural mortality by sex and catchability of the WDS). 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. The simulation model could also test the response of recruitment indices to management, which is of particular interest given the low recruitment event in 2021.

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. VIMS is also working to make this model spatially-explicit.

6.2 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 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 (Liang et al. 2021). The results of this work were presented at the SFGIT 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 Submerged Aquatic Vegetation (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.

6.3 Efficacy of the 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 WDS data have been proposed to estimate relative blue crab abundance in Chesapeake Bay (Sharov et al. 2003, Jensen & Miller 2005, Liang et al. 2017). The relative reliability of the means and variances of abundance estimated from these different approaches has never been evaluated. In partnership with CBSAC, researchers at UMCES are currently working with graduate students to conduct this analysis, and expect it to be completed by Winter 2021.

6.4 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 rate each year and better support mid-season 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, MDNR 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. MDNR is continuing to expand the use of this system for the commercial crabbing fleet. VMRC 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, VMRC plans to

require all crab harvest be reported through the online system beginning in 2022. 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 most recent estimate of recreational harvest in Maryland was generated from a tagging study in Maryland waters in 2014-2015, which suggested that recreational harvest was approximately 6.5% of commercial harvest (Semmler et al. 2021). The last available estimates of recreational harvest for Virginia are from 2002. 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.

6.5 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 (SERC), a large fraction of juvenile blue crabs in shallow water is not sampled by the WDS (Ralph & Lipcius 2014). 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.

6.6 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) Create a data policy workgroup to develop policies to ensure all interests are protected;
B) Determine the best database design and structure; and
C) QA/QC all data prior to uploading into the database

6.7 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.

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

A previous study at UMCES suggested that sperm limitation is not a concern for Chesapeake Bay blue crabs under the current management framework (Rains et al. 2018). However, 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 consideration of a set of indicators that would help determine when management adjustments specific to male crabs would be warranted.

Previous studies at SERC examined population-level impacts of sperm limitation on the Chesapeake Bay stock (Hines & Ogburn 2014), and assessed effects of variation in female sperm stores on brood production (Ogburn et al. 2014). 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. Initial results suggest that nemertean presence can be an indicator of age and spawning frequency in female blue crabs.

6.9 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. While VMRC and PRFC collect fishery-dependent data from mandatory harvest reporting, MDNR has a sampling program in which size and sex composition information are collected by watermen voluntarily. Understanding catch composition by size, sex, and growth phase, both spatially and temporally, as well as effort characterization (section 6.4), 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.

6.10 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. Recent diet studies and anecdotal accounts from watermen suggest that blue catfish (Schmitt et al. 2019) and red drum may be key predators of blue crabs, particularly in Virginia. An analysis of non-harvest mortality could improve reliability of exploitation rate estimates and inform future assessments.

6.11 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 are key sources of uncertainty**.** A new VIMS study examining blue crab age structure, reproduction, and sperm limitation may provide some insight into these critical biological parameters of the Chesapeake Bay population.

Additional Online Resources

Maryland Department of Natural Resources:
https://dnr.maryland.gov/fisheries/pages/blue-crab/index.aspx
Potomac River Fisheries Commission: http://prfc.us/
Virginia Marine Resources Commission: http://www.mrc.state.va.us/
Virginia Institute of Marine Science:
https://www.vims.edu/research/units/programs/bc_winter_dredge/index.php
Chesapeake Bay Program: https://www.chesapeakebay.net/issues/blue_crabs
Chesapeake Bay Stock Assessment Committee:
https://www.chesapeakebay.net/who/group/chesapeake_bay_stock_assessment_committee

CBSAC Members

Pat Geer (Chair)	Virginia Marine Resources Commission
Mandy Bromilow (Coordinator)	ERT/NOAA Chesapeake Bay Office
Ellen Cosby	Potomac River Fisheries Commission
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Appendix A. Estimated abundance of blue crabs from the Chesapeake Bay-wide Winter Dredge Survey, total commercial harvest, and female exploitation rate, 1990-2021*.

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 Harvested (Exploitation rate)
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	50	36
2004	270	143	122	82	60	46
2005	400	243	156	110	59	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	69	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	**42**	**19**
2021	**282**	**86**	**197**	**158**	TBD	TBD

*2021 Bay-wide commercial harvest and exploitation rate will be determined after the close of the 2021 harvest season.

Appendix B. Summary of changes in female blue crab harvest regulations in the three Chesapeake Bay jurisdictions (MDNR, VMRC, PRFC) since implementation of the female-specific management framework in 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
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.
2020	405	185	141	19	Increased bushel limits for one week in Nov.	Extended hard crab pot season to Dec 19.	Status quo.