2015 Chesapeake Bay Blue Crab Advisory Report

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Report Final Draft: June 30th, 2015

1. INTRODUCTION

1.1 Background: Science and Management

The Chesapeake Bay Stock Assessment Committee (CBSAC) combines the expertise of state representatives and scientists from the Chesapeake Bay region with 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, 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 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. Management of the blue crab stock is coordinated among the jurisdictions by 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 the MD DNR, VMRC, PRFC, the Atlantic States Marine Fisheries Commission and the District Department of the Environment.

CBSAC adopted the Baywide 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 are expanded based on the area of Chesapeake Bay, providing an annual estimate of the number of over-wintering crabs by age and sex[2]. An estimate of the mortality during winter is also obtained from the survey results.

1.2 Background: 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 divided by the total number of female crabs (age 0+) estimated in the population at the start of the season. The 2015 exploitation fraction cannot be calculated until the completion of the 2015 fishery and is therefore listed as TBD (to be determined). Crab abundance is estimated from the WDS each year. The current framework recommends monitoring the abundance of female age-1+ crabs 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 (Table 1).

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

Control Rule	Reference Points			Stock Status				
	Period	Target	Threshold	2011	2012	2013	2014	2015
Exploitation Fraction	Current, Female-specific	25.5%	34% (max)	24%	10%	23%	17%	**TBD**
Abundance (millions of crabs)	Current, Female-Specific	215	70 (min)	190	97	147	68.5	101

2. CONTROL RULES

2.1 Control Rule from 2011 Benchmark Assessment

The 2011 benchmark assessment recommended a control rule based on biological reference points for the female component of the population. The application of a control rule to management of the blue crab fisheries was first adopted by the Bi-State Blue Crab Advisory Committee in 2001[3]. The current female-specific targets and thresholds were developed using the MSY concept. 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 75% N_{MSY} (target) and 50% N_{MSY} (threshold). The annual exploitation fractions is calculated as the number of female crabs harvested divided by the total number of age-0+ female crabs in the Bay at the beginning of the fishing season, as estimated by the WDS. As part of this calculation, the juvenile component of the total estimated number of crabs was scaled up by a factor of 2.5 to achieve the best fits of the empirical estimates to the modeled data as determined by the 2011 stock assessment.

2.2 Spawning-age Female Crabs: Reference Points

The 2011 benchmark assessment recommended a threshold abundance of 70 million female spawning-age (age 1+) crabs and a target abundance of 215 million female spawning-age crabs. Approximately 101 million female spawning-age crabs were estimated to be present in the Bay at the start of the 2015 crabbing season (Figure 1). The 2015 estimate of total spawning age female crabs represented a 32% increase with respect to the 2014 estimate of 68.5 million crabs. The 2015 abundance of spawning-age female crab is above the recommended threshold but remains below the recommended target.

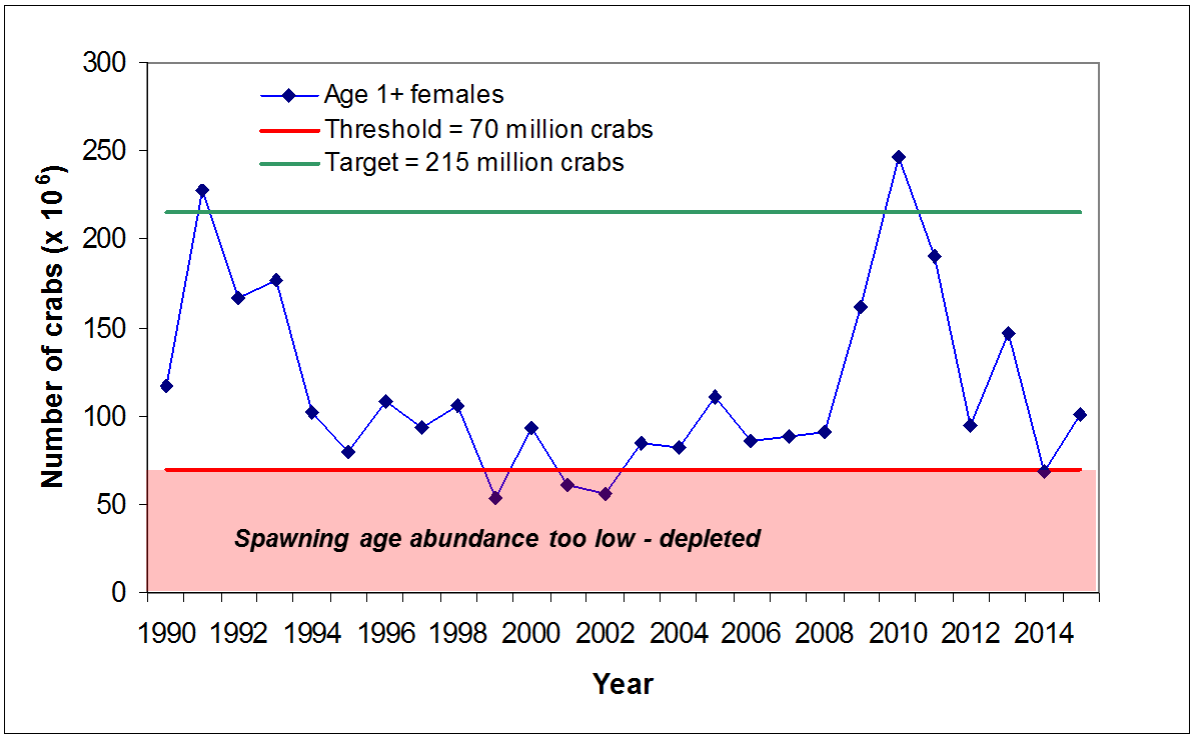

Figure 1. Winter dredge survey estimate of abundance of female blue crabs age one year and older (age 1+) 1990-2015 with female-specific reference points. These are female crabs measuring greater than 60 mm across the carapace and are considered the 'exploitable stock' that could spawn within this year.

2.3 Female Exploitation Fraction: Reference Points

The percentage of all female crabs (ages 0+) removed by fishing (exploitation fraction) in 2014 was approximately 17%. This exploitation fraction is below the target of 25.5% and the threshold of 34% for the seventh consecutive year (Figure 2).

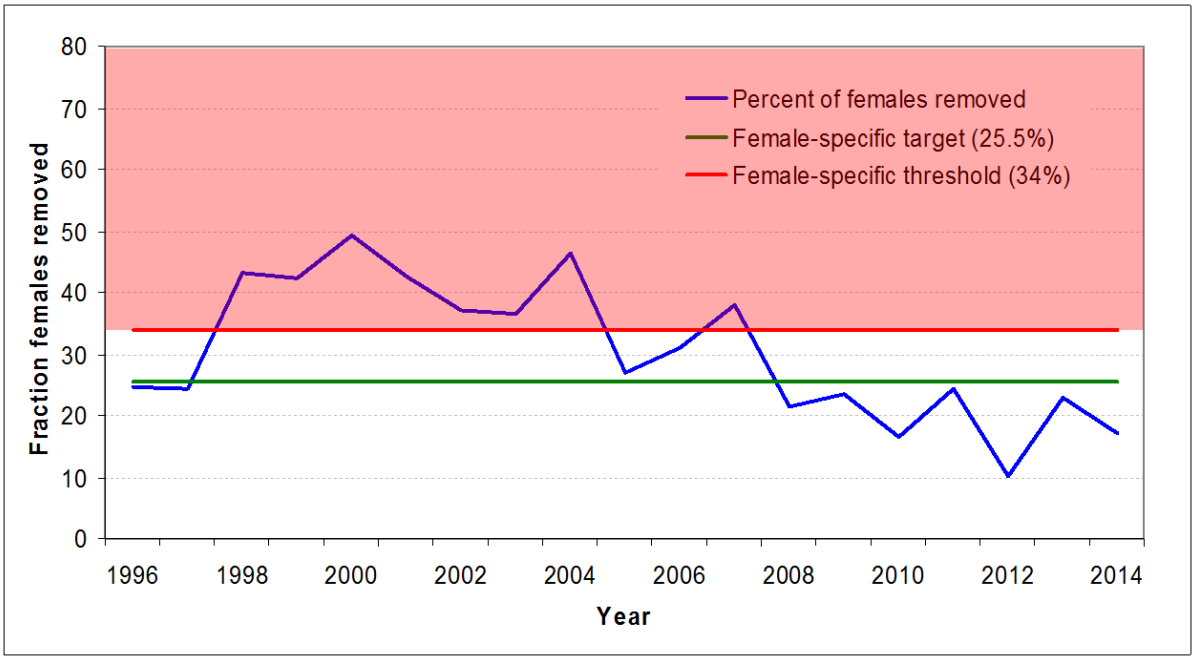

Figure 2. The percentage of all female blue crabs removed from the population each year by fishing relative to the female-specific target (25.5%) and threshold (34%) exploitation rates, 1990 through 2014. Exploitation rate (% removed) is the number of female crabs harvested within a year divided by the female population (age 0 and age 1+) estimated at the beginning of the year.

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3. POPULATION SIZE (ABUNDANCE)

3.1 All Crabs (both sexes, all ages)

The total abundance of all crabs (males and females of all ages) increased by 38% from 297 million crabs in 2014 to 411 million crabs in 2015 (Figure 3).

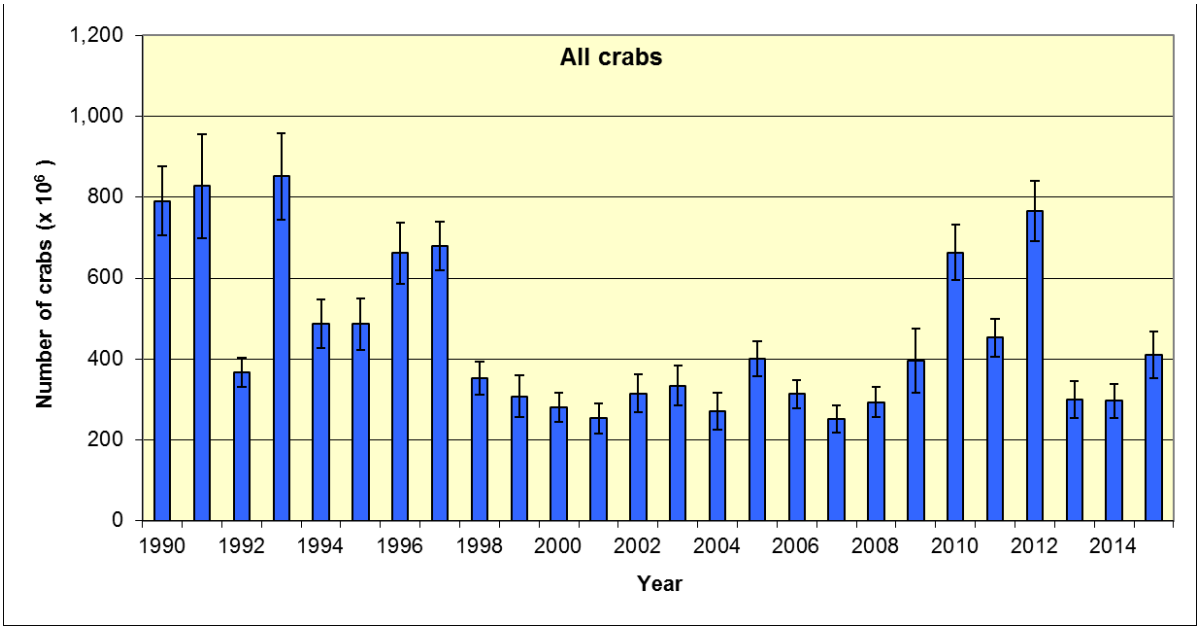

Figure 3. Winter dredge survey estimate of abundance of all crabs (both sexes, all ages) in Chesapeake Bay, 1990 through 2015. Error bars represent 95% confidence intervals.

3.2 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. The estimate of age 0 crabs increased by approximately 36% from 198 million in 2014 to 269 million crabs in 2015 (Figure 4). High recruitment variability is a characteristic of blue crab populations. The sex composition of the 2015 juvenile estimate is approximately 50% male and 50% female.

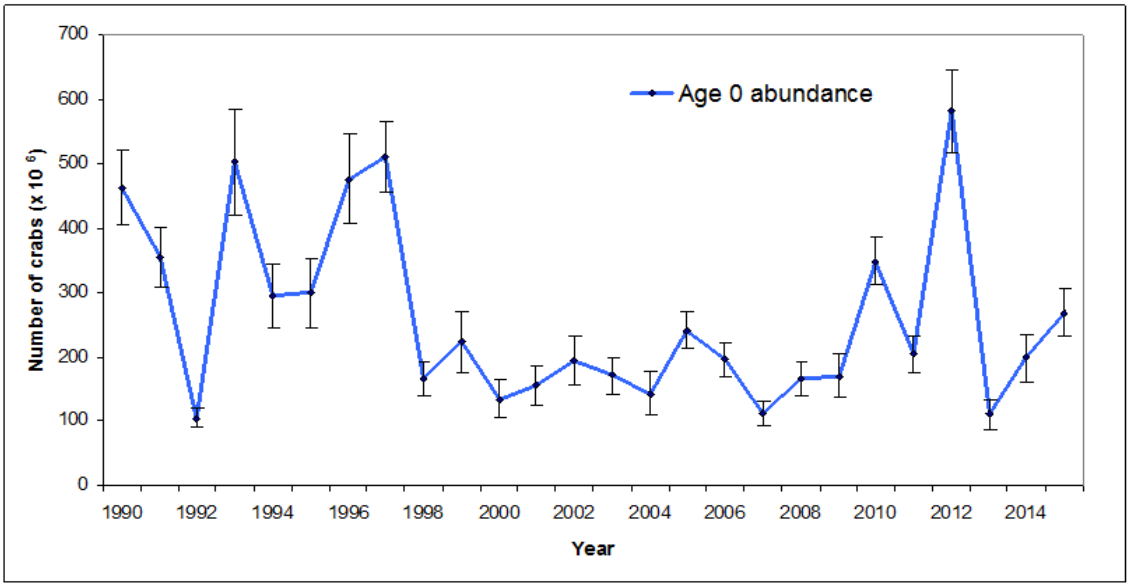

Figure 4. Winter dredge survey estimate of abundance of juvenile blue crabs (age 0), 1990-2015 calculated without the catchability adjustment for juveniles. These are male and female crabs measuring less than 60 mm across the carapace. Error bars represent 95% confidence intervals.

3.3 Age-1+ Male

In 2015, the number of age 1+ male crabs (greater than 60 mm or 2.4 inches carapace width) estimated to be present in the Bay was 43.6 million crabs (Figure 5), a 49% increase from the 2014 estimated adult male abundance of 29.3 million crabs. However, the 2015 male abundance estimate remains relatively low.

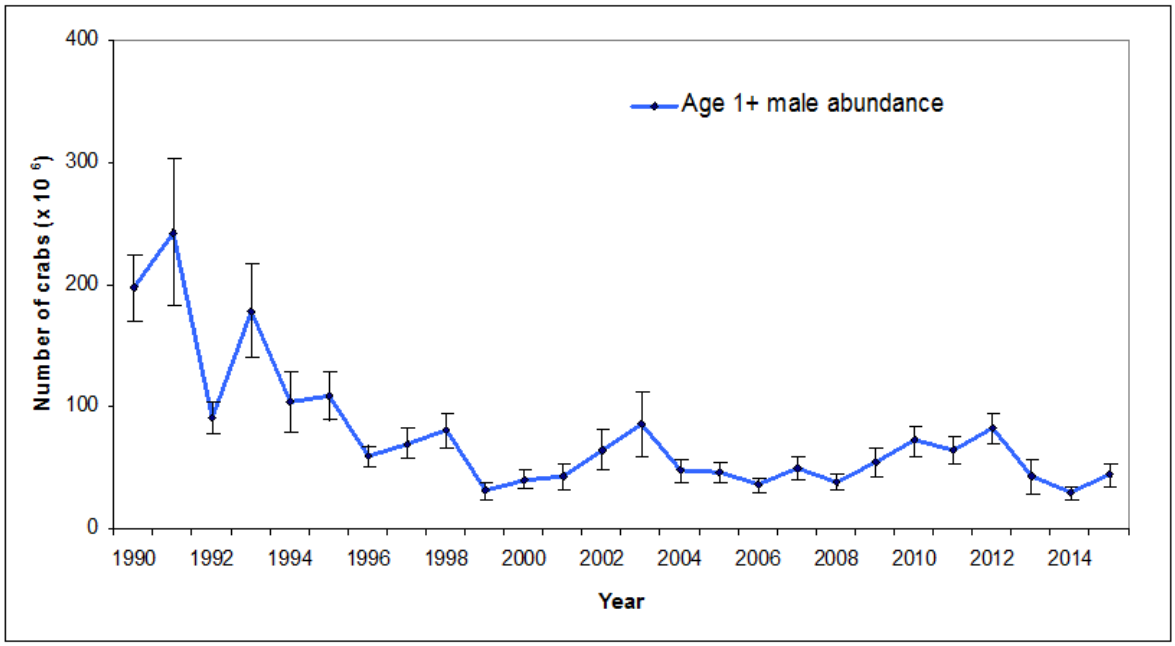

Figure 5. Winter dredge survey estimate of abundance of male blue crabs age one year and older (age 1+) 1990-2015. These are male crabs measuring greater than 60mm across the carapace and are considered the 'exploitable stock' capable of mating within this year. Error bars represent 95% confidence intervals.

3.4 Overwintering Mortality

The 2015 estimates of overwintering mortality of blue crabs in the Bay are some of the highest values in recent history (Table 2).

Table 2. Percent dead crabs found in late winter dredge samples each year from 2012-2015 and the average for 1996-2011.

Baywide Age/sex group	2015	2014	2013	2012	1996-2011 average
All crabs	15.68%	3.79%	4.00%	1.59%	4.78%
Juveniles	10.84%	0.89%	0.00%	0.52%	1.00%
Adult Females	19.25%	7.68%	3.00%	2.69%	9.53%
Adult males	28.11%	13.58%	13.88%	4.90%	9.11%

Overwintering mortality decreased the abundance of all sectors of the blue crab population in 2015 (Table 3).

Table 3. Baywide abundance estimates for 2015 before and after overwintering mortality.

Baywide Age/sex group	Abundance estimate in millions before overwintering mortality (millions of crabs)	Final abundance estimate in millions after overwintering mortality (millions of crabs)	% Overwintering mortality
All crabs	487	411	15.68%
Juveniles	302	269	10.84%
Adult Females	125	101	19.25%
Adult Males	61	44	28.11%

4. HARVEST

4.1 Commercial and Recreational Harvest

The three management jurisdictions implemented additional commercial harvest restrictions, mostly lower bushel limits, for females for the 2014-15 season in response to the depleted abundance of females in 2014. The 2014 commercial harvest for both males and females from the Bay and its tributaries was estimated as 16.5 million pounds in Maryland, 17.0 million pounds in Virginia and 1.7 million pounds in the Potomac River. Maryland's 2014 commercial harvest declined 12% from 2013, Virginia's commercial harvest increased by 5.5%, and the Potomac River's commercial harvest decreased by 15%. The Baywide commercial harvest of 35 million pounds is the lowest harvest recorded in the last 25 years (Figures 6-7).

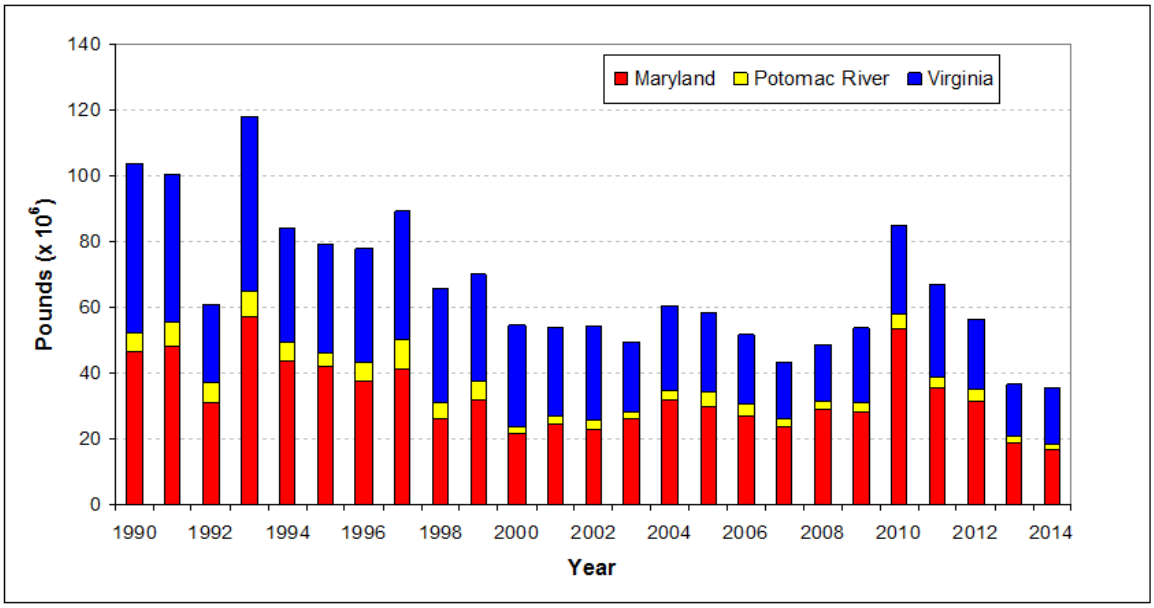

Figure 6. Total commercial blue crab landings (all market categories) in Chesapeake Bay, 1990-2014.

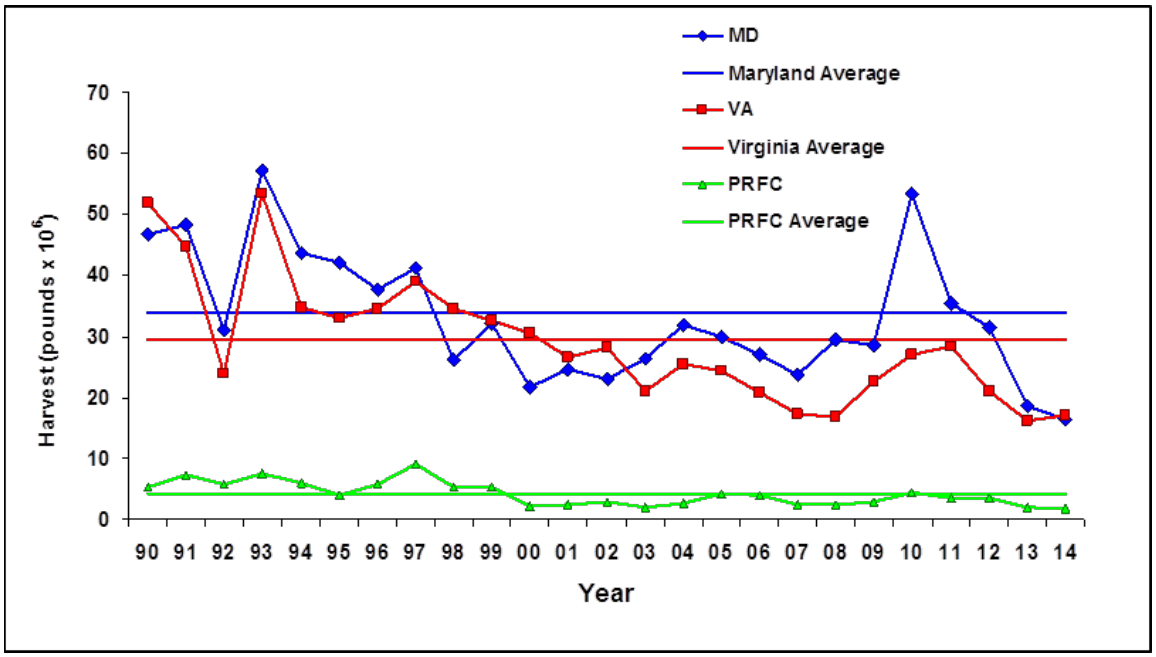

Figure 7. Maryland, Virginia and Potomac River commercial blue crab harvest in millions of pounds, all market categories, 1990-2014.

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 male harvest in those jurisdictions. 2014 Baywide recreational harvest was estimated as 2.3 million pounds, the same as the 2013 recreational harvest estimate. Combining the commercial and recreational harvest, approximately 37.3 million pounds of blue crabs were harvested from Chesapeake Bay and its tributaries during the 2014 crabbing season. The 2014 Baywide blue crab harvest was one of the lowest seen this century.

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5. STOCK STATUS

5.1 Female Reference Points

The Chesapeake Bay blue crab stock is currently between the abundance threshold of 70 million age 1+ female crabs and the abundance target of 215 million age 1+ female crabs outlined in the current management framework. The 2014 exploitation fraction of 17% was below the target (25.5%) and threshold (34%). The stock is **not depleted and overfishing is not occurring** (Figure 1-2). Abundance, harvest and exploitation of all crabs are summarized in Appendix A.

5.2 Male Conservation Triggers

In 2011, CBSAC recommended that male abundance should not be allowed to decline to a critically low level relative to female abundance and a conservation trigger based on male

abundance should be developed. The reference points from the former management framework were used to develop the conservation triggers below.

Previously, estimates of male exploitation that were presented did not utilize the juvenile scalar in calculations, as it has been when calculating female exploitation. The male exploitation rate (Trigger #1) below has been revised to include the scalar (described in Section 2.1), so it is consistent with the female-specific reference points (Trigger #2). This change has no impact on the performance of the metrics or the application of the male conservation triggers described below. The exploitation rate of both sexes combined (Trigger #2) was calculated without the juvenile scalar so the value could be related to the prior management framework.

CBSAC recommended conservation triggers for male crabs based on male exploitation and on the former management framework. Under these triggers, conservation measures should be considered for male blue crabs if either of the following occurs:

1) The male exploitation rate exceeds 33% (calculated with the juvenile scalar as described in section 2.1), 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 biologically significant fishing threshold or target. Rather, this trigger will ensure that the male component of the stock is not more heavily exploited, relative to females, than at levels that have occurred in the last 24 years. The 2014 male exploitation fraction was estimated at 21%, which is below the 33% male exploitation rate conservation trigger (Figure 8).

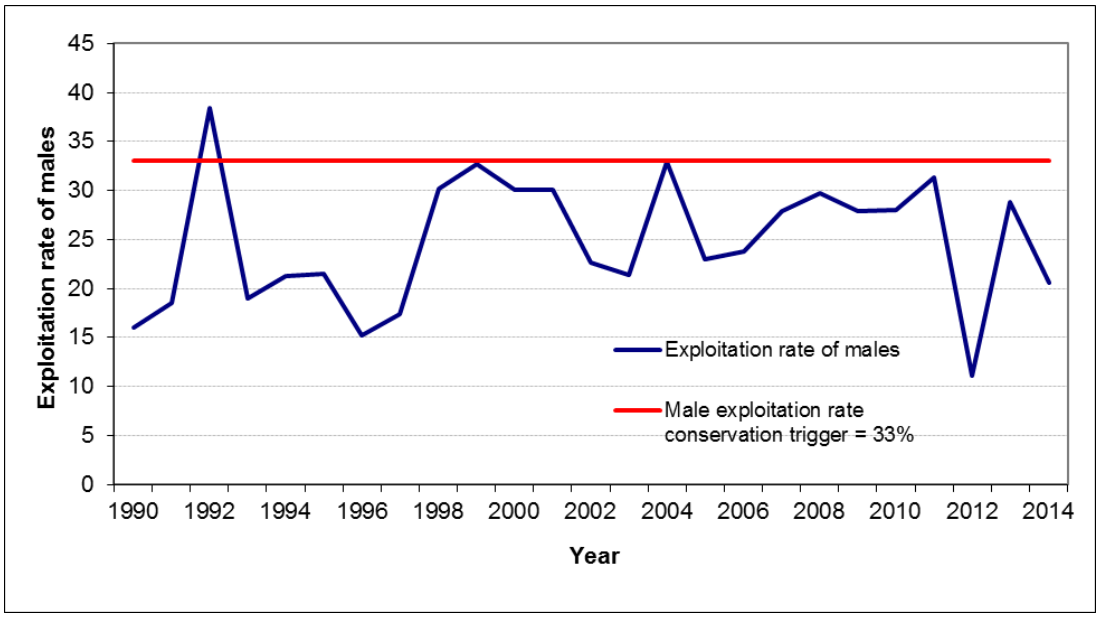

Figure 8. The percentage of male crabs removed from the population each year by fishing, 1990 through 2014. Exploitation rate (% removed) is the number of male crabs harvested within a year divided by the male population estimate (age 0 and age 1+) at the beginning of the year.

2) If female exploitation is below the established overfishing threshold of 34% and the total annual exploitation rate of male and female crabs exceeds the threshold defined by the previous control rule of 53% of crabs, both sexes combined. The 2014 female exploitation was estimated at 17%, which is below the 34% threshold (Figure 7). The 2014 exploitation fraction of males and females combined was estimated at 26%, which is below the 53% threshold (Figure 9).

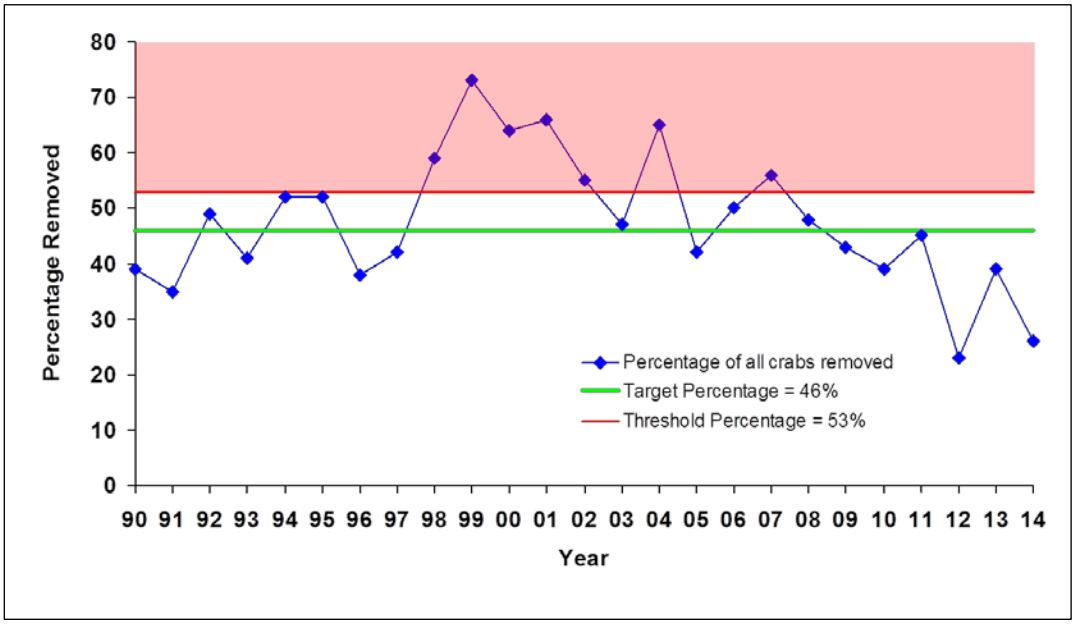

Figure 9. The percentage of male and female crabs removed from the population each year by fishing relative to previously used target (46%) and threshold (53%) exploitation rates, 1990 through 2014. Exploitation rate (% removed) is the number of crabs harvested within a year divided by the population of all crabs estimated at the beginning of the year.

Because neither of the male conservation triggers was reached, no management action is recommended at this time specific to male blue crabs.

5.3 Potential Management Impact

Female exploitation fractions from 1990-2007 were much higher than the exploitation fractions seen from 2008-2013. These lower exploitation fractions in recent years illustrate the probable 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)

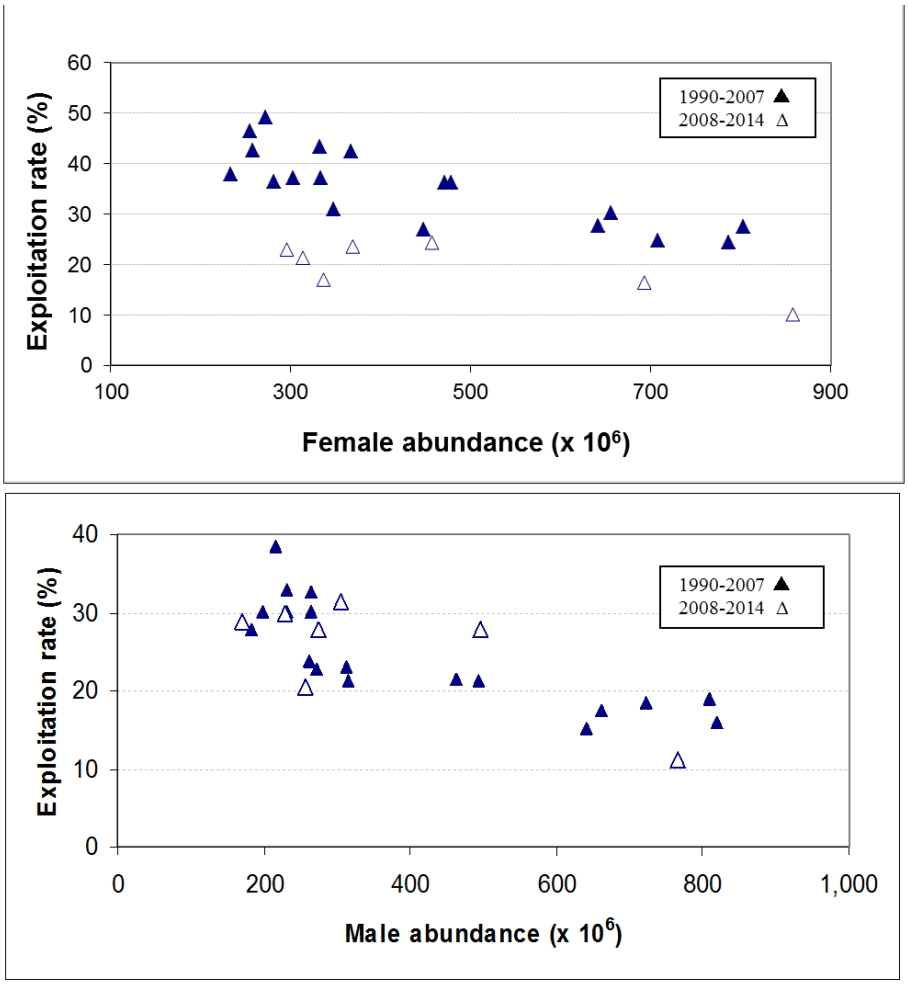

Figure 10. Female (top) and male (bottom) exploitation rate comparison of the time periods prior to and after the 2008 implementation of female-specific management measures.

6. MANAGEMENT ADVICE-SHORT TERM

6.1 Monitor fishery performance and stock status relative to recommended reference points and maintain a risk-averse management approach protecting 2015 recruits

The female exploitation fraction in 2014 was below the recommended target of 25.5% for the seventh consecutive year. The abundance of both juvenile and adult female crabs increased in 2015. However, the number of recruits year to year remains highly variable.

Future catches and ability of the blue crab stock to reach abundance targets could depend heavily on the survival and successful reproduction of the 2016 exploitable female stock. Conservation of this year's juveniles is expected to maintain or increase future spawning potential. CBSAC finds this as justification for a continued risk-averse and cautious management approach that ensures harvest is adequately constrained relative to abundance and the target exploitation fraction.

6.2 Catch Reports

CBSAC again recommends that the jurisdictions implement procedures that provide accurate accountability of all commercial and recreational harvest. All three 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 and are also collaborating with industry groups to pursue new reporting technologies. Maryland has implemented a pilot 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. PRFC is exploring the use of electronic reporting to potentially begin in 2016. Importantly, CBSAC notes that when changes in reporting requirements are implemented, it is vital that an analysis of the impact of the changes in reporting methodology of the estimated harvest be undertaken.

If the jurisdictions continue with a sex-specific regulatory strategy, CBSAC again recommends greater efforts to determine the biological characteristics of all catch, both harvested and discarded.

Update: Shifting management time frame: July to July

For the 2014-15 season, the three management jurisdictions adjusted their management timeframe to run from July 2014 through July 2015. CBSAC recommended this switch in the 2014 Blue Crab Advisory Report. CBSAC is further exploring the potential long-term impacts of a July-July management time frame and will report back at a future date.

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7. MANAGEMENT ADVICE- LONG TERM

7.1 Catch Control

A management strategy that sets annual catch levels based on estimates of abundance from the WDS and that accounts for sex-specific, spatial and seasonal distribution of crabs could potentially balance annual harvests with highly variable recruitment events. The CBSAC supports the commitment by the blue crab management jurisdictions in the 2014 Chesapeake Bay Watershed Agreement to evaluate the establishment of a Baywide 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.

7.2 Annual sanctuary and complementary management measures

CBSAC recommends that Virginia consider establishing a year-round sanctuary for mature females in the lower Bay, and Maryland and PRFC consider complementary sanctuaries or other

management measures in the upper Bay and Potomac River that would promote survival of mature females in their first and subsequent spawning seasons. Protection of mature females in multiple spawning seasons should bolster the spawning stock and recruitment, and provide a buffer for the population from the combined effects of environmental disturbance and high fishing pressure.

7.3 Abundance specific exploitation

In the upcoming 2016-17 stock assessment CBSAC recommends the evaluation of variable targets and thresholds based on the fluctuating abundance of all sectors of the female segment of the population.

7.4 Jurisdictional Management Controls

The blue crab fishery is primarily managed under an effort control framework with limited entry, size limits and seasonal closures serving as the principal tools. Additionally, the blue crab fishery is also managed by output controls such as harvest and bushel limits. In many cases, the amount of effort expended in the fishery remains poorly quantified. CBSAC recommends an increased investment in Baywide effort monitoring that should include actions in all jurisdictions to implement a pot marking system and a Baywide survey of crab pot effort to estimate the total, spatial and temporal patterns of the crab pot fishery.

7.5 Latent effort

In both states, significant numbers of commercial crabbing licenses are unused. An increase in the blue crab population may increase the use of licenses that have, for some time, been inactive. CBSAC recommends that the level and possible re-entry of latent effort into the fishery be estimated and monitored. In addition to increases in latent effort, CBSAC also recognizes that temporal and seasonal shifts in blue crab abundance may alter existing effort exerted by active licenses. The impact of inherent variability of blue crab abundance on both latent and active effort should be investigated as a part of this recommendation.

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8. CRITICAL DATA AND ANALYSIS NEEDS

CBSAC has identified the following list of fishery-dependent and fishery-independent data needs as well as the benefits provided to management. CBSAC recognizes the importance of the upcoming 2016-17 benchmark stock assessment in providing in-depth analyses of the Chesapeake Bay blue crab population and scientific guidance to managers.

8.1 Increased accountability and harvest reporting for both 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 mid-season management changes.

The jurisdictions have been working to implement new harvest reporting technologies over the past few years. Since 2012, the Maryland Blue Crab Design Team has been conducting a pilot electronic reporting system in conjunction with MD DNR 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. There is interest among PRFC stakeholders, and it is possible that PRFC may begin using an electronic reporting system by 2016.

8.2 Gear efficiency pertaining to selectivity of WDS methods:

There is no update on gear efficiency studies from the 2014-15 winter dredge survey due to the severe winter, which imposed time constraints on the survey vessels. The below update still stands from the 2014 Blue Crab Advisory Report.

The WDS survey methods to estimate gear efficiency differ between MD and VA. CBSAC recommends continuation of a comprehensive comparison between MD and VA WDS methodologies and gear efficiency and selectivity with regard to age 0 and age 1+ crabs.

Following the comprehensive comparison, the accuracy and reliability of current scalars and efficiency corrections should be re-evaluated. MD DNR and the Virginia Institute of Marine Science (VIMS) will meet to discuss survey design in an attempt to develop this comparison over the course of the next year. Costs and required time are unknown.

8.3 Improving recruitment estimate through a shallow-water survey:

Based on the results of the 2012-2013 WDS, a large number of recruits observed in the 2011-2012 WDS did not recruit to the fisheries in 2012-2013. Based on the 2011 stock assessment and field experiments by VIMS and the Smithsonian Environmental Research Center, a large fraction of juvenile blue crabs (76-86%) in shallow water are not sampled by the WDS[7]. For the former, CBSAC recommends analyzing pertinent environmental and ecological variables to examine potential hypotheses to explain the poor survival of this record recruitment event and

improve the accuracy of the WDS. This examination includes the definition of viable hypotheses, not the assessment of their veracity. For the latter, CBSAC recommends that funding be pursued at the state and federal levels for shallow-water surveys to assess the potential for interannual bias in the fraction of juveniles that is not sampled by the WDS.

8.4 Investigation of the potential for sperm limitation:

CBSAC recommends continued examination to quantify and better understand the role male crabs on reproductive success and overall population productivity. The potential for sperm limitation resulting from a lower abundance of sexually mature male crabs is discussed in several recent studies[8,9,10]. Further clarity could be brought to this issue through an analysis of the age composition of mature females over the history of the WDS to determine whether the proportion of females in their second reproductive year has increased.

8.5 Other sources of incidental 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. Initial efforts should be focused on better defining analyses that could address the problem.

8.6 Collaborative Baywide fishery independent survey:

A collaborative and coordinated Baywide, fishery-independent survey focused on the spring through fall distribution and sex-specific abundance of blue crabs remains important, especially if agencies are considering regional or spatially-explicit management strategies. Costs and time commitments are unknown.

CBSAC Participants:

Joe Grist (Chair)	Virginia Marine Resource Commission
Ellen Cosby	Potomac River Fisheries Commission
Glenn Davis	Maryland Department of Natural Resources
Lynn Fegley	Maryland Department of Natural Resources
Daniel Hennen	NMFS, Northeast Fisheries Science Center
John Hoenig	Virginia Institute of Marine Science
Eric Johnson	University of North Florida
Rom Lipcius	Virginia Institute of Marine Science
John McConaugha	Old Dominion University
Tom Miller	UMCES, Chesapeake Biological Laboratory
Rob O'Reilly	Virginia Marine Resource Commission
Amy Schueller	NMFS, Southeast Fisheries Science Center
Mike Seebo	Virginia Institute of Marine Science
Alexei Sharov	Maryland Department of Natural Resources
Mike Wilberg	UMCES, Chesapeake Biological Laboratory
Emilie Franke (Coordinator)	ERT/NOAA Chesapeake Bay Office

Literature Cited

1. Miller, T. J. et al. 2011. Stock Assessment of Blue Crab in Chesapeake Bay. 2011. Final Report. Ref: [UMCES] CBL 11-011. UMCES Tech. Ser. No. TS-614-11-CBL.

2. Sharov, A. F., J. H. Volstad, G. R. Davis, B. K. Davis, R. N. Lipcius, and M.M. Montane. 2003. Abundance and exploitation rate of the blue crab (*Callinectes sapidus*) in Chesapeake Bay. Bulletin of Marine Science 72:543-565.

3. Bi-State Blue Crab Advisory Committee. 2001. Taking Action for the Blue Crab: Managing and Protecting the Stock and its Fisheries. A report to the Chesapeake Bay Commission; Annapolis, Md, Richmond, Va. 24p.

4. Ashford, J. R., and C. M. Jones. 2001. Survey of the blue crab recreational fishery in the Chesapeake Bay, 2001. Final Report to the Maryland Department of Natural Resources. Annapolis, MD. 61p.

5. Ashford, J. R., and C. M. Jones. 2002. Survey of the blue crab recreational fishery in Maryland, 2002. Final Report to the Maryland Department of Natural Resources. Annapolis, MD. 31p.

6. Ashford, J. R., and C. M. Jones. 2005. Survey of the blue crab recreational fishery in Maryland, 2005. Final Report to the Maryland Department of Natural Resources. Annapolis, MD. 31p.

7. Ralph, G.M., and R.N. Lipcius. 2014. Critical habitats and stock assessment: age-specific bias In the Chesapeake Bay blue crab population survey. Transactions of the American Fisheries Society *in press*.

8. Ogburn, M.B., P.M. Roberts, K.D. Richie, E.G. Johnson, and A.H. Hines. 2014. Temporal and spatial variation in sperm stores in mature female blue crabs (*Callinectes sapidus*) and potential effects on brood production in Chesapeake Bay. Marine Ecology Progress Series *in press*.

9. Hines, A.H., and M.B. Ogburn. 2014. Evaluating population level impacts of sperm limitation on the Chesapeake blue crab stock. Final Report to NOAA Chesapeake Bay Office for NA11NMF4570230.

10. Rains, S.A. 2014. Potential for sperm limitation in blue crabs of Chesapeake Bay. M.S. thesis, University of Maryland.

Appendix A. Estimated abundance of blue crabs from the Chesapeake Baywide 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	Baywide Commercial Harvest (Millions of Pounds)	Percentage of Female Crabs Harvested
1990	791	463	276	117	96	44
1991	828	356	457	227	90	34
1992	367	105	251	167	53	60
1993	852	503	347	177	107	35
1994	487	295	190	102	77	28
1995	487	300	183	80	72	32
1996	661	476	146	108	69	20
1997	680	512	165	93	77	22
1998	353	166	187	106	56	40
1999	308	223	86	53	62	37
2000	281	135	146	93	49	43
2001	254	156	101	61	47	42
2002	315	194	121	55	50	34
2003	334	172	171	84	47	33
2004	270	143	122	82	48	42
2005	400	243	156	110	54	24
2006	313	197	120	85	49	29
2007	251	112	139	89	43	35
2008	293	166	128	91	49	24
2009	396	171	220	162	54	23
2010	663	340	310	246	85	18
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**	**TBD**	**TBD**

* 2014 Baywide commercial harvest and exploitation rate are preliminary
(TBD= to be determined)